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Civil Engineering

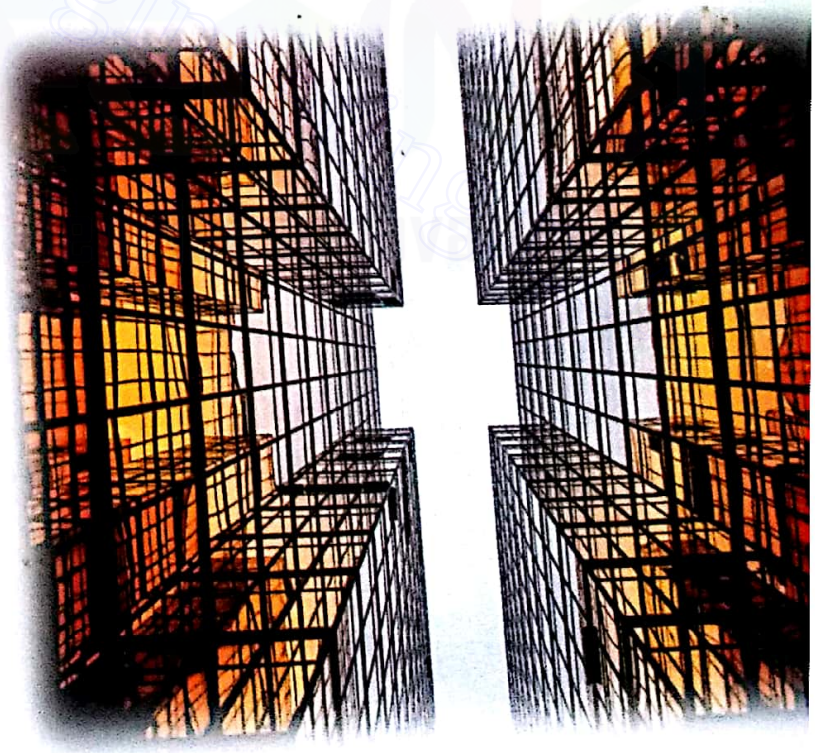
(CONVENTIONAL AND OBJECTIVE TYPE)

4500+

Objective Questions with Hints

FOR PREPARATION OF

- B.Tech/B.E./B.Sc./ Diploma in Engineering
- Engineering Services Examination (ESE) conducted by UPSC
- GATE and other Competitive Exams



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CIVIL ENGINEERING

(CONVENTIONAL AND OBJECTIVE TYPE)

[For the Students of U.P.S.C. (Engg. Services); I.A.S. (Engg. Group); B.Sc. Engg.; Diploma and other Competitive Courses]

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1

Engineering Mechanics

1.1 Introduction

The Engineering Mechanics is that branch of Engineering-science which deals with the principles of mechanics along with their applications to engineering problems. It is sub-divided into the following two main groups:

(*a*) Statics, and (*b*) Dynamics

The *Statics* is that branch of Engineering Mechanics which deals with the forces and their effects, while acting upon the bodies at rest.

The *Dynamics* is that branch of Engineering Mechanics which deals with the forces and their effects, while acting upon the bodies in motion. It is further sub-divided into the following two branches:

(*i*) Kinetics, and (*ii*) Kinematics

The *Kinetics* is that branch of Dynamics, which deals with the bodies in motion due to the application of forces.

The *Kinematics* is that branch of Dynamics which deals with the bodies in motion without taking into account the forces which are responsible for the motion.

1.2 Force

It may be defined as an agent which produces or tends to produce, destroy or tends to destroy the motion of a body. A force while acting on a body may

(*a*) change the motion of a body,
(*b*) retard the motion of a body,
(*c*) balance the forces already acting on a body, and
(*d*) give rise to the internal stresses in a body.

In order to determine the effects of a force acting on a body, we must know the following characteristics of a force:

(*i*) The magnitude of the force,
(*ii*) The line of action of the force,
(*iii*) The nature of the force, *i.e.* push or pull, and
(*iv*) The point at which the force is acting.

In M. K. S. system of units, the magnitude of the force is expressed in kilogram-force (briefly written as kgf) and in S.I. system of units, the force is expressed in newtons (briefly written as N). It may noted that

$$1 \text{ kgf} = 9.81 \text{ N}$$

1.3 Resultant Force

It is a single force which produces the same effect as produced by all the given forces acting on a body. The resultant force may be determined by the following three laws of forces :

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1. *Parallelogram law of forces.* It states that if two forces, acting simultaneously on a particle, be represented in magnitude and direction by the two adjacent sides of a parallelogram, then their resultant may be represented in magnitude and direction by the diagonal of a parallelogram which passes through their points of intersection.

For example, let us consider two forces P and Q acting at angle θ at point O as shown in Fig. 1.1. The resultant is given by,

$$R = \sqrt{P^2 + Q^2 + 2PQ\cos\theta}$$

If the resultant (R) makes an angle α with the force P, then

$$\tan\alpha = \frac{Q\sin\theta}{P + Q\cos\theta}$$

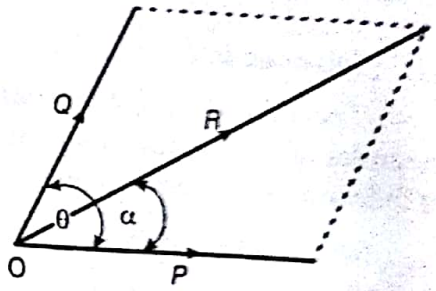

Fig. 1.1

2. *Triangle law of forces.* It states that if two forces, acting simultaneously on a particle, be represented in magnitude and direction by the two sides of a triangle taken in order, then their resultant may be represented in magnitude and direction by the third side of the triangle taken in opposite order.

3. *Polygon law of forces.* It states that if a number of forces, acting simultaneously on a particle, be represented in magnitude and direction by sides of a polygon taken in order, then their resultant is represented in magnitude and direction by the closing side of the polygon taken in opposite order.

Notes : 1. The resultant of more than two intersecting forces may be found out by resolving all the forces horizontally and vertically. In such cases, resultant of the forces is given by

$$R = \sqrt{(\Sigma H)^2 + (\Sigma V)^2}$$

where

ΣH = Sum of resolved parts in the horizontal direction, and

ΣV = Sum of resolved parts in the vertical direction.

If the resultant (R) makes an angle α with the horizontal, then

$$\tan\alpha = \Sigma V / \Sigma H$$

2. If the resultant of a number of forces, acting on a particle, is zero then the particle will be in equilibrium. Such a set of forces, whose resultant is zero, are known as *equilibrium forces*. The force, which brings the set of forces in equilibrium is called an *equilibriant*. It is equal to the resultant force in magnitude but opposite in direction.

3. A number of forces acting on a particle will be in equilibrium when $\Sigma H = 0$ and $\Sigma V = 0$.

1.4 System of Forces

When two or more than two forces act on a body, they are said to form a *system of forces*. Following are the various system of forces:

1. *Coplaner forces* The forces, whose lines of action lie on the same plane are known as coplaner forces.

2. *Concurrent forces.* The forces, which meet at one point, are known as concurrent forces.

3. *Coplaner concurrent forces.* The forces, which meet at one point and their lines of action also lie on the same plane, are called coplaner concurrent forces.

4. *Coplaner non-concurrent forces.* The forces, which do not meet at one point but their lines action lie on the same plane, are known as coplaner non-concurrent forces.

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5. *Non-coplaner concurrent forces.* The forces, which meet at one point but their lines of action do not lie on the same plane are known as non-coplaner concurrent forces.

6. *Non- coplaner non-concurrent forces.* The forces, which do not meet at one point and their lines of actions do not lie on the same plane are called non-coplaner non-concurrent forces.

1.5 Lami's Theorem

It states that if three coplaner forces acting at a point be in equilibrium, then each force is proportional to the sine of the angle between the other two forces. Mathematically

$$\frac{P}{\sin\alpha} = \frac{Q}{\sin\beta} = \frac{R}{\sin\gamma}$$

where P, Q and R are the three forces and α, β and γ are the angles as shown in Fig 1.2.

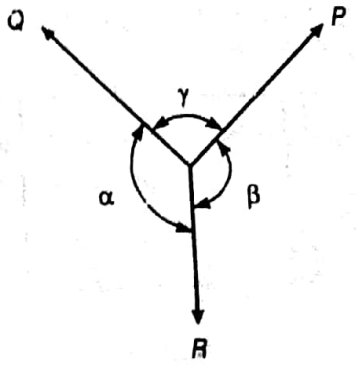

Fig. 1.2

1.6 Moment of a Force

It is the turning effect produced by a force, on the body, on which it acts. The moment of a force is equal to the product of the force and the perpendicular distance of the point, about which the moment is required and the line of action of the force. Mathematically, the moment of a force P about point O as shown in Fig 1.3,

$$= P \times l$$

The unit of moment depends upon the units of force and perpendicular distance. If the force is in newtons and the perpendicular distance in metres, then the unit of moment will be newton-metre (briefly written as N-m).



Fig. 1.3

1.7 Varignon's Principle of Moments (or Law of Moments)

It states that if a number of coplaner forces acting on a particle are in equilibrium, then the algebraic sum of their moments about any point is equal to the moment of their resultant force about the same point.

1.8 Parallel Forces

The forces, whose lines of action are parallel to each other, are said to be *parallel forces*. If the parallel forces act in the same direction then these are known as *like parallel forces*. When the parallel forces act in opposite directions, then these are known as *unlike parallel forces*.

1.9 Couple

The two equal and opposite forces, whose lines of action are different, form a couple, as shown in Fig. 1.4.

The perpendicular distance (x) between the lines of action of two equal and opposite forces is known as arm of the couple. The magnitude of the couple (*i.e.* moment of a couple) is the product of one of the forces and the arm of the couple. Mathematically,

Moment of a couple $= P \times x$

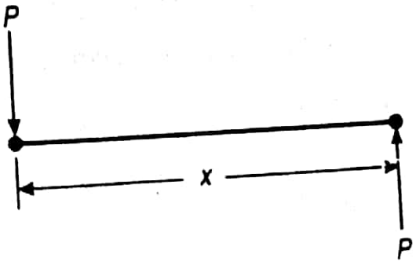

Fig. 1.4

A little consideration will show, that a couple does not produce any translatory motion (*i.e.* motion in a straight line), but a couple produces a motion of rotation of the body on which it acts.

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1.10 Centre of Gravity

The point through which the whole mass of the body acts, irrespective of the position of the body, is known as *centre of gravity* (briefly written as c.g.) The plane geometrical figures (like rectangle, triangle, circle etc.) have only areas but no mass. The centre of area of such figures is known as *centroid* or *centre of gravity* of the area of the body. It may be noted that every body has one, and only one, centre of gravity. The centre of gravity of some simple figures is given below.

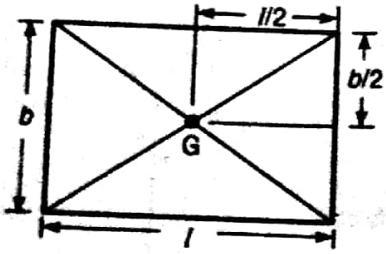


Fig. 1.5

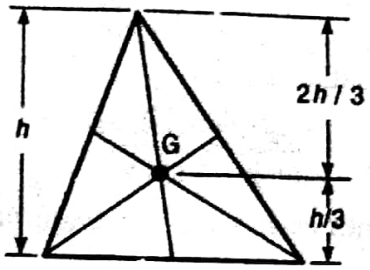


Fig. 1.6

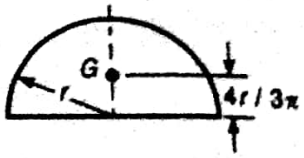


Fig. 1.7

1. The centre of gravity of a uniform rod is at its middle point.

2. The centre of gravity (G) of a rectangle (or parallelogram) lies at a point where its diagonals intersect, as shown in Fig. 1.5.

3. The centre of gravity (G) of a triangle lies at a point where the three medians of the triangle intersect, as shown in Fig. 1.6.

Note : A median is a line joining the vertex and the middle point of the opposite side.

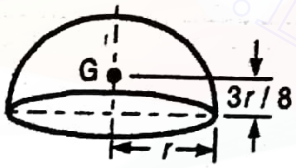


Fig. 1.8

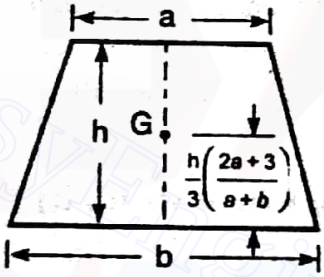


Fig. 1.9

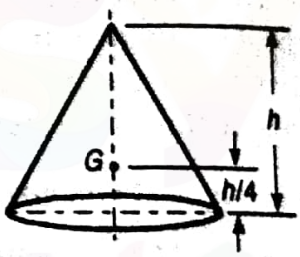


Fig. 1.10

4. The centre of gravity of a semi-circle lies at a distance of $4r / 3\pi$ from its base measured along the vertical radius, as shown in Fig. 1.7.

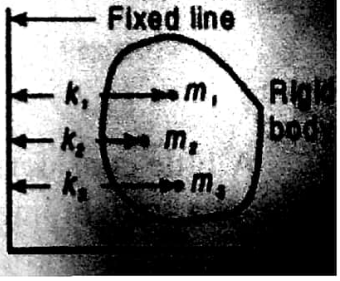
5. The centre of gravity of a hemisphere lies at a distance of $3r / 8$ from its base, measured along the vertical radius, as shown in Fig. 1.8.

6. The centre of gravity of a trapezium with parallel sides a and b, lies at a distance $\frac{h}{3}\left(\frac{2a+3}{a+b}\right)$ measured from side b, as shown in Fig. 1.9.

7. The centre of gravity of a right circular solid cone lies at a distance of $h / 4$ from its base measured along the vertical axis, as shown in Fig. 1.10.

1.11 Moment of Inertia

It may be defined as the moment of the moment *i.e.* second moment of mass or area of a body. It is usually denoted by I.



Consider a body of total mass m. Let it is composed of small particles of masses m_1, m_2, m_3 .....etc. If k_1, k_2, k_3.....etc. are the distances from a fixed line, as shown in Fig. 1.11, then mass moment of intertia of the whole body is given by

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$$I = m_1 (k_1)^2 + m_2 (k_2)^2 + m_3 (k_3)^2 + \ldots\ldots\ldots$$
$$= m.k^2$$

If, instead of mass, the area of the figure is taken into consideration, then moment of inertia of the area is given by

$$I = a_1 (k_1)^2 + a_2 (k_2)^2 + a_3 (k_3)^2 + \ldots\ldots\ldots = a.k^2$$

where k is called the *radius of gyration*. It is defined as *the distance from a given reference where the whole mass or area of the body is assumed to be concentrated to give the same value of I.*

In S.I. units, the unit of mass moment of inertia is kg-m^2 and the moment of intertia of the area is expressed in m^4 or mm^4.

If the moment of inertia of a body about an axis passing through its centre of gravity (*i.e.* I_G) is known, then the moment of inertia about any other parallel axis (*i.e.* I_P) may be obtained by using parallel axis theorem.

According to parallel axis theorem, the moment of inertia about a parallel axis,

$$I_P = I_G + m.h^2 \quad \text{...(considering mass of the body)}$$
$$= I_G + a.h^2 \quad \text{...(considering area of the body)}$$

where h = Distance between two parallel axes

The following are the values of I for simple cases :

1. The moment of inertia of a thin disc of mass m and radius r, about an axis passing through its centre of gravity and perpendicular to the plane of the disc is

$$I_G = m.r^2/2 = 0.5\, mr^2$$

and moment of inertia about a diameter,

$$I_D = m.r^2/4 = 0.25\, mr^2$$

2. The moment of inertia of a thin rod of mass m and length l, about an axis passing through its centre of gravity and perpendicular to its length is

$$I_G = m.l^2/12$$

and moment of inertia about a parallel axis through one end of the rod,

$$I_P = m.l^2/3$$

3. The moment of inertia of a rectangular section having width b and depth d as shown in Fig. 1.12, is given by

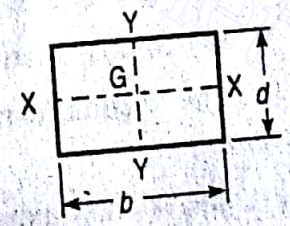

Fig. 1.12

$$I_{XX} = \frac{bd^3}{12} \; ; \text{ and}$$

$$I_{YY} = \frac{db^3}{12}$$

4. The moment of inertia of a hollow rectangular section, as shown in Fig. 1.13, is given by

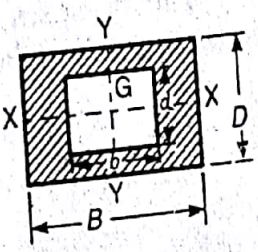

Fig. 1.13

$$I_{XX} = \frac{BD^3}{12} - \frac{bd^3}{12} \; , \text{ and}$$

$$I_{YY} = \frac{DB^3}{12} - \frac{db^3}{12}$$

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5. The moment of inertia of a circular section of diameter D as shown in Fig. 1.14, is given by

$$I_{XX} = I_{YY} = \frac{\pi D^4}{64}$$

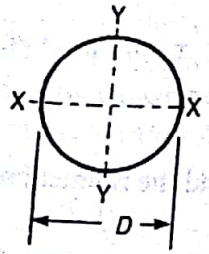

Fig. 1.14

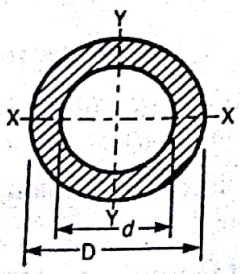

Fig. 1.15

6. The moment of inertia of a hollow circular section of outer diameter D and inner diameter d, as shown in Fig. 1.15, is given by

$$I_{XX} = I_{YY} = \frac{\pi}{64}\left[D^4 - d^4\right]$$

7. The moment of inertia of a triangular section of height h, about an axis passing through its centre of gravity G and parallel to the base BC, as shown in Fig. 1.16, is given by

$$I_G = \frac{bh^3}{36}$$

and moment of inertia about the base BC,

$$I_{BC} = \frac{bh^3}{12}$$

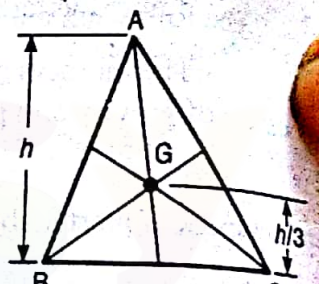

Fig. 1.16

1.12 Friction

A force acting in the opposite direction to the motion of the body is called *force of friction* or simply *friction*. It is of the following two types :

1. Static friction ; and 2. Dynamic friction.

The friction, experienced by a body, when at rest, is known as *static friction*.

The friction experienced by a body, when in motion, is called *dynamic friction*. It is also called *kinetic friction*. It is of the following two types:

(*a*) Sliding friction ; and (*b*) Rolling friction.

The friction, experienced by a body, when it slides over another body, is known as *sliding friction*.

The friction experienced by a body, when balls or rollers are interposed between the two surfaces, is known as *rolling friction*.

1.13 Limiting Friction

The maximum value of frictional force, which comes into play, when a body just begins to slide over the surface of the other body, is known as *limiting friction*.

1.14 Laws of Static Friction

Following are the laws of static friction :

1. The force of friction always acts in a direction, opposite to that in which the body tends to move.

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2. The magnitude of force of friction is exactly equal to the force, which tends the body to move.
3. The magnitude of the limiting friction bears a constant ratio to the normal reaction between the two surfaces.
4. The force of friction is independent of the area of contact between the two surfaces.
5. The force of friction depends upon the roughness of the surfaces.

1.15 Laws of Dynamic or Kinetic Friction

Following are the laws of dynamic or kinetic friction :

1. The force of friction always acts in a direction, opposite to that in which the body tends to move.
2. The magnitude of the kinetic friction bears a constant ratio to the normal reaction between the two surfaces.
3. For moderate speeds, the force of friction remains constant. But it decreases slightly with the increase of speed.

1.16 Coefficient of Friction

It is defined as the ratio of limiting friction (F) to the normal reaction (R_N) between the two bodies. It is generally denoted by μ. Mathematically,

$$\text{Coefficient of friction, } \mu = \frac{F}{R_N}$$

1.17 Limiting Angle of Friction

It is defined as the angle which the resultant reaction (R) makes with the normal reaction (R_N).

Consider a body A of weight W resting on a horizontal plane B as shown in Fig. 1.17. If a horizontal force P is applied to the body, no relative motion takes place until the applied force P is equal to the force of friction F, acting opposite to the direction of motion. The magnitude of this force of friction is $F = \mu\ W = \mu\ .\ R_N$, where R_N is the normal reaction.

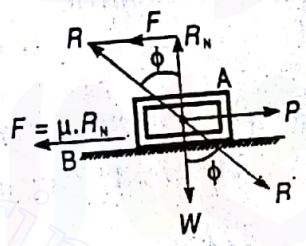

Fig. 1.17

In the limiting case, when the body just begins to move, it is in equilibrium under the action of the following three forces :

1. Weight of the body (W),
2. Applied horizontal force (P), and
3. Reaction (R) between the body A and the plane B.

The reaction R must, therefore, be equal and opposite to the resultant of W and P and will be inclined at an angle ϕ to the normal reaction (R_N). This angle ϕ is called the *limiting angle of friction* or simply *angle of friction*. From Fig. 1.17, we find that

$$\tan\phi = \frac{F}{R_N} = \frac{\mu.R_N}{R_N} = \mu$$

1.18 Angle of Repose

It is the angle of inclination (α) of the plane to the horizonal, at which the body just begins to move down the plane. A little consideration will show that the body will begin to move down the

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of friction (ϕ). From Fig. 1.18, we find that

$$W \sin \alpha = F = \mu . R_N = \mu . W \cos \alpha$$

or $$\tan \alpha = \mu = \tan \phi$$

$$\therefore \quad \alpha = \phi$$

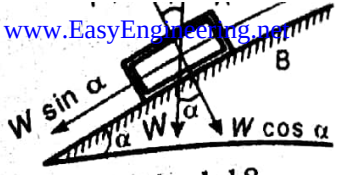

Fig. 1.18

1.19 . Minimum Force Required to Slide a Body on a Rough Horizontal Plane

Let a body A of weight W is resting on a rough horizontal plane B, as shown in Fig. 1.19. Let a effort P is applied at an angle θ to the horizontal, such that the body just begins to move. From Fig. 1.19, we find that

$$P \cos \theta = F = \mu . R_N = \mu (W - P \sin \theta)$$

$$= \tan \phi (W - P \sin \theta) \quad ...(\because \mu = \tan \phi)$$

$$= \frac{\sin \phi (W - P \sin \theta)}{\cos \phi}$$

$$P \cos \theta \cos \phi + P \sin \theta \sin \phi = W \sin \phi$$

$$\therefore \quad P = \frac{W \sin \phi}{\cos (\theta - \phi)}$$

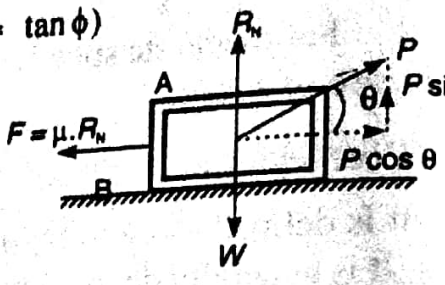

Fig. 1.19

For P to be minimum, $\cos (\theta - \phi)$ should be maximum, *i.e.*

$$\cos (\theta - \phi) = 1 \quad \text{or} \quad \theta - \phi = 0 \quad \text{or} \quad \theta = \phi$$

In other words, the effort P is minimum when its inclination (θ) with the horizontal is equal to th angle of friction (ϕ).

$$\therefore \quad P_{min} = W \sin \theta$$

1.20 Effort Required to Move the Body Up an Inclined Plane

The effort (P) required to move the body up an inclined plane as shown in Fig. 1.20, is given b

$$P = \frac{W \sin (\alpha + \phi)}{\sin [\theta - (\alpha + \phi)]}$$

where

W = Weight of the body,

α = Angle of inclination of the plane with the horizontal,

θ = Angle which the line of action of P makes with the weight of the body W, and

ϕ = Angle of friction.

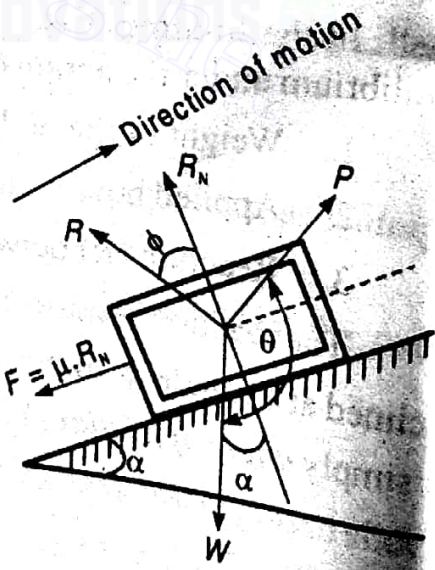

Fig. 1.20

Notes : 1. When friction is neglected, then $\phi = 0$, In that case,

$$P_o = \frac{W \sin \alpha}{\sin (\theta - \alpha)}$$

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2. When effort P is applied horizontally, then $\theta = 90°$. In that case

$$P = \frac{W \sin(\alpha+\phi)}{\cos(\alpha+\phi)} = W \tan(\alpha+\phi)$$

3. When effort P is applied parallel to the plane, then $\theta = 90° + \alpha$. In that case,

$$P = \frac{W \sin(\alpha+\phi)}{\cos\phi} = W(\sin\alpha + \mu\cos\alpha)$$

1.21 Effort Required to Move the Body Down an Inclined Plane

The effort (P) required to Move the body down an inclined plane as shown in Fig. 1.21, is given by

$$P = \frac{W \sin(\alpha - \phi)}{\sin[\theta - (\alpha - \phi)]}$$

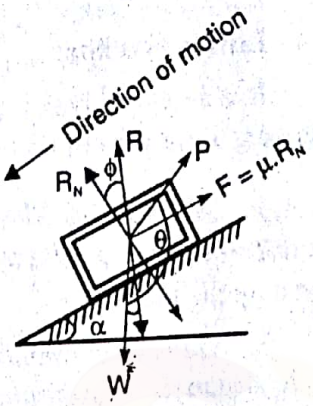

Fig. 1.21

Notes: 1. When friction is neglected, then $\phi = 0$. In that case,

$$P_0 = \frac{W \sin\alpha}{\sin(\theta - \alpha)}$$

2. When effort is applied horizontally, then $\theta = 90°$. In that case,

$$P = \frac{W \sin(\alpha - \phi)}{\cos(\alpha - \phi)} = W \tan(\alpha - \phi)$$

3 When effort is applied parallel to the plane, then $\theta = 90° + \alpha$. In that case,

$$P = \frac{W \sin(\alpha - \phi)}{\cos\phi} = W(\sin\alpha - \mu\cos\alpha)$$

1.22 Efficiency of an Inclined Plane

It is defined as the ratio of the effort required neglecting friction (*i.e.* P_0) to the effort required considering friction (*i.e.* P). Mathematically, efficiency of an inclined plane,

$$\eta = P_0 / P$$

1.23 Screw Jack

The principle, on which a screw jack works is similar to that of an inclined plane. If one complete turn of a screw thread is imagined to be unwound, from the body of the screw jack and developed, it will form an inclined plane, as shown in Fig. 1.22.

From the geometry of the figure,

$$\tan\alpha = \frac{p}{\pi d}$$

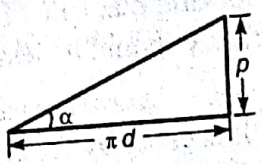

Fig. 1.22

where α = Helix angle,

p = Pitch of thread, and

d = Mean diameter of the screw.

In a screw jack, the effort (P) required at the circumference of screw is same as discussed for inclined plane, *i.e.*

For raising the load, $P = W \tan(\alpha + \phi)$

and for lowering the load, $P = W \tan(\alpha - \phi)$

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Notes: 1. When friction is neglected, then $\phi = 0$. In that case

$$P_o = W \tan \alpha$$

2. The efficiency of a screw jack is given by

$$\eta = \frac{P_o}{P} = \frac{W \tan \alpha}{W \tan (\alpha + \phi)} = \frac{\tan \alpha}{\tan (\alpha + \phi)}$$

3. The efficiency of a screw jack is maximum, when helix angle,

$$\alpha = 45° - \phi / 2$$

and the maximum efficiency is given by

$$\eta_{max} = \frac{1 - \sin \phi}{1 + \sin \phi}$$

1.24 Lifting Machine

It is a device, which enables us to lift a heavy load W, by a comparatively small effort P. The following terms are commonly used in lifting machines :

1. *Mechanical advantage* (*M.A.*). It is the ratio of load lifted (W) to the effort applied (P).
2. *Velocity ratio* (*V.R.*). It is the ratio of the distance moved by the effort (y) to the distance moved by the load (x).
3. *Input of the machine.* It is the workdone on the machine. It is equal to the product of effort and the distance through which it moves (*i.e.* $P \times y$).
4. *Output of the machine.* It is the workdone by the machine. It is equal to the product of load lifted and the distance through which it has been lifted (*i.e.* $W \times x$).
5. *Efficiency of the machine.* It is ratio of output to the input of the machine. Mathematically, efficiency of the machine,

$$\eta = \frac{\text{Output}}{\text{Input}} = \frac{\text{Workdone by the machine}}{\text{Workdone on the machine}} = \frac{W \times x}{P \times y} = \frac{W}{P} \times \frac{1}{y/x} = \frac{M.A.}{V.R.}$$

6. *Ideal machine.* If the efficiency of the machine is 100 %, *i.e* if output is equal to input, then the machine is said to be a perfect or ideal machine.
7. *Reversible machine.* If a machine is capable of doing some work in the reversed direction, after the effort is removed, then the machine is known as reversible machine. The condition for a machine to be reversible is that its efficiency should be more than 50 %.
8. *Non- reversible or self locking machine.* If a machine is not capable of doing some work in the reversed direction, after the effort is removed, then the machine is known as non-reversible or self locking machine. The condition for a machine to be non-reversible or self locking is that its efficiency should be less than 50 %.
9. *Law of the machine.* It is the relationship between the load lifted (W) and the effort applied (P). It is given by the equation,

$$P = m . W + C$$

where

m = A constant (called coefficient of friction) which is equal to the slope of the line AB as shown in Fig. 1.23, and

C = Another constant, which represents the machine friction.

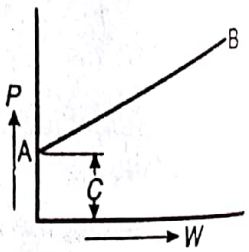

Fig. 1.23

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10. *Maximum mechanical advantage.* The maximum mechanical advantage of a lifting machine is given by

$$\text{Max. } M.A. = 1/m$$

11. *Maximum efficiency.* The maximum efficiency of a lifting machine is given by

$$\text{Max. } \eta = \frac{1}{m \times V.R.}$$

.25 Systems of Pulleys

The following three systems of pulleys are commonly used :

1. *First system of pulleys.* For such a system, velocity ratio, $(V.R.) = 2^n$

where n = Number of pulleys

2. *Second system of pulleys.* For this system, velocity ratio, $(V.R.) = n$

3. *Third system of pulleys.* For such a system, velocity ratio, $(V.R.) = 2^n - 1$

.26 Frame

A frame may be defined as a structure, made up of several bars, riveted or welded together. These are made up of angle irons or channel sections and are called members of the frame or framed structure. The frames may be classified into the following two groups:

1. Perfect frame, and 2. Imperfect frame.

A *perfect frame* is that which is composed of members just sufficient to keep it in equlibrium, when loaded, without any change in its shape. A perfect frame should satisfy the following expression:

$$n = 2j - 3$$

where n = Number of members, and

j = Number of joints.

An *imperfect frame* is one which does not satisfy the above equation $(n = 2j - 3)$. The imperfect frame which has number of members (n) less than $2j - 3$, is known as *deficient frame.* If the number of members are greater than $2j - 3$, then the imperfect frame is known *redundant frame.*

1.27 Speed

It is the rate of change of displacement with respect to its surrounding. Since the speed of a body is irrespective of its direction, therefore it is a scalar quantity.

1.28 Velocity

It is also the rate of change of displacement with respect to its surrounding, in a particular direction. Since the velocity is always expressed in a particular direction, therefore it is a vector quantity.

1.29 Acceleration

It is the rate of change of velocity of a body. It is said to be positive, when the velocity of a body increases with time and it is negative when the velocity decreases with time. The negative acceleration is also called *retardation.*

1.30 Equations of Linear Motion

The following are the equations of linear motion :

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1. $v = u + a.t$

2. $s = u.t + \frac{1}{2} a.t^2$

3. $v^2 = u^2 + 2\,a.s$, and

4. $s = \frac{(u+v)\,t}{2}$

where u = Initial velocity,
v = Final velocity,
a = Acceleration, and
s = Displacement of the body in time t seconds.

Notes: 1. The above equations apply for uniform acceleration.

2. In case of vertical motion, the body is subjected to gravity. Thus the acceleration due to gravity (g) should be substituted in place of a, in the above equations.

3. The value of g is taken as $+ 9.81$ m / s^2 for downward motion, and $- 9.81$ m / s^2 for upward motion.

4. When a body falls from a height h, its velocity v with which it will hit the ground, is given by

$$v = \sqrt{2g.h}$$

1.31 Newton's Laws of Motion

Following are the Newton's three laws of motion:

1. *Newton's first law of motion.* It states that *everybody continues in the state of rest or of uniform motion, in a straight line, unless it is acted upon by some external force.*

2. *Newton's second law of motion.* It states that *the rate of change of momentum is directly propotional to the impressed force, and takes place in the same direction, in which the force acts.*

3. *Newton's third law of motion.* It states that *to every action, there is always an equal and opposite reaction.*

1.32 Mass, Weight and Momentum

The *mass* is a matter contained in a body. It is expressed in kilogram (kg).

The *weight* of a body is a force by which it is attracted towards the centre of the earth. It is expressed in newtons (N). The relation between the mass and weight of a body is given by

$$W = m.g$$

The *momentum* is defined as the total motion possessed by a body. Mathematically,

Momentum = Mass × Velocity

According to Newton's second law of motion, the applied force or impressed force (P) is directly propotional to rate of change of momentum. Thus

$$P \propto m\left(\frac{v-u}{t}\right) \quad \text{or} \quad P \propto m.a \quad \text{or} \quad P = k.m.a$$

where k is a constant of proportionality.

For the sake of convenience, the unit of force adopted is such that it produces unit accelerati (*i.e.* 1 m / s^2) to a body of unit mass (*i.e.* 1 kg).

$$\therefore \quad P = m.a = \text{Mass} \times \text{Accelration}$$

In S.I system of units, the unit of force is newton (briefly written as N). A newton may defined as the force, while acting upon a body of mass 1 kg, produces an acceleration of 1m / s^2 in direction of which it acts. Thus

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$$1\text{N} = 1\text{ kg} \times 1\text{ m/s}^2 = 1\text{ kg-m/s}^2$$

Note : A force equal in magnitude but opposite in direction and collinear with the applied force or impressed force producing the acceleration, is known as *inertia force*. Mathematically, inertia force,

$$F_I = -m.a$$

1.33 D- Alembert's Principle

Consider a rigid body acted upon by a system of forces. The system may be reduced to a single resultant force (P) acting on the body whose magnitude is given by the product of the mass of the body (m) and the linear acceleration (a) of the centre of mass of the body. According to Newton's second law of motion,

$$P = m.a \quad \text{or} \quad P - m.a = 0 \quad \text{or} \quad P + F_I = 0$$

Thus D-Alembert's principle states that *the resultant force acting on the body together with the reversed effective force or inertia force are in equilibrium.*

1.34 Motion of a Lift

Consider a lift (elevator or cage) carrying some mass and moving with uniform acceleration.

Let m = Mass carried by the lift in kg,

a = Uniform acceleration of the lift in m/s^2, and

R = Reaction of the lift or tension in the cable supporting the lift in newtons.

When the lift is moving upwards as shown in Fig. 1.24 (a), then

$$R - m.g = m.a \quad \text{or} \quad R = m.g + m.a = m\,(g + a)$$

When the lift is moving downwards as shown in Fig. 1.24 (b), then

$$m.g - R = m.a \quad \text{or} \quad R = m.g - m.a = m\,(g - a)$$

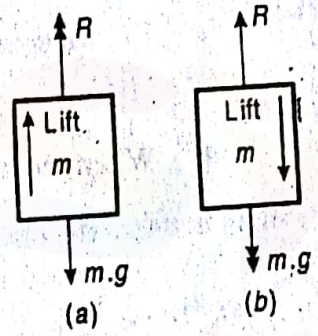

Fig. 1.24

1.35 Motion of Two Bodies Connected by a String

Consider a light inextensible string passing over a smooth pulley, as shown in Fig. 1.25, so that the tension (T) in both the strings is same. Let mass m_1 is greater than mass m_2. Since the string is inextensible, the upward acceleration of mass m_2 will be equal to the downward acceleration of mass m_1. This acceleration is given by

$$a = \frac{g\,(m_1 - m_2)}{m_1 + m_2} \text{ m/s}^2$$

and tension in the string,

$$T = \frac{2m_1.m_2.g}{m_1 + m_2} \text{ N}$$

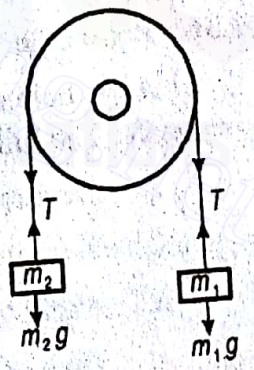

Fig. 1.25

Let us now consider the following cases of motion of two bodies connected by a string.

1. First of all, let us consider the motion of two bodies connected by an inextensible string, one of which is hanging freely and the other is lying on a smooth horizontal plane as shown in Fig. 1.26. Since the string is inextensible, the tension (T) in both the strings will be equal. The acceleration of the system is given by

$$a = \frac{m_1.g}{m_1 + m_2} \text{ m/s}^2$$

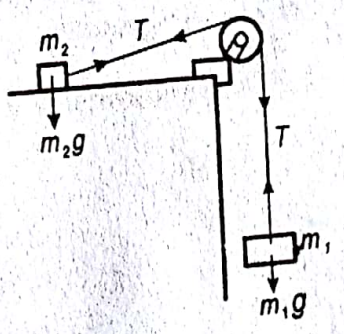

Fig. 1.26

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and $$T = m_2 . a = \frac{m_1 . m_2 . g}{m_1 + m_2} \text{ N}$$

2. If instead of smooth plane, it is a rough horizontal plane, as shown in Fig. 1.27, the frictional force equal to $\mu . R_N = \mu . m_2 . g$, will act in the opposite direction to the motion of mass m_2 where μ is the coefficient of friction. In such a case,

$$a = \frac{g(m_1 - \mu . m_2)}{m_1 + m_2} \text{ m/s}^2$$

and $$T = \frac{m_1 . m_2 . g(1 + \mu)}{m_1 + m_2} \text{ N}$$

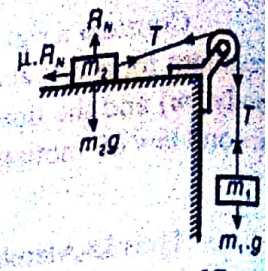

Fig. 1.27

3. When the plane is a smooth inclined plane, as shown in Fig. 1.28, then

$$a = \frac{g(m_1 - m_2 \sin\alpha)}{m_1 + m_2} \text{ m/s}^2$$

and $$T = \frac{m_1 . m_2 . g(1 + \sin\alpha)}{m_1 + m_2} \text{ N}$$

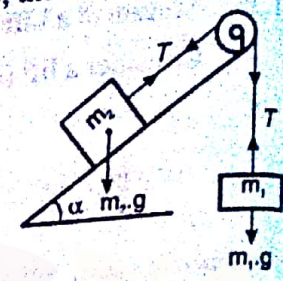

Fig. 1.28

4. When the plane is a rough inclined plane, as shown in Fig. 1.29, then

$$a = \frac{g(m_1 - m_2 \sin\alpha - \mu . m_2 \cos\alpha)}{m_1 + m_2} \text{ m/s}^2$$

and $$T = \frac{m_1 . m_2 . g(1 + \sin\alpha + \mu\cos\alpha)}{m_1 + m_2} \text{ N}$$

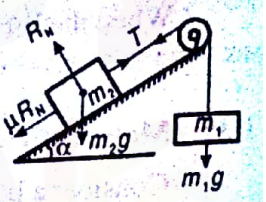

Fig. 1.29

1.36 Projectile

A particle moving under the combined effect of vertical and horizontal forces, is called a *projectile*. The following terms are commonly used in projectiles:

1. *Trajectory.* It is the path traced by a projectile in the space.
2. *Velocity of projection.* It is the velocity with which a projectile is projected.
3. *Angle of projection.* It is the angle, with the horizontal, at which the projectile is projected.
4. *Time of flight.* It is the total time taken by a projectile, to reach maximum height and to return back to the ground.
5. *Range.* It is the distance between the point of projection and the point where the projectile strikes the ground.

1.37 Equation of the Path of a Projectile

Let O = Point of projection,

u = Velocity of projection, and

α = Angle of projection with the horizontal.

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Consider a point P as the position of particle, after time t seconds with x and y as co-ordinates, as shown in Fig. 1.30.

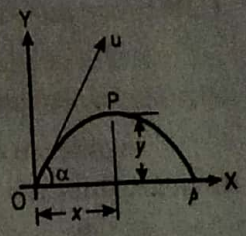

Fig. 1.30

The equation of the path of a projectile or the equation of trajectory is given by

$$y = x \tan \alpha - \frac{g.x^2}{2u^2 \cos^2 \alpha}$$

Since this is the equation of a parabola, therefore the path traced by a projectile is a parabola. The following are the important equations used in projectiles:

1. The time of flight (t) of a projectile on a horizontal plane is given by

$$t = \frac{2u \sin \alpha}{g}$$

2. The horizontal range (R) of a projectile is given by

$$R = \frac{u^2 \sin 2\alpha}{g}$$

For a given velocity of projectile, the range will be maximum when $\sin 2\alpha = 1$ or $\alpha = 45°$.

3. The maximum height (H) of a projectile on a horizontal plane is given by

$$H = \frac{u^2 \sin^2 \alpha}{2g}$$

4. The time of flight of a projectile when it is projected from O on an upward inclined plane as shown in Fig. 1.31, is given by

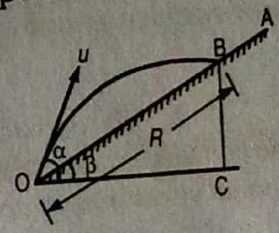

Fig. 1.31

$$t = \frac{2u \sin (\alpha - \beta)}{g \cos \beta}$$

where β is the inclination of plane OA with the horizontal.

When the projectile is projected on a downward inclined plane, then

$$t = \frac{2u \sin (\alpha + \beta)}{g \cos \beta}$$

5. The range of projectile when it is projected from O to B on an upward inclined plane, as shown in Fig. 1.31, is given by

$$R = OB = \frac{2u^2 \sin (\alpha - \beta) \cos \alpha}{g \cos^2 \beta} = \frac{u^2}{g \cos^2 \beta} [\sin (2\alpha - \beta) - \sin \beta]$$

For a given velocity of projectile, the range will be maximum when,

$$\alpha = 45° + \frac{\beta}{2} = \frac{\pi}{4} + \frac{\beta}{2}$$

When the projectile is projected on a downward inclined plane, then

$$R = \frac{2u^2 \sin (\alpha + \beta) \cos \alpha}{g \cos^2 \beta}$$

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1.38 Angular Displacement

It is the angle described by a particle from one point to another, with respect to time. Since th angular displacement has both magnitude and direction, therefore it is a vector quantity.

In order to completely represent an angular displacement by a vector, it must fix the followi three conditions :

1. Direction of the axis of rotation,
2. Magnitude of angular displacement, and
3. Sense of the angular displacement.

1.39 Angular Velocity

It is the rate of change of angular displacement of a body. It is usually expressed in revolutio per minute (r.p.m.) or radians per second (rad / s). It is denoted by a Greek letter ω (omega). Since it h magnitude and direction, therefore it is a vector quantity.

If a body is rotating at N r.p.m, then corresponding angular velocity,

$$\omega = \frac{2\pi N}{60} \text{ rad / s}$$

Note: If the body is rotating at ω rad / s along a circular path of radius r, then its linear velocity (v) is given

$$v = \omega . r$$

1.40 Angular Acceleration

It is the rate of change of angular velocity. It is usually expressed in rad / s^2 and is denoted a Greek letter α (alpha). It is also a vector quantity.

Notes : 1. If the body is moving along a circular path of radius r and with angular acceleration α, then its line acceleration is given by

$$a = \alpha \times r$$

2. *When a body moves along a circular path, its linear acceleration will have two components; one* the normal component and other is tangential component. The normal component of the acceleration is known *normal or centripetal acceleration* (a_c). Its value is given by

$$a_c = \frac{v^2}{r} = \omega^2 . r$$

3. When the body moves along a circular path with uniform velocity, then there will be no tangenti acceleration, but it will have only centripetal acceleration.

4. When the body moves along a straight path, then there will be no centripetal acceleration, but it w have only tangential acceleration, in the same direction as its velocity and displacement.

1.41 Simple Harmonic Motion

A body is said to move or vibrate with simple harmonic motion (briefly written as S.H.M.), if satisfies the following two conditions:

1. Its acceleration is always directed towards the centre known as point of reference or mean position, and
2. Its acceleration is proportional to the distance from that point.

The following terms are commonly used in simple harmonic motion :

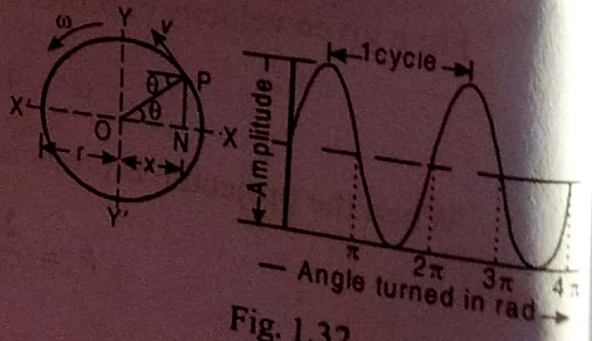

Fig. 1.32

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1. *Amplitude.* It is the maximum displacement of a body from its mean position. In Fig. 1.32, OX and OX' is the amplitude of particle P. The amplitude is always equal to the radius of the circle.

2. *Periodic time.* It is the time taken for one complete revolution of the particle. Mathematically,

$$\text{Periodic time, } t_p = \frac{2\pi}{\omega} \text{ seconds}$$

3. *Frequency.* It is the number of cycles per second and it is the reciprocal of time period (t_p). Mathematically,

$$\text{Frequency, } n = \frac{1}{t_p} = \frac{\omega}{2\pi} \text{ Hz}$$

Note : In S.I. units, the unit of frequency is hertz (briefly written as Hz) which is equal to one cycle per second.

1.42 Velocity and Acceleration of a Particle Moving with Simple Harmonic Motion

Consider a particle, moving round the circumference of a circle of radius r, with a uniform angular velocity ω rad / s, as shown in Fig. 1.32. Let P be any position of the particle after t seconds and θ be the angle turned by the particle in t seconds. We know that

$$\theta = \omega.t, \text{ and } \quad x = r\cos\theta = r\cos\omega t$$

The velocity of N (which is the projection of P on XX') is the component of the velocity of P parallel to XX'.

$$\therefore \quad v_N = v \sin\theta = \omega.r \sin\theta$$
$$= \omega\sqrt{r^2 - x^2} \qquad \ldots(\because r\sin\theta = NP = \sqrt{r^2 - x^2})$$

The velocity is maximum, when $x = 0$, *i.e.* when N passes through O (*i.e.* mean position).

$$\therefore \quad v_{max} = \omega.r$$

The acceleration of N is the component of the acceleration of P parallel to XX' and is directed towards the centre O.

$$\therefore \quad a_N = \omega^2.r\cos\theta = \omega^2.x$$

The acceleration is maximum, when $x = r$, *i.e.* when P is at X or X'.

$$\therefore \quad a_{max} = \omega^2.r$$

1.43 Simple Pendulum

A simple pendulum, in its simplest form, consists of a heavy bob suspended at the end of a light inextensible and flexible string as shown in Fig. 1.33. The other end of the string is fixed at O. When the bob is at A, it is in equilibrium or mean position. It may be noted that when the angle θ (through which the string is displaced) is less than 4°, then the bob will oscillate between B and C with simple harmonic motion.

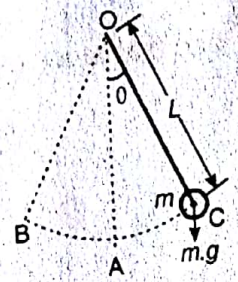

Fig. 1.33

For a simple pendulum, periodic time,

$$t_p = 2\pi\sqrt{\frac{L}{g}}$$

and frequency of oscillation,

$$n = \frac{1}{t_p} = \frac{1}{2\pi}\sqrt{\frac{g}{L}}$$

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Notes : 1. The motion of the bob from one extremity to the other (*i.e.* from *B* to *C* or *C* to *B*) is known as *beat* or *swing*. Thus one beat = 1/2 oscillation, and periodic time for one beat,

$$t_p = \pi\sqrt{\frac{L}{g}}$$

2. A pendulum, which executes one beat per second (*i.e.* one complete oscillation in two seconds) is known as *second's pendulum*.

1.44 Closely Coiled Helical Spring

Consider a closely coiled helical spring whose one end is fixed and the other end carries a load $W = m.g$, as shown in Fig. 1.34. Let AA be the equilibrium position of the spring after the load is attached. If the spring is streched upto BB and then released, the load will move up and down with simple harmonic motion.

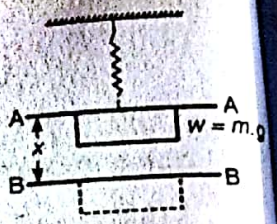

Fig. 1.34

For a closely coiled helical spring, periodic time,

$$t_p = 2\pi\sqrt{\frac{m}{s}} = 2\pi\sqrt{\frac{\delta}{g}} \text{ second} \quad \ldots\left(\because \delta = \frac{m.g}{s}\right)$$

and frequency of oscillation,

$$n = \frac{1}{t_p} = \frac{1}{2\pi}\sqrt{\frac{s}{m}} = \frac{1}{2\pi}\sqrt{\frac{g}{\delta}} \text{ Hz}$$

where s = Stiffness of the spring, and

δ = Deflection of the spring.

If the mass of the spring (m_1) is also taken into consideration, then frequency of oscillation,

$$n = \frac{1}{2\pi}\sqrt{\frac{s}{m + \frac{m_1}{3}}}$$

1.45 Compound Pendulum

When a rigid body is suspended vertically and it oscillates with a small amplitude under the action of force of gravity, the body is known as compound pendulum, as shown in Fig. 1.35.

For a compound pendulum, the periodic time is given by

$$t_p = 2\pi\sqrt{\frac{(k_G)^2 + h^2}{g.h}}$$

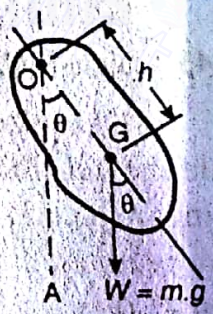

Fig. 1.35

and frequency of oscillation,

$$n = \frac{1}{t_p} = \frac{1}{2\pi}\sqrt{\frac{g.h}{(k_G)^2 + h^2}}$$

where k_G = Radius of gyration about an axis through the centre of gravity and perpendicular to the plane of motion, and

h = Distance of point of suspension O from the centre of gravity

Notes : 1. The equivalent length of a simple pendulum (L) which gives the same frequency as that of compou pendulum is given by

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$$L = \frac{(k_G)^2 + h^2}{h}$$

2. The periodic time of compound pendulum is minimum when the distance between the point of suspension and the centre of gravity (*i.e.* h) is equal to the radius of gyration of the body about its centre of gravity (*i.e.* k_G).

∴ Minimum periodic time of a compound pendulum,

$$t_{p\ (min)} = 2\pi\sqrt{\frac{2k_G}{g}}$$

1.46 Centre of Percussion

Sometimes, the centre of oscillation is termed as *centre of percussion*. It is defined as that point at which a blow may be struck on a suspended body so that the reaction at the support is zero. It may be noted that

1. The centre of percussion (C) is below the centre of gravity (G), as shown in Fig. 1.36, and at a distance of

$$l = \frac{(k_G)^2}{h}$$

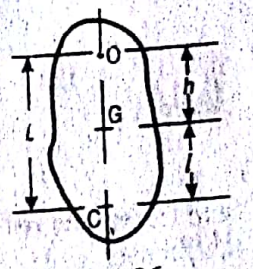

Fig. 1.36

2. The distance between the centre of suspension (O) and the centre of percussion (C) is equal to the equivalent length of simple pendulum, *i.e.*

$$L = l + h$$

3. The centre of suspension (O) and the centre of percussion (C) are inter-changeable.

1.47 Torsional Pendulum

It is used to find the moment of inertia of a body experimentally. The body (say a disc or flywheel) whose moment of inertia is to be determined is suspended by three long flexible wires A, B and C as shown in Fig. 1.37. When the body is twisted about its axis through a small angle θ and then released, it will oscillate with simple harmonic motion.

For a torsional pendulum, the periodic time is given by

$$t_p = \frac{2\pi k}{r}\sqrt{\frac{l}{g}}$$

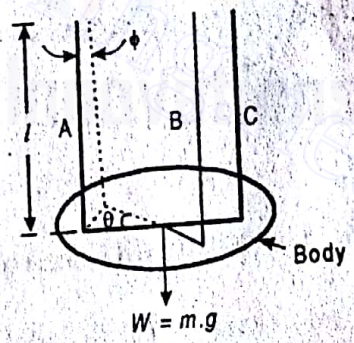

Fig. 1.37

and frequency of oscillation,

$$n = \frac{1}{t_p} = \frac{r}{2\pi k}\sqrt{\frac{g}{l}}$$

where r = Distance of each wire from the axis of the body,

k = Radius of gyration, and

l = Length of each wire.

1.48 Centripetal and Centrifugal Force

When a body of mass m kg is moving with angular velocity ω rad / s, in a circular path of radius r, then centripetal force,

$$F_c = m.\omega^2.r$$

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This force acts radially inwards and is essential for circular motion. According to Newt third law of motion, the body must exert a force radially outwards of equal magnitude. This forc known as centrifugal force, whose magnitude is given by

$$F_c = m.\omega^2.r$$

1.49 Superelevation

Whenever a roadway (or railway) is laid on a curved path, then its outer edge is always m higher than the inner edge, to keep the vehicle in equilibrium while in motion. The amount by wh the outer edge is raised, is known as *cant* or *superelevation*. In case of roadways, the proces providing superelevation is known as banking of the road. The general practice, to define superelevation in roadways, is to mention the angle of inclination (also called angle of banking) of road surface, such that

$$\tan \theta = \frac{v^2}{g.r}$$

where v = Velocity of the vehicle, and

r = Radius of circular path.

In case of railways, the general practice to define the superelevation, is to mention difference of levels between the two rails. In such a case, superelevation is given by

$$S = \frac{G.v^2}{g.r}$$

where G = Gauge of the track.

Notes : 1. When a vehicle is moving on a level circular path, then the maximum velocity of the vehicle, in or to avoid overturning is given by

$$v_{max} = \sqrt{\frac{g.r.a}{h}}$$

and in order to avoid skidding,

$$v_{max} = \sqrt{\mu.g.r}$$

where h = Height of C.G. of the vehicle from the ground level,

$2a$ = Distance between the outer and inner wheel, and

μ = Coefficient of friction between the wheels of the vehicle and the grou

2. When a vehicle moves on a level circular path, the reaction at the inner wheel

$$= \frac{m.g}{2}\left(1 - \frac{v^2.h}{g.r.a}\right)$$

and reaction at the outer wheel

$$= \frac{m.g}{2}\left(1 + \frac{v^2.h}{g.r.a}\right)$$

where m = Mass of the vehicle in kg.

1.50 Collision of Two Bodies

Consider the impact between two bodies which move with different velocities along the sam straight line. It is assumed that the point of impact lies on the line joining the centres of gravity of th

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two bodies. The behaviour of these colliding bodies during the complete period of impact will depend upon the properties of the materials of which they are made. The material of the two bodies may be perfectly elastic or perfectly inelastic.

The bodies which rebound after impact are called *elastic bodies* and the bodies which does not rebound at all after its impact are called *inelastic bodies*. The impact between two lead spheres or two clay spheres is approximately an inelastic impact.

The loss of kinetic energy (E_L) during impact of inelastic bodies is given by

$$E_L = \frac{m_1 . m_2}{2(m_1 + m_2)} (u_1 - u_2)^2$$

where m_1 = Mass of the first body,

m_2 = Mass of the second body,

u_1 and u_2 = Velocities of the first and second bodies respectively.

The loss of kinetic energy (E_L) during impact of elastic bodies is given by

$$E_L = \frac{m_1 . m_2}{2(m_1 + m_2)} (u_1 - u_2)^2 (1 - e^2)$$

where e = Coefficient of restitution.

$$= \frac{\text{Relative velocity after impact}}{\text{Relative velocity before impact}} = \frac{v_2 - v_1}{u_1 - u_2}$$

Notes : 1. The relative velocity of two bodies after impact is always less than the relative velocity before impact.

2. The value of $e = 0$, for perfectly inelastic bodies and $e = 1$, for perfectly elastic bodies. In case the bodies are neither perfectly inelastic nor perfectly elastic, then the value of e lies between zero and one.

1.51 Work

Whenever a force (F) acts on a body and the body undergoes a displacement (x) in the direction of the force, then the work is said to be done. Mathematically,

$$\text{Workdone} = F \times x$$

If the force varies from 0 to a maximum value of F, then

$$\text{Work done} = \frac{0 + F}{2} \times x = \frac{F}{2} \times x$$

The unit of work depends upon the unit of force and the displacement. In S.I. system of units, the practical unit of work is N-m. It is the work done by a force of 1 newton when it displaces a body through 1 metre. The work of 1 N-m is known as joule (briefly written as J), such that 1 N-m = 1 J.

Note : If a couple or torque (T) acting on a body causes the angular displacement (θ) about an axis perpendicular to the plane of the couple, then,

$$\text{Workdone} = T . \theta$$

1.52 Power

It is the rate of doing work or workdone per unit time. In S.I. system of units, the unit of power is watt (briefly written as W) which is equal to 1N-m / s or 1J / s. Generally a bigger unit of power called kilowatt (briefly written as kW) is used which is equal to 1000 W.

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Note : If T is the torque transmitted in N-m or J and ω is the angular speed in rad / s, then

$$\text{Power} = T.\omega = T \times \frac{2\pi N}{60} \text{ watts}$$

where N = Speed in r.p.m.

1.53 Energy

It is the capacity of doing work. The mechanical energy is equal to the workdone on a body in altering either its position or its velocity. Following are the three types of mechanical energies :

1. *Potential energy.* It is the energy possessed by a body for doing work, by virtue of its position.

Let m = Mass of the body,

W = Weight of the body = $m.g$, and

h = Distance through which the body falls.

$\therefore$ Potential energy = $W.h = m.g.h$

2. *Strain energy.* It is the potential energy stored by an elastic body when deformed. A compressed spring posseses this type of energy, because it can do some work in recovering its original shape. Thus if a compressed spring of stiffness s newton per unit extension or compression, is deformed through a distance x by a load W, then

$$\text{Strain energy} = \text{Workdone} = \frac{1}{2} W \times x = \frac{1}{2} s.x^2 \quad \ldots(\because W = s \times x)$$

3. *Kinetic energy.* It is the energy possessed by a body, for doing work, by virtue of its mass (m) and velocity of motion (v). Mathematically, kinetic energy of the body or kinetic energy of translation.'

$$= \frac{1}{2} m.v^2$$

Notes: 1. When a body of mass moment of inertia (I) about a given axis is rotated about that axis with an angular velocity ω, then it possesses some kinetic energy. In this case,

$$\text{Kinetic energy of rotation} = \frac{1}{2} I.\omega^2$$

2. When the body has both linear and angular motions *e.g.* in the locomotive driving wheels and wheels of a moving car, then total kinetic energy of the body

$$= \frac{1}{2} m.v^2 + \frac{1}{2} I.\omega^2$$

OBJECTIVE TYPE QUESTIONS

1. The term 'force' may be defined as an agent which produces or tends to produce, destroys or tends to destrdy motion.

(*a*) Agree (*b*) Disagree

2. A force while acting on a body may

(*a*) change its motion (*b*) balance the forces, already acting on it

(*c*) give rise to the internal stresses in it (*d*) all of these

3. In order to determine the effects of a force, acting on a body, we must know

(*a*) magnitude of the force (*b*) line of action of the force

(*c*) nature of the force *i.e.* whether the force is push or pull

(*d*) all of the above

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4. The unit of force in S.I. system of units is
(a) dyne (b) kilogram (c) newton (d) watt

5. One kg force is equal to
(a) 7.8 N (b) 8.9 N (c) 9.8 N (d) 12 N

6. A resultant force is a single force which produces the same effect as produced by all the given forces acting on a body.
(a) True (b) False

7. The process of finding out the resultant force is called..... of forces.
(a) composition (b) resolution

8. The algebraic sum of the resolved parts of a number of forces in a given direction is equal to the resolved part of their resultant in the same direction. This is known as
(a) principle of independence of forces (b) principle of resolution of forces
(c) principle of transmissibility of forces (d) none of these

9. Vectors method for the resultant force is also called polygon law of forces.
(a) Correct (b) Incorrect

10. The resultant of two forces P and Q acting at an angle θ is
(a) $\sqrt{P^2 + Q^2 + 2PQ \sin\theta}$ (b) $\sqrt{P^2 + Q^2 + 2PQ \cos\theta}$
(c) $\sqrt{P^2 + Q^2 - 2PQ \cos\theta}$ (d) $\sqrt{P^2 + Q^2 - 2PQ \tan\theta}$

11. If the resultant of two forces P and Q acting at an angle θ, makes an angle α with the force P, then
(a) $\tan\alpha = \dfrac{P \sin\theta}{P + Q\cos\theta}$ (b) $\tan\alpha = \dfrac{P \cos\theta}{P + Q\cos\theta}$
(c) $\tan\alpha = \dfrac{Q \sin\theta}{P + Q\cos\theta}$ (d) $\tan\alpha = \dfrac{Q \cos\theta}{P + Q\sin\theta}$

12. The resultant of two forces P and Q (such that $P > Q$) acting along the same straight line, but in opposite direction, is given by
(a) $P + Q$ (b) $P - Q$ (c) P/Q (d) Q/P

13. The resultant of two equal forces P making an angle θ, is given by
(a) $2P \sin\theta/2$ (b) $2P \cos\theta/2$ (c) $2P \tan\theta/2$ (d) $2P \cot\theta/2$

14. The resultant of two forces each equal to P and acting at right angles is
(a) $P/\sqrt{2}$ (b) $P/2$ (c) $P/2\sqrt{2}$ (d) $\sqrt{2}P$

15. The angle between two forces when the resultant is maximum and minimum respectively are
(a) 0° and 180° (b) 180° and 0° (c) 90° and 180° (d) 90° and 0°

16. If the resultant of two equal forces has the same magnitude as either of the forces, then the angle between the two forces is
(b) 60° (c) 90° (d) 120°

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17. The resultant of the two forces P and Q is R. If Q is doubled, the new resultant is perpendicular to P. Then

(*a*) $P = Q$ (*b*) $Q = R$ (*c*) $Q = 2R$ (*d*) none of these

18. Two forces are acting at an angle of 120°. The bigger force is 40N and the resultant is perpendicular to the smaller one. The smaller force is

(*a*) 20N (*b*) 40N (*c*) 80N (*d*) none of these

19. The terms 'leverage' and 'mechanical advantage' of a compound lever have got the same meaning.

(*a*) Right (*b*) Wrong

20. A number of forces acting at a point will be in equilibrium, if

(*a*) all the forces are equally inclined

(*b*) sum of all the forces is zero

(*c*) sum of resolved parts in the vertical direction is zero (*i.e.* $\Sigma V = 0$)

(*d*) sum of resolved parts in the horizontal direction is zero (*i.e.* $\Sigma H = 0$)

21. If a number of forces are acting at a point, their resultant is given by

(*a*) $(\Sigma V)^2 + (\Sigma H)^2$ (*b*) $\sqrt{(\Sigma V)^2 + (\Sigma H)^2}$

(*c*) $(\Sigma V)^2 + (\Sigma H)^2 + 2(\Sigma V)(\Sigma H)$ (*d*) $\sqrt{(\Sigma V)^2 + (\Sigma H)^2 + 2(\Sigma V)(\Sigma H)}$

22. Fig. 1.38 shows the two equal forces at right angles acting at a point. The value of force R acting along their bisector and in opposite direction is

(*a*) $P/2$ (*b*) $2P$

(*c*) $\sqrt{2}P$ (*d*) $P/\sqrt{2}$

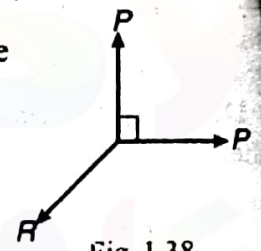

Fig. 1.38

23. If a number of forces are acting at a point, their resultant will be inclined at an angle θ with the horizontal, such that

(*a*) $\tan\theta = \Sigma H / \Sigma V$ (*b*) $\tan\theta = \Sigma V / \Sigma H$

(*c*) $\tan\theta = \Sigma V \times \Sigma H$ (*c*) $\tan\theta = \sqrt{\Sigma V + \Sigma H}$

24. The triangle law of forces states that if two forces acting simultaneously on a particle, be represented in magnitude and direction by the two sides of a triangle taken in order, then their resultant may be represented in magnitude and direction by the third side of a triangle, taken in opposite order.

(*a*) True (*b*) False

25. The polygon law of forces states that if a number of forces, acting simultaneously on a particle, be represented in magnitude and direction by the sides a polygon taken in order, then their resultant is represented in magnitude and direction by the closing side of the polygon, taken in opposite direction.

(*a*) Correct (*b*) Incorrect

26. Concurrent forces are those forces whose lines of action

(*a*) lie on the same line (*b*) meet at one point

(*c*) meet on the same plane (*d*) none of these

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27. If the resultant of a number of forces acting on a body is zero, then the body will not be in equilibrium.

(*a*) Yes (*b*) No

28. The forces, which meet at one point and their lines of action also lie on the same plane, are known as

(*a*) coplaner concurrent forces (*b*) coplaner non-concurrent forces

(*c*) non-coplaner concurrent forces (*d*) non-coplaner non-concurrent forces

29. The forces, which do not meet at one point, but their lines of action lie on the same plane, are known as coplaner concurrent forces.

(*a*) Agree (*b*) Disagree

30. The forces which meet at one point, but their lines of action ..... on the same plane, are known as non-coplaner concurrent forces.

(*a*) lie (*b*) do not lie

31. The forces which do not meet at one point and their lines of action do not lie on the same plane are known as

(*a*) coplaner concurrent forces (*b*) coplaner non-concurrent forces

(*c*) non-coplaner concurrent forces (*d*) none of these

32. Coplaner non-concurrent forces are those forces which ..... at one point, but their lines of action lie on the same plane.

(*a*) meet (*b*) do not meet

33. Coplaner concurrent forces are those forces which

(*a*) meet at one point, but their lines of action do not lie on the same plane

(*b*) do not meet at one point and their lines of action do not lie on the same plane

(*c*) meet at one point and their lines of action also lie on the same plane

(*d*) do not meet at one point, but their lines of action lie on the same plane

34. Non-coplaner concurrent forces are those forces which

(*a*) meet at one point, but their lines of action do not lie on the same plane

(*b*) do not meet at one point and their lines of action do not lie on the same plane

(*c*) meet at one point and their lines of action also lie on the same plane

(*d*) do not meet at one point, but their lines of action lie on the same plane

35. Non-coplaner non-concurrent forces are those forces which

(*a*) meet at one point, but their lines of action do not lie on the same plane

(*b*) do not meet at one point and their lines of action do not lie on the same plane

(*c*) do not meet at one point but their lines of action lie on the same plane

(*d*) none of the above

36. If three coplaner forces acting on a point are in equilibrium, then each force is proportional to the sine of the angle between the other two.

(*a*) Right (*b*) Wrong

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37. Fig. 1.39 shows the three coplaner forces P, Q and R acting at a point O. If these forces are in equilibrium, then

(*a*) $\frac{P}{\sin\beta} = \frac{Q}{\sin\alpha} = \frac{R}{\sin\gamma}$ (*b*) $\frac{P}{\sin\alpha} = \frac{Q}{\sin\beta} = \frac{R}{\sin\gamma}$

(*c*) $\frac{P}{\sin\gamma} = \frac{Q}{\sin\alpha} = \frac{R}{\sin\beta}$ (*d*) $\frac{P}{\sin\alpha} = \frac{Q}{\sin\gamma} = \frac{R}{\sin\beta}$

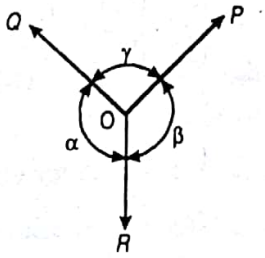

Fig. 1.39

38. According to lami's theorem

(*a*) the three forces must be equal

(*b*) the three forces must be at 120° to each other

(*c*) the three forces must be in equilibrium

(*d*) if the three forces acting at a point are in equilibrium, then each force is proportional to the sine of the angle between the other two

39. If a given force (or a given system of forces) acting on a body..... the position of the body, but keeps it in equilibrium, then its effect is to produce internal stress in the body.

(*a*) change (*b*) does not change

40. If three forces acting at a point are represented in magnitude and direction by the three sides of a triangle, taken in order, then the forces are in equilibrium.

(*a*) Yes (*b*) No

41. If a number of forces acting at a point be represented in magnitude and direction by the three sides of a triangle, taken in order, then the forces are not in equilibrium.

(*a*) Agree (*b*) Disagree

42. The moment of a force

(*a*) is the turning effect produced by a force, on the body, on which it acts

(*b*) is equal to the product of force acting on the body and the perpendicular distance of a point and the line of action of the force

(*c*) is equal to twice the area of the traingle, whose base is the line representing the force and whose vertex is the point, about which the moment is taken

(*d*) all of the above

43. The moment of the force P about O as shown in Fig. 1.40, is

(*a*) $P \times OA$ (*b*) $P \times OB$

(*c*) $P \times OC$ (*d*) $P \times AC$

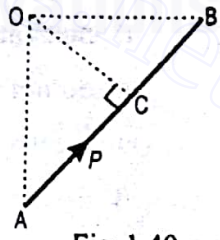

Fig. 1.40

44. If a number of coplaner forces acting at a point be in equilibrium, the sum of clockwise moments must be..... the sum of anticlockwise moments, about any point.

(*a*) equal to (*b*) less than (*c*) greater than

45. Varingon's theorem of moments states that if a number of coplaner forces acting on a particle re in equilibrium, then

(*a*) their algebraic sum is zero (*b*) their lines of action are at equal distances

(*c*) the algebraic sum of their moments about any point in their plane is zero

(*d*) the algebraic sum of their moments about any point is equal to the moment of their resultant force about the same point.

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46. According to the law of moments, if a number of coplaner forces acting on a particle are in equilibrium, then

(*a*) their algebraic sum is zero

(*b*) their lines of action are at equal distances

(*c*) the algebraic sum of their moments about any point in their plane is zero

(*d*) the algebraic sum of their moments about any point is equal to the moment of their resultant force about the same point.

47. For any system of coplaner forces, the condition of equilibrium is that the

(*a*) algebraic sum of the horizontal components of all the forces should be zero

(*b*) algebraic sum of the vertical components of all the forces should be zero

(*c*) algebraic sum of moments of all the forces about any point should be zero

(*d*) all of the above

48. The forces, whose lines of action are parallel to each other and act in the same directions, are known as

(*a*) coplaner concurrent forces (*b*) coplaner non-concurrent forces

(*c*) like parallel forces (*d*) unlike parallel forces

49. The three forces of 100 N, 200 N and 300 N have their lines of action parallel to each other but act in the opposite directions. These forces are known as

(*a*) coplaner concurrent forces (*b*) coplaner non-concurrent forces

(*c*) like parallel forces (*d*) unlike parallel forces

50. Two like parallel forces are acting at a distance of 24 mm apart and their resultant is 20 N. If the line of action of the resultant is 6 mm from any given force, the two forces are

(*a*) 15 N and 5 N (*b*) 20 N and 5 N (*c*) 15 N and 15 N (*d*) none of these

51. If a body is acted upon by a number of coplaner non-concurrent forces, it may

(*a*) rotate about itself without moving

(*b*) move in any one direction rotating about itself

(*c*) be completely at rest (*d*) all of these

52. A smooth cylinder lying on its convex surface remains in ..... equilibrium.

(*a*) stable (*b*) unstable (*c*) neutral

53. Three forces acting on a rigid body are represented in magnitude, direction and line of action by the three sides of a triangle taken in order. The forces are equivalent to a couple whose moment is equal to

(*a*) area of the triangle (*b*) twice the area of the triangle

(*c*) half the area of the triangle (*d*) none of these

54. The principle of transmissibility of forces states that, when a force acts upon a body, its effect is

(*a*) same at every point on its line of action

(*b*) different at different points on its line of action

(*c*) mini-num, if it acts at the centre of gravity of the body

(*d*) maximum, if it acts at the centre of gravity of the body

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55. A smooth cylinder lying on a ..... is in neutral equilibrium.

(*a*) curved surface (*b*) convex surface (*c*) horizontal surface

56. If three forces acting at a point be represented in magnitude and direction by the three sides of a triangle, taken in order, the forces shall be in equilibrium.

(*a*) True (*b*) False

57. Two equal and opposite parallel forces whose lines of action are different, can be replaced by a single force parallel to the given forces.

(*a*) Correct (*b*) Incorrect

58. Two equal and opposite parallel forces whose lines of action are different form a couple.

(*a*) Right (*b*) Wrong

59. A couple produces

(*a*) translatory motion (*b*) rotational motion

(*c*) combined translatory and rotational motion

(*d*) none of the above

60. Which of the following statement is correct?

(*a*) The algebraic sum of the forces, constituting the couple is zero.

(*b*) The algebraic sum of the forces, constituting the couple, about any point is the same.

(*c*) A couple cannot be balanced by a single force but can be balanced only by a couple of opposite sense.

(*d*) all of the above

61. Match the correct answer from *Group B* for the statements given in *Group A*.

Group A	*Group B*
(*a*) The resultant of two forces P and Q ($P > Q$) acting along the same straight line, but in opposite direction, is	(*A*) $P+Q$
(*b*) The resultant of two like parallel forces, P and Q, is	(*B*) $P-Q$
(*c*) The resultant of two equal forces P making an angle θ, is	(*C*) $\dfrac{Q\sin\theta}{P+Q\cos\theta}$
(*d*) The angle of inclination of the resultant of the two forces P and Q, with the force P, is	(*D*) $2P\cos\dfrac{\theta}{2}$

62. The force induced in the string AB due to the load W, as shown in Fig. 1.41, is

(*a*) $W\sin\theta$ (*b*) $W\cos\theta$

(*c*) $W\sec\theta$ (*d*) $W\operatorname{cosec}\theta$

63. The force induced in the string BC due to the load W as shown in Fig. 1.41, is

(*a*) $W\sin\theta$ (*b*) $W\cos\theta$

(*c*) $W\tan\theta$ (*d*) $W\cot\theta$

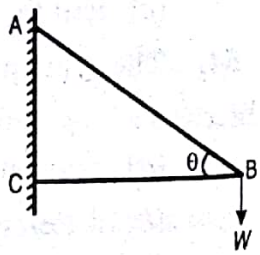

Fig. 1.41

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64. The point, through which the whole weight of the body acts, irrespective of its position, is known as

(*a*) moment of inertia (*b*) centre of gravity

(*c*) centre of percussion (*d*) centre of mass

65. The term 'centroid' is

(*a*) the same as centre of gravity

(*b*) the point of suspension

(*c*) the point of application of the resultant of all the forces tending to cause a body to rotate about a certain axis

(*d*) none of the above

66. An irregular body may have more than one centre of gravity.

(*a*) Yes (*b*) No

67. The centre of gravity of a rectangle lies at a point where its two diagonals meet each other.

(*a*) Agree (*b*) Disagree

68. The centre of gravity of a triangle lies at a point where its medians intersect each other.

(*a*) True (*b*) False

69. The centre of gravity of an isosceles triangle with base (p) and sides (q) from its base is

(*a*) $\frac{\sqrt{4p^2-q^2}}{6}$ (*b*) $\frac{4p^2-q^2}{6}$ (*c*) $\frac{p^2-q^2}{4}$ (*d*) $\frac{p^2+q^2}{4}$

70. The centre of gravity of an equilateral triangle with each side a, is.....from any of the three sides.

(*a*) $\sqrt{3}\,a/2$ (*b*) $2\sqrt{3}\,a$ (*c*) $a/2\sqrt{3}$ (*d*) $3\sqrt{2}\,a$

71. The centre of gravity of a semi-circle lies at a distance of.....from its base measured along the vertical radius.

(*a*) $3r/8$ (*b*) $4r/3\pi$ (*c*) $8r/3$ (*d*) $3r/4\pi$

72. The centre of gravity of a hemisphere lies at a distance of $3r/8$ from its base measured along the vertical radius.

(*a*) Right (*b*) Wrong

73. The centre of gravity of a trapezium with parallel sides a and b lies at a distance of y from the base b, as shown in Fig. 1.42. The value of y is

(*a*) $h\left(\frac{2a+b}{a+b}\right)$ (*b*) $\frac{h}{2}\left(\frac{2a+b}{a+b}\right)$

(*c*) $\frac{h}{3}\left(\frac{2a+b}{a+b}\right)$ (*d*) $\frac{h}{3}\left(\frac{a+b}{2a+b}\right)$

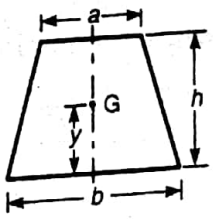

Fig. 1.42

74. The centre of gravity of a right circular solid cone is at a distance of.....from its base, measured along the vertical axis.

(*a*) $h/2$ (*b*) $h/3$ (*c*) $h/4$ (*d*) $h/6$

where h = Height of a right circular solid cone.

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75. The centre of gravity of a right angled triangle lies at its geometrical centre.

(*a*) Correct (*b*) Incorrect

76. Match the correct answer from *Group B* for the statements given in *Group A*.

Group A	*Group B*
(*a*) C.G. of a rectangle	(*A*) is at its centre
(*b*) C.G. of a triangle	(*B*) is at intersection of its diagonals
(*c*) C.G. of a circle	(*C*) is at $4r / 3\pi$ from its base along the vertical radius
(*d*) C.G. of a semicircle	(*D*) is at $h / 4$ from its base along the vertical axis
(*e*) C.G. of a hemisphere	(*E*) is at intersection of its medians
(*f*) C.G. of a right circular cone	(*F*) is at $3r / 8$ from its base along the vertical radius

77. The centre of gravity of a quadrant of a circle lies along its central radius (r) at a distance of

(*a*) $0.5r$ (*b*) $0.6r$ (*c*) $0.7r$ (*d*) $0.8r$

78. The centre of gravity a *T*-section 100 mm × 150 mm × 50 mm from its bottom is

(*a*) 50 mm (*b*) 75 mm (*c*) 87.5 mm (*d*) 125 mm

79. A circular hole of 50 mm diameter is cut out from a circular disc of 100 mm diameter as shown in Fig. 1.43. The centre of gravity of the section will lie

(*a*) in the shaded area (*b*) in the hole (*c*) at O

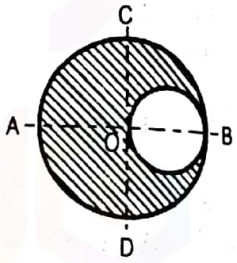

Fig. 1.43

80. Moment of inertia is the

(*a*) second moment of force (*b*) second moment of area

(*c*) second moment of mass (*d*) all of these

81. The unit of moment of inertia of an area is

(*a*) kg-m^2 (*b*) kg-m-s^2 (*c*) kg / m^2 (*d*) m^4

82. The unit of mass moment of inertia in S.I. units is kg - m^2.

(*a*) True (*b*) False

83. A spherical body is symmetrical about its perpendicular axis. According to Routh's rule, the moment of inertia of a body about an axis passing through its centre of gravity is

(*a*) $\frac{MS}{3}$ (*b*) $\frac{MS}{4}$ (*c*) $\frac{MS}{5}$ (*d*) none of these

where M = Mass of the body, and

S = Sum of the squares of the two semi-axes.

84. The radius of gyration is the distance where the whole mass (or area) of a body is assumed to be concentrated.

(*a*) Correct (*b*) Incorrect

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85. Mass moment of inertia of a uniform thin rod of mass M and length (l) about its mid-point and perpendicular to its length is

(a) $\frac{2}{3} Ml^2$ (b) $\frac{1}{3} M l^2$ (c) $\frac{3}{4} Ml^2$ (d) $\frac{4}{3} Ml^2$

86. Mass moment of inertia of a thin rod about its one end is.....the mass moment of inertia of the same rod about its mid-point

(a) same as (b) twice (c) thrice (d) four times

87. Moment of inertia of a rectangular section having width (b) and depth (d) about an axis passing through its C.G. and parallel to the width (b), is

(a) $\frac{db^3}{12}$ (b) $\frac{bd^3}{12}$ (c) $\frac{db^3}{36}$ (d) $\frac{bd^3}{36}$

88. Moment of inertia of a rectangular section having width (b) and depth (d) about an axis passing through its C.G. and parallel to the depth (d), is

(a) $\frac{db^3}{12}$ (b) $\frac{bd^3}{12}$ (c) $\frac{db^3}{36}$ (d) $\frac{bd^3}{36}$

89. The moment of inertia of a square of side (a) about an axis through its centre of gravity is

(a) $a^4/4$ (b) $a^4/8$ (c) $a^4/12$ (d) $a^4/36$

90. The moment of inertia of a rectangular section 3cm wide and 4cm deep about X–X axis is

(a) $9\,cm^4$ (b) $12\,cm^4$ (c) $16\,cm^4$ (d) $20\,cm^4$

91. The moment of inertia of a square of side a about its base is $a^4/3$.

(a) True (b) False

92. The moment of inertia of a square of side a about its diagonal is

(a) $a^2/8$ (b) $a^3/12$ (c) $a^4/12$ (d) $a^4/16$

93. Moment of inertia of a hollow rectangular section as shown in Fig. 1.44, about X-X axis, is

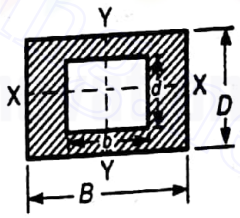

Fig. 1.44

(a) $\frac{BD^3}{12} - \frac{bd^3}{12}$ (b) $\frac{DB^3}{12} - \frac{db^3}{12}$

(c) $\frac{BD^3}{36} - \frac{bd^3}{36}$ (d) $\frac{DB^3}{36} - \frac{db^3}{36}$

94. Moment of inertia of a hollow rectangular section as shown Fig. 1.44, about Y-Y axis, is not the same as that about X-X axis.

(a) Yes (b) No

95. Moment of inertia of a circular section about its diameter (d) is

(a) $\pi d^3/16$ (b) $\pi d^3/32$ (c) $\pi d^4/32$ (d) $\pi d^4/64$

96. Moment of inertia of a circular section about an axis perpendicular to the section is

(a) $\pi d^3/16$ (b) $\pi d^3/32$ (c) $\pi d^4/32$ (d) $\pi d^4/64$

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97. Moment of inertia of a hollow circular section, as shown in Fig. 1.45, about X-X axis, is

(a) $\frac{\pi}{16}(D^2 - d^2)$ (b) $\frac{\pi}{16}(D^3 - d^3)$

(c) $\frac{\pi}{32}(D^4 - d^4)$ (d) $\frac{\pi}{64}(D^4 - d^4)$

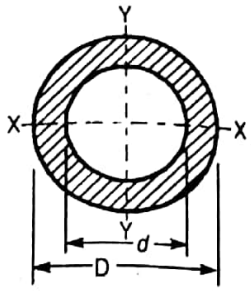

Fig. 1.45

98. Moment of inertia of a hollow circular section, as shown in Fig. 1.45, about an axis perpendicular to the section, is..... than that about X-X axis.

(a) two times (b) same (c) half

99. Moment of inertia of a triangular section of base (b) and height (h) about an axis passing through its C.G. and parallel to the base, is

(a) $bh^3/4$ (b) $bh^3/8$ (c) $bh^3/12$ (d) $bh^3/36$

100. Moment of inertia of a triangular section of base (b) and height (h) about an axis through its base, is

(a) $bh^3/4$ (b) $bh^3/8$ (c) $bh^3/12$ (d) $bh^3/36$

101. Moment of inertia of a triangular section of base (b) and height (h) about an axis passing through its vertex and parallel to the base, is.....than that passing through its C.G. and parallel to the base.

(a) nine times (b) six times (c) four times (d) two times

102. According to parallel axis theorem, the moment of inertia of a section about an axis parallel to the axis through centre of gravity (*i.e.* I_P) is given by

(a) $I_P = I_G + Ah^2$ (b) $I_P = I_G - Ah^2$ (c) $I_P = I_G / Ah^2$ (d) $I_P = \frac{Ah^2}{I_G}$

where A = Area of the section,

I_G = Moment of inertia of the section about an axis passing through its C.G., and

h = Distance between C.G. and the parallel axis.

103. The moment of inertia of a thin disc of mass m and radius r, about an axis through its centre of gravity and perpendicular to the plane of the disc is

(a) $mr^2/2$ (b) $mr^2/4$ (c) $mr^2/6$ (d) $mr^2/8$

104. The moment of inertia of a thin rod of mass m and length l, about an axis through its centre of gravity and perpendicular to its length is

(a) $ml^2/4$ (b) $ml^2/6$ (c) $ml^2/8$ (d) $ml^2/12$

105. The moment of inertia of a solid cylinder of mass m, radius r and length l about the longitudinal axis or polar axis is

(a) $mr^2/2$ (b) $mr^2/4$ (c) $mr^2/6$ (d) $mr^2/8$

106. The moment of inertia of a thin spherical shell of mass m and radius r, about its diameter is

(a) $mr^2/3$ (b) $2mr^2/3$ (c) $2mr^2/5$ (d) $3mr^2/5$

107. The moment of inertia of a sphere of mass m and radius r, about an axis tangential to it, is

(a) $2mr^2/3$ (b) $2mr^2/5$ (c) $7mr^2/3$ (d) $7mr^2/5$

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108. The moment of inertia of a solid sphere of mass m and radius r is

(*a*) $2mr^2/3$ (*b*) $2mr^2/5$ (*c*) mr^2 (*d*) $mr^2/2$

109. The moment of inertia of a solid cone of mass m and base radius r about its vertical axis is

(*a*) $3mr^2/5$ (*b*) $3mr^2/10$ (*c*) $2mr^2/5$ (*d*) $4mr^2/5$

110. A force acting in the opposite direction to the motion of the body is called force of friction.

(*a*) Agree (*b*) Disagree

111. The maximum frictional force, which comes into play, when a body just begins to slide over the surface of the other body, is known as

(*a*) static friction (*b*) dynamic friction

(*c*) limiting friction (*d*) coefficient of friction

112. The friction experienced by a body, when at rest, is known as

(*a*) static friction (*b*) dynamic friction

(*c*) limiting friction (*d*) coefficient of friction

113. The ratio of static friction to dynamic friction is always

(*a*) equal to one (*b*) less than one

(*c*) greater than one (*d*) none of these

114. The friction experienced by a body, when in motion, is known as

(*a*) rolling friction (*b*) dynamic friction

(*c*) limiting friction (*d*) static friction

115. The static friction

(*a*) bears a constant ratio to the normal reaction between the two surfaces

(*b*) is independent of the area of contact, between the two surfaces

(*c*) always acts in a direction, opposite to that in which the body tends to move

(*d*) all of the above

116. Static friction is always.....dynamic friction.

(*a*) equal to (*b*) less than (*c*) greater than

117. The angle of the inclined plane at which a body just begins to slide down the plane, is called helix angle.

(*a*) True (*b*) False

118. The angle which the normal reaction makes with the resultant reaction is called angle of friction.

(*a*) Agree (*b*) Disagree

119. The angle of inclination of the plane at which the body begins to move down the plane, is called

(*a*) angle of friction (*b*) angle of repose (*c*) angle of projection (*d*) none of these

120. The minimum force required to slide a body of weight W on a rough horizontal plane is

(*a*) $W \sin \theta$ (*b*) $W \cos \theta$ (*c*) $W \tan \theta$ (*d*) none of these

121. A body will begin to move down an inclined plane if the angle of inclination of the plane is.....the angle of friction.

(*a*) equal to (*b*) less than (*c*) greater than

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122. A body of weight W is required to move up on rough inclined plane whose angle of inclination with the horizontal is α. The effort applied parallel to the plane is given by

(*a*) $P = W \tan \alpha$ (*b*) $P = W \tan (\alpha + \phi)$

(*c*) $P = W (\sin \alpha + \mu \cos \alpha)$ (*d*) $P = W (\cos \alpha + \mu \sin \alpha)$

where $\mu = \tan \phi$ = Coefficient of friction between the plane and the body.

123. Coefficient of friction is the ratio of the limiting friction to the normal reaction between the two bodies.

(*a*) Yes (*b*) No

124. Coefficient of friction depends upon

(*a*) area of contact only (*b*) nature of surface only

(*c*) both (*a*) and (*b*) (*d*) none of these

125. The force required to move the body up the plane will be minimum if it makes an angle with the inclined plane..... the angle of friction.

(*a*) equal to (*b*) less than (*c*) greater than

126. A ladder is resting on a smooth ground and leaning against a rough vertical wall. The force of friction will act

(*a*) towards the wall at its upper and (*b*) away from the wall at its upper end

(*c*) downward at its upper end (*d*) upward at its upper end

127. A ladder is resting on a rough ground and leaning against a smooth vertical wall. The force of friction will act

(*a*) downward at its upper end (*b*) upward at its upper end

(*c*) zero at its upper end (*d*) perpendicular to the wall at its upper end

128. In a screw jack, the effort required to lift the load is given by

(*a*) $P = W \tan (\alpha - \phi)$ (*b*) $P = W \tan (\alpha + \phi)$

(*c*) $P = W \tan (\phi - \alpha)$ (*d*) $P = W \cos (\alpha + \phi)$

where W = Load lifted, α = Helix angle, and ϕ = Angle of friction.

129. In a screw jack, the effort required to lower the load is ..... the effort required to raise the same load.

(*a*) less than (*b*) equal to (*c*) more than

130. Efficiency of a screw jack is given by

(*a*) $\dfrac{\tan(\alpha+\phi)}{\tan\alpha}$ (*b*) $\dfrac{\tan\alpha}{\tan(\alpha+\phi)}$ (*c*) $\dfrac{\tan(\alpha-\phi)}{\tan\alpha}$ (*d*) $\dfrac{\tan\alpha}{\tan(\alpha-\phi)}$

where α = Helix angle, and ϕ = Angle of friction.

131. The efficiency of a screw jack is maximum, when

(*a*) $\alpha = 45° + \phi/2$ (*b*) $\alpha = 45° - \phi/2$ (*c*) $\alpha = 90° + \phi$ (*d*) $\alpha = 90° - \phi$

where α = Helix angle, and ϕ = Angle of friction.

132. The maximum efficiency of a screw jack is

(*a*) $\dfrac{1-\sin\phi}{1+\sin\phi}$ (*b*) $\dfrac{1+\sin\phi}{1-\sin\phi}$ (*c*) $\dfrac{1-\tan\phi}{1+\tan\phi}$ (*d*) $\dfrac{1+\tan\phi}{1-\tan\phi}$

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133. The velocity ratio in case of an inclined plane inclined at angle θ to the horizontal and weight being pulled up the inclined plane by vertical effort is

(*a*) sin θ (*b*) cos θ (*c*) tan θ (*d*) cosec θ

134. An ideal machine is one whose efficiency is

(*a*) between 60 and 70 % (*b*) between 70 and 80%

(*c*) between 80 and 90 % (*d*) 100 %

135. The mechanical advantage of a lifting machine is the ratio of

(*a*) distance moved by effort to the distance moved by load

(*b*) load lifted to the effort applied (*c*) output to the input

(*d*) all of the above

136. The efficiency of a lifting machine is the ratio of

(*a*) output to the input

(*b*) work done by the machine to the work done on the machine

(*c*) mechanical advantage to the velocity ratio

(*d*) all of the above

137. If the efficiency of a lifting machine is kept constant, its velocity ratio is.....propotional to its mechanical advantage.

(*a*) directly (*b*) inversely

138. In ideal machines, mechanical advantage is.....velocity ratio.

(*a*) equal to (*b*) less than (*c*) greater than

139. In actual machines, mechanical advantage is.....velocity ratio.

(*a*) equal to (*b*) less than (*c*) greater than

140. A lifting machine lifts a load of 1000N through a distance of 0.2 m by means of an effort of 200N through a distance of 1m. This machine is an ideal one.

(*a*) Right (*b*) Wrong

141. A machine having an efficiency less than 50%, is known as

(*a*) reversible machine (*b*) non-reversible machine

(*c*) neither reversible nor non-reversible machine

(*d*) ideal machine

142. A machine having an efficiency greater than 50%, is known as

(*a*) reversible machine (*b*) non-reversible machine

(*c*) neither reversible nor non-reversible machine

(*d*) ideal machine

143. A machine which is capable of doing work in the reversed direction, after the effort is removed, is called a non-reversible machine.

(*a*) Yes (*b*) No

144. A machine which is not capable of doing any work in the reversed direction, after the effort is removed, is called a reversible machine.

(*a*) True (*b*) False

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145. A non-reversible machine is also called a self-locking machine.
(*a*) Agree (*b*) Disagree

146. A screw jack used for lifting the loads is
(*a*) a reversible machine (*b*) a non-reversible machine
(*c*) an ideal machine (*d*) none of these

147. A weight of 1000 N can be lifted by an effort of 80 N. If the velocity ratio is 20, the machine is
(*a*) reversible (*b*) non-reversible (*c*) ideal

148. For a self locking machine, the efficiency must be
(*a*) equal to 50% (*b*) less than 50% (*c*) greater than 50% (*d*) 100%

149. The law of the machine is
(*a*) $P = mW - C$ (*b*) $P = m/W + C$ (*c*) $P = mW + C$ (*d*) $P = C - mW$
where P = Effort applied to lift the load,
m = A constant which is equal to the slope of the line,
W = Load lifted, and
C = Another constant which represents the machine friction.

150. The maximum mechanical advantage of a lifting machine is
(*a*) $1 + m$ (*b*) $1 - m$ (*c*) $1/m$ (*d*) m

151. The maximum efficiency of a lifting machine is
(*a*) $1/m$ (*b*) $V.R./m$ (*c*) $m/V.R.$ (*d*) $1/m \times V.R.$

152. The velocity ratio for the first system of pulleys is
(*a*) n (*b*) n^2 (*c*) 2^n (*d*) $2^n - 1$
where n is the number of pulleys.

153. The velocity ratio for the second system of pulleys is n.
(*a*) True (*b*) False

154. The velocity ratio for the third system of pulleys is
(*a*) n (*b*) n^2 (*c*) 2^n (*d*) $2^n - 1$

155. The velocity ratio of a differential pulley block with D and d as the diameters of larger and smaller pulley, is
(*a*) $\frac{D}{D-d}$ (*b*) $\frac{D}{D+d}$ (*c*) $\frac{2D}{D-d}$ (*d*) $\frac{2D}{D+d}$

156. Which of the following statement is wrong?
(*a*) A force acting in the opposite direction to the motion of the body is called force of friction.
(*b*) The ratio of the limiting friction to the normal reaction is called coefficient of friction.
(*c*) A machine whose efficiency is 100% is known as an ideal machine.
(*d*) The velocity ratio of a machine is the ratio of load lifted to the effort applied.

57. The velocity ratio of a first system of pulleys with 4 pulleys is
(*a*) 4 (*b*) 8 (*c*) 16 (*d*) 20

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158. Match the correct answer from *Group B* for the statements given in *Group A*.

Group A	*Group B*
(*a*) M.I. of a circular section about its diameter (*d*)	(*A*) $\frac{1-\sin\phi}{1+\sin\phi}$
(*b*) Efficiency of a screw jack	(*B*) $1/m$
(*c*) Maximum efficiency of a screw jack	(*C*) $\frac{\pi}{64}\times d^4$
(*d*) Maximum mechanical advantage of a lifting machine	(*D*) $\frac{1}{m\times \text{V.R.}}$
(*e*) Maximum efficiency of a lifting machine	(*E*) $\frac{\tan\alpha}{\tan(\alpha+\phi)}$

159. If the number of pulleys in a system is equal to its velocity ratio, then it is a.....system of pulleys

(*a*) first (*b*) second (*c*) third

160. The velocity ratio of a simple wheel and axle with *D* and *d* as the diameters of effort wheel and load axle, is

(*a*) $D+d$ (*b*) $D-d$ (*c*) $D\times d$ (*d*) D/d

161. The velocity ratio of a differential wheel and axle with *D* as the diameter of effort wheel and d_1 and d_2 as the diameters of larger and smaller axles respectively, is

(*a*) $\frac{D}{d_1+d_2}$ (*b*) $\frac{D}{d_1-d_2}$ (*c*) $\frac{2D}{d_1+d_2}$ (*d*) $\frac{2D}{d_1-d_2}$

162. The velocity ratio of a single purchase crab winch can be increased by

(*a*) increasing the length of the handle

(*b*) increasing the radius of the load drum

(*c*) increasing the number of teeth of the pinion

(*d*) all of the above

163. A differential pulley block has larger and smaller diameters of 100 mm and 80 mm respectively. Its velocity ratio is

(*a*) 5 (*b*) 10 (*c*) 20 (*d*) 40

164. In a single threaded worm and worm wheel, the number of teeth on the worm is 50. The diameter of the effort wheel is 100 mm and that of load drum is 50 mm. The velocity ratio is

(*a*) 50 (*b*) 100 (*c*) 150 (*d*) 200

165. In a wormed geared pulley block, if the number of teeth on the worm wheel is doubled, then its velocity ratio is also doubled.

(*a*) True (*b*) False

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166. The velocity ratio of a simple screw jack with p as the pitch of the screw and l as the length of effort arm, is

(a) $\frac{2\pi l}{p}$ (b) $\frac{\pi l}{p}$ (c) $\frac{2\pi p}{l}$ (d) $\frac{2\pi p}{l}$

167. All the steel trusses of the bridges, have one of their end roller supported, and other end hinged. The main advantage of such a support is that the truss remains stable.

(a) True (b) False

168. A framed structure is perfect, if the number of members are.....$(2j - 3)$, where j is the number of joints.

(a) equal to (b) less than (c) greater than (d) either (b) or (c)

169. A framed structure is imperfect, if the number of members are.....$(2j - 3)$.

(a) equal to (b) less than (c) greater than (d) either (b) or (c)

170. A redundant frame is also called.....frame.

(a) perfect (b) imperfect (c) deficient

171. A framed structure as shown in Fig. 1.46, is a

(a) perfect frame
(b) deficient frame
(c) redundant frame
(d) none of the above

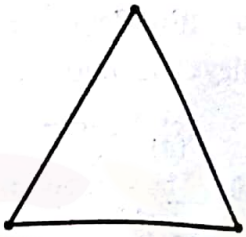

Fig. 1.46

172. In a framed structure, as shown in Fig. 1.47, the force in the member BC is

(a) $W/\sqrt{3}$ (compression)
(b) $W/\sqrt{3}$ (tension)
(c) $2W/\sqrt{3}$ (compression)
(d) $2W/\sqrt{3}$ (tension)

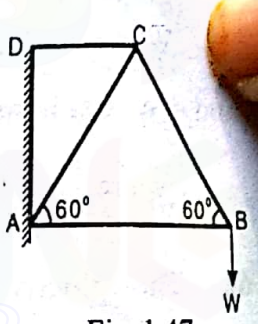

Fig. 1.47

173. In a framed structure, as shown in Fig. 1.47, the force in the member AC is numerically equal to the force in member BC.

(a) Right (b) Wrong

174. In a framed structure, as shown in Fig. 1.47, the force in the member AB is .....the force in member AC.

(a) half (b) equal to (c) double

175. In a framed structure, as shown in Fig. 1.47, the force in the member CD is tensile in nature.,

(a) Agree (b) Disagree

176. In a framed structure, as shown in Fig. 1.48, the forces in the members AB and BC are respectively .

(a) $\sqrt{3}W$ (tensile) and $2W$ (compressive)

(b) $2W$ (tensile) and $\sqrt{3}W$ (compressive)

(c) $2\sqrt{3}W$ (tensile) and $2\sqrt{3}W$ (compressive)

(d) none of the above

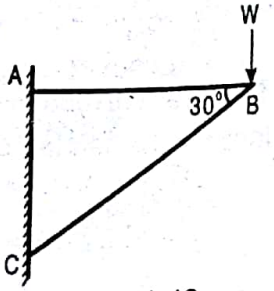

Fig. 1.48

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177. Which of the following is a scalar quantity?
(*a*) Force (*b*) Speed (*c*) Velocity (*d*) Acceleration

178. The rate of change of displacement of a body is called
(*a*) velocity (*b*) acceleration (*c*) momentum (*d*) none of these

179. Which of the following are vector quantities?
(*a*) Linear displacement (*b*) Linear velocity (*c*) Linear acceleration (*d*) all of these

180. The negative acceleration is called retardation.
(*a*) True (*b*) False

181. If the body falls freely under gravity, then the gravitational acceleration is taken as
(*a*) $+8.9\ m/s^2$ (*b*) $-8.9\ m/s^2$ (*c*) $+9.8\ m/s^2$ (*d*) $-9.8\ m/s^2$

182. If a body is thrown upwards, then the gravitational acceleration is taken as zero.
(*a*) Right (*b*) Wrong

183. If the gravitational acceleration at any place is doubled, then the weight of a body will be
(*a*) $g/2$ (*b*) g (*c*) $\sqrt{2}\,g$ (*d*) $2g$

184. The velocity of a body on reaching the ground from a height h, is
(*a*) $2\sqrt{gh}$ (*b*) $\sqrt{gh}$ (*c*) $\sqrt{2gh}$ (*d*) $2g\sqrt{h}$

185. The acceleration of a body sliding down an inclined surface is
(*a*) $g \sin\theta$ (*b*) $g \cos\theta$ (*c*) $g \tan\theta$ (*d*) none of these

186. Which of the following is an equation of linear motion?
(*a*) $v = u + a.t$ (*b*) $s = u.t + \frac{1}{2}at^2$ (*c*) $v^2 = u^2 + 2a.s$ (*d*) all of these

where u and v = Initial and final velocity of the body,
a = Acceleration of the body, and
s = Displacement of the body in time t seconds.

187. According to Newton's first law of motion,
(*a*) every body continues in its state of rest or of uniform motion, in a straight line, unless it is acted upon by some external force
(*b*) the rate of change of momentum is directly proportional to the impressed force, and takes place in the same direction, in which the force acts
(*c*) to every action, there is always an equal and opposite reaction
(*d*) none of the above

188. Newton's second law motion.....a relation between force and mass of a moving body.
(*a*) gives (*b*) does not give

189. A science teacher claimed that Newton's third law of motion is involved while studying the notion of rockets. His statement is
(*a*) justified (*b*) not justified

190. D' Alembert's principle basically depends upon Newton's second law of motion.
(*a*) Correct (*b*) Incorrect

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191. The rate of change of momentum is directly proportional to the impressed force, and takes place in the same direction in which the force acts. This statement is known as

(*a*) Newton's first law of motion (*b*) Newton's second law of motion

(*c*) Newton's third law of motion (*d*) none of these

192. The law of motion involved in the recoil of gun is

(*a*) Newton's first law of motion (*b*) Newton's second law of motion

(*c*) Newton's third law of motion (*d*) none of these

193. If P is the force acting on the body, m is the mass of the body and a is the acceleration of the body, then according to Newton's second law of motion,

(*a*) $P + m.a = 0$ (*b*) $P - m.a = 0$ (*c*) $P \times m.a = 0$ (*d*) $P / m.a = 0$

194. The matter contained in a body, is called

(*a*) impulsive force (*b*) mass (*c*) weight (*d*) momentum

195. The force, by which the body is attracted, towards the centre of the earth, is called

(*a*) impulsive force (*b*) mass (*c*) weight (*d*) momentum

196. When a body falls freely under gravitational force, it possesses.....weight.

(*a*) no (*b*) minimum (*c*) maximum

197. The total motion possessed by a body, is called

(*a*) impulsive force (*b*) mass (*c*) weight (*d*) momentum

198. A newton is defined as the force while acting upon a mass of one kg, produces an acceleration of 1 m / s^2 in the direction of which it acts.

(*a*) Yes (*b*) No

199. The force applied on a body of mass 100 kg to produce an acceleration of 5 m/s^2, is

(*a*) 20 N (*b*) 100 N (*c*) 500 N (*d*) none of these

200. A lift moves downwards with an acceleration of 9.8 m/s^2. The pressure exerted by a man on the floor of the lift is zero.

(*a*) True (*b*) False

201. When the lift is moving upwards with some acceleration, the pressure exerted by a man is.....proportional to its acceleration.

(*a*) directly (*b*) inversely

202. Tension in the cable supporting a lift is more when the lift is moving.....with an acceleration.

(*a*) upwards (*b*) downwards

203. If tension in the cable supporting a lift moving downwards is half the tension when it is moving upwards, the acceleration of the lift is

(*a*) $g / 2$ (*b*) $g / 3$

(*c*) $g / 4$ (*d*) none of these

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204. Two bodies of masses m_1 and m_2 are hung from the ends of a rope, passing over a frictionless pulley as shown in Fig. 1.49, The acceleration of the string will be

(a) $\frac{g(m_1 - m_2)}{m_1 + m_2}$ (b) $\frac{2g(m_1 - m_2)}{m_1 + m_2}$

(c) $\frac{g(m_1 + m_2)}{m_1 - m_2}$ (d) $\frac{2g(m_1 + m_2)}{m_1 - m_2}$

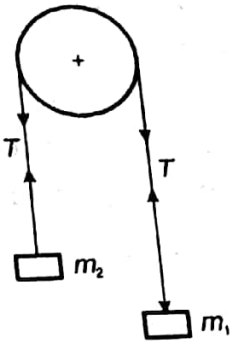

Fig. 1.49

205. In the above question, as shown in Fig. 1.49, the tension (T) in the string will be

(a) $\frac{m_1 . m_2 . g}{m_1 + m_2}$ (b) $\frac{2m_1 . m_2 . g}{m_1 + m_2}$

(c) $\frac{m_1 + m_2}{m_1 . m_2 . g}$ (d) $\frac{m_1 + m_2}{2m_1 . m_2 . g}$

206. If the masses of both the bodies, as shown in Fig. 1.49, are doubled, then the acceleration in the string will be

(a) same (b) half (c) double

207. If the masses of both the bodies, as shown in Fig. 1.49, are reduced to 50 percent, then tension in the string will be

(a) same (b) half (c) double

208. Two blocks A and B of masses 150 kg and 50 kg respectively are connected by means of a string as shown in Fig. 1.50. The tension in all the three strings.....be same.

(a) will (b) will not

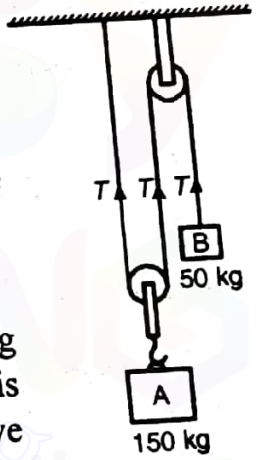

Fig. 1.50

209. If two blocks of equal mass are attached to the two ends of a light string and one of the blocks is placed over a smooth horizontal plane while the other is hung freely after passing over a smooth pulley, then the two blocks will have some motion.

(a) Agree (b) Disagree

210. A block of mass 20 kg lying on a rough horizontal plane is connected by a light string passing over a smooth pulley to another mass 5 kg, which can move freely in the vertical direction as shown in Fig. 1.51. The tension in the string will.....with the increase in coefficient of friction.

(a) increase (b) decrease (c) not be effected

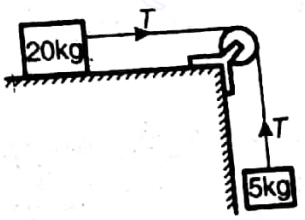

Fig. 1.51

211. A block of mass m_1 placed on an inclined smooth plane is connected by a light string passing over a smooth pulley to mass m_2, which moves vertically downwards as shown in Fig. 1.52. The tension in the string is

(a) m_1 / m_2 (b) $m_1 . g \sin \alpha$

(c) $m_1 . m_2 / m_1 + m_2$ (d) $\frac{m_1 . m_2 . g(1 + \sin \alpha)}{m_1 + m_2}$

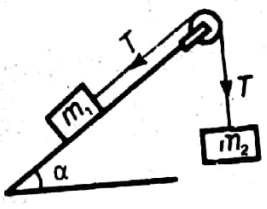

Fig. 1.52

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212. In Fig. 1.52, if the angle of inclination of the plane is increased, then acceleration of the system will

(*a*) increase (*b*) decrease (*c*) remain the same

213. In Fig. 1.52, if the mass m_1 is placed on an inclined rough plane having coefficient of friction μ, then the tension in the string will be

(*a*) $\dfrac{m_1 . m_2 . g\,(1+\sin\alpha+\mu\cos\alpha)}{m_1+m_2}$ (*b*) $\dfrac{m_1 . m_2 . g\,(1+\sin\alpha+\mu\cos\alpha)}{m_1+m_2}$

(*c*) $\dfrac{m_1 . m_2 . g\,(1+\mu\cos\alpha)}{m_1+m_2}$ (*d*) $\dfrac{m_1 . m_2 . g\,(1+\mu\cos\alpha)}{m_1+m_2}$

214. Which of the following statement is correct in connection with projectiles?

(*a*) A path, traced by a projectile in the space, is known as trajectory.

(*b*) The velocity with which a projectile is projected, is known as the velocity of projection.

(*c*) The angle, with the horizontal, at which a projectile is projected is known as angle of projection.

(*d*) all of the above

215. The total time taken by a projectile to reach maximum height and to return back to the ground, is known as time of flight.

(*a*) Yes (*b*) No

216. The cartesian equation of trajectory is

(*a*) $y = \dfrac{gx^2}{2u^2\cos^2\alpha} + x\tan\alpha$ (*b*) $y = \dfrac{gx^2}{2u^2\cos^2\alpha} - x\tan\alpha$

(*c*) $y = x\tan\alpha - \dfrac{gx^2}{2u^2\cos^2\alpha}$ (*d*) $y = x\tan\alpha + \dfrac{gx^2}{2u^2\cos^2\alpha}$

where u = Velocity of projection,

α = Angle of projection, and

x, y = Co-ordinates of any point on the trajectory after t seconds.

217. The path of the projectile is a parabola.

(*a*) True (*b*) False

218. The time of flight (t) of a projectile on a horizontal plane is given by

(*a*) $t = \dfrac{2u\sin\alpha}{g}$ (*b*) $t = \dfrac{2u\cos\alpha}{g}$ (*c*) $t = \dfrac{2u\tan\alpha}{g}$ (*d*) $t = \dfrac{2u}{g\sin\alpha}$

219. The distance, between the point of projection and the point where the projectile strikes the ground, is known as range.

(*a*) Correct (*b*) Incorrect

220. The horizontal range of a projectile (R) is given by

(*a*) $R = \dfrac{u^2\cos 2\alpha}{g}$ (*b*) $R = \dfrac{u^2\sin 2\alpha}{g}$ (*c*) $R = \dfrac{u^2\cos\alpha}{g}$ (*d*) $R = \dfrac{u^2\sin\alpha}{g}$

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221. The range of a projectile is maximum, when the angle of projection is

(a) 30° (b) 45° (c) 60° (d) 90°

222. The maximum height of a projectile on a horizontal plane, is

(a) $\frac{u^2 \sin^2 \alpha}{2g}$ (b) $\frac{u^2 \cos^2 \alpha}{2g}$ (c) $\frac{u^2 \sin^2 \alpha}{g}$ (d) $\frac{u^2 \cos^2 \alpha}{g}$

223. The time of flight (t) of a projectile on an upward inclined plane is

(a) $t = \frac{g \cos \beta}{2u \sin(\alpha - \beta)}$ (b) $t = \frac{2u \sin(\alpha - \beta)}{g \cos \beta}$

(c) $t = \frac{g \cos \beta}{2u \sin(\alpha + \beta)}$ (d) $t = \frac{2u \sin(\alpha + \beta)}{g \cos \beta}$

where u = Velocity of projection,

α = Angle of projection, and

β = Inclination of the plane with the horizontal.

224. The time of flight of a projectile on downward inclined plane depends upon

(a) angle of projection (b) angle of inclination of the plane

(c) both (a) and (b) (d) none of these

225. The range of projectile (R) on an upward inclined plane is

(a) $\frac{g \cos^2 \beta}{2u^2 \sin(\alpha + \beta) \cos \alpha}$ (b) $\frac{2u^2 \sin(\alpha + \beta) \cos \alpha}{g \cos^2 \beta}$

(c) $\frac{g \cos^2 \beta}{2u^2 \sin(\alpha - \beta) \cos \alpha}$ (d) $\frac{2u^2 \sin(\alpha - \beta) \cos \alpha}{g \cos^2 \beta}$

226. The range of projectile will be maximum for a given velocity of projectile, when the angle of projection (α) is

(a) $\beta/2$ (b) $30° + \beta/2$ (c) $45° + \beta/2$ (d) $60° + \beta/2$

227. The range of projectile on a downward inclined plane is.....the range on upward inclined plane for the same velocity of projection and angle of projection.

(a) less than (b) more than (c) equal to

228. Match the correct answer from *Group B* for the given statements in *Group A*.

Group A	*Group B*
(a) The cartesion equation of trajectory is	(A) $\frac{2u \sin \alpha}{g}$
(b) The time of flight of a projectile on a horizontal plane is	(B) $\frac{2u \sin(\alpha - \beta)}{g \cos \beta}$
(c) The horizontal range of projectile is	(C) $\frac{u^2 \sin 2\alpha}{g}$
(d) The maximum height of a projectile on a horizontal plane is	(D) $x \tan \alpha - \frac{gx^2}{2u^2 \cos^2 \alpha}$
(e) The time of flight of a projectile on an upward inclined plane is	(E) $\frac{u^2 \sin^2 \alpha}{2g}$

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229. The unit of angular velocity is
(*a*) m/min (*b*) rad / s (*c*) revolutions / min (*d*) all of these

230. The angular velocity (in rad / s) of a body rotating at N revolutions per minute is
(*a*) $\pi N/60$ (*b*) $\pi N/180$ (*c*) $2\pi N/60$ (*d*) $2\pi N/180$

231. The unit of angular acceleration is
(*a*) N-m (*b*) m / s (*c*) m / s^2 (*d*) rad / s^2

232. The linear velocity of a body rotating at ω rad / s along a circular path of radius r is given by
(*a*) ω / r (*b*) $\omega.r$ (*c*) ω^2 / r (*d*) $\omega^2.r$

233. The linear acceleration (a) of a body rotating along a circular path of radius (r) with an angular acceleration of α rad / s^2, is
(*a*) $a = \alpha / r$ (*b*) $a = \alpha.r$ (*c*) $a = r / \alpha$ (*d*) none of these

234. Which of the following are vector quantities?
(*a*) Angular displacement (*b*) Angular velocity
(*b*) Angular acceleration (*d*) all of these

235. The motion of a particle round a fixed axis is
(*a*) translatory (*b*) rotary
(*c*) circular (*d*) translatory as well as rotatry

236. In order to completely specify angular displacement by a vector, it must fix
(*a*) direction of the axis of rotation (*b*) magnitude of angular displacement
(*c*) sense of angular displacement (*d*) all of these

237. When a particle moves along a circular path, its acceleration has two components, one is normal component and the other is tangential component of acceleration.
(*a*) True (*b*) False

238. When a particle moves along a straight path, there will be centripetal acceleration as well as tangential acceleration.
(*a*) Right (*b*) Wrong

239. When a particle moves along a circular path with uniform velocity, there will be no tangential acceleration.
(*a*) Correct (*b*) Incorrect

240. The maximum displacement of a body, from its mean position is called amplitude.
(*a*) Right (*b*) Wrong

241. Frequency of vibrations means the number of cycles per second.
(*a*) Yes (*b*) No

242. The time taken by a particle for one complete oscillation is known as periodic time.
(*a*) Agree (*b*) Disagree

243. The periodic time of a particle with simple harmonic motion is.....proportional to the angular velocity.
(*a*) directly (*b*) inversely

244. The amplitude is always.....radius of the circle.
(*a*) equal to (*b*) less than (*c*) greater than

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245. The periodic time (T) is given by

(*a*) $\omega / 2\pi$ (*b*) $2\pi / \omega$ (*c*) $2\pi \times \omega$ (*d*) π / ω

where ω = Angular velocity of particle in rad / s.

246. A body is said to move or vibrate with simple harmonic motion if its acceleration is directed towards the mean position.

(*a*) True (*b*) False

247. The velocity of a particle moving with simple harmonic motion is.....at the mean position.

(*a*) zero (*b*) minimum (*c*) maximum

248. The acceleration of a particle moving with simple harmonic motion is.....at the mean position.

(*a*) zero (*b*) minimum (*c*) maximum

249. The velocity of a particle (v) moving with simple harmonic motion, at any instant is given by

(*a*) $\omega\sqrt{y^2 - r^2}$ (*b*) $\omega\sqrt{r^2 - y^2}$ (*c*) $\omega^2\sqrt{y^2 - r^2}$ (*d*) $\omega^2\sqrt{r^2 - y^2}$

where r = Amplitude of motion, and

y = Displacement of the particle from mean position.

250. The acceleration of a particle moving with simple harmonic motion, at any instant is given by

(*a*) $\omega . y$ (*b*) $\omega^2 . y$ (*c*) ω^2 / y (*d*) $\omega^3 . y$

251. The maximum velocity of a particle moving with simple harmonic motion is

(*a*) ω (*b*) ωr (*c*) $\omega^2 r$ (*d*) ω / r

252. The maximum acceleration of a particle moving with simple harmonic motion is

(*a*) ω (*b*) ωr (*c*) $\omega^2 r$ (*d*) ω / r

253. One end of a helical spring is fixed while the other end carries the load W which moves with simple harmonic motion. The frequency of motion is given by

(*a*) $2\pi\sqrt{\frac{g}{\delta}}$ (*b*) $\frac{1}{2\pi}\sqrt{\frac{g}{\delta}}$ (*c*) $2\pi\sqrt{\frac{\delta}{g}}$ (*d*) $\frac{1}{2\pi}\sqrt{\frac{\delta}{g}}$

where δ = Deflection of the spring.

254. The acceleration of a particle moving with simple harmonic motion is proportional to the displacement of the particle from the mean position.

(*a*) True (*b*) False

255. The periodic time of one oscillation for a simple pendulum is

(*a*) $\frac{1}{2\pi}\sqrt{\frac{l}{g}}$ (*b*) $\frac{1}{2\pi}\sqrt{\frac{g}{l}}$ (*c*) $2\pi\sqrt{\frac{l}{g}}$ (*d*) $2\pi\sqrt{\frac{g}{l}}$

where l = Length of the pendulum.

256. In order to double the period of simple pendulum, the length of the string should be

(*a*) halved (*b*) doubled (*c*) quadrupled

257. The motion of the body from one extremity to the other is known as a beat.

(*a*) Agree (*b*) Disagree

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258. A pendulum which executes one beat per second is known as

(*a*) simple pendulum (*b*) compound pendulum

(*c*) torsional pendulum (*d*) second's pendulum

259. If a pendulum is taken 1 km below the earth surface in a mine, it will.....in time.

(*a*) gain (*b*) loose

260. The length of a second's pendulum is

(*a*) 94.9 cm (*b*) 99.4 cm (*c*) 100 cm (*d*) 101 cm

261. When a rigid body is suspended vertically, and it oscillates with a small amplitude under the action of the force of gravity, the body is known as

(*a*) simple pendulum (*b*) compound pendulum

(*c*) torsional pendulum (*d*) second's pendulum

262. The frequency of oscillation of a compound pendulum is

(*a*) $2\pi\sqrt{\frac{gh}{k_G^2+h^2}}$ (*b*) $2\pi\sqrt{\frac{k_G^2+h^2}{gh}}$ (*c*) $\frac{1}{2\pi}\sqrt{\frac{gh}{k_G^2+h^2}}$ (*d*) $\frac{1}{2\pi}\sqrt{\frac{k_G^2+h^2}{gh}}$

where k_G = Radius of gyration about the centroidal axis, and

h = Distance between the point of suspension and *C.G.* of the body.

263. The centre of oscillation and centre of suspension for a compound pendulum are interchangeable.

(*a*) True (*b*) False

264. The equivalent length of a simple pendulum which gives the same frequency as compound pendulum is

(*a*) $\frac{h}{k_G^2+h^2}$ (*b*) $\frac{k_G^2+h^2}{h}$ (*c*) $\frac{h^2}{k_G^2+h^2}$ (*d*) $\frac{k_G^2+h^2}{h^2}$

265. The centre of percussion is below the centre of gravity of the body and is at a distance equal to

(*a*) h / k_G (*b*) h^2 / k_G (*c*) k_G^2 / h (*d*) $h \times k_G$

266. The frequency of oscillation of a torsional pendulum is

(*a*) $\frac{2\pi k}{r}\times\sqrt{\frac{g}{l}}$ (*b*) $\frac{r}{2\pi k}\times\sqrt{\frac{l}{g}}$ (*c*) $\frac{2\pi r}{k}\times\sqrt{\frac{g}{l}}$ (*d*) $\frac{r}{2\pi k}\times\sqrt{\frac{g}{l}}$

267. Which of the following statement is correct?

(*a*) The periodic time of a particle moving with simple harmonic motion is the time taken by a particle for one complete oscillation.

(*b*) The periodic time of a particle moving with simple harmonic motion is directly proportional to its angular velocity.

(*c*) The velocity of the particle moving with simple harmonic motion is zero at the mean position.

(*d*) The acceleration of the particle moving with simple harmonic motion is maximum at the mean position.

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268. Match the correct answer from *Group B* for the given statements in *Group A*, in connection with simple harmonic motion.

Group A	*Group B*
(*a*) The maximum displacement of a body from its mean position is	(*A*) frequency
(*b*) The number of cycles per second is	(*B*) end of extremeties
(*c*) The velocity of the particle is zero at the	(*C*) mean position
(*d*) The acceleration of the particle is zero at the	(*D*) amplitude

269. The motion of a wheel of a car is

(*a*) purely translation (*b*) purely rotational

(*c*) combined translation and rotational (*d*) none of these

270. When a person, on a bicycle, drives round a curve, he has to lean.....to maintain equilibrium.

(*a*) inward (*b*) outward

271. The angle of inclination of a vehicle when moving along a circular path.....upon its mass.

(*a*) depends (*b*) does not depend

272. The angle of inclination with the vertical is ..... if the cyclist is running at a faster speed than that when he is running at a slower speed.

(*a*) more (*b*) less

273. The force which acts along the radius of a circle and directed towards the centre of the circle is known as centripetal force.

(*a*) True (*b*) False

274. The force which acts along the radius of a circle and directed away from the centre of the circle is called centrifugal force.

(*a*) Agree (*b*) Disagree

275. The slope on the road surface generally provided on the curves is known as

(*a*) angle of friction (*b*) angle of repose

(*c*) angle of banking (*d*) none of these

276. The ideal angle of banking provided on the curves on roads depends upon

(*a*) weight of the vehicle

(*b*) (velocity)^2 of the vehicle

(*c*) nature of the road surface

(*d*) coefficient of friction between the road and vehicle contact point

277. When a train is rounding a curve, the side thrust on the wheel flanges is prevented by raising the outer edge of the rail.

(*a*) Yes (*b*) No

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278. The amount by which the outer edge of the rail is raised, is known as super-elevation.

(*a*) Agree (*b*) Disagree

279. In railways, the super-elevation is expressed in terms of the difference of level between the two rails.

(*a*) True (*b*) False

280. The super-elevation is given by

(*a*) $\frac{g r}{G v^2}$ (*b*) $\frac{v^2 r}{g G}$ (*c*) $\frac{G v^2}{g r}$ (*d*) $\frac{G g}{v^2 r}$

where G = Gauge of the track.

v = Velocity of the vehicle, and

r = Radius of the circular path.

281. The maximum velocity of a vehicle in order to avoid over-turning on a level circular path, is

(*a*) $\frac{h}{gra}$ (*b*) $\frac{gra}{h}$ (*c*) $\frac{h}{\sqrt{gra}}$ (*d*) $\sqrt{\frac{gra}{h}}$

282. When a vehicle moves on a level circular path, the reaction at the inner wheel is

(*a*) $\frac{mg}{2}\left(1-\frac{gra}{v^2 h}\right)$ (*b*) $\frac{mg}{2}\left(\frac{gra}{v^2 h}-1\right)$ (*c*) $\frac{mg}{2}\left(1-\frac{v^2 h}{gra}\right)$ (*d*) $\frac{mg}{2}\left(1+\frac{v^2 h}{gra}\right)$

where m = Mass of the vehicle,

v = Velocity of the vehicle,

h = Height of *C.G.* of the vehicle from ground level,

$2a$ = Distance between outer and inner wheel, and

r = Radius of the circular path.

283. The maximum velocity of a vehicle in order to avoid skidding away on a level circular path, is

(*a*) $\mu g r$ (*b*) $\frac{1}{2}\mu g r$ (*c*) $\sqrt{\mu g r}$ (*d*) $\frac{1}{2}\sqrt{\mu g r}$

284. The overturning of a vehicle on a level circular path can be avoided if the velocity of vehicle is..... $\sqrt{gra}/h$.

(*a*) less than (*b*) greater than

285. The skidding away of the vehicle on a level circular path can be avoided if the force of friction between the wheels and the ground is..... the centrifugal force.

(*a*) less than (*b*) greater than

286. The total momentum of a system of masses (*i.e.* moving bodies) in any one direction remains constant, unless acted upon by an external force in that direction. This statement is called

(*a*) Newton's first law of motion (*b*) Newton's second law of motion

(*c*) principle of conservation of energy (*d*) principle of conservation of momentum

287. The bodies which rebound after impact are called

(*a*) inelastic bodies (*b*) elastic bodies

(*c*) neither elastic nor inelastic bodies (*d*) none of these

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288. The loss of kinetic energy during inelastic impact, is given by

(*a*) $\frac{m_1 m_2}{2(m_1 + m_2)}(u_1 - u_2)^2$ (*b*) $\frac{2(m_1 + m_2)}{m_1 m_2}(u_1 - u_2)^2$

(*c*) $\frac{m_1 m_2}{2(m_1 + m_2)}(u_1^2 - u_2^2)$ (*d*) $\frac{2(m_1 + m_2)}{m_1 m_2}(u_1^2 - u_2^2)$

where m_1 = Mass of the first body,

m_2 = Mass of the second body, and

u_1 and u_2 = Velocities of the first and second bodies respectively.

289. The impact between two lead spheres is approximately equal to an.....impact.

(*a*) elastic (*b*) inelastic

290. In collision of elastic bodies, the coefficient of restitution is the ratio of the relative velocity after impact to the relative velocity before impact.

(*a*) True (*b*) False

291. The coefficient of restitution for inelastic bodies is

(*a*) zero (*b*) one

(*c*) between zero and one (*d*) more than one

292. The coefficient of restitution for elastic bodies is one.

(*a*) Right (*b*) Wrong

293. During elastic impact, the relative velocity of the two bodies after impact is.....the relative velocity of the two bodies before impact.

(*a*) equal to (*b*) equal and opposite to

(*c*) less than (*d*) greater than

294. The loss of kinetic energy during elastic impact is zero.

(*a*) Agree (*b*) Disagree

295. The loss of kinetic energy due to direct impact of two bodies.....upon the value of coefficient of restitution.

(*a*) depends (*b*) does not depend

296. Which of the following statement is correct?

(*a*) The kinetic energy of a body during impact remains constant.

(*b*) The kinetic energy of a body before impact is equal to the kinetic energy of a body after impact.

(*c*) The kinetic energy of a body before impact is less than the kinetic energy of a body after impact.

(*d*) The kinetic energy of a body before impact is more than the kinetic energy of a body after impact.

297. When two elastic bodies collide with each other,

(*a*) the two bodies will momentarily come to rest after collision

(*b*) the two bodies tend to compress and deform at the surface of contact

(*c*) the two bodies begin to regain their original shape

(*d*) all of the above

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298. Two balls of equal mass and of perfectly elastic material are lying on the floor. One of the ball with velocity v is made to struck the second ball. Both the balls after impact will move with a velocity

(a) v (b) $v/2$ (c) $v/4$ (d) $v/8$

299. A lead ball with a certain velocity is made to strike a wall, it falls down, but rubber ball of same mass and with same velocity strikes the same wall, it rebounds. Select the correct reason from the following :

(a) both the balls undergo an equal change in momentum

(b) the change in momentum suffered by rubber ball is more than the lead ball

(c) the change in momentum suffered by rubber ball is less than the lead ball

(d) none of the above

300. If u_1 and u_2 are the velocities of two moving bodies in the same direction before impact and v_1 and v_2 are their velocities after impact, then coefficient of restitution is given by

(a) $\frac{v_1 - v_2}{u_1 - u_2}$ (b) $\frac{v_2 - v_1}{u_1 - u_2}$ (c) $\frac{u_1 - u_2}{v_1 - v_2}$ (d) $\frac{u_2 + u_1}{v_2 + v_1}$

301. A body of mass m moving with a constant velocity v strikes another body of same mass m moving with same velocity but in opposite direction. The common velocity of both the bodies after collision is

(a) v (b) $2v$ (c) $4v$ (d) $8v$

302. A rubber ball is dropped from a height of 2 m. If there is no loss of velocity after rebounding, the ball will rise to a height of

(a) 1m (b) 2m (c) 3m (d) 4m

303. Whenever a force acts on a body and the body undergoes a displacement, then

(a) work is said to be done (b) power is being transmitted

(c) body has kinetic energy of translation (d) none of these

304. The unit of work in S.I. units is

(a) newton (b) erg (c) kg-m (d) joule

305. One joule is equal to

(a) 0.1 N-m (b) 1 N-m (c) 10 N-m (d) 100 N-m

306. Work done is said to be zero, when

(a) some force acts on a body, but displacement is zero

(b) no force acts on a body but some displacement takes place

(c) either (a) or (b)

(d) none of the above

307. One joule means that

(a) work is done by a force of 1 N when it displaces a body through 1m

(b) work is done by a force of 1 kg when it displaces a body through 1 m

(c) work is done by a force of 1 dyne when it displaces a body through 1 cm

(d) work is done by a force of 1 g when it displaces a body through 1 cm

308. Joule is the unit of

(a) force (b) work (c) power (d) energy

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309. The rate of doing work is known as
(a) potential energy (b) kinetic energy (c) power (d) none of these

310. The unit of power in S.I. units is
(a) horsepower (b) joule (c) watt (d) kg-m

311. One watt is equal to
(a) 0.1 joule / s (b) 1 joule / s (c) 10 joules / s (d) 100 joules / s

312. The power developed by a body acted upon by a torque T newton metre (N - m) and revolving at ω radian / s is given by
(a) $T.\omega$ (in watts) (b) $T.\omega / 60$ (in watts)
(c) $T.\omega / 75$ (in kilowatts) (d) $T.\omega / 4500$ (in kilowatts)

313. Energy may be defined as the capacity of doing work.
(a) Correct (b) Incorrect

314. The unit of energy in S.I. units is
(a) dyne (b) watt (c) kg - m (d) joule

315. The energy possessed by a body, for doing work by virtue of its position, is called
(a) potential energy (b) kinetic energy (c) electrical energy (d) chemical energy

316. The kinetic energy of a body.....upon its mass and velocity.
(a) does not depend (b) depends

317. The potential energy stored by a spring in compression, is called strain energy.
(a) Yes (b) No

318. When a body of mass m attains a velocity v from rest in time t, then the kinetic energy of translation is
(a) mv^2 (b) mgv^2 (c) $0.5\,mv^2$ (d) $0.5\,mgv^2$

319. When a body of mass moment of inertia I (about a given axis) is rotated about that axis with an angular velocity ω, then the kinetic energy of rotation is
(a) $I\,\omega$ (b) $I\,\omega^2$ (c) $0.5\,I\,\omega$ (d) $0.5\,I\,\omega^2$

320. The wheels of a moving car possess
(a) potential energy only
(b) kinetic energy of translation only
(c) kinetic energy of rotation only
(d) kinetic energy of translation and rotation both

321. According to principle of conservation of energy, the total momentum of a system of masses in any direction remains constant unless acted upon by an external force in that direction.
(a) True (b) False

322. The total energy possessed by a system of moving bodies
(a) is constant at every instant
(b) varies from point to point
(c) is maximum in the start and minimum at the end
(d) is minimum in the start and maximum at the end

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323. The potential energy of a vertically raised body is.....the kinetic energy of a vertically falling body.

(a) equal to (b) less than (c) greater than

324. When the spring of a watch is wound, it will possess

(a) strain energy (b) kinetic energy (c) heat energy (d) electrical energy

325. If two bodies having masses m_1 and m_2 ($m_1 > m_2$) have equal kinetic energies, the momentum of body having mass m_1 is.....the momentum of body having mass m_2.

(a) equal to (b) less than (c) greater than

ANSWERS

1.	(a)	2.	(d)	3.	(d)	4.	(c)	5.	(c)
6.	(a)	7.	(a)	8.	(b)	9.	(a)	10.	(b)
11.	(c)	12.	(b)	13.	(b)	14.	(d)	15.	(a)
16.	(d)	17.	(b)	18.	(a)	19.	(a)	20.	(c), (d)
21.	(b)	22.	(c)	23.	(b)	24.	(a)	25.	(a)
26.	(b)	27.	(b)	28.	(a)	29.	(a)	30.	(b)
31.	(d)	32.	(b)	33.	(c)	34.	(a)	35.	(b)
36.	(a)	37.	(b)	38.	(d)	39.	(b)	40.	(a)
41.	(b)	42.	(d)	43.	(c)	44.	(a)	45.	(d)
46.	(c)	47.	(d)	48.	(c)	49.	(d)	50.	(a)
51.	(d)	52.	(b)	53.	(b)	54.	(c)	55.	(c)
56.	(a)	57.	(b)	58.	(a)	59.	(b)	60.	(d)
61.	(B), (A), (D), (C)	62.	(d)	63.	(d)	64.	(b)	65.	(a)
66.	(a)	67.	(a)	68.	(a)	69.	(a)	70.	(c)
71.	(b)	72.	(a)	73.	(c)	74.	(c)	75.	(b)
76.	(B), (E), (A), (C), (F), (D)	77.	(b)	78.	(c)	79.	(a)	80.	(d)
81.	(d)	82.	(a)	83.	(c)	84.	(a)	85.	(b)
86.	(d)	87.	(b)	88.	(a)	89.	(c)	90.	(c)
91.	(a)	92.	(c)	93.	(a)	94.	(a)	95.	(d)
96.	(c)	97.	(d)	98.	(a)	99.	(d)	100.	(c)
101.	(a)	102.	(a)	103.	(a)	104.	(d)	105.	(a)
106.	(b)	107.	(d)	108.	(b)	109.	(b)	110.	(a)
111.	(c)	112.	(a)	113.	(c)	114.	(b)	115.	(d)
116.	(c)	117.	(b)	118.	(a)	119.	(a)	120.	(c)
121.	(c)	122.	(c)	123.	(a)	124.	(b)	125.	(a)
126.	(d)	127.	(c)	128.	(b)	129.	(a)	130.	(b)
131.	(b)	132.	(a)	133.	(a)	134.	(d)	135.	(b)
136.	(d)	137.	(a)	138.	(a)	139.	(b)	140.	(a)
141.	(b)	142.	(a)	143.	(b)	144.	(b)	145.	(a)
146.	(b)	147.	(a)	148.	(b)	149.	(c)	150.	(c)
151.	(d)	152.	(c)	153.	(a)	154.	(d)	155.	(c)
156.	(d)	157.	(c)	158.	(C), (E), (A), (B), (D)	159.	(b)	160.	(d)
161.	(d)	162.	(a)	163.	(b)	164.	(b)	165.	(a)
166.	(a)	167.	(a)	168.	(a)	169.	(d)	170.	(b)
171.	(a)								

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172. (d) 173. (a) 174. (a) 175. (a) 176. (a) 177. (b)
178. (a) 179. (d) 180. (a) 181. (c) 182. (b) 183. (d)
184. (c) 185. (a) 186. (d) 187. (a) 188. (a) 189. (a)
190. (a) 191. (b) 192. (c) 193. (b) 194. (b) 195. (c)
196. (a) 197. (d) 198. (a) 199. (c) 200. (a) 201. (a)
202. (a) 203. (d) 204. (a) 205. (b) 206. (a) 207. (b)
208. (a) 209. (a) 210. (a) 211. (d) 212. (b) 213. (a)
214. (d) 215. (a) 216. (c) 217. (a) 218. (a) 219. (a)
220. (b) 221. (b) 222. (a) 223. (b) 224. (c) 225. (d)
226. (c) 227. (b) 228. (D), (A), (C), (E), (B) 229. (b), (c) 230. (c)
231. (d) 232. (b) 233. (b) 234. (d) 235. (c) 236. (d)
237. (a) 238. (b) 239. (a) 240. (a) 241. (a) 242. (a)
243. (b) 244. (a) 245. (b) 246. (a) 247. (c) 248. (a)
249. (b) 250. (b) 251. (b) 252. (c) 253. (b) 254. (a)
255. (c) 256. (c) 257. (a) 258. (d) 259. (a) 260. (b)
261. (b) 262. (c) 263. (a) 264. (b) 265. (c) 266. (d)
267. (a) 268. (D), (A) (B), (C) 269. (c) 270. (a) 271. (b)
272. (a) 273. (a) 274. (a) 275. (c) 276. (b) 277. (a)
278. (a) 279. (a) 280. (c) 281. (d) 282. (c) 283. (c)
284. (a) 285. (b) 286. (d) 287. (b) 288. (a) 289. (b)
290. (a) 291. (a) 292. (b) 293. (b) 294. (a) 295. (a)
296. (d) 297. (d) 298. (b) 299. (b) 300. (b) 301. (b)
302. (b) 303. (a) 304. (d) 305. (b) 306. (c) 307. (a)
308. (b) 309. (c) 310. (c) 311. (b) 312. (a) 313. (a)
314. (d) 315. (a) 316. (b) 317. (a) 318. (c) 319. (d)
320. (d) 321. (b) 322. (a) 323. (a) 324. (a) 325. (c)

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Strength of Materials

2.1 Introduction

The strength of materials may broadly be defined as that branch of Engineering - science, which deals with the ability of various types of materials to resist its failure and their behaviour under the action of the forces.

2.2 Stress

When some external system of forces or loads act on a body, the internal forces (equal and opposite) are set up at various sections of the body, which resist the external forces. This internal force per unit area at any section of the body is known as *unit stress* or simply *stress*. Mathematically,

$$\text{Stress, } \sigma = P/A$$

where P = Force or load acting on the body, and

A = Cross-sectional area of the body.

In S.I. units, the stress is usually expressed in Pascal (Pa) such that 1 Pa = 1N / m^2. In actual practice, we use bigger unit of stress *i.e.*, megapascal (MPa) and gigapascal (GPa) such that

$$1\text{ MPa} = 1 \times 10^6\text{ N/m}^2 = 1\text{N/mm}^2$$
$$1\text{ GPa} = 1 \times 10^9\text{ N/m}^2 = 1\text{kN/mm}^2$$

2.3 Strain

When a system of forces act on a body, it undergoes some deformation. This deformation per unit length is known as *unit strain* or simply a *strain*. Mathematically,

$$\text{Strain, } \varepsilon = \delta l / l$$

where δl = Change in length of the body, and

l = Original length of the body.

2.4 Tensile Stress and Strain

When a body is subjected to two equal and opposite axial pulls, as a result of which the body tends to extend its length, the stress and strain induced is known as *tensile stress* and *tensile strain*.

2.5 Compressive Stress and Strain

When a body is subjected to two equal and opposite axial pushes, as a result of which the body tends to decrease its length, the stress and strain induced is known as *compressive stress* and *compressive strain*.

2.6 Young's Modulus or Modulus of Elasticity

Hooke's law states that when a material is loaded within elastic limit, the stress is directly proportional to strain, *i.e.*

$$\sigma \propto \varepsilon \quad \text{or} \quad \sigma = E.\varepsilon \quad \text{or} \quad E = \frac{\sigma}{\varepsilon} = \frac{P \times l}{A \times \delta l}$$

where E is a constant of proportionality and is known as *Young's Modulus* or *Modulus of elasticity*.

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2.7 Shear Stress and Strain

When a body is subjected to two equal and opposite forces, acting tangentially across the resisting section, as a result of which the body tends to shear off the section, then the stress induced is called *shear stress*. The corresponding strain is known as *shear strain* and it is measured by the angular deformation accompanying the shear stress.

2.8 Shear Modulus or Modulus of Rigidity

It has been found experimentally that within elastic limit, the shear stress is directly proportional to shear strain. Mathematically,

$$\tau \propto \phi \quad \text{or} \quad \tau = C.\phi \quad \text{or} \quad \tau / \phi = C$$

where τ = Shear stress ; ϕ = Shear strain, and C = Constant of proportionality, known as *Shear modulus* or *modulus of rigidity*. It is also denoted by N or G.

2.9 Stress in a Bar due to its own Weight

Consider a bar of length (l) and diameter (d) rigidly fixed at the upper end and hanging freely as shown in Fig. 2.1. The stress at any section in a bar due to its own weight is directly proportional to the distance from the free end. Therefore, stress at a distance x from the free end

$$= w.x$$

and total elongation of the bar,

$$\delta l = w.l^2 / 2E$$

where w = Weight per unit volume of the bar.

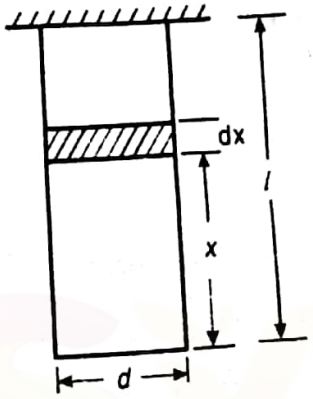

Fig. 2.1

Note : When a conical bar of length (l) and base diameter (d) is rigidly fixed with its base diameter at the upper end and is hanging freely, then the total elongation of the bar due to its own weight is given by

$$\delta l = \frac{w.l^2}{6E}$$

2.10. Stresses in Bars of Varying Sections

When a bar is made up of different lengths having different cross-sectional areas, and is subjected to an axial force P, as shown in Fig 2.2, then the total deformation of the bar,

$$\delta l = \delta l_1 + \delta l_2 + \delta l_3 + \ldots\ldots$$

$$= \frac{P.l_1}{A_1.E} + \frac{P.l_2}{A_2.E} + \frac{P.l_3}{A_3.E} + \text{-----}$$

$$= \frac{P}{E}\left(\frac{l_1}{A_1} + \frac{l_2}{A_2} + \frac{l_3}{A_3} + \text{-----}\right)$$

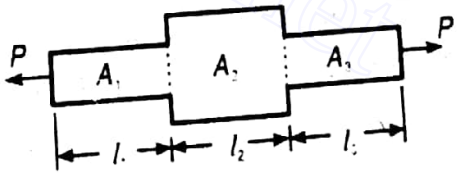

Fig. 2.2

2.11 Stresses in Bars of Uniformly Tapering Circular Section

When a bar of uniformly tapering circular section is subjected to an axial force P, as shown in Fig. 2.3, then the elongation of the bar,

$$\delta l = \frac{4\,P.l}{\pi E d_1 d_2}$$

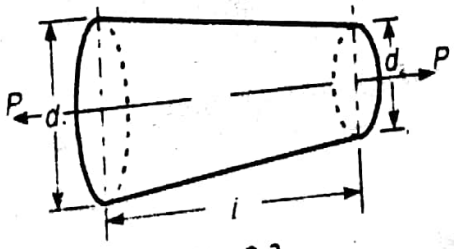

Fig. 2.3

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2.12 Stresses in Composite Bars

A composite bar may be defined as a bar made up of two or more different materials, joined together in such a manner, that the system extends or contracts as one unit, equally, when subjected to tension or compression.

Consider a composite bar made up of two different materials as shown in Fig. 2.4.

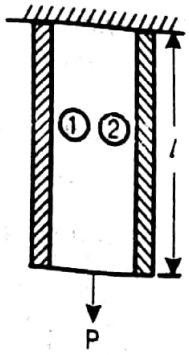


Fig. 2.4

Load shared by bar 1, $P_1 = P \times \frac{A_1.E_1}{A_1.E_1 + A_2.E_2}$

and load shared by bar 2, $P_2 = P \times \frac{A_2.E_2}{A_1.E_1 + A_2.E_2}$

Since the elongation for both the bars in same (*i.e.* $\delta l_1 = \delta l_2$), therefore

$$\frac{P_1.l}{A_1.E_1} = \frac{P_2.l}{A_2.E_2} \quad \text{or} \quad \frac{\sigma_1}{E_1} = \frac{\sigma_2}{E_2}$$

$$\therefore \quad \sigma_1 = \frac{E_1}{E_2} \times \sigma_2 \text{ ; and } \quad \sigma_2 = \frac{E_2}{E_1} \times \sigma_1$$

The ratio E_1 / E_2 is known as *modular ratio* of the two materials.

2.13 Stresses due to Change in Temperature — Thermal Stresses

Whenever there is some increase or decrease in the temperature of a body, it causes the body to expand or contract. A little consideration will show that if the body is allowed to expand or contract freely, with the rise or fall of the temperature, no stresses are induced in the body. But, if the deformation of the body is prevented, some stresses are induced in the body. Such stresses are known as *thermal stresses* or *temperature stresses* and the corresponding strains are called *thermal strains* or *temperature strains*.

When a bar of length (l) is subjected to an increase in temperature (t), then the increase in length when the bar is free to expand is given by

$$\delta l = l.\alpha.t$$

where α = Coefficient of linear expansion.

If the ends of the bar are fixed to rigid supports so that its expansion is prevented, then compressive thermal strain induced in the bar,

$$\varepsilon = \delta l / l = l.\alpha.t/l = \alpha.t$$

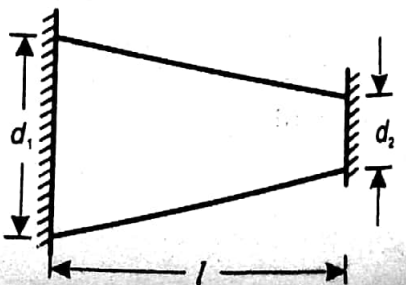
and thermal stress $= \varepsilon.E = \alpha.t.E$

Note: If the supports yield by an amount equal to δ, then the actual expansion that has taken place is given by

$$\delta l = l.\alpha.t - \delta$$

2.14 Thermal Stresses in Bars of Tapering Section

When a circular bar of uniformly tapering section fixed at its ends is subjected to an increase in temperature (t) as shown in Fig. 2.5, then thermal stress induced



$$= \frac{\alpha.t.E.d_1}{d_2}$$

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.15 Primary or Linear Strain

The deformation of the bar, per unit length in the direction of the force (*i.e.* $\delta l / l$) is known as *primary* or *linear strain*.

2.16 Secondary or Lateral Strain

Every direct stress is always accompanied by a strain in its own direction, and an opposite kind of strain in every direction, at right angles to it. Such a strain is known as *secondary* or *lateral strain*.

2.17 Poisson's Ratio

The ratio of lateral strain to linear strain is called Poisson's ratio.

2.18 Volumetric Strain

The ratio of change in volume to the original volume is known as volumetric strain.

The volumetric strain of a rectangular bar of length (l), breadth (b) and thickness (t) and subjected to an axial force (P) is given by

$$\frac{\delta V}{V} = \frac{P}{b.t.E}\left(1 - \frac{2}{m}\right) = \varepsilon\left(1 - \frac{2}{m}\right)$$

.19 Bulk Modulus

When a body is subjected to three mutually perpendicular stresses, of equal intensity, the ratio of direct stress to the corresponding volumetric strain is known as *bulk modulus*. It is usually denoted by K.

When a cube is subjected to three mutually perpendicular tensile stresses of equal intensity (σ), then the volumetric strain,

$$\frac{\delta V}{V} = \frac{3\sigma}{E}\left(1 - \frac{2}{m}\right)$$

The relation between bulk modulus and Young's modulus is given by

$$K = \frac{m.E}{3(m-2)}$$

The relation between modulus of elasticity (E) and modulus of rigidity (C) is given by

$$C = \frac{m.E}{2(m+1)}$$

nd the relation between E, C and K is given by

$$E = \frac{9\,K.C}{3K + C}$$

.20 Bearing Stress or Crushing Stress

A localised compressive stress at the surface of contact etween two members that are relatively at rest is known as *earing stress* or *crushing stress*. The bearing stress is taken to account in riveted joints, cotter joints, knuckle joints etc. et us consider a riveted joint as shown in Fig. 2.6. In such a ase, the bearing or crushing stress (*i.e.* the stress at the surce of contact between the rivet and the plate),

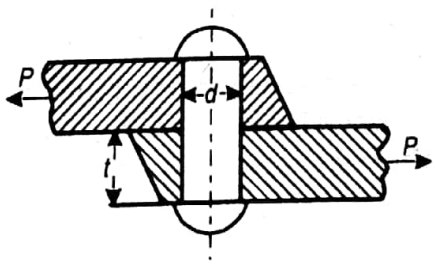

Fig. 2.6

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$$\sigma_b \text{ (or } \sigma_c) = \frac{P}{d.t.n}$$

where d = Diameter of the rivet,

t = Thickness of the plate,

$d.t$ = Projected area of the rivet, and

n = Number of rivets per pitch length in bearing or crushing.

2.21 Principal Stresses and Strains

It has been observed that at any point in a strained material, there are three planes, mutually perpendicular to each other, which carry direct stresses only, and no shear stresses. A little consideration will show that out of these three direct stresses, one will be maximum, the other minimum and the third an intermediate between the two. These particular planes, which have no shear stress, are known as *principal planes*. The magnitude of direct stress, across a principal plane, is known as *principal stress*.

2.22 Stress on an Oblique Section of a Body Subjected to Direct Stresses in One Plane

Consider a rectangular body $ABCD$ of uniform cross-sectional area (A) and unit thickness subjected to principal tensile stress σ as shown in Fig. 2.7.

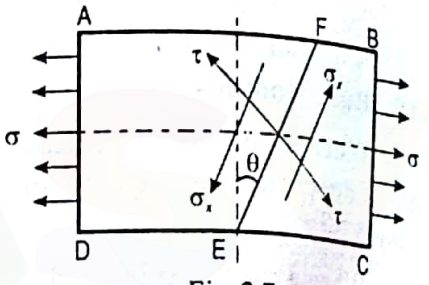

Fig. 2.7

On a section EF, which is inclined at an angle θ to the normal cross-section, the normal and tangential stress will be induced. The normal stress across the section EF is given by

$$\sigma_n = \frac{\text{Force normal to the section } EF}{\text{Area of section } EF}$$

$$= \frac{\sigma A \cos\theta}{A \sec\theta} = \sigma \cos^2\theta \quad \ldots(i)$$

and tangential stress (*i.e.* shear stress) across the section EF,

$$\tau = \frac{\text{Force along the section } EF}{\text{Area of section } EF} = \frac{\sigma A \sin\theta}{A \sec\theta} = \sigma \sin\theta . \cos\theta$$

$$= \frac{\sigma}{2} \times 2 \sin\theta \cos\theta = \frac{\sigma}{2} \times \sin 2\theta \quad \ldots(ii)$$

From equation (i), we see that the normal stress across the section EF will be maximum, when $\cos^2\theta = 1$ or $\cos\theta = 1$ or $\theta = 0°$. In other words, the normal cross-section will carry the maximum direct stress.

$\therefore$ Maximum normal stress,

$$\sigma_n = \sigma \cos 0° = \sigma$$

From equation (ii), we see that the tangential or shear stress across the section EF will be maximum, when $\sin 2\theta = 1$ or $2\theta = 90°$ or $270°$ or $\theta = 45°$ or $135°$. In other words, the shear stress will be maximum on two planes inclined at 45° and 135° to the normal section.

$\therefore$ Maximum tangential or shear stress,

$$\tau_{max} = \frac{\sigma}{2} \sin 90° = \sigma / 2$$

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From above, we see that the maximum tangential or shear stress is *one-half* the maximum normal stress.

The resultant stress is given by

$$\sigma_R = \sqrt{(\sigma_n)^2 + (\tau)^2}$$

Note : The above relations hold good for compressive stress also.

2.23 Stresses on an Oblique Section of a Body Subjected to Direct Stresses in Two Mutually Perpendicular Directions

When a body of uniform cross-sectional area and unit thickness is subjected to mutually perpendicular principal tensile stresses σ_x and σ_y as shown in Fig. 2.8, then the normal stress across the section *EF* is given by

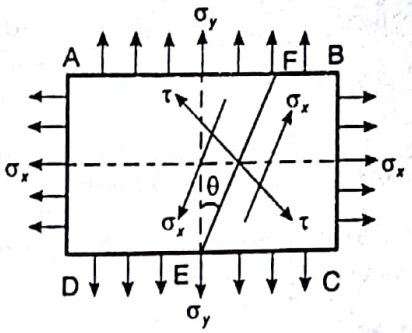

Fig. 2.8

$$\sigma_n = \frac{\sigma_x + \sigma_y}{2} + \frac{\sigma_x - \sigma_y}{2} \cos 2\theta \qquad ...(i)$$

Tangential stress (*i.e.* shear stress) across the section *EF*,

$$\tau = (\sigma_x - \sigma_y) \sin\theta \cos\theta = \frac{\sigma_x - \sigma_y}{2} \sin 2\theta \qquad ...(ii)$$

and resultant stress is given by

$$\sigma_R = \sqrt{(\sigma_n)^2 + \tau^2} = \sqrt{(\sigma_x \cos\theta)^2 + (\sigma_y \sin\theta)^2}$$

From equation (*i*), we see that the normal stress across the section *EF* will be maximum when $\cos 2\theta = 1$ or $\theta = 0°$. Therefore maximum normal stress when $\theta = 0°$ is σ_x. Similarly, the normal stress across the section *EF* will be minimum when $\cos 2\theta = -1$ or $2\theta = 180°$ or $\theta = 90°$. Therefore minimum normal stress when $\theta = 90°$ is σ_y. Thus we see that there are two principal planes at right angles to each other, one of which carries the maximum direct stress and the other minimum direct stress. These principal planes do not carry any shear stress.

From equation (*ii*), we see that the shear stress across the section *EF* will be maximum when $\sin 2\theta = 1$ or $2\theta = 90°$ or $270°$ or $\theta = 45°$ or $135°$. In other words, the shear stress will be maximum on two planes inclined at 45° and 135° to the normal section. Therefore maximum shear stress when $\theta = 45°$ or 135° is

$$\tau_{max} = \frac{\sigma_x - \sigma_y}{2}$$

2.24 Stresses on an Oblique Section of a Body in One Plane Accompanied by a Simple Shear Stress

When a body of uniform cross-sectional area and unit-thickness is subjected to a tensile stress (σ_x) in one plane accompanied by a shear stress (τ_{xy}) as shown in Fig. 2.9, then the maximum normal stress is given by

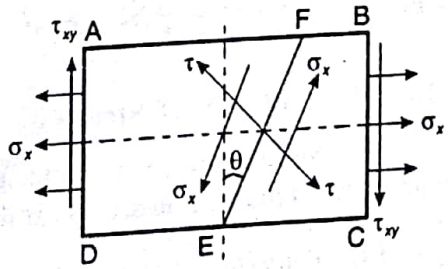

Fig. 2.9

$$(\sigma_n)_{max} = \frac{\sigma_x}{2} + \sqrt{\left(\frac{\sigma_x}{2}\right)^2 + (\tau_{xy})^2} = \frac{\sigma_x}{2} + \frac{1}{2}\sqrt{(\sigma_x)^2 + 4(\tau_{xy})^2}$$

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Minimum normal stress,

$$(\sigma_n)_{min} = \frac{\sigma_x}{2} - \sqrt{\left(\frac{\sigma_x}{2}\right)^2 + (\tau_{xy})^2} = \frac{\sigma_x}{2} - \frac{1}{2}\sqrt{(\sigma_x)^2 + 4(\tau_{xy})^2}$$

and maximum shear stress,

$$\tau_{max} = \frac{(\sigma_n)_{max} - (\sigma_n)_{min}}{2} = \sqrt{\left(\frac{\sigma_x}{2}\right)^2 + (\tau_{xy})^2} = \frac{1}{2}\sqrt{(\sigma_x)^2 + 4(\tau_{xy})^2}$$

Note : When the expression $\frac{1}{2}\sqrt{(\sigma_x)^2 + 4(\tau_{xy})^2}$ is greater than $\frac{\sigma_x}{2}$, then the nature of $(\sigma_n)_{min}$ will be opposite to that of $(\sigma_n)_{max}$ [*i.e.* if $(\sigma_n)_{max}$ is tensile, $(\sigma_n)_{min}$ will be compressive and vice versa]

2.25 Stresses on an Oblique Section of a Body Subjected to Direct Stresses in Two Mutually Perpendicular Directions Accompanied by a Simple Shear Stress

When a body of uniform cross-sectional area and unit thickness is subjected to tensile stresses (σ_x and σ_y) in two mutually perpendicular planes accompanied by a simple shear stress (τ_{xy}),as shown in Fig. 2.10, then the maximum normal stress is given by

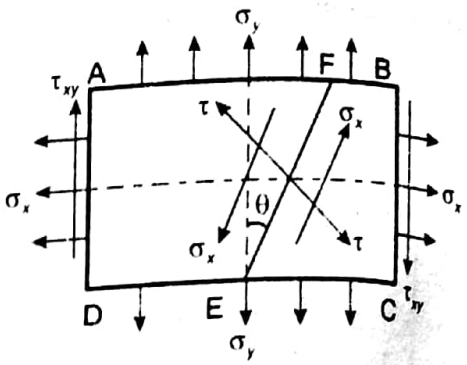

Fig. 2.10

$$(\sigma_n)_{max} = \frac{\sigma_x + \sigma_y}{2} + \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + (\tau_{xy})^2} = \frac{\sigma_x + \sigma_y}{2} + \frac{1}{2}\sqrt{(\sigma_x - \sigma_y)^2 + 4(\tau_{xy})^2}$$

Minimum normal stress,

$$(\sigma_n)_{min} = \frac{\sigma_x + \sigma_y}{2} - \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + (\tau_{xy})^2} = \frac{\sigma_x + \sigma_y}{2} - \frac{1}{2}\sqrt{(\sigma_x - \sigma_y)^2 + 4(\tau_{xy})^2}$$

and maximum shear stress,

$$\tau_{max} = \frac{(\sigma_n)_{max} - (\sigma_n)_{min}}{2} = \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + (\tau_{xy})^2}$$

$$= \frac{1}{2}\sqrt{(\sigma_x - \sigma_y)^2 + 4(\tau_{xy})^2}$$

2.26 Mohr's Circle of Stresses

The Mohr's circle is a graphical method of finding the normal, tangential and resultant stresses on an inclined plane. It is drawn for the following two cases:

(*a*) *When the two mutually perpendicular principal stresses are unequal and alike.* Let σ_x and σ_y be two unequal tensile (or compressive) principal stresses acting on a rectangular body. It is required to find the normal,tangential and resultant stresses on an oblique section making an angle θ with the minor tensile stress.

The Mohr's circle of stresses, as shown in Fig. 2.11, is drawn as discussed below :

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1. Take $OA = \sigma_x$ and $OB = \sigma_y$ with some suitable scale on the same side of O (because the two stresses are alike).
2. Bisect BA at C. Now with C as centre and radius equal to CB or CA, draw a circle.
3. Through C, draw CP making an angle 2θ with CA and draw PQ perpendicular to OA. Join OP.
4. Now OQ and PQ will give the required normal and tangential stresses on the oblique section, to the scale. OP is the resultant stress. The angle POA is called the *angle of obliquity*.

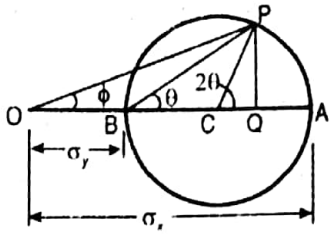

Fig. 2.11

Notes : 1. Since A and B are the ends of the horizontal diameter, therefore maximum normal stress will be equal to σ_x and the minimum principal stress will be σ_y.

2. The maximum shear stress will be equal to the radius of the Mohr's circle and will act on planes at 45° to the principal planes.

3. The angle of obliquity will be maximum when OP is tangential to the Mohr's circle.

(*b*) *When the two mutually perpendicular principal stresses are unequal and unlike.* Let σ_x be the principal tensile stress and σ_y be the principal compressive stress acting on a rectangular body. It is required to find the normal, tangential and resultant stresses on an oblique section making an angle θ.

The Mohr's circle of stresses, as shown in Fig. 2.12, is drawn as discussed below :

1. Take $OA = \sigma_x$ and $OB = \sigma_y$ with some suitable scale on the opposite sides of O (because the two stresses are unlike).
2. Bisect BA at C. Now with C as centre and radius equal to CB or CA, draw a circle.
3. Through C, draw CP making an angle 2θ with CA and draw PQ perpendicular to OA. Join OP.
4. Now OQ and PQ will give the required normal and tangential stresses on the oblique section, to the scale. OP is the required resultant stress, to the scale.

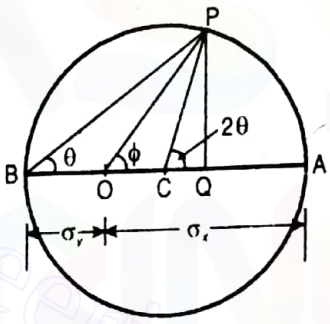

Fig. 2.12

2.27 Resilience

The strain energy stored in a body due to external loading within the elastic limit is known as *resilience*.

Notes : 1. The maximum strain energy which can be stored in a body upto the elastic limit is called *proof resilience*.

2. The proof resilience per unit volume of a material is known as *modulus of resilience*.

3. The strain energy stored in a body (or resilience) when it is subjected to direct tensile or compressive load

$$= \frac{\sigma^2}{2E} \times V$$

and modulus of resilience $= \dfrac{\sigma^2}{2E}$

where σ = Stress induced in the body,

E = Young's modulus for the material of the body, and

V = Volume of the body.

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4. The strain energy stored in a body (or resilience) when it is subjected to shear stress (τ)

$$= \frac{\tau^2}{2C} \times V$$

and modulus of shear resilience

$$= \frac{\tau^2}{2C}$$

where C = Modulus of rigidity for the material of the body.

2.28 Stress Induced in a Body Under Different Modes of Loading

A load W may be applied to a body in the following three ways:

1. Gradually applied load, 2. Suddenly applied load, and
3. Falling load (also called impact or shock load).

When load W is applied gradually to a body, then the stress induced in a body is given by

$$\sigma = \frac{W}{A}$$

where A = Cross-sectional area of the body.

When load W is applied suddenly to a body, then the stress induced in a body is *twice* the stress induced when the same load is applied gradually, *i.e.*

$$\sigma = 2 \times \frac{W}{A}$$

When load W is dropped from a height h, on to a body of length l and cross-sectional area A, then the stress induced (also called impact stress) is given by

$$\sigma_i = \frac{W}{A}\left[1+\sqrt{1+\frac{2h.A.E}{W.l}}\right]$$

2.29 Types of Beams

Following are the various types of beams :

1. *Cantilever beam.* A beam fixed at one end and free at the other end is known as a cantilever beam.

2. *Simply supported beam.* A beam supported at its both ends is known as simply supported beam.

3. *Overhanging beam.* A beam having its end portion extended beyond the support, is known as overhanging beam. A beam may be overhanging on one side or on both sides.

4. *Fixed beam.* A beam whose both ends are fixed, is known as fixed beam.

5. *Continuous beam.* A beam supported on more than two supports is known as continuous beam.

2.30 Types of Loading

A beam may be subjected to the following types of loads:

1. *Concentrated or point load.* A load acting at a point of a beam is known as a concentrated or point load.

2. *Uniformly distributed load.* A load which is spread over a beam in such a manner that each unit length is loaded to the same extent, is known as a uniformly distributed load (briefly written as U.D.L.).

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3. *Uniformly varying load.* A load which is spread over a beam, in such a manner that it varies uniformly on each unit length, is known as uniformly varying load. Sometimes, the load is zero at one end and increases uniformly to the other. Such a load is known as triangular load.

2.31 Shear Force and Bending Moment Diagrams

The shear force (briefly written as S.F.) at the cross-section of a beam may be defined as the algebraic sum of all the forces on either side of the section.

The bending moment (briefly written as B.M.) at the cross-section of a beam may be defined as the algebraic sum of all the moments of the forces on either side of the section.

The following figures show the shear force and bending moment diagrams for different types of beams and loading.

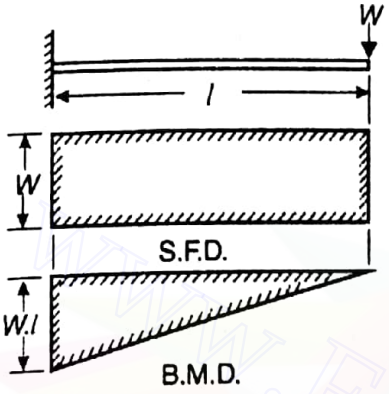

Fig. 2.13. Cantilever beam with a point load at the free end.

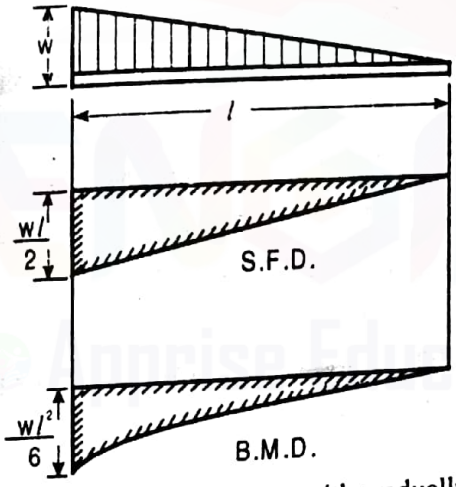

Fig. 2.15. Cantilever beam with gradually varying load.

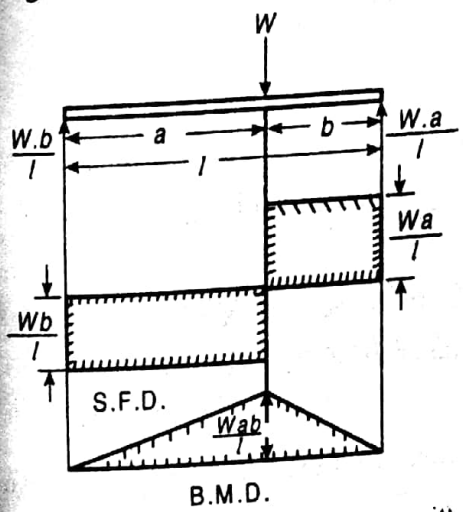

Fig. 2.17. Simply supported beam with an eccentric point load.

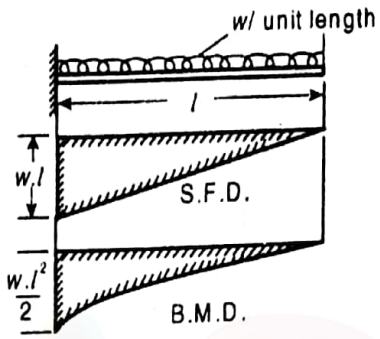

Fig. 2.14. Cantilever beam with uniformly distributed load (*w*/unit length).

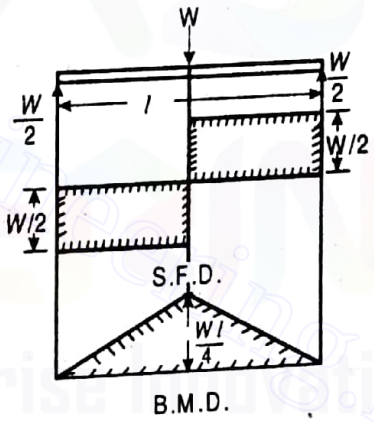

Fig. 2.16. Simply supported beam with point load at its mid point.

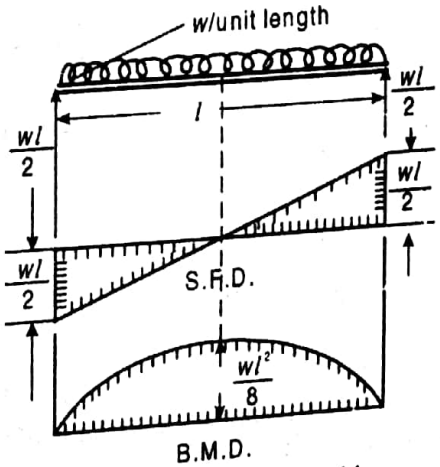

Fig. 2.18. Simply supported beam with a U.D.L.

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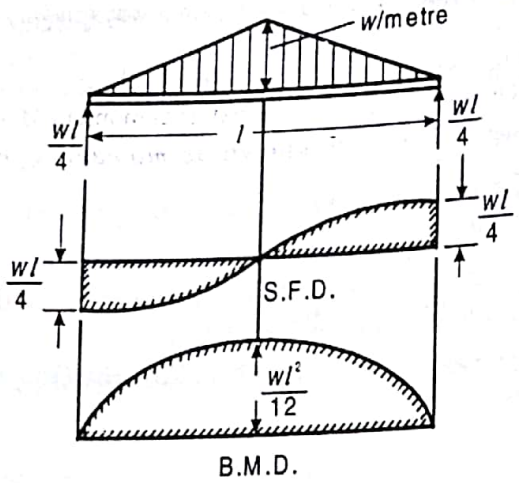

Fig. 2.19. Simply supported beam with a triangular load varying gradually from zero at both ends to w per metre at the centre.

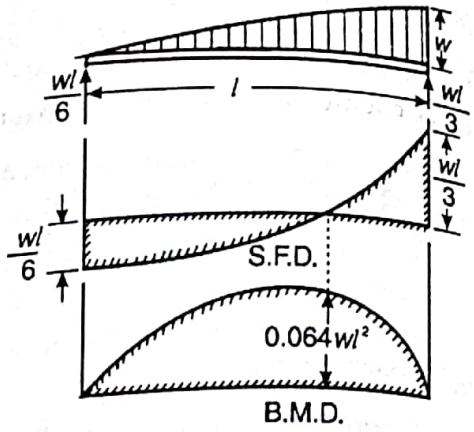

Fig. 2.20. Simply supported beam with a gradually varying load, from zero at one end to w per metre at the other end.

Notes : 1. The bending moment is maximum where shear force diagram changes sign from positive to negative or vice versa. In other words, the bending moment is maximum at a point where shear force is zero.

2. The point where the bending moment changes sign (or zero) is known as *point of contraflexure*. This point generally occurs in overhanging beams.

2.32 Assumptions in Theory of Bending

The following assumptions are made in the theory of simple bending:

1. The material of the beam is perfectly homogeneous (*i.e.* of the same kind throughout) and isotropic (*i.e.* of equal elastic properties in all directions).
2. The beam material is stressed within its elastic limit and thus obey's Hooke's law.
3. The transverse sections which are plane before bending, remain plane after bending also.
4. Each layer of the beam is free to expand or contract independently of the layer, above or below it.
5. The value of Young's modulus for the material of beam is same in tension and compression.

2.33 Bending Equation for Beams in Simple Bending

The following is the bending equation for beams in simple bending :

$$\frac{M}{I} = \frac{\sigma}{y} = \frac{E}{R}$$

where

M = Bending moment,

I = Moment of inertia of the area of cross-section,

σ = Bending stress,

y = Distance of extreme fibre from the neutral axis,

E = Young's modulus for the material of the beam, and

R = Radius of curvature.

Notes : 1. The line of intersection of the neutral layer with any normal cross-section of a beam is known as *neutral axis* of that section.

2. On one side of the neutral axis there are compressive stresses, and on the other side there are tensile

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stresses. At neutral axis there is no stress of any kind. The neutral axis of a section always passes through its centroid.

3. Since there are compressive stresses on one side of the neutral axis and tensile stresses on the other side, therefore these stresses form a couple whose moment must be equal to the external moment M. The moment of this couple which resist the external bending moment, is known as *moment of resistance*.

4. From the bending equation $\frac{M}{I} = \frac{\sigma}{y}$, we have

$$M = \sigma \times \frac{I}{y} \quad \text{or} \quad M = \sigma \times Z$$

where Z is known as section modulus or modulus of section.

2.34 Beams of Uniform Strength

A beam in which bending stress developed is constant and is equal to the allowable stress, is called a *beam of uniform strength*. It can be achieved by

1. Keeping the width uniform and varying the depth,
2. Keeping the depth uniform and varying the width,
3. Varying the width and depth both.

The common method of obtaining the beam of uniform strength is by keeping the width uniform and varying the depth.

2.35 Beams of Composite Section (Flitched Beams)

A beam made up of two or more different materials joined together in such a manner that they behave like a unit piece, is called a *composite beam* or *flitched beam*. Such beams are used when one material, if used alone, requires a larger cross-sectional area which is not suited to the space available and also to reinforce the beam at regions of high bending moment or to equalise the strength of the beam in tension or compression.

A beam of two materials, as shown in Fig. 2.21, is most common, such as wooden beam reinforced by metal strips and concrete beams reinforced with steel rods. In such cases, the total moment of resistance will be equal to the sum of the moment of resistances of the individual sections, *i.e.*

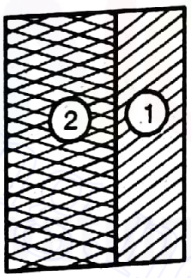

Fig. 2.21

$$M = M_1 + M_2 = \sigma_1 . Z_1 + \sigma_2 . Z_2 \qquad \ldots (i)$$

We also know that at any distance, from the neutral axis, strain in both the materials will be same, *i.e.*

$$\frac{\sigma_1}{E_1} = \frac{\sigma_2}{E_2} \quad \text{or} \quad \sigma_1 = \frac{E_1}{E_2} \times \sigma_2 = m.\sigma_2 \qquad \ldots (ii)$$

where $m = E_1/E_2 =$ Modular ratio.

From the above two relations, we can find out the moment of resistance of a composite beam or the stresses in the two materials.

2.36 Shear Stresses in Beams

The maximum shear stress developed in a beam of rectangular cross-section, as shown in Fig. 2.22, is given by

$$\tau_{max} = 1.5\, \tau_{av}$$

where τ_{av} = Average shear stress = Load / Area

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The maximum shear stress developed in a beam of circular cross-section, as shown in Fig. 2.23, is given by

$$\tau_{max} = \frac{4}{3}\tau_{av}$$

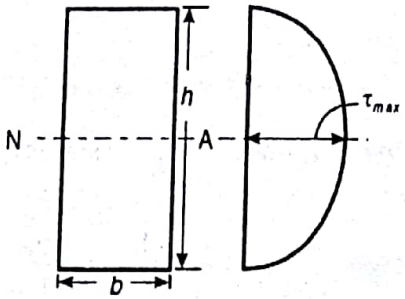

Fig. 2.22

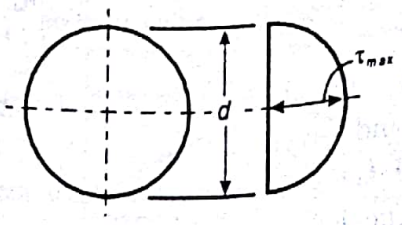

Fig. 2.23

It may be noted that the shear stress in a beam is not uniformly distributed over the cross-section, but varies from zero at outer fibres to a maximum at the neutral surface as shown in Fig 2.22 and Fig. 2.23.

2.37 Deflection of Beams

The general equation for the deflection of beams is

$$M = EI\frac{d^2y}{dx^2}$$

where M = Bending moment,

E = Young's modulus, and

I = Moment of inertia.

The product of $E.I$ is known as *flexural rigidity*. Let us now consider the following cases :

1. *Simply supported beam with a central point load.* A simply supported beam AB of length l and carrying a point load at the centre of the beam at C is shown in Fig. 2.24. The deflection at point C (it is the maximum deflection) is

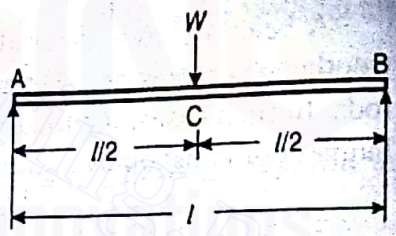

Fig. 2.24

$$y_C = \frac{Wl^3}{48EI}$$

2. *Simply supported beam with an eccentric point load.* A simply supported beam AB of length l and carrying an eccentric point load at C is shown in Fig. 2.25. The deflection at point C is given by

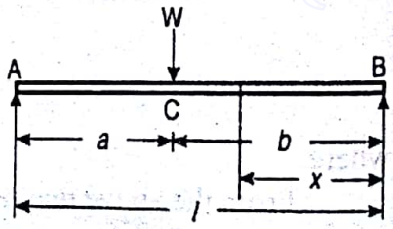

Fig. 2.25

$$y_C = \frac{Wab}{6EIl}(l^2 - a^2 - b^2) = \frac{Wa^2b^2}{3EIl}$$

Since $b > a$, therefore maximum deflection occurs in CB and its distance from B is given by

$$x = \sqrt{\frac{l^2 - a^2}{3}}$$

and maximum deflection,

$$y_{max} = \frac{W.a}{9\sqrt{3}\,EIl}(l^2 - a^2)^{3/2}$$

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3. *Simply supported beam with a uniformly distributed load.* A simply supported beam AB with a uniformly distributed load w / unit length is shown in Fig. 2.26.

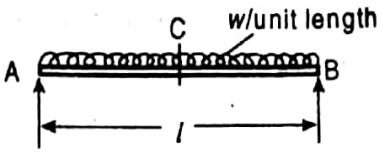

Fig. 2.26

The maximum deflection occurs at the mid point C and is given by

$$y_C = \frac{5wl^4}{384\,EI} = \frac{5Wl^3}{384\,EI} \qquad \ldots(\because W = w.l)$$

4. *Simply supported beam with a gradually varying load.* A simply supported beam AB of length l and carrying a gradually varying load from zero at B to w / unit length at A, is shown in Fig. 2.27.

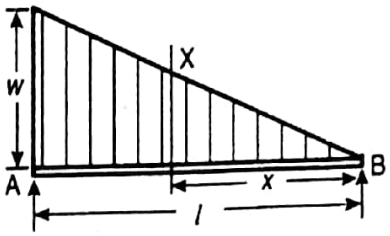

Fig. 2.27

The deflection at any section X of the beam at a distance x from B is given by

$$y = \frac{1}{EI} = \left(\frac{wlx^3}{36} - \frac{wx^5}{120l} - \frac{7wl^3x}{360}\right)$$

The maximum deflection occurs when $x = 0.519\,l$ and its value is given by

$$y_{max} = \frac{0.006\,52\;wl^4}{EI}$$

5. *Cantilever beam with a point load at the free end.* A cantilever beam AB of length l carrying a point load at the free end is shown in Fig 2.28. The deflection at any section X at a distance x from the free end is given by



Fig. 2.28

$$y = \frac{1}{EI}\left(\frac{wl^2x}{2} - \frac{wx^3}{6} - \frac{wl^3}{3}\right)$$

The maximum deflection occurs at the free end (when $x = 0$) and its value is given by

$$y_B = \frac{Wl^3}{3EI}$$

6. *Cantilever beam with a uniformly distributed load.* A cantilever beam AB of length l carrying a uniformly distributed load w / unit length is shown in Fig. 2.29. The deflection at any section X at a distance x from B is given by

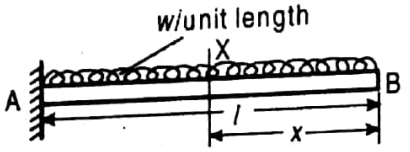

Fig. 2.29

$$y = \frac{1}{EI}\left(\frac{wl^3x}{6} - \frac{wx^4}{24} - \frac{wl^4}{8}\right)$$

The maximum deflection occurs at the free end (when $x = 0$) and its value is given by

$$y_B = \frac{wl^4}{8EI} = \frac{Wl^3}{8EI} \qquad \ldots(\because W = w.l)$$

...ally loaded as shown in Fig. 2.30, then the deflection at point C (at a

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7. *Cantilever beam with a gradually varying load.* A cantilever beam AB of length l carrying a gradually varying load from zero at B to w / unit length at A is shown in Fig. 2.31. The deflection at any section X at a distance x from B is given by

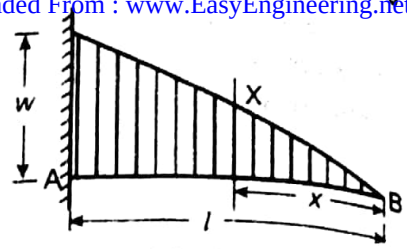

Fig. 2.31

$$y = \frac{1}{EI}\left(\frac{wl^3x}{24} - \frac{wx^5}{120l} - \frac{wl^4}{30}\right)$$

The maximum deflection occurs at the free end (when $x = 0$) and its value is given by

$$y_B = \frac{wl^4}{30\,EI}$$

8. *Fixed beam carrying a central point load.* A fixed beam AB of length l carrying a point load at the centre of the beam at C is shown in Fig. 2.32. The maximum deflection occurs at C and its value is given by

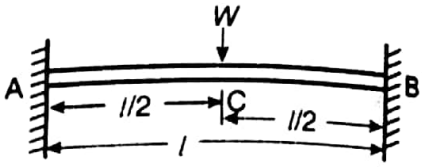

Fig. 2.32

$$y_C = \frac{Wl^3}{192\,EI}$$

9. *Fixed beam carrying an eccentric point load.* A fixed beam AB of length l carrying an eccentric point load at C is shown in Fig. 2.33. The deflection at any section X at a distance x from A is given by

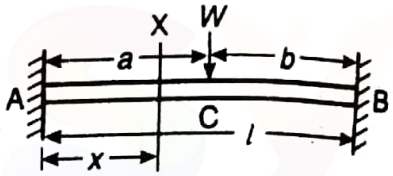

Fig. 2.33

$$y = \frac{Wb^2x^2}{6EIl^3}\left[x(3a+b) - 3al\right]$$

The maximum deflection occurs when $x = \dfrac{2al}{3a+b}$

$\therefore$ Maximum deflection,

$$y_{max} = \frac{2}{3} \times \frac{Wa^2b^2}{EI\,(3a+b)^2}$$

and deflection under the load at C,

$$y_C = \frac{Wa^3b^3}{3EIl^3}$$

10. *Fixed beam carrying a uniformly distributed load.* A fixed beam AB of length l carrying a uniformly distributed load of w / unit length is shown in Fig. 2.34. The deflection at any section X at a distance x from A is given by

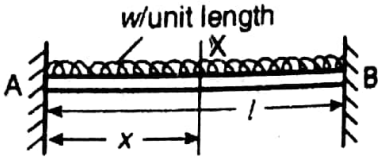

Fig. 2.34

$$y = \frac{1}{EI}\left(\frac{w.l.x^3}{12} - \frac{w.x^4}{24} - \frac{wl^2.x^2}{24}\right)$$

The maximum deflection occurs at the centre of the beam and its value is given by

$$y_{max} = \frac{wl^4}{384\,EI} = \frac{Wl^3}{384\,EI} \qquad \ldots(\because W = w.l)$$

2.38 Shear Stress in Shafts

When a shaft fixed at one end is subjected to a torque (or twisting moment) at the other end, then every cross-section of the shaft will be subjected to shear stresses. It may be noted that the

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shear stress is zero at the centroidal axis of the shaft and maximum at the outer surface. The maximum shear stress at the outer surface of the shaft may be obtained by the following equation, known as torsion equation.

$$\frac{\tau}{R} = \frac{T}{J} = \frac{C\theta}{l} \qquad ...(i)$$

where τ = Shear stress induced at the outer surface of the shaft or maximum shear stress,

R = Radius of the shaft,

T = Torque or twisting moment,

J = Polar moment of inertia. It is the second moment of area of the section about its polar axis = $I_{xx} + I_{yy}$

C = Modulus of rigidity for the shaft material,

l = Length of the shaft, and

θ = Angle of twist in radians on a length l.

The above equation is based on the following assumptions :

1. The material of the shaft is uniform throughout.
2. The twist along the shaft is uniform.
3. The normal cross-section of the shaft, which were plane and circular before twist, remain plane and circular after twist.
4. All diameters of the normal cross-section which were straight before twist, remain straight with their magnitude unchanged, after twist.

The following points may be noted :

1. The shear stress on any cross-section normal to the axis of the shaft is directly proportional to the distance from the centre of the shaft. Thus shear stress at a distance x from the centre of the shaft is given by

$$\frac{\tau_x}{x} = \frac{\tau}{R}$$

2. The strength of a shaft means the maximum torque or power transmitted by the shaft. From equation (i), we have

$$\frac{\tau}{R} = \frac{T}{J} \quad \text{or} \quad T = \tau \times \frac{J}{R}$$

For a solid shaft of diameter (D), the polar moment of inertia,

$$J = I_{xx} + I_{yy} = \frac{\pi D^4}{64} + \frac{\pi D^4}{64} = \frac{\pi D^4}{32}$$

$$\therefore \quad T = \tau \times \frac{\pi D^4}{32} \times \frac{2}{D} = \frac{\pi}{16} \times \tau D^3$$

For a hollow shaft with external diameter (D) and internal diameter (d), the polar moment of inertia,

$$J = \frac{\pi}{32}(D^4 - d^4); \quad \text{and} \quad R = \frac{D}{2}$$

$$\therefore \quad T = \frac{\pi}{16} \times \tau \left(\frac{D^4 - d^4}{D}\right) = \frac{\pi}{16} \times \pi \times D^3 (1 - k^4) \text{ where } k = \frac{d}{D}$$

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3. The term J / R is known as polar modulus. The polar modulus for a solid shaft,

$$Z_p = \frac{\pi}{16} D^3$$

and polar modulus for a hollow shaft,

$$Z_p = \frac{\pi}{16}\left(\frac{D^4 - d^4}{D}\right)$$

4. The term T / θ is known as *torsional rigidity* of the shaft.

5. The power transmitted by a shaft (in watts) is given by

$$P = T.\omega = \frac{2\pi NT}{60} \quad \ldots \left(\because \omega = \frac{2\pi N}{60}\right)$$

where T = Torque transmitted in N-m,

N = Speed of the shaft in r.p.m., and

ω = Angular speed in rad /s.

2.39 Strain Energy due to Torsion

The total strain energy stored in a solid shaft of diameter D and length l is given by

$$U = \frac{\tau^2}{4C} \times V$$

where V = Volume of the shaft $= \frac{\pi}{4} \times D^2 \times l$

and total strain energy stored in a hollow shaft of external diameter (D) and internal diameter (d) is given by

$$U = \frac{\tau^2}{4C}\left(\frac{D^2 + d^2}{D^2}\right) V$$

2.40 Shaft Subjected to Combined Bending and Torsion

When a shaft is subjected to a twisting moment or torque (T) and a bending moment (M) due to self weight of the shaft and pulleys mounted on it, then the maximum normal stress in the shaft is given by

$$\sigma_{b\,(max)} = \frac{1}{2}\left(\sigma_b + \sqrt{(\sigma_b^2) + 4\tau^2}\right) \quad \ldots(i)$$

and minimum normal stress,

$$\sigma_{b\,(min)} = \frac{1}{2}\left(\sigma_b - \sqrt{(\sigma_b)^2 + 4\tau^2}\right) \quad \ldots(ii)$$

where σ_b = Bending stress induced in the shaft due to bending moment (M), and

τ = Shear stress induced in the shaft due to twisting moment (T).

We know that for a shaft of diameter (D),

$$\sigma_b = \frac{32\,M}{\pi D^3}, \quad \text{and} \quad \tau = \frac{16T}{\pi D^3}$$

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Substituting these values in equations (*i*) and (*ii*),

Maximum normal stress,

$$\sigma_{b\,(max)} = \frac{32}{\pi D^3}\left[\frac{1}{2}\left(M + \sqrt{M^2 + T^2}\right)\right] = \frac{16}{\pi D^3}\left[M + \sqrt{M^2 + T^2}\right]$$

and minimum normal stress,

$$\sigma_{b\,(min)} = \frac{32}{\pi D^3}\left[\frac{1}{2}\left(M - \sqrt{M^2 + T^2}\right)\right] = \frac{16}{\pi D^3}\left[M - \sqrt{M^2 + T^2}\right]$$

The expression $\left[\frac{1}{2}\left(M + \sqrt{M^2 + T^2}\right)\right]$ is known as *equivalent bending moment* and is denoted by M_e. The equivalent bending moment is defined as that bending moment which when acting alone produces the same tensile or compressive stress (σ_b) as the actual bending moment.

We know that maximum shear stress in the shaft

$$\tau_{max} = \frac{\sigma_{b\,(max)} - \sigma_{b\,(min)}}{2} = \frac{1}{2}\sqrt{(\sigma_b)^2 + \tau^2} = \frac{16}{\pi D^3}\left(\sqrt{M^2 + T^2}\right)$$

The expression $\sqrt{M^2 + T^2}$ is known *as equivalent twisting moment* and is denoted by T_e. The equivalent twisting moment is defined as that twisting moment which when acting alone produces the same shear stress (τ) as the actual twisting moment.

Note : For a hollow shaft of external diameter (D) and internal diameter (d), the maximum normal stress,

$$\sigma_{b\,(max)} = \frac{16D}{\pi(D^4 - d^4)}\left(M + \sqrt{M^2 + T^2}\right)$$

Minimum normal stress,

$$\sigma_{b\,(min)} = \frac{16D}{\pi(D^4 - d^4)}\left(M - \sqrt{M^2 + T^2}\right)$$

and maximum shear stress,

$$\tau_{max} = \frac{16D}{\pi(D^4 - d^4)}\left(\sqrt{M^2 + T^2}\right)$$

2.41 Springs

A spring is a device whose function is to distort when loaded and to recover its original shape when the load is removed. The various important applications of springs are as follows:

1. To cushion, absorb or control energy due to either shock or vibration as in car springs, railway buffers, shock absorbers and vibration dampers.
2. To apply forces as in brakes, clutches and spring loaded valves.
3. To control motion by maintaining contact between two elements as in cams and followers.
4. To measure forces as in spring balances and engine indicators.
5. To store energy as in watches, toys etc.

2.42 Stiffness of a Spring

The load required to produce a unit deflection in a spring is called stiffness of a spring.

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2.43 Carriage Spring or Leaf Springs

The maximum bending stress developed in the spring is given by

$$\sigma = \frac{3Wl}{2nbt^2}$$

and deflection,

$$\delta = \frac{3Wl^3}{8Enbt^3}$$

where W = Load on the spring,

l = Span of the spring,

t = Thickness of the plates,

b = Width of the plates,

n = Number of plates, and

E = Young's modulus for the material of the plates.

2.44 Closely Coiled Helical Springs

When a closely coiled helical spring of mean diameter (D) is subjected to an axial load W, then the twisting moment due to the load W is given by

$$T = W.R = W \times \frac{D}{2} = \frac{\pi}{16} \times \tau \times d^3$$

Deflection of the spring,

$$\delta = \frac{64WR^3n}{Cd^4} = \frac{8\,WD^3n}{Cd^4}$$

Energy stored in the spring,

$$U = \frac{1}{2}\,W.\delta$$

and stiffness of the spring,

$$s = \frac{W}{\delta} = \frac{Cd^4}{64\,R^3n} = \frac{Cd^4}{8\,D^3\,n}$$

where R = Mean radius of the spring coil = $D/2$

d = Diameter of the spring wire,

n = Number of turns or coils,

C = Modulus of rigidity for the spring material,

τ = Maximum shear stress induced in the wire due to twisting.

2.45 Springs in Series and Parallel

When two springs having stiffness k_1 and k_2 are connected in series as shown in Fig. 2.35 (a), then the combined stiffness of the springs (k) is given by

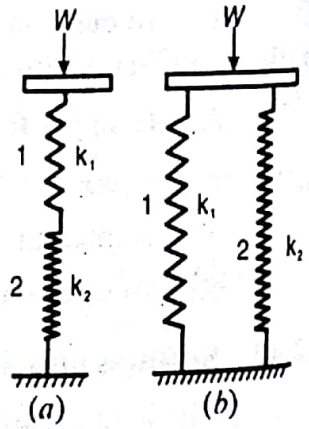

Fig. 2.35

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$$k = \frac{k_1}{k} = \frac{1}{k_1} + \frac{1}{k_2} \quad \text{or} \quad k = \frac{k_1 k_2}{k_1 + k_2}$$

When the springs are connected in parallel as shown in Fig. 2.35 (*b*), then

$$k = k_1 + k_2$$

2.46 Riveted Joints

Following are two types of riveted joints, depending upon the way in which the members are connected:

1. Lap joint, and 2. Butt joint.

A *lap joint* is that in which one plate overlaps the other and the two plates are riveted together.

A butt joint is that in which the main plates are kept in alignment butting (*i.e.* touching) each other and a cover plate (*i.e.*strap) is placed on one side or on both sides of the main plates. The cover plate is then riveted together with the main plates. Butt joints are of the following two types:

1. Single strap butt joint, and 2. Double strap butt joint.

In a *single strap butt joint*, the edges of the main plates butt against each other and only one cover plate is placed on one side of the main plates and then riveted together.

In a *double strap butt joint*, the edges of the main plates butt against each other and two cover plates are placed on both sides of the main plates and then riveted together.

In addition to the above, following are the types of riveted joints depending upon the number of rows of the rivets.

1. Single riveted joint, and 2. Double riveted joint.

A *single riveted joint* is that in which there is a single row of rivets in a lap joint and there is a single row of rivets on each side in a butt joint.

A *double riveted joint* is that in which there are two rows of rivets in a lap joint and there are two rows of rivets on each side in a butt joint.

Similarly the joints may be triple riveted or quadruple riveted.

Note : When the rivets in the various rows are opposite to each other, then the joint is said to be *chain riveted.* On the other hand, if the rivets in the adjacent rows are staggered in such a way that every rivet is in the middle of the two rivets of the opposite row, then the joint is said to be *zig-zag riveted.*

2.47 Important Terms Used in Riveted Joints

Following are important terms used in riveted joints :

1. *Pitch.* It is the distance from the centre of one rivet to the centre of the next rivet measured parallel to the seam.

2. *Back pitch.* It is the perpendicular distance between the centre lines of the successive rows.

3. *Diagonal pitch.* It is the distance between the centres of the rivets in adjacent rows of zig zag riveted joint.

4. *Margin or marginal pitch.* It is the distance between the centre of rivet hole to the nearest edge of the plate.

2.48 Failures of Riveted Joints

A riveted joint may fail in the following ways :

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1. *Tearing of the plate at an edge.* This can be avoided by keeping the margin $(m) = 1.5\ d$, where d is the diameter of rivet hole.

2. *Tearing of the plate across the row of rivets.* The tearing resistance or pull required to tear off the plate per pitch length is given by

$$P_t = (p - d)\, t.\, \sigma_t$$

where p = Pitch of the rivets,

d = Diameter of the rivet hole.

t = Thickness of the plate, and

σ_t = Permissible tensile stress for the plate material.

3. *Shearing of rivets.* The shearing resistance or pull required to shear off the rivet per pitch length is given by

$$P_s = n \times \frac{\pi}{4} d^2 \times \tau \quad \text{... (in single shear)}$$

$$= n \times 2 \times \frac{\pi}{4} d^2 \times \tau \quad \text{...(in double shear)}$$

where n = Number of rivets per pitch length, and

τ = Permissible shear stress for the rivet material.

4. *Crushing of rivets.* The crushing resistance or pull required to crush the rivet per pitch length is given by

$$P_c = n.\, d.\, t.\, \sigma_c$$

where σ_c = Permissible crushing stress for the rivet material.

Notes : 1. The strength of the riveted joint is equal to the least value of P_t, P_s and P_c.

2. The ratio of strength of the riveted joint to the strength of the unriveted plate per pitch length is called efficiency of the riveted joint. Mathematically, efficiency of the riveted joint,

$$\eta = \frac{\text{Least value of } P_t, P_s \text{ and } P_c}{p.t.\sigma_t}$$

2.49 Welded Joints

The strength of the transverse fillet welded joints is given by

$$P = \frac{1}{\sqrt{2}}\, s.l.\sigma_t \quad \text{...(For single fillet weld)}$$

$$= \sqrt{2}\, s.\, l.\, \sigma_t \quad \text{.... (For double fillet weld)}$$

where s = Leg or size of weld,

l = Length of weld, and

σ_t = Allowable tensile stress for the weld metal.

The strength of parallel fillet welded joints is given by

$$P = \frac{1}{\sqrt{2}}\, s.l.\tau \quad \text{... (For single parallel fillet weld)}$$

$$= \sqrt{2}\, s.l.\tau \quad \text{... (For double parallel fillet weld)}$$

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Note : The transverse fillet welded joints are designed for tensile strength and parallel fillet welded joints are designed for shear strength.

2.50 Thin Cylindrical and Spherical Shells

If the thickness of the wall of a shell is less than 1 / 10 to 1 / 15 of its diameter, it is known as *thin shell*. It may be noted that whenever a cylindrical shell is subjected to an internal pressure, its walls are subjected to the following two types of tensile stresses:

1. Circumferential stress or hoop stress, and 2. Longitudinal stress.

In case of thin shells, the stresses are assumed to be uniformly distributed throughout the wall thickness. When a thin cylindrical shell of diameter (d), thickness (t) and length (l) is subjected to an internal pressure (p), then the circumferential or hoop stress induced in the shell,

$$\sigma_c = \frac{p.d}{2t.\eta}$$

and longitudinal stress, $$\sigma_l = \frac{p.d}{4t.\eta}$$

where η = Efficiency of the riveted joint, when the shell is made of desired capacity by joining different plates, by means of rivets.

Notes : 1. The circumferential stress has the tendency to split up the cylindrical shell into two troughs.

2. The longitudinal stress has the tendency to split up the cylindrical shell into two cylinders.

3. The longitudinal stress is half of the circumferential or hoop stress.

2.51 Change in Dimensions of a Thin Cylindrical Shell

When a thin cylindrical shell is subjected to an internal pressure, its walls will be subjected to lateral strain, the effect of which is to cause some change in the dimensions (*i.e.* length and diameter) of the shell. The circumferential strain is given by

$$\varepsilon_c = \frac{p.d}{2tE}\left(1-\frac{1}{2m}\right)$$

and longitudinal strain,

$$\varepsilon_l = \frac{p.d}{2tE}\left(\frac{1}{2}-\frac{1}{m}\right)$$

where E = Young's modulus for the shell material, and

$1/m$ = Poisson's ratio.

The change in diameter is given by

$$\delta d = \varepsilon_c.d = \frac{p.d^2}{2tE}\left(1-\frac{1}{2m}\right)$$

and change in length, $$\delta l = \varepsilon_l.l = \frac{p.d.l}{2tE}\left(\frac{1}{2}-\frac{1}{m}\right)$$

It may be noted that when the shell is subjected to an internal pressure, there will be an increase in the diameter as well as the length of the shell.

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The change in volume is given by

$$\delta V = V\left(2\varepsilon_c + \varepsilon_l\right), \quad \text{where } V = \frac{\pi}{4} \times d^2 \times l$$

and volumetric strain, $$\frac{\delta V}{V} = 2\varepsilon_c + \varepsilon_l = \frac{p.d}{4tE}\left(5 - \frac{4}{m}\right)$$

2.52 Thin Spherical Shells

When a thin spherical shell of diameter (d) and thickness (t) is subjected to an internal pressure (p), then the stress induced in the shell material,

$$\sigma = \frac{p.d}{4\ t.\eta}$$

The change in diameter is given by

$$\delta d = \frac{p.d^2}{4tE}\left(1 - \frac{1}{m}\right)$$

and change in volume, $$\delta V = \frac{\pi\, pd^4}{8tE}\left(1 - \frac{1}{m}\right)$$

2.53 Thick Cylindrical and Spherical Shells

If the thickness of the wall of a shell is greater than 1 / 10 to 1 / 15 of its diameter, it is known as *thick shell*. The thick shells are, generally, used to withstand high pressures. Sometimes, even, compound thick shells are used to withstand very high pressures or to contain chemicals under high pressure.

The problem of thick cylinders is, somewhat, complex and is solved by *Lame's theory.*

2.54 Direct and Bending Stresses

When an eccentric load acts upon a body, then the direct and bending stresses are induced. Consider a column subjected to a compressive load P acting at an eccentricity of e as shown in Fig. 2.36.

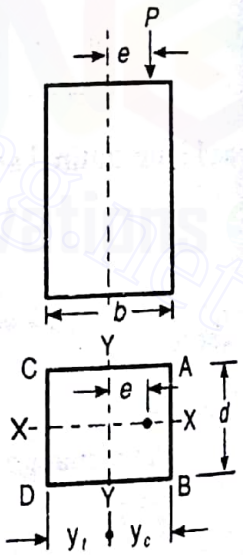

Fig. 2.36

The magnitude of direct compressive stress over the entire cross-section of the column is given by

$$\sigma_o = P / A$$

where A = Cross-sectional area of the column.

The magnitude of bending stress at the edge AB is given by

$$\sigma_b = \frac{P.e.y_c}{I} \quad \text{(compressive)}$$

and bending stress at the edge CD,

$$\sigma_b = \frac{P.e.y_t}{I} \quad \text{(tensile)}$$

where y_c and y_t = Distances of the extreme fibres on the compressive and tensile sides, from the neutral axis respectively, and

I = Second moment of area of the section about the neutral axis *i.e.* Y-axis = $db^3 / 12$.

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The maximum or resultant compressive stress at the edge AB is given by

$$\sigma_c = \frac{P.e.y_c}{I} + \frac{P}{A} = \frac{M}{Z} + \frac{P}{A} = \sigma_b + \sigma_o$$

... ($\because$ $M = P.e$, and $Z = I / y_c$)

and the maximum or resultant tensile stress at the edge CD is

$$\sigma_t = \frac{P.e.y_t}{I} - \frac{P}{A} = \frac{M}{Z} - \frac{P}{A} = \sigma_b - \sigma_o$$

Notes : 1. When the member is subjected to a tensile load, then the above equations may be used by interchanging the subscripts c and t.

2. When the direct stress σ_o is greater than or equal to bending stress σ_b, then the compressive stress shall be present all over the cross-section.

3. When the direct stress σ_o is less than the bending stress σ_b, then the tensile stress will occur in the left hand portion of the cross-section and compressive stress on the right hand portion of the cross-section.

2.55 Limit of Eccentricity

It is the maximum distance between the geometrical axis of a column section and the point of loading such that no tensile stress comes into play at any section of the column. We have seen above that the resultant tensile stress at the edge CD,

$$\sigma_t = \sigma_b - \sigma_o = \frac{M}{Z} - \frac{P}{A}$$

If the tensile stress is not to be permitted to come into play, then the bending stress (σ_b) should be less than the direct stress (σ_o)or at the most, it may be equal to the direct stress, *i.e.*

$$\sigma_b \le \sigma_o \quad \text{or} \quad \frac{M}{Z} \le \frac{P}{A} \quad \text{or} \quad \frac{P.e}{Z} \le \frac{P}{A} \quad \text{or} \quad e \le \frac{Z}{A}$$

The limit of eccentricity (e) for various sections is as follows :

1. For a rectangular section of width (b) and depth (d), $e \le d/6$
2. For a hollow rectangular section with B and D outer width and depth respectively and b and d inner width and depth respectively,

$$e \le \frac{BD^3 - bd^3}{6D(BD - bd)}$$

3. For a circular section of diameter (d), $e \le d/8$
4. For a hollow circular section of outer and inner diameter D and d respectively,

$$e \le \frac{D^2 + d^2}{8D}$$

2.56 Columns and Struts

A structural member, subjected to an axial compressive force, is called a *strut*. A strut may be horizontal, inclined or even vertical. But a vertical strut, used in buildings or frames, is called a *column*.

According to Euler's column theory, the critical load (P) on the column for different types of end conditions is as follows :

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1. For both ends hinged, $P = \dfrac{\pi^2 EI}{l^2}$

2. For one end fixed and other end free, $P = \dfrac{\pi^2 EI}{4l^2}$

3. For both ends fixed, $P = \dfrac{4\pi^2 EI}{l^2}$

4. For one end fixed and other end hinged, $P = \dfrac{2\pi^2 EI}{l^2}$

In general, Euler's formula is given by

$$P = \frac{\pi^2 EI}{Cl^2}$$

where C is a constant, representing the end condition of the column. It may be noted that

(*a*) $C = 1$, for a column with both ends hinged.

(*b*) $C = 4$, for a column with one end fixed and other end free.

(*c*) $C = 1/4$, for a column with both ends fixed.

(*d*) $C = 1/2$, for a column with one end fixed and the other end hinged.

There is another way of representing the Euler's formula, for the crippling load, by an equivalent length or effective length of a column. The equivalent length, of a given column with given end conditions, is the length of an equivalent column of the same material and cross-section with hinged ends and having the value of crippling load equal to that of the given column.

The equivalent lengths (L) for the given end conditions are given in the following Table.

S. No.	*End conditions*	*Crippling load*	*Relation between equivalent length and actual length.*
1.	Both ends hinged	$\dfrac{\pi^2 EI}{l^2} = \dfrac{\pi^2 EI}{L^2}$	$L = l$
2.	One end fixed and the other end free	$\dfrac{\pi^2 EI}{4l^2} = \dfrac{\pi^2 EI}{(2l)^2} = \dfrac{\pi^2 EI}{L^2}$	$L = 2l$
3.	Both ends fixed	$\dfrac{4\pi^2 EI}{l^2} = \dfrac{\pi^2 EI}{\left(\frac{l}{2}\right)^2} = \dfrac{\pi^2 EI}{L^2}$	$L = \dfrac{l}{2}$
4.	One end fixed and the other end hinged	$\dfrac{2\pi^2 EI}{l^2} = \dfrac{\pi^2 EI}{\left(\frac{l}{\sqrt{2}}\right)^2} = \dfrac{\pi^2 EI}{L^2}$	$L = \dfrac{l}{\sqrt{2}}$

Notes : 1. The vertical column will have two moments of inertia (*i.e.* I_{xx} and I_{yy}). Since the column will tend to buckle in the direction of least moment of inertia, therefore the least value of the two moments of inertia is to be used in the Euler's formula.

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2. The Euler's formula is given by

$$P = \frac{\pi^2 EI}{l^2} = \frac{\pi^2 E.Ak^2}{l^2} = \frac{\pi^2 EA}{(l/k)^2}$$

... ($\because$ $I = A.k^2$, where A is the area and k is the least radius of gyration of the section).

3. The ratio l/k is known as *slenderness ratio*.

4. Sometimes, the columns whose slenderness ratio is more than 80, are known as *long columns* and those whose slenderness ratio is less than 80 are known as *short columns*.

5. Euler's formula holds good only for long columns.

2.57 Rankine's Formula For Columns

The Rankine's formula for crippling load (P) is given by

$$P = \frac{\sigma_c . A}{1 + a\left(\frac{L}{k}\right)^2}$$

where

σ_c = Crushing stress of the column material,

A = Cross-sectional area of the column,

a = Rankine's constant = $\frac{\sigma_c}{\pi^2 E}$

L = Equivalent length of the column, and

k = Least radius of gyration.

The values of Rankine's constant (a) are as follows :

1. For wrought iron, $a = 1/9000$;
2. For mild steel, $a = 1/7500$
3. For cast iron, $a = 1/1600$
4. For timber $a = 1/750$

2.58 Dams and Retaining Walls

A dam is constructed to store large quantity of water, which is used for the purpose of irrigation and power generation. A dam constructed with earth is called an *earthen dam* whereas a dam constructed with cement concrete is called *masonry* or *gravity dam*. A dam may be of any cross-section, but the dams of trapezoidal cross-section are very popular these days. A retaining wall is generally constructed to retain earth in hilly areas.

The following two forces generally act on a dam :

1. The weight of the dam acting downward; and
2. The pressure of water acting horizontally.

Consider a trapezoidal dam of unit length having its water face vertical as shown in Fig. 2.37.

Let

a = Top width of dam,

b = Bottom width of dam,

H = Height of dam,

ρ = Specific weight of the dam masonry,

h = Height of water retained by the dam, and

w = Specific weight of water.

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We know that weight of the dam per unit length,

$$W = \frac{a+b}{2} \times H \times 1 \times \rho$$

and total pressure on a unit length of a trapezoidal dam,

$$P = \frac{w.h^2}{2}$$

Horizontal distance between *C.G.* of the dam and the point where resultant *R* cuts the base (*i.e.* distance *JK*)

$$= \frac{P}{W} \times \frac{h}{3}$$

Distance between the toe of the dam *A* and the point where the resultant *R* cuts the base (*i.e.* distance *AK*),

$$x = AJ + JK = AJ + \frac{P}{W} \times \frac{h}{3}$$

Resolving the resultant *R* acting at point *K* into two components *i.e.* the horizontal component (*P*) and the vertical component (*W*). The horizontal component does not affect the stresses at the base.

The stresses which are developed at the base of the dam are, therefore, due to the weight of the dam (*W*), which acts with an eccentricity *OK* where *O* is the mid point of *AB*. From Fig. 2.37, we find that eccentricity.

$$OK = e = AK - AO = AJ + JK - \frac{b}{2}$$

The maximum stress (σ_{max}) occurs across the base at *B* and minimum stress (σ_{min}) occurs at *A*, such that

$$\sigma_{max} = \frac{W}{b}\left(1 + \frac{6e}{b}\right)$$

and

$$\sigma_{min} = \frac{W}{b}\left(1 - \frac{6e}{b}\right)$$

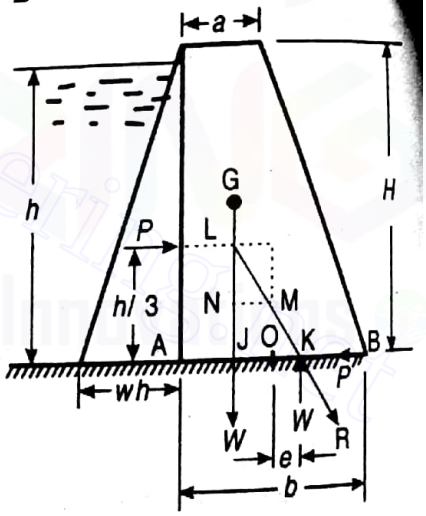

Fig. 2.37

2.59 Conditions for Stability of a Dam

A masonry dam may fail due to

1. Tension in the masonry at the base of the dam,
2. Overturning of the dam,
3. Sliding of the dam, and
4. Crushing of masonry at the base of the dam.

Following conditions must be satisfied for the stability of a dam :

1. In order to avoid tension in the masonry of the dam at its base, the resultant must lie within the middle third of the base width.

2. When the resultant lies within middle third of the base width, the overturning of the dam is also avoided.

3. In order to avoid sliding of the masonry dam, the force of friction between the dam and the soil should be at least 1.5 times the total water pressure per metre length.

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4. In order to prevent the crushing of masonry at the base of the dam, the maximum stress should be less than the permissible stress in the masonry.

2.60 Active Earth Pressure

The pressure, exerted by the retained material, called back fill, on the retaining wall is known as active earth pressure. As a result of the active pressure, the retaining wall tends to slide away from the retained earth.

2.61 Passive Earth Pressure

Sometimes, the retaining wall moves laterally against the retaining earth, which gets compressed. As a result of the movement of the retaining wall, the compressed earth is subjected to a pressure (which is in the opposite direction of the active pressure) known as passive earth pressure.

2.62 Rankine's Theory for Active Earth Pressure

According to Rankine's theory, the horizontal thrust (P) offered by the retaining wall on the retained material is given by

$$P = \frac{w.h^2}{2}\left(\frac{1-\sin\phi}{1+\sin\phi}\right)$$

where w = Specific weight of the retained material,

h = Height of retaining wall, and

ϕ = Angle of repose of the retained earth.

If the retained material is subjected to some superimposed or surcharged load (*i.e.* pressure due to traffic etc.), it will cause a constant pressure on the retaining wall from top to bottom. The total horizontal pressure (P) due to surcharged load is given by

$$P = p\left(\frac{1-\sin\phi}{1+\sin\phi}\right)$$

where p = Intensity of supercharged load.

2.63 Reinforced Cement Concrete Beam

The following assumptions are made in the theory of reinforced cement concrete.

1. All the tensile stresses are taken up by the steel reinforcement only.
2. There is a sufficient bond between the steel and concrete.
3. The modulus of elasticity for steel and concrete is constant.
4. The steel and concrete is stressed within elastic limit.

2.64 Critical and Actual Neutral Axis

The critical neutral axis of a section is based on the principle that the neutral axis is situated at the centre of gravity of a given section.

The actual neutral axis of a section is based on the principle that the moment of areas of compression and tension zones are equal.

Notes : 1. A beam is said to be *under-reinforced beam* when the amount of reinforcement is less than the proper requirement. In this case, the depth of actual neutral axis will be less than that of the critical neutral axis.

2. A beam is said to be *balanced beam* when the amount of reinforcement is equal to the proper requirement. In this case, the depth of actual neutral axis will be the same as that of critical neutral axis.

3. A beam is said to be *over-reinforced beam* when the amount of reinforcement is more than the proper requirement. In this case, the depth of actual neutral axis will be more than the critical neutral axis.

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2.65 Mechanical Properties of Materials

In general, all the materials used by the engineers, may be classified, on the basis of their physical properties, into the following four types:

1. *Elastic materials.* When a material regains its original position, on the removal of the external force, it is called an elastic material.
2. *Plastic materials.* When a material does not regain its original position, on the removal of the external force, it is called a plastic material.
3. *Ductile materials.* When a material can undergo a considerable deformation without rupture (*e.g.* when a material can be drawn into wires), it is called a ductile material.
4. *Brittle materials.* When a material cannot undergo any deformation (like glass) and it fails by rupture, it is called a brittle material.

2.66 Stress-Strain Diagram for a Mild Steel Under Tensile Test

The stress-strain diagram for a mild steel specimen under tensile test is shown in Fig. 2.38. We see that from O to A is a straight line which represents that the stress is proportional to strain. It is thus obvious that Hooke's law holds good upto point A, which is called *elastic limit*. When the material is stressed beyond this limit (*i.e.* point A), the strain increases more quickly than the stress. The points B and C are called *upper yield point* and *lower yield point* respectively. The stress corresponding to point D is called the *ultimate stress*. After the specimen has reached the ultimate stress, a neck is formed which decreases the cross-sectional area of the specimen. A little consideration will show that the stress (or load) necessary to break away the specimen at point E is less than the ultimate stress. The stress corresponding to point E is called *breaking stress*.

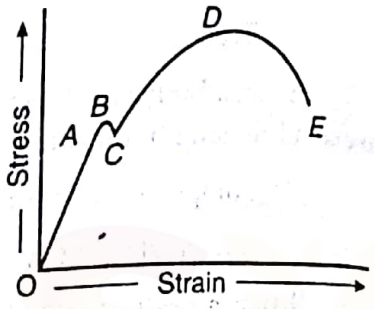

Fig. 2.38

It may be noted that

1. Ultimate stress $= \dfrac{\text{Ultimate load}}{\text{Original cross-sectional area}}$
2. Breaking stress $= \dfrac{\text{Breaking load}}{\text{Original cross-sectional area}}$
3. Percentage reduction in area $= \dfrac{\text{Original area} - \text{Final area}}{\text{Original area}} \times 100$
4. Percentage elongation $= \dfrac{\text{Final length} - \text{Original length}}{\text{Original length}} \times 100$

Notes : 1. The tensile test is performed on ductile materials and the compression test is performed on brittle materials.

2. The ratio of ultimate stress to the working stress is known as *factor of safety*. Its value is more than one.

OBJECTIVE TYPE QUESTIONS

1. Whenever some external system of forces acts on a body, it undergoes some deformation. As the body undergoes some deformation, it sets up some resistance to the deformation. This resistance per unit area to deformation, is called

(*a*) strain
(*b*) stress
(*c*) pressure
(*d*) modulus of elasticity

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2. The unit of stress in S.I. units is
(a) N/mm^2 (b) kN/mm^2 (c) N/m^2 (d) any one of these

3. The deformation per unit length is called
(a) tensile stress (b) compressive stress
(c) shear stress (d) strain

4. The unit of strain is
(a) N-mm (b) N/mm (c) mm (d) no unit

5. Strain is equal to
(a) $l / \delta l$ (b) $\delta l / l$ (c) $l.\delta l$ (d) $l + \delta l$
where l = Original length, and δl = Change in length.

6. When a body is subjected to two equal and opposite pushes, as a result of which the body tends to reduce its length, the stress and strain induced is compressive.
(a) True (b) False

7. When a body is subjected to two equal and opposite pulls, as a result of which the body tends to extend its length, the stress and strain induced is
(a) compressive stress, tensile strain (b) tensile stress,compressive strain
(c) tensile stress, tensile strain (d) compressive stress, compressive strain

8. When a body is subjected to two equal and opposite forces, acting tangentially across the resisting section, as a result of which the body tends to shear off across the section, the stress and strain induced is
(a) tensile stress, tensile strain (b) compressive stress, compressive strain
(c) shear stress, tensile strain (d) shear stress, shear strain

9. Which of the following is a proper sequence?
(a) proportional limit, elastic limit, yielding, failure
(b) elastic limit, proportional limit, yielding, failure
(c) yielding, proportional limit, elastic limit, failure
(d) none of the above

10. Hook's law holds good up to
(a) yield point (b) elastic limit (c) plastic limit (d) breaking point

11. Whenever a material is loaded within elastic limit, stress is ..... strain.
(a) equal to (b) directly proportional to
(c) inversely proportional to

12. The ratio of linear stress to the linear strain is called
(a) modulus of rigidity (b) modulus of elasticity
(c) bulk modulus (d) Poisson's ratio

13. The unit of modulus of elasticity is same as those of
(a) stress, strain and pressure (b) stress, force and modulus of rigidity
(c) strain, force and pressure (d) stress, pressure and modulus of rigidity

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14. When a change in length takes place, the strain is known as
(*a*) linear strain (*b*) lateral strain (*c*) volumetric strain (*d*) shear strain

15. The change in length due to a tensile or compressive force acting on a body is given by

(*a*) $\frac{P.l.A}{E}$ (*b*) $\frac{Pl}{AE}$ (*c*) $\frac{E}{P.l.A}$ (*d*) $\frac{AE}{Pl}$

where P = Tensile or compressive force acting on the body,
l = Original length of the body,
A = Cross-sectional area of the body, and
E = Young's modulus for the material of the body.

16. The modulus of elasticity for mild steel is approximately equal to
(*a*) 10 kN/mm^2 (*b*) 80 kN/mm^2 (*c*) 100 kN/mm^2 (*d*) 210 kN/mm^2

17. Young's modulus may be defined as the ratio of
(*a*) linear stress to lateral strain (*b*) lateral strain to linear strain
(*c*) linear stress to linear strain (*d*) shear stress to shear strain

18. Modulus of rigidity may be defined as the ratio of
(*a*) linear stress to lateral strain (*b*) lateral strain to linear strain
(*c*) linear stress to linear strain (*d*) shear stress to shear strain

19. The unit of Young's modulus is same as that of stress.
(*a*) True (*b*) False

20. Two bars of different materials and same size are subjected to the same tensile force. If the bars have unit elongation in the ratio of 2 : 5, then the ratio of modulus of elasticity of the two materials will be
(*a*) 2 : 5 (*b*) 5 : 2 (*c*) 4 : 3 (*d*) 3 : 4

21. When a bar of length l and diameter d is rigidly fixed at the upper end and hanging freely, then the total elongation produced in the bar due to its own weight is

(*a*) $\frac{wl}{2E}$ (*b*) $\frac{wl^2}{2E}$ (*c*) $\frac{wl^3}{2E}$ (*d*) $\frac{wl^4}{2E}$

where w = Weight per unit volume of the bar.

22. The deformation of a bar under its own weight is ..... the deformation, if the same body is subjected to a direct load equal to weight of the body.
(*a*) equal to (*b*) half (*c*) double (*d*) quadruple

23. The elongation of a conical bar under its own weight is ..... that of prismatic bar of the same length.
(*a*) equal to (*b*) half (*c*) one-third (*d*) two-third

24. The length of a conical bar is l, diameter of base is d and weight per unit volume is w. It is fixed at its upper end and hanging freely. The elongation of the bar under the action of its own weight will be

(*a*) $\frac{wl^2}{2E}$ (*b*) $\frac{wl^2}{4E}$ (*c*) $\frac{wl^2}{6E}$ (*d*) $\frac{wl^2}{8E}$

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25. Strain rosetters are used to

(a) measure shear strain (b) measure linear strain

(c) measure volumetric strain (d) relieve strain

26. A bar of length L metres extends by l mm under a tensile force of P. The strain produced in the bar is

(a) l/L (b) $0.1l/L$ (c) $0.01\,l/L$ (d) $0.001\,l/L$

27. The extension of a circular bar tapering uniformly from diameter d_1 at one end to diameter d_2 at the other end, and subjected to an axial pull of P is given by

(a) $\delta l = \dfrac{4PE}{\pi l d^2}$ (b) $\delta l = \dfrac{4\pi l d^2}{PE}$ (c) $\delta l = \dfrac{4Pl}{\pi E d_1 d_2}$ (d) $\delta l = \dfrac{4PlE}{\pi d_1 d_2}$

28. The extension of a circular bar tapering uniformly from diameter d_1 at one end to diameter d_2 at the other end, and subjected to an axial pull of P is ..... the extension of a circular bar of diameter $\sqrt{d_1 d_2}$ subjected to the same load P.

(a) equal to (b) less than (c) greater than

29. The ultimate tensile stress for mild steel is ..... the ultimate compressive stress.

(a) equal to (b) less than (c) more than

30. The maximum stress produced in a bar of tapering section is at

(a) smaller end (b) larger end (c) middle (d) anywhere

31. Modular ratio of the two materials is the ratio of

(a) linear stress to linear strain (b) shear stress to shear strain

(c) their modulus of elasticities (d) their modulus of rigidities

32. The shear modulus of most materials with respect to the modulus of elasticity is

(a) equal to half (b) less than half (c) more than half (d) none of these

33. A rod is enclosed centrally in a tube and the assembly is tightened by rigid washers. If the assembly is subjected to a compressive load, then

(a) rod is under compression (b) tube is under compression

(c) both rod and tube are under compression

(d) tube is under tension and rod is under compression

34. A bolt is made to pass through a tube and both of them are tightly fitted with the help of washers and nuts. If the nut is tightened, then

(a) bolt and tube are under tension (b) bolt and tube are under compression

(c) bolt is under compression and tube is under tension

(d) bolt is under tension and tube is under compression

35. When a bar is subjected to a change of temperature and its deformation is prevented, the stress induced in the bar is

(a) tensile stress (b) compressive stress

(c) shear stress (d) thermal stress

36. A steel bar of 5 mm is heated from 15° C to 40° C and it is free to expand. The bar will induce

(a) no stress (b) shear stress (c) tensile stress (d) compressive stress

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37. When a bar is cooled to $-5^{\circ}C$, it will develop
(a) no stress (b) shear stress
(c) tensile stress (d) compressive stress

38. A bar of copper and steel form a composite system, which is heated to a temperature of $40^{\circ}C$. The stress induced in the copper bar will be
(a) tensile (b) compressive (c) shear (d) zero

39. The thermal stress in a bar is ..... proportional to the change in temperature.
(a) directly (b) indirectly

40. The thermal stress ..... upon the cross-sectional area of the bar.
(a) depends (b) does not depend

41. If there is a fall in the temperature of a composite body, then a member having greater coefficient of linear expansion will be subjected to compressive stress.
(a) True (b) False

42. The thermal or temperature stress is a function of
(a) increase in temperature (b) modulus of elasticity
(c) coefficient of linear expansion (d) all of these

43. When a circular bar tapering uniformly from diameter d_1 at one end to diameter d_2 at the other end, is subjected to an increase in temperature (t), then the thermal stress induced is
(a) $\frac{\alpha.t.E.d_1}{d_2}$ (b) $\frac{\alpha.t.d_1}{d_2.E}$ (c) $\frac{\alpha.t.d_2}{d_1.E}$ (d) $\frac{d_1.t}{\alpha.E.d_2}$
where α = Coefficient of linear expansion, and
E = Modulus of elasticity for the bar material.

44. Which of the following statement is correct?
(a) The stress is the pressure per unit area.
(b) The strain is expressed in mm.
(c) Hook's law holds good upto the breaking point.
(d) Stress is directly proportional to strain within elastic limit.

45. The deformation of the bar per unit length in the direction of the force is known as
(a) linear strain (b) lateral strain (c) volumetric strain (d) shear strain

46. Every direct stress is always accompanied by a strain in its own direction and an opposite kind of strain in every direction, at right angles to it. Such a strain is known as
(a) linear strain (b) lateral strain (c) volumetric strain (d) shear strain

47. The ratio of the lateral strain to the linear strain is called
(a) modulus of elasticity (b) modulus of rigidity
(c) bulk modulus (d) Poisson's ratio

48. Poisson's ratio is the ratio of linear strain to the volumetric strain.
(a) True (b) False

49. A steel bar 2 m long, 20 mm wide and 10 mm thick is subjected to a pull of 2 kN. If the same bar is subjected to a push of 2 kN, the Poission's ratio of the bar in tension will be ..... the Poisson's ratio for the bar in compression.
(a) equal to (b) less than (c) greater than

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50. The Poisson's ratio for steel varies from
(a) 0.23 to 0.27 (b) 0.25 to 0.33 (c) 0.31 to 0.34 (d) 0.32 to 0.42

51. The Poisson's ratio for cast iron varies from
(a) 0.23 to 0.27 (b) 0.25 to 0.33 (c) 0.31 to 0.34 (d) 0.32 to 0.42

52. When a bar of length l, width b and thickness t is subjected to a pull of P, its
(a) length, width and thickness increases
(b) length, width and thickness decreases
(c) length increases, width and thickness decreases
(d) length decreases, width and thickness increases

53. The ratio of change in volume to the original volume is called
(a) linear strain (b) lateral strain (c) volumetric strain (d) Poisson's ratio

54. When a bar of length l, width b and thickness t is subjected to a push of P, its
(a) length, width and thickness increases
(b) length, width and thickness decreases
(c) length increases, width and thickness decreases
(d) length decreases, width and thickness increases

55. The volumetric strain is the ratio of the
(a) original thickness to the change in thickness
(b) change in thickness to the original thickness
(c) original volume to the change in volume
(d) change in volume to the original volume

56. When a rectangular bar of length l, breadth b and thickness t is subjected to an axial pull of P, then linear strain (ε) is given by

(a) $\varepsilon = \dfrac{P}{b.t.E}$ (b) $\varepsilon = \dfrac{b.t.E}{P}$ (c) $\varepsilon = \dfrac{b.t}{P.E}$ (d) $\varepsilon = \dfrac{P.E}{b.t}$

where E = Modulus of elasticity.

57. When a rectangular bar of length l, breadth b and thickness t is subjected to an axial pull of P, then volumetric strain is

(a) $\varepsilon(1-2m)$ (b) $\varepsilon(2m-1)$ (c) $\varepsilon\left(1-\dfrac{2}{m}\right)$ (d) $\varepsilon\left(\dfrac{2}{m}-1\right)$

where ε = Linear strain, and
$1/m$ = Poisson's ratio.

58. When a body is subjected to three mutually perpendicular stresses, of equal intensity, the ratio of direct stress to the corresponding volumetric strain is known as
(a) Young's modulus (b) modulus of rigidity
(c) bulk modulus (d) Poisson's ratio

59. The relation between Young's modulus (E) and bulk modulus (K) is given by

(a) $K = \dfrac{3m-2}{mE}$ (b) $K = \dfrac{mE}{3m-2}$ (c) $K = \dfrac{3(m-2)}{mE}$ (d) $K = \dfrac{mE}{3(m-2)}$

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60. The ratio of bulk modulus to Young's modulus for a Poisson's ratio of 0.25 will be

(*a*) 1 / 3 (*b*) 2 / 3 (*c*) 1 (*d*) 3 / 2

61. When a cube is subjected to three mutually perpendicular tensile stresses of equal intensity (σ), the volumetric strain is

(*a*) $\frac{3\sigma}{E}\left(1-\frac{2}{m}\right)$ (*b*) $\frac{E}{3\sigma}\left(1-\frac{2}{m}\right)$ (*c*) $\frac{3\sigma}{E}\left(\frac{2}{m}-1\right)$ (*d*) $\frac{E}{3\sigma}\left(\frac{2}{m}-1\right)$

62. The relation between modulus of elasticity (E) and modulus of rigidity (C) is given by

(*a*) $C=\frac{mE}{2(m+1)}$ (*b*) $C=\frac{2(m+1)}{mE}$ (*c*) $C=\frac{2mE}{m+1}$ (*d*) $C=\frac{m+1}{2mE}$

63. If the modulus of elasticity of a material is twice its modulus of rigidity, then the Poisson's ratio of the material is equal to zero.

(*a*) Correct (*b*) Incorrect

64. The relation between Young's modulus (E), shear modulus (C) and bulk modulus (K) is given by

(*a*) $E=\frac{3K.C}{3K+C}$ (*b*) $E=\frac{6K.C}{3K+C}$ (*c*) $E=\frac{9K.C}{3K+C}$ (*d*) $E=\frac{12K.C}{3K+C}$

65. The ratio of shear modulus to the modulus of elasticity for a Poisson's ratio of 0.4 will be

(*a*) 5 / 7 (*b*) 7 / 5 (*c*) 5 / 14 (*d*) 14 / 5

66. If the modulus of elasticity for a given material is twice its modulus of rigidity, then bulk modulus is equal to

(*a*) 2 C (*b*) 3 C (*c*) $\frac{2C}{3}$ (*d*) $\frac{3C}{2}$

67. The Young's modulus of a material is 125 GPa and Poissons ratio is 0.25. The modulus of rigidity of the material is

(*a*) 30 GPa (*b*) 50 GPa (*c*) 80 GPa (*d*) 100 GPa

68. Which of the following statement is wrong?

(*a*) The deformation of the bar per unit length in the direction of the force is called linear strain.

(*b*) The Poisson's ratio is the ratio of lateral strain to the linear strain.

(*c*) The ratio of change in volume to the original volume is called volumetric strain.

(*d*) The bulk modulus is the ratio of linear stress to the linear strain.

69. A shear stress across a plane, is always accompanied by a balancing shear stress across the plane and normal to it.

(*a*) True (*b*) False

70. Within elastic limit, shear stress is..... shear strain.

(*a*) equal to (*b*) less than

(*c*) directly proportional to (*d*) inversely proportional to

71. Shear modulus is the ratio of

(*a*) linear stress to linear strain (*b*) linear stress to lateral strain

(*c*) volumetric strain to linear strain (*d*) shear stress to shear strain

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72. A localised compressive stress at the area of contact between two members is known as

(*a*) tensile stress (*b*) bending stress (*c*) crushing stress (*d*) shear stress

73. Match the correct answer from *Group B* for the given statements in *Group A*.

Group A	*Group B*
(*a*) The change in length due to a tensile or compressive load is	(*A*) $\frac{mE}{3(m-2)}$
(*b*) The extension of a circular bar tapering from d_1 to d_2 is	(*B*) $\varepsilon\left(1-\frac{2}{m}\right)$
(*c*) The volumetric strain of a rectangular bar is	(*C*) $\frac{Pl}{AE}$
(*d*) The relation between Young's modulus (E) and bulk modulus (K) is	(*D*) $\frac{4Pl}{\pi E d_1 d_2}$
(*e*) The relation between modulus of elasticity (E) and modulus of rigidity (C) is	(*E*) $\frac{mE}{2(m+1)}$

74. The maximum diameter of the hole that can be punched from a plate of maximum shear stress $1/4^{th}$ of its maximum crushing stress of punch, is equal to

(*a*) t (*b*) $2t$ (*c*) $4t$ (*d*) $8t$

where t = Thickness of the plate.

75. The planes, which carry no shear stress, are known as principal planes.

(*a*) True (*b*) False

76. When a body is subjected to a direct tensile stress (σ) in one plane, then normal stress on an oblique section of the body inclined at an angle θ to the normal of the section is

(*a*) $\sigma \cos\theta$ (*b*) $\sigma \cos^2\theta$ (*c*) $\sigma \sin\theta$ (*d*) $\sigma \sin^2\theta$

77. In the above question, the normal stress on an oblique section will be maximum, when θ is equal to

(*a*) 0° (*b*) 30° (*c*) 45° (*d*) 90°

78. The direct stress, across a principal plane, is known as principal stress.

(*a*) Yes (*b*) No

79. When a body is subjected to a direct tensile stress (σ) in one plane, then tangential or shear stress on an oblique section of the body inclined at an angle θ to the normal of the section is

(*a*) $\sigma \sin 2\theta$ (*b*) $\sigma \cos 2\theta$ (*c*) $\frac{\sigma}{2}\sin 2\theta$ (*d*) $\frac{\sigma}{2}\cos 2\theta$

80. The resultant stress on an inclined plane which is inclined at an angle θ to the normal cross-section of a body which is subjected to a direct tensile stress (σ) in one plane, is

(*a*) $\sigma \sin\theta$ (*b*) $\sigma \cos\theta$ (*c*) $\sigma \sin 2\theta$ (*d*) $\sigma \cos 2\theta$

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81. When a body is subjected to a direct tensile stress (σ) in one plane, then maximum normal stress occurs at a section inclined at ..... to the normal of the section.

(*a*) 0° (*b*) 30° (*c*) 45° (*d*) 90°

82. When a body is subjected to a direct tensile stress (σ), the maximum normal stress is equal to the direct tensile stress.

(*a*) Agree (*b*) Disagree

83. A body is subjected to a direct tensile stress (σ) in one plane. The shear stress is maximum at a section inclined at ..... to the normal of the section.

(*a*) 45° and 90° (*b*) 45° and 135° (*c*) 60° and 150° (*d*) 30° and 135°

84. When a body is subjected to a direct tensile stress (σ) in one plane, the maximum shear stress is ..... the maximum normal stress.

(*a*) equal to (*b*) one-half (*c*) two-third (*d*) twice

85. Principle plane is a plane on which the shear stress is

(*a*) zero (*b*) minimum (*c*) maximum

86. When a body is subjected to a direct tensile stress (σ_x) in one plane accompanied by a simple shear stress (τ_{xy}), the maximum normal stress is

(*a*) $\frac{\sigma_x}{2} + \frac{1}{2}\sqrt{\sigma_x^2 + 4\tau_{xy}^2}$ (*b*) $\frac{\sigma_x}{2} - \frac{1}{2}\sqrt{\sigma_x^2 + 4\tau_{xy}^2}$

(*c*) $\frac{\sigma_x}{2} + \frac{1}{2}\sqrt{\sigma_x^2 - 4\tau_{xy}^2}$ (*d*) $\frac{1}{2}\sqrt{\sigma_x^2 + 4\tau_{xy}^2}$

87. When a body is subjected to a direct tensile stress (σ_x) in one plane accompanied by a simple shear stress (τ_{xy}), the minimum normal stress is

(*a*) $\frac{\sigma_x}{2} + \frac{1}{2}\sqrt{\sigma_x^2 + 4\tau_{xy}^2}$ (*b*) $\frac{\sigma_x}{2} - \frac{1}{2}\sqrt{\sigma_x^2 + 4\tau_{xy}^2}$

(*c*) $\frac{\sigma_x}{2} + \frac{1}{2}\sqrt{\sigma_x^2 - 4\tau_{xy}^2}$ (*d*) $\frac{1}{2}\sqrt{\sigma_x^2 + 4\tau_{xy}^2}$

88. When a body is subjected to a direct tensile stress (σ_x) in one plane accompanied by a simple shear stress (τ_{xy}), the maximum shear stress is

(*a*) $\frac{\sigma_x}{2} + \frac{1}{2}\sqrt{\sigma_x^2 + 4\tau_{xy}^2}$ (*b*) $\frac{\sigma_x}{2} - \frac{1}{2}\sqrt{\sigma_x^2 + 4\tau_{xy}^2}$

(*c*) $\frac{\sigma_x}{2} + \frac{1}{2}\sqrt{\sigma_x^2 - 4\tau_{xy}^2}$ (*d*) $\frac{1}{2}\sqrt{\sigma_x^2 + 4\tau_{xy}^2}$

89. A body is subjected to a direct tensile stress of 300 MPa in one plane accompanied by a simple shear stress of 200 MPa. The maximum normal stress will be

(*a*) – 100 MPa (*b*) 250 MPa (*c*) 300 MPa (*d*) 400 MPa

90. For the above question, the minimum normal stress will be

(*a*) – 100 MPa (*b*) 250 MPa (*c*) 300 MPa (*d*) 400 MPa

91. For Question No. 89, the maximum shear stress will be

(*a*) – 100 MPa (*b*) 250 MPa (*c*) 300 MPa (*d*) 400 MPa

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92. When a body is subjected to bi-axial stress *i.e.* direct stresses (σ_x) and (σ_y) in two mutually perpendicular planes accompanied by a simple shear stress (τ_{xy}), then maximum normal stress is

(*a*) $\frac{\sigma_x+\sigma_y}{2}+\frac{1}{2}\sqrt{(\sigma_x-\sigma_y)^2+4\tau_{xy}^2}$ (*b*) $\frac{\sigma_x+\sigma_y}{2}-\frac{1}{2}\sqrt{(\sigma_x-\sigma_y)^2+4\tau_{xy}^2}$

(*c*) $\frac{\sigma_x-\sigma_y}{2}+\frac{1}{2}\sqrt{(\sigma_x+\sigma_y)^2+4\tau_{xy}^2}$ (*d*) $\frac{\sigma_x-\sigma_y}{2}-\frac{1}{2}\sqrt{(\sigma_x+\sigma_y)^2+4\tau_{xy}^2}$

93. When a body is subjected to bi-axial stress *i.e.* direct stresses (σ_x) and (σ_y) in two mutually perpendicular planes accompanied by a simple shear stress (τ_{xy}), then minimum normal stress is

(*a*) $\frac{\sigma_x+\sigma_y}{2}+\frac{1}{2}\sqrt{(\sigma_x-\sigma_y)^2+4\tau_{xy}^2}$ (*b*) $\frac{\sigma_x+\sigma_y}{2}-\frac{1}{2}\sqrt{(\sigma_x-\sigma_y)^2+4\tau_{xy}^2}$

(*c*) $\frac{\sigma_x-\sigma_y}{2}+\frac{1}{2}\sqrt{(\sigma_x+\sigma_y)^2+4\tau_{xy}^2}$ (*d*) $\frac{\sigma_x-\sigma_y}{2}-\frac{1}{2}\sqrt{(\sigma_x+\sigma_y)^2+4\tau_{xy}^2}$

94. When a body is subjected to bi-axial stress *i.e.* direct stresses (σ_x) and (σ_y) in two mutually perpendicular planes accompanied by a simple shear stress (τ_{xy}), then maximum shear stress is

(*a*) $\frac{1}{2}\sqrt{(\sigma_x-\sigma_y)^2+4\tau_{xy}^2}$ (*b*) $\frac{1}{2}\sqrt{(\sigma_x+\sigma_y)^2+4\tau_{xy}^2}$

(*c*) $\sqrt{(\sigma_x-\sigma_y)^2+\tau_{xy}^2}$ (*d*) $\sqrt{(\sigma_x+\sigma_y)^2+\tau_{xy}^2}$

95. A body is subjected to a tensile stress of 1200 MPa on one plane and another tensile stress of 600 MPa on a plane at right angles to the former. It is also subjected to a shear stress of 400 MPa on the same planes. The maximum normal stress will be

(*a*) 400 MPa (*b*) 500 MPa (*c*) 900 MPa (*d*) 1400 MPa

96. For the above question, the minimum normal stress will be

(*a*) 400 MPa (*b*) 500 MPa (*c*) 900 MPa (*d*) 1400 MPa

97. For Question No. 95, the maximum shear stress will be

(*a*) 400 MPa (*b*) 500 MPa (*c*) 900 MPa (*d*) 1400 MPa

98. A body is subjected to two normal stresses 20 kN / m^2 (tensile) and 10 kN / m^2 (compressive) acting perpendicular to each other. The maximum shear stress is

(*a*) 5 kN / m^2 (*b*) 10 kN / m^2 (*c*) 15 kN / m^2 (*d*) 20 kN / m^2

99. For biaxial stress, the planes of maximum shear are at right angles to each other and are inclined at 45^0 to the principal planes.

(*a*) True (*b*) False

100. The state of stress at a point in a loaded member is shown in Fig. 2.39. The magnitude of maximum shear stress is

(*a*) 10 MPa (*b*) 30 MPa

(*c*) 50 MPa (*d*) 100 MPa

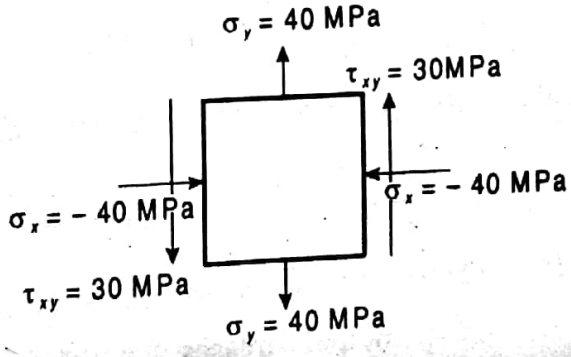

Fig. 2.39

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101. The maximum shear stress is ..... the algebraic difference of maximum and minimum normal stresses.

(*a*) equal to (*b*) one-fourth (*c*) one-half (*d*) twice

102. Fig. 2.40 shows the Mohr's circle of stress for two unequal and like principal stresses (σ_x and σ_y) acting at a body across two mutually perpendicular planes. The normal stress on an oblique section making an angle θ with the minor principle plane is given by

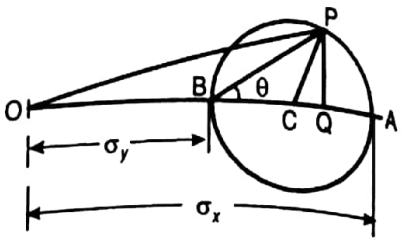

Fig. 2.40

(*a*) *OC* (*b*) *OP* (*c*) *OQ* (*d*) *PQ*

103. In Fig. 2.40, the tangential stress is given by

(*a*) *OC* (*b*) *OP* (*c*) *OQ* (*d*) *PQ*

104. In Fig. 2.40, the resultant stress is given by

(*a*) *OC* (*b*) *OP* (*c*) *OQ* (*d*) *PQ*

105. The radius of the Mohr's circle in Fig. 2.40, is equal to

(*a*) sum of two principal stresses
(*b*) difference of two principal stresses
(*c*) half the sum of two principal stresses
(*d*) half the difference of two principal stresses

106. The maximum shear stress, in Fig. 2.40, is equal to ..... of the Mohr's circle.

(*a*) radius (*b*) diameter (*c*) circumference (*d*) area

107. Mohr's circle is used to determine the stresses on an oblique section of a body subjected to

(*a*) direct tensile stress in one plane accompanied by a shear stress
(*b*) direct tensile stress in two mutually perpendicular directions
(*c*) direct tensile stress in two mutually perpendicular directions accompanied by a simple shear stress
(*d*) all of the above

108. When a body is subjected to direct tensile stresses (σ_x and σ_y) in two mutually perpendicular directions, accompanied by a simple shear stress τ_{xy}, then in Mohr's circle method, the circle radius is taken as

(*a*) $\frac{\sigma_x - \sigma_y}{2} + \tau$ (*b*) $\frac{\sigma_x + \sigma_y}{2} + \tau$

(*c*) $\frac{1}{2}\sqrt{(\sigma_x - \sigma_y)^2 + 4\tau_{xy}^2}$ (*d*) $\frac{1}{2}\sqrt{(\sigma_x + \sigma_y)^2 + 4\tau_{xy}^2}$

109. In Mohr's circle, the centre of circle from Y-axis is taken as

(*a*) $\frac{\sigma_x - \sigma_y}{2}$ (*b*) $\frac{\sigma_x + \sigma_y}{2}$ (*c*) $\frac{\sigma_x - \sigma_y}{2} + \tau$ (*d*) $\frac{\sigma_x + \sigma_y}{2} + \tau$

110. The extremeties of any diameter on Mohr's circle represent

(*a*) principal stresses
(*b*) normal stresses on planes at 45°
(*c*) shear stresses on planes at 45°
(*d*) normal and shear stresses on a plane

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111. The maximum shear stress is equal to the radius of Mohr's circle.
(a) Correct (b) Incorrect

112. The energy stored in a body when strained within elastic limit is known as
(a) resilience (b) proof resilience (c) strain energy (d) impact energy

113. The total strain energy stored in a body is termed as
(a) resilience (b) proof resilience
(c) impact energy (d) modulus of resilience

114. The proof resilience is the maximum strain energy which can be stored in a body.
(a) Yes (b) No

115. The proof resilience per unit volume of a material is known as modulus of resilience.
(a) True (b) False

116. Strain energy is the
(a) energy stored in a body when strained within elastic limits
(b) energy stored in a body when strained upto the breaking of a specimen
(c) maximum strain energy which can be stored in a body
(d) proof resilience per unit volume of a material

117. The strain energy stored in a body, when suddenly loaded, is ..... the strain energy stored when same load is applied gradually.
(a) equal to (b) one-half (c) twice (d) four times

118. Resilience is the
(a) energy stored in a body when strained within elastic limits
(b) energy stored in a body when strained upto the breaking of the specimen
(c) maximum strain energy which can be stored in a body
(d) none of the above

119. The total strain energy stored in a body is called proof resilience.
(a) Agree (b) Disagree

120. Modulus of resilience is the proof resilience per unit volume of a material.
(a) Correct (b) Incorrect

121. The strain energy stored in a body, when the load is gradually applied, is
(a) $\frac{\sigma E}{V}$ (b) $\frac{\sigma V}{E}$ (c) $\frac{\sigma^2 E}{2V}$ (d) $\frac{\sigma^2 V}{2E}$

where σ = Stress in the material of the body,
V = Volume of the body, and
E = Modulus of elasticity of the material.

122. The stress induced in a body, when suddenly loaded, is ..... the stress induced when the same load is applied gradually.
(a) equal to (b) one-half (c) twice (d) four times

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123. The strain energy stored in a spring, when subjected to maximum load, without suffering permanent distortion, is known as

(*a*) impact energy (*b*) proof resilience

(*c*) proof stress (*d*) modulus of resilience

124. The capacity of a strained body for doing work on the removal of the straining force, is called

(*a*) strain energy (*b*) resilience (*c*) proof resilience (*d*) impact energy

125. Which of the following statement is correct?

(*a*) The energy stored in a body, when strained within elastic limit is known as strain energy.

(*b*) The maximum strain energy which can be stored in a body is termed as proof resilience.

(*c*) The proof resilience per unit volume of a material is known as modulus of resilience.

(*d*) all of the above

126. The strain energy stored in a body due to shear stress, is

(*a*) $\frac{\tau}{2C} \times V$ (*b*) $\frac{2C}{\tau V}$ (*c*) $\frac{\tau^2}{2C} \times V$ (*d*) $\frac{2C}{\tau^2 V}$

where τ = Shear stress,

C = Shear modulus, and

V = Volume of the body.

127. A beam which is fixed at one end and free at the other is called

(*a*) simply supported beam (*b*) fixed beam

(*c*) overhanging beam (*d*) cantilever beam

128. A beam supported at its both ends is not a simply supported beam.

(*a*) True (*b*) False

129. A beam extending beyond the supports is called

(*a*) simply supported beam (*b*) fixed beam

(*c*) overhanging beam (*d*) cantilever beam

130. A beam encastered at both the ends is called

(*a*) simply supported beam (*b*) fixed beam

(*c*) cantilever beam (*d*) continuous beam

131. A beam supported on more than two supports is called

(*a*) simply supported beam (*b*) fixed beam

(*c*) overhanging beam (*d*) continuous beam

132. A cantilever beam is one which is

(*a*) fixed at both ends (*b*) fixed at one end and free at the other end

(*c*) supported at its ends (*d*) supported on more than two supports

133. A simply supported beam is one which is supported on more than two supports.

(*a*) True (*b*) False

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134. An overhanging beam must overhang on both sides.

(*a*) Right (*b*) Wrong

135. A fixed beam is one which is fixed at..... of its ends.

(*a*) one (*b*) both

136. A continuous beam is one which is

(*a*) fixed at both ends (*b*) fixed at one end and free at the other end

(*c*) supported on more than two supports (*d*) extending beyond the supports

137. A concentrated load is one which

(*a*) acts at a point on a beam

(*b*) spreads non-uniformly over the whole length of a beam

(*c*) spreads uniformly over the whole length of a beam

(*d*) varies uniformly over the whole length of a beam

138. A load which acts at a point on a beam is not called uniformly distributed load.

(*a*) Agree (*b*) Disagree

139. A uniformly distributed load may be assumed to behave like a point load at the centre of gravity of the load for all sorts of calculations.

(*a*) Right (*b*) Wrong

140. A load which is spread over a beam in such a manner that it varies uniformly over the whole length of a beam is called uniformly ..... load.

(*a*) distributed (*b*) varying

141. The shear force at a point on a beam is the algebraic ..... of all the forces on either side of the point.

(*a*) sum (*b*) difference

142. The bending moment at a point on a beam is the algebraic ..... of all the moments on either side of the point.

(*a*) sum (*b*) difference

143. The bending moment on a section is maximum where shear force is

(*a*) minimum (*b*) maximum (*c*) changing sign (*d*) zero

144. The shear force at a certain point on a beam changes sign from +ve value to – ve value or vice versa. The bending moment at that point will be zero.

(*a*) True (*b*) False

145. When a load on the free end of a cantilever beam is increased, failure will occur

(*a*) at the free end (*b*) at the fixed end

(*c*) in the middle of the beam (*d*) at a distance $2l/3$ from free end

146. The bending moment at the free end of a cantilever beam is

(*a*) zero (*b*) minimum (*c*) maximum

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147. A cantilever beam of length l and carrying a point load W at the free end is shown in Fig. 2.41. Which of the following is correct?

(*a*) *A* is the bending moment diagram and *C* is the shear force diagram

(*b*) *A* is the shear force diagram and *C* is the bending moment diagram

(*c*) *B* is the bending moment diagram and *D* is the shear force diagram

(*d*) *B* is the shear force diagram and *D* is the bending moment diagram

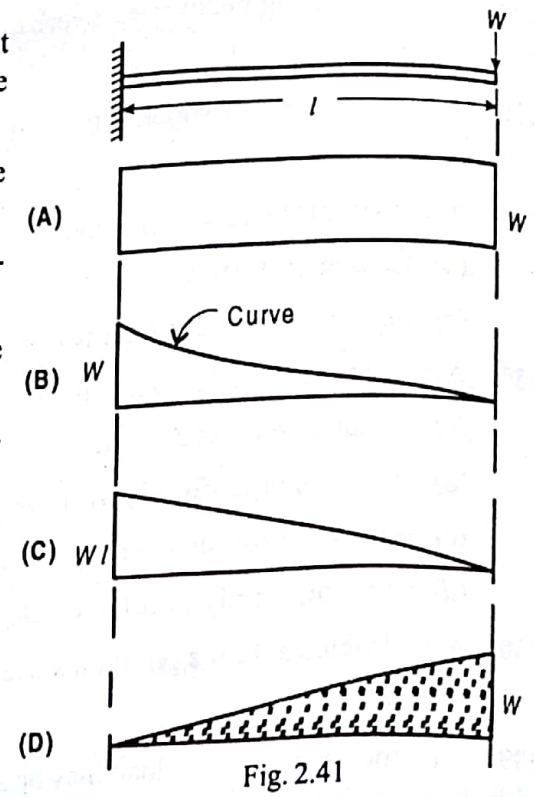

Fig. 2.41

148. When a cantilever beam is loaded with concentrated loads, the bending moment diagram will be a

(*a*) horizontal straight line

(*b*) vertical straight line

(*c*) inclined straight line

(*d*) parabolic curve

149. The bending moment diagram for a cantilever beam loaded with uniformly distributed load will be a parabolic curve.

(*a*) Correct (*b*) Incorrect

150. The maximum bending moment of a cantilever beam as shown in Fig. 2.41, lies at

(*a*) the free end (*b*) the fixed end

(*c*) middle of its length (*d*) $l/4$ from fixed end

151. The shear force of a cantilever beam as shown in Fig. 2.41, is

(*a*) zero at the free end and W at the fixed end

(*b*) W at free end and zero at the fixed end

(*c*) W throughout its length

(*d*) Wl throughout its length

152. The shear force of a cantilever beam of length l carrying a uniformly distributed load of w per unit length is ..... at the free end.

(*a*) zero (*b*) $wl/4$ (*c*) $wl/2$ (*d*) wl

153. The shear force of a cantilever beam of length l carrying a uniformly distributed load of w per unit length is ..... at the fixed end.

(*a*) zero (*b*) $wl/4$ (*c*) $wl/2$ (*d*) wl

154. The shear force diagram of a cantilever beam of length l and carrying a uniformly distributed load of w per unit length will be

(*a*) a right angled triangle (*b*) an issoscles triangle

(*c*) an equilateral triangle (*d*) a rectangle

155. The bending moment of a cantilever beam of length l and carrying a uniformly distributed load of w per unit length is ..... at the free end.

(*a*) zero (*b*) $wl/4$ (*c*) $wl/2$ (*d*) wl

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156. The shear force and bending moment are zero at the free end of a cantilever beam, if it carries a
(a) point load at the free end
(b) point load at the middle of its length
(c) uniformly distributed load over the whole length
(d) none of the above

157. The bending moment of a cantilever beam of length l and carrying a uniformly distributed load of w per unit length is .....at the fixed end.
(a) $wl/4$ (b) $wl/2$ (c) wl (d) $wl^2/2$

158. The maximum bending moment of a cantilever beam of length l and carrying a uniformly distributed load of w per unit length lies at the middle of its length.
(a) True (b) False

159. The shear force diagram for a cantilever beam of length l and carrying a gradually varying load from zero at free end and w per unit length at the fixed end is a
(a) horizontal straight line (b) vertical straight line
(c) inclined line (d) parabolic curve

160. The bending moment diagram for a cantilever beam of length l and carrying a gradually varying load from zero at the free end and w per unit length at the fixed end is a parabolic curve.
(a) Agree (b) Disagree

161. The shear force of a cantilever beam of length l and carrying a gradually varying load from zero at the free end and w per unit length at the fixed end is ..... at the fixed end.
(a) zero (b) $wl/4$ (c) $wl/2$ (d) wl

162. The bending moment of a cantilever beam of length l and carrying a gradually varying load from zero at free end and w per unit length at the fixed end is ..... at the fixed end.
(a) $wl/2$ (b) wl (c) $wl^2/2$ (d) $wl^2/6$

163. The bending moment at the ends of a simply supported beam will be zero.
(a) Yes (b) No

164. The maximum bending moment of a simply supported beam of span l and carrying a point load W at the centre of beam, is
(a) $Wl/4$ (b) $Wl/2$ (c) Wl (d) $Wl^2/4$

165. The bending moment diagram for a simply supported beam loaded in its centre is
(a) a right angled triangle (b) an issoscles triangle
(c) an equilateral triangle (d) a rectangle

166. The maximum bending moment of a simply supported beam with central point load lies at the point of loading.
(a) True (b) False

167. The shear force of a simply supported beam carrying a central point load changes sign at its mid point.
(a) Correct (b) Incorrect

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168. A simply supported beam is loaded as shown in Fig. 2.42. The bending moment diagram will be

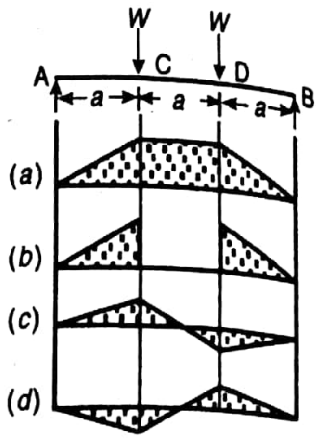

Fig. 2.42

169. The shear force in the centre of a simply supported beam carrying a uniformly distributed load of w per unit length, is

(a) zero (b) $wl^2/2$
(c) $wl^2/4$ (d) $wl^2/8$

170. The bending moment in the centre of a simply supported beam carrying a uniformly distributed load of w per unit length is

(a) zero (b) $wl^2/2$
(c) $wl^2/4$ (d) $wl^2/8$

171. The shear force at the ends of a simply supported beam carrying a uniformly distributed load of w per unit length is

(a) zero at its both ends
(b) wl at one end and $-wl$ at the other end
(c) $wl/2$ at one end and $-wl/2$ at the other end
(d) $wl^2/2$ at one end and $-wl^2/2$ at the other end

172. The shear force diagram for a simply supported beam carrying a uniformly distributed load of w per unit length, consists of

(a) one right angled triangle (b) two right angled triangles
(c) one equilateral triangle (d) two equilateral triangles

173. The bending moment diagram for a simply supported beam carrying a uniformly distributed load of w per unit length, will be

(a) a horizontal line (b) a vertical line
(c) an inclined line (d) a parabolic curve

174. The shear force at the centre of a simply supported beam with a gradually varying load from zero at both ends to w per metre at the centre, is

(a) zero (b) $wl/4$ (c) $wl/2$ (d) $wl^2/2$

175. The bending moment at the centre of a simply supported beam with a gradually varying load from zero at both ends to w per metre at the centre is $wl/4$.

(a) Yes (b) No

176. The maximum bending moment for a simply supported beam with a gradually varying load from zero at both ends and w per metre at the centre, lies at the centre of a beam.

(a) Agree (b) Disagree

177. A simply supported beam with a gradually varying load from zero at B and w per unit length at A is shown in Fig. 2.43. The shear force at B is equal to

(a) $wl/6$ (b) $wl/3$
(c) wl (d) $2wl/3$



Fig. 2.43

178. For the beam shown in Fig. 2.43, the shear force at A is equal to

(a) $wl/6$ (b) $wl/3$ (c) wl (d) $2wl/3$

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179. For the beam shown in Fig. 2.43, the shear force diagram between A and B is

(*a*) a horizontal line (*b*) a vertical line

(*c*) an inclined line (*d*) a parabolic curve

180. The maximum bending moment for the beam shown in Fig. 2.43, is

(*a*) $\frac{wl^2}{3\sqrt{3}}$ (*b*) $\frac{wl^2}{6\sqrt{3}}$ (*c*) $\frac{wl^2}{9\sqrt{3}}$ (*d*) $\frac{wl^2}{12\sqrt{3}}$

181. The maximum bending moment for the beam shown in Fig. 2.43, lies at a distance of ..... from the end B.

(*a*) $l/2$ (*b*) $l/3$ (*c*) $l/\sqrt{2}$ (*d*) $l/\sqrt{3}$

182. The point of contraflexure is a point where

(*a*) shear force changes sign (*b*) bending moment changes sign

(*c*) shear force is maximum (*d*) bending moment is maximum

183. When shear force at a point is zero, then bending moment is ..... at that point.

(*a*) zero (*b*) minimum (*c*) maximum (*d*) infinity

184. In a simply supported beam carrying a uniformly distributed load w per unit length, the point of contraflexure

(*a*) lies in the centre of the beam (*b*) lies at the ends of the beam

(*c*) depends upon the length of beam (*d*) does not exist

185. When there is a sudden increase or decrease in shear force diagram between any two points, it indicates that there is a

(*a*) point load at the two points (*b*) no loading between the two points

(*c*) uniformly distributed load between the two points

(*d*) uniformly varying load between the two points

186. When the shear force diagram between any two points is an inclined straight line, it indicates that there is a uniformly varying load between the two points.

(*a*) Yes (*b*) No

187. When the shear force diagram is a parabolic curve between two points, it indicates that there is a

(*a*) point load at the two points (*b*) no loading between the two points

(*c*) uniformly distributed load between the two points

(*d*) uniformly varying load between the two points

188. When there is no increase or decrease in shear force between two points, it indicates that there is no change in the bending moment between these points.

(*a*) True (*b*) False

189. Which of the following statement is correct?

(*a*) A continuous beam has only two supports at the ends.

(*b*) A uniformly distributed load spreads uniformly over the whole length of a beam.

(*c*) The bending moment is maximum where shear force is maximum.

(*d*) The maximum bending moment of a simply supported beam of length l with a central point load W is $Wl/8$.

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190. Match the correct answer from *Group B* for the given statements in *Group A*.

Group A	*Group B*
(*a*) The shear force at the free end of a cantilever beam carrying uniformly distributed load is	(*A*) maximum
(*b*) The bending moment at the fixed end of a beam is	(*B*) $wl^2/8$
(*c*) The maximum bending moment of a simply supported beam carrying a uniformly distributed of *w* per unit length is	(*C*) $wl^2/12$
(*d*) The bending moment at the centre of a simply supported beam with a gradually varying load from zero at both ends to *w* per metre at the centre is	(*D*) zero

191. In a beam where shear force changes sign, the bending moment will be

(*a*) zero (*b*) minimum (*c*) maximum (*d*) infinity

192. The point of contraflexure occurs in

(*a*) cantilever beams (*b*) simply supported beams

(*c*) overhanging beams (*d*) fixed beams

193. The bending moment at a section tends to bend or deflect the beam and the internal stresses resist its bending. The resistance offered by the internal stresses, to the bending, is called

(*a*) compressive stress (*b*) shear stress

(*c*) bending stress (*d*) elastic modulus

194. The assumption, generally, made in the theory of simple bending is that

(*a*) the beam material is perfectly homogenous and isotropic

(*b*) the beam material is stressed within its elastic limit

(*c*) the plane sections before bending remain plane after bending

(*d*) all of the above

195. In a simple bending theory, one of the assumption is that the material of the beam is isotropic. This assumption means that the

(*a*) normal stress remains constant in all directions

(*b*) normal stress varies linearly in the material

(*c*) elastic constants are same in all the directions

(*d*) elastic constants varies linearly in the material

196. In a simple bending of beams, the stress in the beam varies

(*a*) linearly (*b*) parabolically (*c*) hyperbolically (*d*) elliptically

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197. In a simple bending theory, one of the assumption is that the plane sections before bending remain plane after bending. This assumption means that

(*a*) stress is uniform throughout the beam

(*b*) strain is uniform throughout the beam

(*c*) stress is proportional to the distance from the neutral axis

(*d*) strain is proportional to the distance from the neutral axis

198. A rectangular beam subjected to a bending moment is shown in Fig. 2.44. The upper layer of the beam will be in tension.

(*a*) True (*b*) False

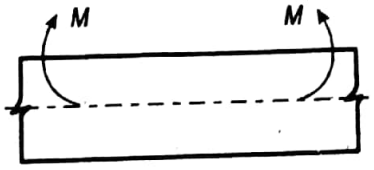

Fig. 2.44

199. The lower layer of the beam as shown in Fig. 2.44, will be

(*a*) in tension

(*b*) in compression

(*c*) neither in tension nor in compression

200. The layer at the centre of gravity of the beam as shown in Fig. 2.44, will be

(*a*) in tension (*b*) in compression

(*c*) neither in tension nor in compression

201. When a beam is subjected to a bending moment, the strain in a layer is ..... the distance from the neutral axis.

(*a*) equal to (*b*) directly proportional to

(*c*) inversely proportional to (*d*) independent of

202. The bending equation is

(*a*) $\frac{M}{I} = \frac{\sigma}{y} = \frac{E}{R}$ (*b*) $\frac{T}{J} = \frac{\tau}{r} = \frac{C\theta}{l}$ (*c*) $\frac{M}{y} = \frac{\sigma}{I} = \frac{E}{R}$ (*d*) $\frac{T}{r} = \frac{\tau}{J} = \frac{C\theta}{l}$

203. A section of beam is said to be in pure bending, if it is subjected to

(*a*) constant bending moment and constant shear force

(*b*) constant shear force and zero bending moment

(c) constant bending moment and zero shear force

(*d*) none of the above

204. When a beam is subjected to bending moment, the stress at any point is ..... the distance of the point from the neutral axis.

(*a*) equal to (*b*) directly proportional to

(*c*) inversely proportional to (*d*) independent of

205. The line of intersection of the neutral layer with any normal cross-section of the beam is called neutral axis.

(*a*) True (*b*) False

206. The neutral axis of the cross-section a beam is that axis at which the bending stress is

(*a*) zero (*b*) minimum (*c*) maximum (*d*) infinity

207. The neutral axis of the symmetrical beam does not pass through the centroid of the beam.

(*a*) Agree (*b*) Disagree

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208. The section modulus (Z) of a beam is given by
(a) I/y (b) $I.y$ (c) y/I (d) M/I

209. The section modulus of a rectangular section about an axis through its $C.G.$, is
(a) $b/2$ (b) $d/2$ (c) $bd^2/2$ (d) $bd^2/6$

210. The bending stress in a beam is ..... section modulus.
(a) directly proportional to (b) inversely proportional to

211. The section modulus of a circular section about an axis through its $C.G.$,is
(a) $\pi d^2/4$ (b) $\pi d^2/16$ (c) $\pi d^3/16$ (d) $\pi d^3/32$

212. If the section modulus of a beam is increased, the bending stress in the beam will
(a) not change (b) increase (c) decrease

213. For a given stress, the ratio of moment of resistance of a beam of square cross-section wh placed with its two sides horizontal to the moment of resistance with its diagonal horizontal, is
(a) 1/2 (b) 1 (c) $1/\sqrt{2}$ (d) $\sqrt{2}$

214. A square beam and a circular beam have the same length, same allowable stress and the sa bending moment. The ratio of weights of the square beam to the circular beam is
(a) 1/2 (b) 1 (c) 1/1.12 (d) $1/\sqrt{2}$

215. Two beams, one of circular cross-section and the other of square cross-section, have equ areas of cross-sections. When these beams are subjected to bending,
(a) both beams are equally economical (b) square beam is more economical
(c) circular beam is more economical (d) none of these

216. In a beam of uniform strength, the bending stress developed is constant and is equal to t allowable stress at every section of the beam.
(a) True (b) False

217. When a cantilever beam is loaded at its free end, the maximum compressive stress sha develop at
(a) bottom fibre (b) top fibre (c) neutral axis (d) centre of gravi

218. A beam of uniform strength may be obtained by
(a) keeping the width uniform and varying the depth
(b) keeping the depth uniform and varying the width
(c) varying the width and depth both
(d) any one of the above

219. If the depth is kept constant for a beam of uniform strength, then its width will vary in propo tional to
(a) M (b) $\sqrt{M}$ (c) M^2 (d) M^3
where M = Bending moment.

220. A beam of uniform strength has
(a) same cross-section throughout the beam (b) same bending stress at every section
(c) same bending moment at every section (d) same shear stress at every section

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221. The bending stress in a beam is ..... bending moment.
(a) equal to (b) less than
(c) more than (d) directly proportional to

222. At the neutral axis of a beam
(a) the layers are subjected to maximum bending stress
(b) the layers are subjected to minimum bending stress
(c) the layers are subjected to compression
(d) the layers do not undergo any strain

223. The neutral axis of a beam is subjected to ..... stress.
(a) zero (b) maximum tensile
(c) minimum tensile (d) maximum compressive

224. The neutral axis of a transverse section of a beam passes through the centre of gravity of the section and is
(a) in the vertical plane (b) in the horizontal plane
(c) in the same plane in which the beam bends
(d) at right angle to the plane in which the beam bends

225. On one side of a neutral axis of a beam, there is a tensile stress and on the other side of the beam there is a compressive stress.
(a) Agree (b) Disagree

226. In a beam subjected to pure bending, the intensity of stress in any fibre is ..... the distance of the fibre from the neutral axis.
(a) equal to (b) less than
(c) more than (d) directly proportional to

227. The rectangular beam '*A*' has length *l*, width *b* and depth *d*. Another beam '*B*' has the same length and width but depth is double that of '*A*'. The elastic strength of beam *B* will be ..... as compared to beam *A*.
(a) same (b) double (c) four times (d) six times

228. The rectangular beam '*A*' has length *l*, width *b* and depth *d*. Another beam '*B*' has the same length and depth but width is double that of '*A*'. The elastic strength of beam '*B*' will be .....as compared to beam *A*.
(a) same (b) double (c) four times (d) six times

229. The rectangular beam '*A*' has length *l*, width *b* and depth *d*. Another beam '*B*' has the same width and depth but length is double that of '*A*'. The elastic strength of beam '*B*' will be .....as compared to beam *A*.
(a) same (b) one-half (c) one-fourth (d) one-eighth

230. When a rectangular beam is loaded transversely, the maximum tensile stress is developed on the
(a) top layer (b) bottom layer
(c) neutral axis (d) every cross-section

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231. When a rectangular beam is loaded transversely, the maximum compressive stress developed on the
(a) top layer (b) bottom layer
(c) neutral axis (d) every cross-section

232. When a rectangular beam is loaded transversely, the zero stress is developed on the neutral axis.
(a) True (b) False

233. When a rectangular beam is loaded longitudinally, the shear force develops on the top layer
(a) Agree (b) Disagree

234. At the neutral axis of a beam, the shear stress is
(a) zero (b) minimum (c) maximum (d) infinity

235. The maximum shear stress developed in a beam of rectangular section is ..... the average shear stress.
(a) equal to (b) 4 / 3 times (c) 1.5 times (d) twice

236. The maximum shear stress developed in a beam of circular section is ..... the average shear stress.
(a) equal to (b) 4 / 3 times (c) 1.5 times (d) twice

237. The ratio of maximum shear stress developed in a rectangular beam and a circular beam of same cross-sectional area is
(a) 2 / 3 (b) 3 / 4 (c) 1 (d) 9 / 8

238. A beam of triangular section is placed with its base horizontal. The maximum shear stress occurs at
(a) apex of the triangle (b) mid of the height
(c) centre of gravity of the triangle (d) base of the triangle

239. The maximum shear stress of a beam of triangular section occurs above the neutral axis.
(a) Correct (b) Incorrect

240. A beam of *T*-section is subjected to a shear force of *F*. The maximum shear force will occur at the
(a) top of the section (b) bottom of the section
(c) neutral axis of the section (d) junction of web and flange

241. Which of the following statement is wrong?
(a) In the theory of simple bending, the assumption is that the plane sections before bending remains plane after bending.
(b) In a beam subjected to bending moment, the strain is directly proportional to the distance from the neutral axis.
(c) At the neutral axis of a beam, the bending stress is maximum.
(d) The bending stress in a beam is inversely proportional to the section modulus.

242. A flitched beam is used to
(a) change the shape of the beam
(b) effect the saving in material
(c) equalise the strength in tension and compression
(d) increase the cross-section of the beam

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A rectangular beam of length l supported at its two ends carries a central point load W. The imum deflection occurs

(a) at the ends (b) at $l/3$ from both ends

(b) at the centre (d) none of these

A simply supported beam of length l carries a point load W at a nt C as shown in Fig. 2.45. The maximum deflection lies at

(a) point A (b) point B

(c) point C (d) between points B and C

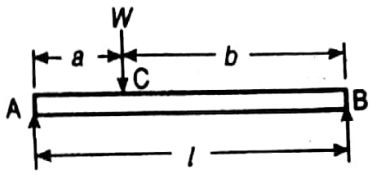

Fig. 2.45

For a beam, as shown in Fig. 2.45, the maximum deflection is $\frac{Wa^2b^2}{3EIl}$.

(a) True (b) False

For a beam, as shown in Fig. 2.45, the deflection at C is

(a) $\frac{Wl^3}{48EI}$ (b) $\frac{Wa^2b^2}{3EIl}$ (c) $\frac{Wa}{a\sqrt{3}EIl}\left(l^2-a^2\right)^{3/2}$ (d) $\frac{5Wl^3}{384EI}$

where E = Young's modulus for the beam material, and

I = Moment of inertia of the beam section.

For a beam, as shown in Fig. 2.45, the maximum deflection lies at

(a) $\frac{l}{3}$ from B (b) $\frac{l}{3}$ from A

(c) $\sqrt{\frac{l^2-a^2}{3}}$ from B (d) $\sqrt{\frac{l^2-b^2}{3}}$ from A

For a beam, as shown in Fig. 2.45, when the load W is applied in the centre of the beam, the ximum deflection is

(a) $\frac{Wl^3}{48EI}$ (b) $\frac{5Wl^3}{384EI}$ (c) $\frac{Wl^3}{192EI}$ (d) $\frac{Wl^3}{384EI}$

A simply supported beam of length l is loaded with a uniformly distributed load of w per unit ngth. The maximum deflection is $\frac{5wl^4}{384EI}$ and lies at the centre of the beam.

(a) True (b) False

The simply supported beam 'A' of length l carries a central point load W. Another beam 'B' is aded with a uniformly distributed load such that the total load on the beam is W. The ratio of aximum deflections between beams A and B is

(a) 5/8 (b) 8/5 (c) 5/4 (d) 4/5

The maximum deflection of a cantilever beam of length l with a point load W at the free end is

(a) $\frac{Wl^3}{3EI}$ (b) $\frac{Wl^3}{8EI}$ (c) $\frac{Wl^3}{16EI}$ (d) $\frac{Wl^3}{48EI}$

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252. The maximum deflection of a cantilever beam of length l with a uniformly distributed load of w per unit length is

(a) $\frac{Wl^3}{3EI}$ (b) $\frac{Wl^3}{8EI}$ (c) $\frac{Wl^3}{16EI}$ (d) $\frac{Wl^3}{48EI}$

where $W = wl$

253. In a cantilever beam of length l subjected to a uniformly distributed load of w per unit length, the maximum deflection lies at the fixed end.

(a) Yes (b) No

254. Two cantilever beams A and B are shown in Fig. 2.46. The ratio of maximum deflection of beam A to the beam B is



Fig. 2.46

(a) 8/7 (b) 16/7 (c) 32/7 (d) 48/7

255. Two cantilever beams A and B are shown in Fig. 2.47. The ratio of maximum deflection of beam A to the beam B is



Fig. 2.47

(a) 3/8 (b) 8/3 (c) 6/15 (d) 15/6

256. A cantilever beam of length l carries a gradually varying load from zero at free end and w per unit length at the fixed end. The maximum deflection lies at

(a) free end (b) fixed end (c) mid-span

257. The value of the maximum deflection for a beam given in Question No. 256 is

(a) $\frac{wl^3}{8EI}$ (b) $\frac{wl^3}{16EI}$ (c) $\frac{wl^4}{30EI}$ (d) $\frac{wl^4}{48EI}$

258. The maximum deflection of a fixed beam carrying a central point load lies at

(a) fixed ends (b) centre of beam

(c) $l/3$ from fixed ends (d) none of these

259. The maximum deflection of a fixed beam of length l carrying a central point load W is

(a) $\frac{Wl^3}{48EI}$ (b) $\frac{Wl^3}{96EI}$ (c) $\frac{Wl^3}{192EI}$ (d) $\frac{Wl^3}{384EI}$

260. The maximum deflection of a fixed beam of length l carrying a total load W uniformly distributed over the whole length is

(a) $\frac{Wl^3}{48EI}$ (b) $\frac{Wl^3}{96EI}$ (c) $\frac{Wl^3}{192EI}$ (d) $\frac{Wl^3}{384EI}$

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261. Two fixed beams *A* and *B* are shown in Fig. 2.48. The ratio of maximum deflection of beam '*A*' to maximum deflection of beam '*B*' is



Fig. 2.48

(*a*) 1/2 (*b*) 1/3 (*c*) 1/4 (*d*) 1/8

262. The product of Young's modulus (*E*) and moment of inertia (*I*) is known as

(*a*) modulus of rigidity (*b*) bulk modulus

(*c*) flexural rigidity (*d*) torsional rigidity

263. A simply supported beam '*A*' of length *l*, breadth *b* and depth *d* carries a central load *W*. Another beam '*B*' of the same dimensions carries a central load equal to 2 *W*. The deflection of beam '*B*' will be ..... as that of beam '*A*'.

(*a*) one-fourth (*b*) one-half (*c*) double (*d*) four times

264. A simply supported beam '*A*' of length *l*, breadth *b*, and depth *d* carries a central point load *W*. Another beam '*B*' has the same length and depth but its breadth is doubled. The deflection of beam '*B*' will be ..... as compared to beam '*A*'.

(*a*) one-fourth (*b*) one-half (*c*) double (*d*) four times

265. A simply supported beam '*A*' of length *l*, breadth *b* and depth *d* carries a central point load *W*. Another bream '*B*' has the same length and breadth but its depth is doubled. The deflection of beam '*B*' will be double as compared to beam '*A*'.

(*a*) Right (*b*) Wrong

266. Two simply supported beams '*A*' and '*B*' of same breadth and depth carries a central load *W* as shown in Fig. 2.49. The deflection of beam '*B*' will be ..... as that of beam '*A*'.

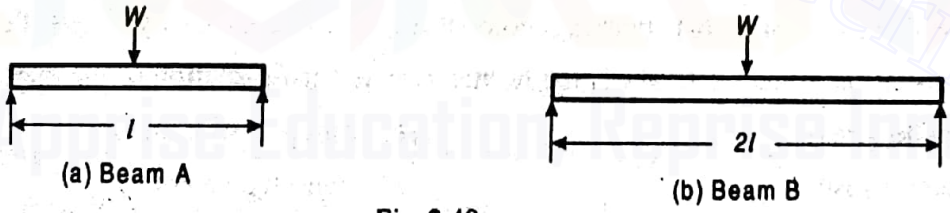

Fig. 2.49

(*a*) one-half (*b*) double (*c*) four times (*d*) eight times

267. Two beams '*A*' and '*B*' carrying a central point load *W* are shown in Fig. 2.50. The deflection of beam '*A*' will be ..... as compared to beam '*B*'.



Fig. 2.50

(*a*) one-eighth (*b*) one-fourth (*c*) one-half (*d*) double

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268. Match the correct formula for deflection given in *Group B* for the beams given in *Group A*.

Group A (Type of beam)	Group B (Deflection)
(a) W, l	(A) $\frac{Wl^3}{8EI}$
(b) Total load W, l	(B) $\frac{Wl^3}{192EI}$
(c) $\frac{l}{2}$, W, l	(C) $\frac{Wl^3}{3EI}$
(d) Total load W, l	(D) $\frac{5Wl^3}{384EI}$
(e) W, l	(E) $\frac{Wl^3}{48EI}$
(f) Total load W, l	(F) $\frac{Wl^3}{384EI}$

269. The product of the tangential force acting on the shaft and its distance from the axis of the shaft (*i.e.* radius of shaft) is known as

(*a*) bending moment (*b*) twisting moment (*c*) torsional rigidity (*d*) flexural rigidity

270. When a shaft is subjected to a twisting moment, every cross-section of the shaft will be under

(*a*) tensile stress (*b*) compressive stress

(*c*) shear stress (*d*) bending stress

271. The shear stress at the centre of a circular shaft under torsion is

(*a*) zero (*b*) minimum (*c*) maximum (*d*) infinity

272. The shear stress at the outermost fibres of a circular shaft under torsion is

(*a*) zero (*b*) minimum (*c*) maximum (*d*) infinity

273. The torsional rigidity of a shaft is given by

(*a*) T/J (*b*) T/θ (*c*) T/r (*d*) T/G

274. When a shaft is subjected to torsion, the shear stress induced in the shaft varies from

(*a*) minimum at the centre to maximum at the circumference

(*b*) maximum at the centre to minimum at the circumference

(*c*) zero at the centre to maximum at the circumference

(*d*) maximum at the centre to zero at the circumference

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275. The torsional rigidity of a shaft is expressed by the torque required to produce a twist of one radian per unit length of a shaft.
(a) True (b) False

276. For a shaft, the shear stress at a point is ..... the distance from the axis of the shaft.
(a) equal to (b) directly proportional to
(c) inversely proportional to

277. The polar moment of inertia of a solid circular shaft of diameter (D) is

(a) $\frac{\pi D^3}{16}$ (b) $\frac{\pi D^3}{32}$ (c) $\frac{\pi D^4}{32}$ (d) $\frac{\pi D^4}{64}$

278. The polar moment of inertia of a hollow shaft of outer diameter (D) and inner diameter (d) is

(a) $\frac{\pi}{16}\left(D^3 - d^3\right)$ (b) $\frac{\pi}{16}\left(D^4 - d^4\right)$ (c) $\frac{\pi}{32}\left(D^4 - d^4\right)$ (d) $\frac{\pi}{64}\left(D^4 - d^4\right)$

279. Which of the following is the correct torsion equation?

(a) $\frac{M}{I} = \frac{\sigma}{y} = \frac{E}{R}$ (b) $\frac{T}{J} = \frac{\tau}{R} = \frac{C\theta}{l}$ (c) $\frac{M}{R} = \frac{T}{J} = \frac{C\theta}{l}$ (d) $\frac{T}{l} = \frac{\tau}{J} = \frac{R}{C\theta}$

280. The torque transmitted by a solid shaft of diameter (D) is

(a) $\frac{\pi}{4} \times \tau \times D^3$ (b) $\frac{\pi}{16} \times \tau \times D^3$ (c) $\frac{\pi}{32} \times \tau \times D^3$ (d) $\frac{\pi}{64} \times \tau \times D^3$

where τ = Maximum allowable shear stress.

281. Two solid shafts 'A' and 'B' are made of the same material. The shaft 'A' is of 50 mm diameter and shaft 'B' is of 100 mm diameter. The strength of shaft 'B' is ..... as that of shaft A.
(a) one-half (b) double (c) four times (d) eight times

282. In the torsion equation $\frac{T}{J} = \frac{\tau}{R} = \frac{C\theta}{l}$, the term J/R is called
(a) shear modulus (b) section modulus (c) polar modulus (d) none of these

283. The polar modulus for a solid shaft of diameter (D) is

(a) $\frac{\pi D^2}{4}$ (b) $\frac{\pi D^3}{16}$ (c) $\frac{\pi D^3}{32}$ (d) $\frac{\pi D^4}{64}$

284. The polar modulus for a hollow shaft of outer diameter (D) and inner diameter (d) is

(a) $\frac{\pi}{4}\left(\frac{D^2 - d^2}{D}\right)$ (b) $\frac{\pi}{16}\left(\frac{D^3 - d^3}{D}\right)$

(c) $\frac{\pi}{16}\left(\frac{D^4 - d^4}{D}\right)$ (d) $\frac{\pi}{32}\left(\frac{D^4 - d^4}{D}\right)$

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285. The torque transmitted by a hollow shaft of outer diameter (D) and inner diameter (d) is

(a) $\frac{\pi}{4} \times \tau \left(\frac{D^3 - d^3}{D} \right)$ (b) $\frac{\pi}{16} \times \tau \left(\frac{D^3 - d^3}{D} \right)$

(c) $\frac{\pi}{16} \times \tau \left(\frac{D^4 - d^4}{D} \right)$ (d) $\frac{\pi}{32} \times \tau \left(\frac{D^4 - d^4}{D} \right)$

286. A shaft revolving at ω rad / s transmits torque (T) in N-m. The power developed is

(a) $T\omega$ watts (b) $2\pi T\omega$ watts (c) $\frac{2\pi T\omega}{75}$ watts (d) $\frac{2\pi T\omega}{4500}$ watts

287. Two shafts 'A' and 'B' transmit the same power. The speed of shaft 'A' is 250 r.p.m. and that of shaft 'B' is 300 r.p.m. The shaft 'B' has the greater diameter.

(a) True (b) False

288. Two shafts 'A' and 'B' have the same material. The shaft 'A' is solid of diameter 100 mm. The shaft 'B' is hollow with outer diameter 100 mm and inner diameter 50 mm. The torque transmitted by shaft 'B' is ..... as that of shaft 'A'.

(a) 1 / 6 (b) 1 / 8 (c) 1 / 4 (d) 15/16

289. The strength of the shaft is judged by the torque transmitted by the shaft.

(a) Yes (b) No

290. Two shafts 'A' and 'B' are made of same material. The shaft 'A' is solid and has diameter D. The shaft 'B' is hollow with outer diameter D and inner diameter $D / 2$. The strength of hollow shaft in torsion is .....as that of solid shaft.

(a) 1 / 16 (b) 1 / 8 (c) 1 / 4 (d) 15 / 16

291. Two shafts 'A' and 'B' are made of same material. The shaft 'A' is of diameter D and shaft 'B' is of diameter $D / 2$. The strength of shaft 'B' is ..... as that of shaft 'A'.

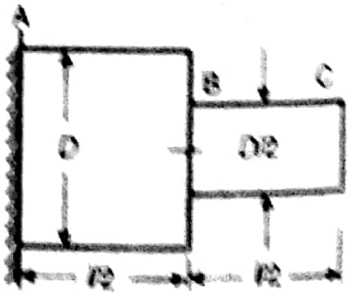
(a) one-eighth (b) one-fourth (c) one-half (d) four times

292. When two shafts of same length, one of which is hollow, transmit equal torques and have equal maximum stress, then they should have equal

(a) polar moment of inertia (b) polar modulus

(c) diameter (d) angle of twist

293. A circular shaft fixed at A has diameter D for half of its length and diameter $D / 2$ over the other half, as shown in Fig. 2.51. If the rotation of B relative to A is 0.1 radian, the rotation of C relative to B will be



(T, l and G are same in both cases)

Fig. 2.51

(a) 0.4 radian (b) 0.8 radian

(c) 1.6 radian (d) 3.2 radian

294. For the two shafts connected in parallel and subjected to twisting moment, the angle of twist of each shaft will be same.

(a) Yes (b) No

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295. The strain energy stored in a solid circular shaft subjected to shear stress (τ) is

(a) $\frac{\tau}{2C} \times$ Volume of shaft (b) $\frac{\tau^2}{2C} \times$ Volume of shaft

(c) $\frac{\tau}{4C} \times$ Volume of shaft (d) $\frac{\tau^2}{4C} \times$ Volume of shaft

where C = Modulus of rigidity for the shaft material.

296. The strain energy stored in a hollow circular shaft of outer diameter (D) and inner diameter (d) subjected to shear stress is

(a) $\frac{\tau^2}{2C}\left(\frac{D^2-d^2}{D}\right) \times$ Volume of shaft (b) $\frac{\tau^2}{2C}\left(\frac{D^2+d^2}{D}\right) \times$ Volume of shaft

(c) $\frac{\tau^2}{4C}\left(\frac{D^2-d^2}{D}\right) \times$ Volume of shaft (d) $\frac{\tau^2}{4C}\left(\frac{D^2+d^2}{D}\right) \times$ Volume of shaft

297. When a shaft of diameter (D) is subjected to a twisting moment (T) and a bending moment (M), then equivalent bending moment (M_e) is given by

(a) $\sqrt{M^2+T^2}$ (b) $\sqrt{M^2-T^2}$

(c) $\frac{1}{2}\left(M+\sqrt{M^2+T^2}\right)$ (d) $\frac{1}{2}\left(M-\sqrt{M^2+T^2}\right)$

298. When a shaft of diameter D is subjected to a twisting moment (T) and a bending moment (M), then the equivalent twisting moment (T_e) is given by

(a) $\sqrt{M^2+T^2}$ (b) $\sqrt{M^2-T^2}$

(c) $\frac{1}{2}\left(M+\sqrt{M^2+T^2}\right)$ (d) $\frac{1}{2}\left(M-\sqrt{M^2+T^2}\right)$

299. When a shaft of diameter D is subjected to a twisting moment (T) and a bending moment (M), then the maximum normal stress is given by

(a) $\frac{16}{\pi D^3}\left[\sqrt{M^2+T^2}\right]$ (b) $\frac{16}{\pi D^3}\left[\sqrt{M^2-T^2}\right]$

(c) $\frac{16}{\pi D^3}\left[M+\sqrt{M^2+T^2}\right]$ (d) $\frac{16}{\pi D^3}\left[M-\sqrt{M^2+T^2}\right]$

300. When a shaft of diameter D is subjected to a twisting moment (T) and a bending moment (M), then the maximum shear stress is given by

(a) $\frac{16}{\pi D^3}\left[\sqrt{M^2+T^2}\right]$ (b) $\frac{16}{\pi D^3}\left[\sqrt{M^2-T^2}\right]$

(c) $\frac{16}{\pi D^3}\left[M+\sqrt{M^2+T^2}\right]$ (d) $\frac{16}{\pi D^3}\left[M-\sqrt{M^2+T^2}\right]$

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301. A shaft of diameter D is subjected to a twisting moment (T) and a bending moment (M). If the maximum bending stress is equal to maximum shear stress developed, then M is equal to
(a) $T/2$ (b) T (c) $2T$ (d) $4T$

302. In spring balances, the spring is used
(a) to apply forces (b) to measure forces
(c) to absorb shocks (d) to store strain energy

303. In watches, the spring is used to absorb shocks and vibrations.
(a) Yes (b) No

304. The springs in cars are used to store strain energy.
(a) Correct (b) Incorrect

305. The springs in brakes and clutches are used to
(a) to apply forces (b) to measure forces
(c) to store strain energy (d) to absorb shocks

306. A spring, when loaded, is permanently distorted and recover its original shape when the load is removed.
(a) Agree (b) Disagree

307. In a watch, the spring is used to store strain energy. This energy is released
(a) to stop the watch (b) to run the watch (c) to change the time (d) all of these

308. A spring used to absorb shocks and vibrations is
(a) conical spring (b) torsion spring (c) leaf spring (d) disc spring

309. The load required to produce a unit deflection in a spring is called
(a) flexural rigidity (b) torsional rigidity
(c) spring stiffness (d) Young's modulus

310. In leaf springs, the maximum bending stress developed in the plates is
(a) $\frac{Wl}{nbt^2}$ (b) $\frac{3Wl}{2nbt^2}$ (c) $\frac{2Wl}{nbt^2}$ (d) $\frac{3Wl}{nbt^2}$

where W = Load acting on the spring,
l = Span of the spring,
n = Number of plates,
b = Width of plates, and
t = Thickness of plates.

311. In a leaf spring, the length of all the leaves are equal.
(a) True (b) False

312. A leaf spring is supported at the
(a) ends and loaded at the centre (b) centre and loaded at the ends
(c) ends and loaded anywhere (d) centre and loaded anywhere

313. In a leaf spring, the deflection at the centre is
(a) $\frac{Wl^3}{8Enbt^3}$ (b) $\frac{Wl^3}{4Enbt^3}$ (c) $\frac{3Wl^3}{8Enbt^3}$ (d) $\frac{Wl^3}{2Enbt^3}$

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314. When a closely-coiled helical spring is subjected to an axial load, it is said to be under
(a) bending (b) shear (c) torsion (d) crushing

315. When a closely-coiled helical spring of mean diameter (D) is subjected to an axial load (W), the deflection of the spring (δ) is given by

(a) $\frac{W D^3 n}{Cd^4}$ (b) $\frac{2W D^3 n}{Cd^4}$ (c) $\frac{4W D^3 n}{Cd^4}$ (d) $\frac{8W D^3 n}{Cd^4}$

where d = Diameter of spring wire,
n = No. of turns of the spring, and
C = Modulus of rigidity for the spring material.

316. When a closely-coiled helical spring of mean diameter (D) is subjected to an axial load (W), the stiffness of the spring is given by

(a) $\frac{Cd^4}{D^3 n}$ (b) $\frac{Cd^4}{2D^3 n}$ (c) $\frac{Cd^4}{4D^3 n}$ (d) $\frac{Cd^4}{8D^3 n}$

317. Two closely-coiled helical springs 'A' and 'B' of the same material, same number of turns and made from same wire are subjected to an axial load W. The mean diameter of spring 'A' is double the mean diameter of spring 'B'. The ratio of deflections in spring 'B' to spring 'A' will be
(a) 1/2 (b) 1/4 (c) 2 (d) 4

318. In the above question, the ratio of stiffness of spring 'B' to spring 'A' will be
(a) 2 (b) 4 (c) 6 (d) 8

319. A closely coiled helical spring is of mean diameter (D) and spring wire diameter (d). The spring index is the ratio of
(a) $1/d$ (b) $1/D$ (c) D/d (d) d/D

320. Two closely coiled helical springs 'A' and 'B' are equal in all respects but the number of turns of spring 'A' is half that of spring 'B'. The ratio of deflections in spring 'A' to spring 'B' is
(a) 1/8 (b) 1/4 (c) 1/2 (d) 2

321. The stiffness of a closely-coiled helical spring is ..... proportional to number of turns.
(a) directly (b) inversely

322. Two closely coiled helical springs 'A' and 'B' are equal in all respects but the diameter of wire of spring 'A' is double that of spring 'B'. The stiffness of spring 'B' will be ..... that of spring 'A'.
(a) one-sixteenth (b) one-eighth (c) one-fourth (d) one-half

323. Two closely-coiled helical springs 'A' and 'B' are equal in all respects but the number of turns of spring 'A' is double that of spring 'B'. The stiffness of spring 'A' will be ..... that of spring 'B'.
(a) one-sixteenth (b) one-eighth (c) one-fourth (d) one-half

324. A closely coiled helical spring is cut into two halves. The stiffness of the resulting spring will be
(a) same (b) double (c) half (d) one-fourth

325. A composite shaft consisting of two stepped portions having spring constants k_1 and k_2 is held between two rigid supports at the ends. Its equivalent spring constant is
(a) $\frac{k_1 + k_2}{2}$ (b) $\frac{k_1 + k_2}{k_1 k_2}$ (c) $\frac{k_1 k_2}{k_1 + k_2}$ (d) $k_1 + k_2$

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326. If the composite shaft in the above question is fixed at one end and the other end is subjected to a torque, then its equivalent spring constant is

(a) $\frac{k_1 + k_2}{2}$ (b) $\frac{k_1 + k_2}{k_1 k_2}$ (c) $\frac{k_1 k_2}{k_1 + k_2}$ (d) $k_1 + k_2$

327. A closely-coiled helical spring of stiffness k is cut into (n) equal parts. The stiffness in each part of the spring will be

(a) $k\sqrt{n}$ (b) $n\sqrt{k}$ (c) nk (d) nk^2

328. The rivets are made from ductile material.

(a) Yes (b) No

329. For riveting, the size of hole drilled in plates is ..... shank diameter of rivet.

(a) equal to (b) less than (c) greater than

330. For a 25 mm hole drilled in plates, the diameter of rivet shank should be

(a) 23 mm (b) 24.5 mm (c) 25 mm (d) 26 mm

331. According to Unwin's formula, the relation between diameter of rivet hole (d) and thickness of plate (t) is given by

(a) $d = t$ (b) $d = 1.6\sqrt{t}$ (c) $d = 2t$ (d) $d = 6\sqrt{t}$

where d and t are in mm.

332. The rivets are used for ..... fastenings.

(a) permanent (b) temporary

333. When one plate overlaps the other and the two plates are riveted together with two rows of rivets, the joint is known as

(a) single riveted lap joint

(b) double riveted lap joint

(c) double riveted single cover butt joint

(d) double riveted double cover butt joint

334. When two main plates are kept in alignment butting each other and riveted with cover plate on both sides of the main plates with two rows of rivets in each main plate, the joint is known as ..... double cover butt joint.

(a) single riveted (b) double riveted

335. In a riveted joint, when the rivets in the various rows are opposite to each other, the joint is said to be

(a) chain riveted (b) zig-zag riveted (c) diamond riveted (d) none of these

336. In a riveted joint, when the rivets in the adjacent rows are staggered in such a way that every rivet is in the middle of the two rivets of the opposite row, the joint is said to be diamond riveted.

(a) Yes (b) No

337. In a riveted joint, when the number of rivets decreases from the inner most row to outer most row, the joint is said to be

(a) chain riveted (b) zig-zag riveted (c) diamond riveted (d) none of these

338. The centre to centre distance, between two consecutive rivets in a row, is called

(a) margin (b) pitch (c) back pitch (d) diagonal pitch

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339. The distance between the centre of a rivet hole to the nearest edge of plate, is called
(a) margin (b) pitch (c) back pitch (d) diagonal pitch

340. The distance between the centres of rivets in adjacent rows of zig-zag riveted joint, is called back pitch.
(a) True (b) False

341. The perpendicular distance between the centre lines of the successive rows, is called pitch.
(a) Agree (b) Disagree

342. Rivets are generally specified by
(a) thickness of plates to be joined (b) overall length
(c) shank diameter (d) diameter of head

343. The object of caulking in a riveted joint is to make the joint
(a) free from corrosion (b) stronger in tension
(c) free from stresses (d) leak-proof

344. A riveted joint may fail by
(a) tearing of the plate at an edge (b) tearing of the plate across a row of rivets
(c) shearing of rivets (d) any one of these

345. In order to avoid tearing off the plate at an edge, the distance from the centre of the rivet hole to the nearest edge of the plate (*i.e.* margin) should be
(a) d (b) $1.5\,d$ (c) $2d$ (d) $2.5\,d$

where d = Diameter of rivet hole in mm.

346. A lap joint is always in ..... shear.
(a) single (b) double

347. A double strap butt joint with equal straps is
(a) always in single shear (b) always in double shear
(c) either in single shear or double shear (d) none of these

348. The pull required to tear off the plate per pitch length is
(a) $(p-2d)\,t\times\sigma_c$ (b) $(p-d)\,t\times\tau$ (c) $(p-d)\,t\times\sigma_t$ (d) $(2p-d)\,t\times\sigma_t$

where p = Pitch of rivets,
t = Thickness of plates, and
σ_t, τ and σ_c = Permissible tensile, shearing and crushing stresses respectively.

349. The pull required to shear off a rivet, in double shear, per pitch length is
(a) $\frac{\pi}{4}\times d^2\times\sigma_t$ (b) $\frac{\pi}{4}\times d^2\times\tau$ (c) $\frac{\pi}{2}\times d^2\times\sigma_t$ (d) $\frac{\pi}{2}\times d^2\times\tau$

350. The pull required to crush the rivet per pitch length is
(a) $p.t.\sigma_t$ (b) $d.t.\sigma_c$ (c) $\frac{\pi}{4}\times d^2\times\sigma_t$ (d) $\frac{\pi}{4}\times d^2\times\sigma_c$

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351. The strength of a riveted joint is equal to the
(*a*) pull required to tear off the plate per pitch length (P_t)
(*b*) pull required to shear off the rivet per pitch length (P_s)
(*c*) pull required to crush the rivet per pitch length (P_c)
(*d*) minimum value of P_t, P_s or P_c.

352. The strength of the un-riveted or solid plate per pitch length is
(*a*) $d.t.\sigma_c$ (*b*) $p.t.\sigma_t$ (*c*) $(p-d)\,t.\,\sigma_t$ (*d*) $\frac{\pi}{2}\times d^2\times\tau$

353. The efficiency of a riveted joint is the ratio of the strength of the joint to the strength of the solid plate.
(*a*) True (*b*) False

354. In calculating the strength of a riveted joint in tearing, shearing and crushing, the
(*a*) actual diameter of rivet is used
(*b*) actual diameter of hole drilled for rivet is used
(*c*) mean diameter of hole drilled and rivet is used
(*d*) smaller of the rivet diameter and hole diameter is used

355. If the tearing efficiency of a riveted joint is 50%, then ratio of rivet hole diameter to the pitch of rivets is
(*a*) 0.20 (*b*) 0.30 (*c*) 0.50 (*d*) 0.60

356. A welded joint as compared to a riveted joint has ..... strength.
(*a*) same (*b*) less (*c*) more

357. Transverse fillet welds are designed for
(*a*) tensile strength (*b*) compressive strength
(*c*) shear strength (*d*) bending strength

358. Parallel fillet welds are designed for bending strength.
(*a*) Agree (*b*) Disagree

359. The tensile strength of the welded joint for double fillet is
(*a*) $0.5\,s.l\,\sigma_t$ (*b*) $s.l.\sigma_t$ (*c*) $\sqrt{2}\,s.l.\sigma_t$ (*d*) $2.\,s.\,l.\,\sigma_t$

where s = Leg or size of the weld,
l = Length of weld, and
σ_t = Allowable tensile stress for weld metal.

360. Shear strength of the welded joint for double parallel fillet is
(*a*) $0.5\,s.l\tau$ (*b*) $s.l.\tau$ (*c*) $\sqrt{2}\,s.l.\tau$ (*d*) $2.\,s.l.\tau$

where τ = Allowable shear stress for weld metal.

361. Which of the following statement is correct?
(*a*) The size of hole drilled in riveting plates is less than the actual size of rivet.
(*b*) The centre to centre distance between two consecutive rivets in a row is called margin.
(*c*) Rivets are generally specified by its shank diameter.
(*d*) Tearing of plates can be avoided by taking the pitch of rivets equal to 1.5 times the diameter of rivet hole.

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362. A pressure vessel is said to be a thin shell when it is made of thin sheets.

(*a*) Agree (*b*) Disagree

363. A pressure vessel is said to be a thick shell, when

(*a*) it is made of thick sheets

(*b*) the internal pressure is very high

(*c*) the ratio of wall thickness of the vessel to its diameter is less than 1 / 10.

(*d*) the ratio of wall thickness of the vessel to its diameter is greater than 1 / 10.

364. A pressure vessel is said to be a thin shell when the ratio of wall thickness of the vessel to its diameter is ..... 1 / 10.

(*a*) equal to (*b*) less than (*c*) greater than

365. A thick pressure vessel is always used for the generation of steam, as it can withstand high pressures.

(*a*) True (*b*) False

366. If the diameter of pressure vessel is 15 times the wall thickness, the vessel is said to be a thick shell.

(*a*) Agree (*b*) Disagree

367. A thin cylindrical shell of diameter (d), length (l) and thickness (t)is subjected to an internal pressure (p). The hoop stress in the shell is

(*a*) pd/t (*b*) $pd/2t$ (*c*) $pd/4t$ (*d*) $pd/6t$

368. A thin cylindrical shell of diameter (d) length (l) and thickness (t) is subjected to an internal pressure (p). The longitudinal stress in the shell is

(*a*) pd/t (*b*) $pd/2t$ (*c*) $pd/4t$ (*d*) $pd/6t$

369. In a thin cylindrical shell subjected to an internal pressure p, the ratio of longitudinal stress to the hoop stress is

(*a*) 1 / 2 (*b*) 3 / 4 (*c*) 1 (*b*) 1.5

370. The design of thin cylindrical shells is based on

(*a*) hoop stress

(*b*) longitudinal stress

(*c*) arithmetic mean of the hoop and the longitudinal stress

(*d*) geometric mean of the hoop and longitudinal stress

371. The hoop stress in a thin cylindrical shell is

(*a*) longitudinal stress (*b*) compressive stress

(*c*) radial stress (*d*) circumferential tensile stress

372. The maximum shear stress in a thin cylindrical shell subjected to internal pressure p is

(*a*) $\frac{pd}{t}$ (*b*) $\frac{pd}{2t}$ (*c*) $\frac{pd}{4t}$ (*d*) $\frac{pd}{8t}$

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373. A thin cylindrical shell of diameter (d), length (l) and thickness (t), is subjected to an internal pressure (p). The circumferential or hoop strain is

(a) $\frac{pd}{2tE}\left(1-\frac{1}{2m}\right)$ (b) $\frac{pd}{4tE}\left(1-\frac{1}{2m}\right)$ (c) $\frac{pd}{2tE}\left(\frac{1}{2}-\frac{1}{m}\right)$ (d) $\frac{pd}{4tE}\left(\frac{1}{2}-\frac{1}{m}\right)$

where $1/m$ = Poisson's ratio.

374. A thin cylindrical shell of diameter (d), length (l) and thickness (t) is subjected to an internal pressure (p). The longitudinal strain is

(a) $\frac{pd}{2tE}\left(1-\frac{1}{2m}\right)$ (b) $\frac{pd}{4tE}\left(1-\frac{1}{2m}\right)$ (c) $\frac{pd}{2tE}\left(\frac{1}{2}-\frac{1}{m}\right)$ (d) $\frac{pd}{4tE}\left(\frac{1}{2}-\frac{1}{m}\right)$

375. When a thin cylindrical shell is subjected to an internal pressure, the volumetric strain is

(a) $2\varepsilon_1-\varepsilon_2$ (b) $2\varepsilon_1+\varepsilon_2$ (c) $2\varepsilon_2-\varepsilon_1$ (d) $2\varepsilon_2+\varepsilon_1$

where ε_1 = Hoop strain, and

ε_2 = Longitudinal strain.

376. A thin cylindrical shell of diameter (d), length (l) and thickness (t) is subjected to an internal pressure (p). The ratio of longitudinal strain to hoop strain is

(a) $\frac{m-2}{2m-1}$ (b) $\frac{2m-1}{m-2}$ (c) $\frac{m-2}{2m+1}$ (d) $\frac{2m+1}{m-2}$

377. When a thin cylindrical shell is subjected to an internal pressure, there will be

(a) a decrease in diameter and length of the shell

(b) an increase in diameter and decrease in length of the shell

(c) a decrease in diameter and increase in length of the shell

(d) an increase in diameter and length of the shell

378. The hoop stress in a riveted cylindrical shell of diameter (d), thickness (t) and subjected to an internal pressure (p) is

(a) $\frac{pd}{t\eta}$ (b) $\frac{pd}{2t\eta}$ (c) $\frac{pd}{4t\eta}$ (d) $\frac{pd}{8t\eta}$

where η = Efficiency of the riveted joint.

379. The longitudinal stress in a riveted cylindrical shell of diameter (d), thickness (t) and subjected to an internal pressure (p) is

(a) $\frac{pd}{t\eta}$ (b) $\frac{pd}{2t\eta}$ (c) $\frac{pd}{4t\eta}$ (d) $\frac{pd}{8t\eta}$

380. A thin spherical shell of diameter (d) and thickness (t) is subjected to an internal pressure (p). The stress in the shell material is

(a) $\frac{pd}{t}$ (b) $\frac{pd}{2t}$ (c) $\frac{pd}{4t}$ (d) $\frac{pd}{8t}$

381. The maximum shear stress in a thin spherical shell subjected to an internal pressure (p) is zero.

(a) Yes (b) No

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382. A thin spherical shell of diameter (d) and thickness (t) is subjected to an internal pressure (p). The volumetric strain is

(a) $\frac{pd}{4tE}\left(1-\frac{1}{m}\right)$ (b) $\frac{pd}{2tE}\left(1-\frac{1}{m}\right)$ (c) $\frac{3pd}{4tE}\left(1-\frac{1}{m}\right)$ (d) $\frac{pd}{tE}\left(1-\frac{1}{m}\right)$

383. A thin cylindrical shell of diameter (d) and thickness (t) is subjected to an internal pressure (p). The volumetric strain is

(a) $\frac{pd}{tE}\left(2-\frac{1}{m}\right)$ (b) $\frac{pd}{2tE}\left(3-\frac{2}{m}\right)$ (c) $\frac{pd}{3tE}\left(4-\frac{3}{m}\right)$ (d) $\frac{pd}{4tE}\left(5-\frac{4}{m}\right)$

384. A thin cylindrical shell of diameter (d) and thickness (t) is subjected to an internal pressure (p). The ratio of longitudinal strain to volumetric strain is

(a) $\frac{m-1}{2m-1}$ (b) $\frac{2m-1}{m-1}$ (c) $\frac{m-2}{3m-4}$ (d) $\frac{m-2}{5m-4}$

385. The thickness of a thin cylindrical shell with hemispherical ends is ..... that of spherical ends.

(a) equal to (b) more than (c) less than

386. The hoop stress in a thick cylindrical shell is maximum at the inner radius.

(a) True (b) False

387. Lame's theory is associated with

(a) thin cylindrical shells (b) thick cylindrical shells

(c) direct and bending stresses (d) none of these

388. In a thick cylindrical shell subjected to an internal pressure (p), the tangential stress across the thickness of a cylinder is

(a) maximum at the outer surface and minimum at the inner surface

(b) maximum at the inner surface and minimum at the outer surface

(c) maximum at the outer surface and zero at the inner surface

(d) maximum at the inner surface and zero at the outer surface

389. In a thick cylindrical shell subjected to an internal pressure (p), the radial stress across the thickness of the cylinder is

(a) maximum at the outer surface and minimum at the inner surface

(b) maximum at the inner surface and minimum at the outer surface

(c) maximum at the outer surface and zero at the inner surface

(d) maximum at the inner surface and zero at the outer surface

390. In a thick cylindrical shell subjected to an internal pressure (p), the tangential stress is always a tensile stress where as the radial stress is a compressive stress

(a) Correct (b) Incorrect

391. In a thick cylindrical shell subjected to an internal pressure (p), the maximum radial stress at the inner surface of the shell is

(a) zero (b) p (tensile) (c) $-p$ (compressive) (d) $2p$ (tensile)

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392. A thick cylindrical shell having r_o and r_i as outer and inner radii, is subjected to an internal pressure (p). The maximum tangential stress at the inner surface of the shell is

(a) $\frac{p\left(r_o^2+r_i^2\right)}{r_o^2-r_i^2}$ (b) $\frac{p\left(r_o^2-r_i^2\right)}{r_o^2+r_i^2}$ (c) $\frac{2pr_i^2}{r_o^2-r_i^2}$ (d) $\frac{r_o^2-r_i^2}{2pr_i^2}$

393. A thick cylindrical shell having r_o and r_i as outer and inner radii, is subjected to an internal pressure (p). The minimum tangential stress at the outer surface of the shell is

(a) $\frac{p\left(r_o^2+r_i^2\right)}{r_o^2-r_i^2}$ (b) $\frac{p\left(r_o^2-r_i^2\right)}{r_o^2+r_i^2}$ (c) $\frac{2pr_i^2}{r_o^2-r_i^2}$ (d) $\frac{r_o^2-r_i^2}{2pr_i^2}$

394. The maximum tangential stress in a thick cylindrical shell is always ..... the internal pressure acting on the shell.

(a) equal to (b) less than (c) greater than

395. When a column is subjected to an eccentric load, the stress induced in the column will be

(a) direct stress only (b) bending stress only

(c) shear stress only (d) direct and bending stress both

396. If the magnitude of direct stress and bending stress is equal, then there will be zero stress at one of the extreme ends of a column.

(a) Agree (b) Disagree

397. For no tension condition in the base of a short column of circular section, the line of action of the load should be within a circle of diameter equal to ..... of the main circle.

(a) one-half (b) one-third (c) one-fourth (d) one-eighth

398. The limit of eccentricity is based upon no tension condition.

(a) True (b) False

399. The limit of eccentricity for no tensile conditions for a column of circular section of diam (d) is

(a) $d/4$ (b) $d/8$ (c) $d/12$ (d) $d/16$

400. The load at which the column just buckles, is known as

(a) buckling load (b) critical load (c) crippling load (d) any one of these

401. For long columns, the value of buckling load is ..... crushing load.

(a) equal to (b) less than (c) more than

402. Compression members always tend to buckle in the direction of the

(a) axis of load (b) perpendicular to the axis of load

(c) minimum cross section (d) least radius of gyration

403. The direct stress induced in a long column is ..... as compared to bending stress.

(a) same (b) more (c) less (d) negligible

404. A column that fails due to direct stress, is called

(a) short column (b) long column (c) weak column (d) medium column

405. The assumption made in Euler's column theory is that

(a) the failure of column occurs due to buckling alone

(b) the length of column is very large as compared to its cross-sectional dimensions

(c) the column material obeys Hooke's law (d) all of the above

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406. According to Euler's column theory, the crippling load for a column length (l) hinged at both ends, is

(a) $\frac{\pi^2 EI}{l^2}$ (b) $\frac{\pi^2 EI}{4l^2}$ (c) $\frac{4\pi^2 EI}{l^2}$ (d) $\frac{2\pi^2 EI}{l^2}$

407. According to Euler's column theory, the crippling load for a column of length (l) fixed at both ends is ..... the crippling load for a similar column hinged at both ends.

(a) equal to (b) two times (c) four times (d) eight times

408. According to Euler's column theory, the crippling load for a column of length (l) with one end fixed and the other end free is ..... the crippling load for a similar column hinged at both the ends.

(a) equal to (b) less than (c) more than

409. According to Euler's column theory, the crippling load for a column of length (l) with one end fixed and the other end hinged, is

(a) $\frac{\pi^2 EI}{l^2}$ (b) $\frac{\pi^2 EI}{4l^2}$ (c) $\frac{2\pi^2 EI}{l^2}$ (d) $\frac{4\pi^2 EI}{l^2}$

410. According to Euler's column theory, the crippling load of a column is given by $P = \pi^2 EI / Cl^2$. In this equation, the value of C for a column with both ends hinged, is

(a) 1 / 4 (b) 1 / 2 (c) 1 (d) 2

411. In the Euler's formula, the value of C for a column with one end fixed and the other end hinged, is 1 / 2.

(a) True (b) False

412. In the Euler's formula, the value of C for a column with both ends fixed is 4.

(a) Agree (b) Disagree

413. In the Euler's formula, the value of C for a column with one end fixed and the other end free, is

(a) 1 / 2 (b) 1 (c) 2 (d) 4

414. A column of length (l) with both ends fixed may be considered as equivalent to a column of length ..... with both ends hinged.

(a) l / 8 (b) l / 4 (c) l / 2 (d) l

415. A column of length (l) with both ends fixed may be considered as equivalent to a column of length ..... with one end fixed and the other end free.

(a) l / 8 (b) l / 4 (c) l / 2 (d) l

416. The equivalent length, of a given column with given end conditions, is the length of an equivalent column of the same material and cross-section with hinged ends, and having the value of crippling load equal to that of the given column.

(a) True (b) False

417. The buckling load for a given column depends upon

(a) area of cross-section of the column

(b) length and least radius of gyration of the column

(c) modulus of elasticity for the material of the column

(d) all of the above

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418. The values of equivalent length (L) and actual length (l) of a column for both ends hinged is the same

(*a*) Yes (*b*) No

419. The relation between equivalent length (L) and actual length (l) of a column for both ends fixed is

(*a*) $L = l/2$ (*b*) $L = l/\sqrt{2}$ (*c*) $L = l$ (*d*) $L = 2l$

420. The relation between equivalent length (L) and actual length (l) of a column for one end fixed and the other end hinged is

(*a*) $L = l/2$ (*b*) $L = l/\sqrt{2}$ (*c*) $L = l$ (*d*) $L = 4l$

421. The value of equivalent length is taken to be half of the actual length of a column with one end fixed and the other end free.

(*a*) Agree (*b*) Disagree

422. A vertical column has two moments of inertia (*i.e.* I_{xx} and I_{yy}). The column will tend to buckle in the direction of the

(*a*) axis of load (*b*) perpendicular to the axis of load

(*c*) maximum moment of inertia (*d*) minimum moment of inertia

423. The slenderness ratio is the ratio of

(*a*) area of column to least radius of gyration

(*b*) length of column to least radius of gyration

(*c*) least radius of gyration to area of column

(*d*) least radius of gyration to length of column

424. The columns whose slenderness ratio is less than 80, are known as

(*a*) short columns (*b*) long columns

(*c*) weak columns (*d*) medium columns

425. In order to know whether a column is long or short, we must know its slenderness ratio.

(*a*) True (*b*) False

426. A column with maximum equivalent length has

(*a*) both ends hinged (*b*) both ends fixed

(*c*) one end fixed and the other end hinged

(*d*) one end fixed and the other end free

427. Euler's formula holds good only for

(*a*) short columns (*b*) long columns

(*c*) both short and long columns (*d*) weak columns

428. A column is said to be a short column, when

(*a*) its length is very small

(*b*) its cross-sectional area is small

(*c*) the ratio of its length to the least radius of gyration is less than 80.

(*d*) the ratio of its length to the least radius of gyration is more than 80.

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429. If the slenderness ratio for a column is 100, then it is said to be a ..... column.

(*a*) long (*b*) medium (*c*) short

430. The Rankine's formula for columns is

(*a*) $\frac{\sigma_c . a}{1 + A\left(\frac{L}{k}\right)^2}$ (*b*) $\frac{\sigma_c . A}{1 + a\left(\frac{L}{k}\right)^2}$ (*c*) $\frac{\sigma_c . a}{1 - A\left(\frac{L}{k}\right)^2}$ (*d*) $\frac{\sigma_c . A}{1 - a\left(\frac{L}{k}\right)^2}$

where σ_c = Crushing stress for the column material,

A = Cross-sectional area of the column,

a = Rankine's constant,

L = Equivalent length of the column, and

k = Least radius of gyration.

431. The Rankine's constant for a mild steel column with both ends hinged is

(*a*) 1/750 (*b*) 1/1600 (*c*) 1/7500 (*d*) 1/9000

432. The Rankine's formula holds good for

(*a*) short columns (*b*) long columns

(*c*) both short and long columns (*d*) weak columns

433. In case of eccentrically loaded struts ..... is preferred.

(*a*) solid section (*b*) hollow section

(*c*) composite section (*d*) reinforced section

434. A masonry dam may fail due to

(*a*) tension in the masonry of the dam and its base

(*b*) overturning of the dam

(*c*) crushing of masonry at the base of the dam

(*d*) any one of the above

435. In order to avoid sliding of masonry dam, the force of friction between the dam and soil should be at least ..... the total water pressure per metre length.

(*a*) equal to (*b*) 1.5 times (*c*) double (*d*) 2.5 times

436. In order to prevent crushing of masonry at the base of the dam, the maximum stress should be ..... the permissible stress of the soil.

(*a*) equal to (*b*) less than (*c*) more than

437. The Rankine's theory for active earth pressure is based on the assumption that

(*a*) the retained material is homogeneous and cohesionless

(*b*) the frictional resistance between the retaining wall and the retained material is neglected

(*c*) the failure of the retained material takes place along a plane called rupture plane

(*d*) all of the above

438. When the retained material is subjected to some superimposed or surcharged load, the total horizontal pressure due to surcharged load is

(*a*) $p \times \frac{1 - \sin\phi}{1 + \sin\phi}$ (*b*) $p \times \frac{1 + \sin\phi}{1 - \sin\phi}$ (*c*) $p \times \frac{1 - \cos\phi}{1 + \cos\phi}$ (*d*) $p \times \frac{1 + \cos\phi}{1 - \cos\phi}$

where p = Intensity of the supercharged load.

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439. The horizontal thrust offered by the retaining wall on the retained material is

(a) $\frac{wh^2}{2}\left(\frac{1-\sin\phi}{1-\sin\phi}\right)$ (b) $\frac{wh^2}{2}\left(\frac{1-\sin\phi}{1+\sin\phi}\right)$

(c) $\frac{wh^2}{2}\left(\frac{1+\cos\phi}{1-\cos\phi}\right)$ (d) $\frac{wh^2}{2}\left(\frac{1-\cos\phi}{1+\cos\phi}\right)$

where w = Specific weight of the retained material,

h = height of retaining wall, and

ϕ = Angle of repose of the retained earth.

440. A reinforced cement concrete beam is considered to be made of

(a) homogeneous material (b) hetrogeneous material

(c) composite material (d) isotropic material

441. The steel bars in a reinforced cement concrete beam are embedded ..... of the beam.

(a) in the centre (b) near the bottom (c) near the top (d) at any position

442. The assumption made in the theory of the reinforced cement concrete beam is that

(a) all the tensile stresses are taken up by the steel reinforcement only

(b) there is a sufficient bond between steel and concrete

(c) the steel and concrete are stressed within its elastic limit

(d) all of the above

443. The critical neutral axis of a reinforced cement concrete beam is based on the principle that the neutral axis is situated at the centre of gravity of a given section.

(a) True (b) False

444. The actual neutral axis of a reinforced cement concrete beam is based on the principle that the moment of areas of compression and tension zones at the neutral axis are equal.

(a) Agree (b) Disagree

445. In case of an under-reinforced beam, the depth of actual neutral axis is ..... that of the critical neutral axis.

(a) same as (b) less than (c) greater than

446. The moment of resistance of a reinforced section is

(a) $\frac{bn\sigma_c}{2}\left(\frac{n}{3}-d\right)$ (b) $\frac{bn\sigma_c}{2}\left(d-\frac{n}{3}\right)$ (c) $\frac{bn\sigma_c}{2}(3d-n)$ (d) $\frac{bn\sigma_c}{2}(n-3d)$

where b = Width of beam,

d = Effective depth of beam,

b = Depth of neutral axis from top of the beam, and

σ_c = Allowable stress in concrete.

447. In case of an over-reinforced beam, the depth of actual neutral axis is the same as that of the critical neutral axis.

(a) True (b) False

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448. The moment of resistance of a balanced reinforced concrete beam is based on the stresses in
(*a*) steel only (*b*) concrete only
(*c*) steel and concrete both (*d*) none of these

449. In a stress-strain diagram for mild steel, as shown in Fig. 2.52, the point *A* represents
(*a*) elastic limit (*b*) upper yield point
(*c*) lower yield point (*d*) breaking point

450. In Fig. 2.52, the point *C* represents
(*a*) elastic limit (*b*) upper yield point
(*c*) lower yield point (*d*) breaking point

451. In Fig. 2.52, the point *B* represents upper yield point.
(*a*) Right (*b*) Wrong

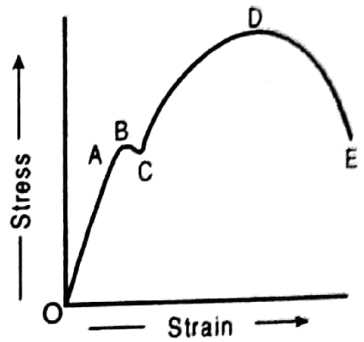

Fig. 2.52

452. In Fig. 2.52, the point *E* represents the maximum stress.
(*a*) True (*b*) False

453. In Fig. 2.52, the stress corresponding to point *D* is
(*a*) yield point stress (*b*) breaking stress (*c*) ultimate stress (*d*) elastic limit

454. In Fig. 2.52, stress is proportional to strain, for the portion
(*a*) from *O* to *A* (*b*) from *A* to *C* (*c*) from *A* to *D* (*d*) from *D* to *E*

455. In Fig. 2.52, Hook's law holds good, for the portion from *O* to *A*.
(*a*) Agree (*b*) Disagree

456. In Fig. 2.52, the plastic range occurs
(*a*) before point *A* (*b*) beyond point *A*
(*c*) between points *A* and *D* (*d*) between points *D* and *E*

457. In a tensile test, when the material is stressed beyond elastic limit, the tensile strain ..... as compared to the stress.
(*a*) decreases slowly (*b*) increases slowly
(*c*) decreases more quickly (*d*) increases more quickly

458. The stress at which the extension of the material takes place more quickly as compared to the increase in load, is called
(*a*) elastic limit (*b*) yield point (*c*) ultimate point (*d*) breaking point

459. The breaking stress is ..... the ultimate stress.
(*a*) equal to (*b*) less than (*c*) greater than

460. The stress developed in the material without any permanent set is called
(*a*) elastic limit (*b*) yield stress (*c*) ultimate stress (*d*) breaking stress

461. When a material is loaded within elastic limit, the material will regain its shape and size when the load is removed.
(*a*) Agree (*b*) Disagree

462. The ratio of the largest load in a test to the original cross-sectional area of the test piece is called
(*a*) elastic limit (*b*) yield stress (*c*) ultimate stress (*d*) breaking stress

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463. The tensile test is carried on ..... materials.
(*a*) ductile (*b*) brittle (*c*) malleable (*d*) plastic

464. The compression test is carried on ..... materials.
(*a*) ductile (*b*) brittle (*c*) malleable (*d*) plastic

465. The tensile strength of ductile materials is ..... its compressive strength.
(*a*) equal to (*b*) less than (*c*) greater than

466. The compressive strength of brittle materials is ..... its tensile strength.
(*a*) equal to (*b*) less than (*c*) greater than

467. A tensile test is performed on a mild steel round bar. Its diameter after fracture will
(*a*) remain same (*b*) increase
(*c*) decrease (*d*) depend upon rate of loading

468. A tensile test is performed on a round bar. After fracture it has been found that the diameter remains approximately same at fracture. The material under test was
(*a*) mild steel (*b*) cast iron (*c*) glass (*d*) copper

469. If percentage reduction in area of a certain specimen made of material '*A*' under tensile test is 60% and the percentage reduction in area of a specimen with same dimensions made of material '*B*' is 40%, then
(*a*) the material *A* is more ductile than material *B*
(*b*) the material *B* is more ductile than material *A*
(*c*) the ductility of material *A* and *B* is equal
(*d*) the material *A* is brittle and material *B* is ductile

470. If percentage elongation of a certain specimen made of a material '*A*' under tensile test is 30% and the percentage elongation of a specimen with same dimensions made of another material '*B*' is 40%, then material '*B*' is more ductile than material '*A*'.
(*a*) Right (*b*) Wrong

471. In a stress-strain diagram as shown in Fig. 2.53, the curve *A* represents
(*a*) mild steel (*b*) soft brass
(*c*) low carbon steel (*d*) cold rolled steel

472. In Fig. 2.53, ... represents glass.
(*a*) curve *A* (*b*) curve *B*
(*c*) curve *C* (*d*) curve *D*

473. In Fig. 2.53, curve *C* represents soft brass.
(*a*) True (*b*) False

474. In Fig. 2.53, curve *D* represents mild steel.
(*a*) Yes (*b*) No

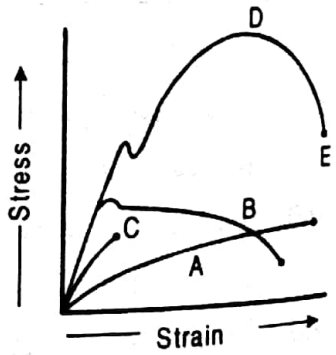

Fig. 2.53

475. The ductility of a material ..... with the increase in percentage reduction in area of a specimen under tensile test.
(*a*) increases (*b*) decreases (*c*) remains same

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476. The ductility of the material ..... with the decrease in percentage elongation of a specimen under tensile test.
(a) increases (b) decreases (c) remains same

477. Factor of safety is defined as the ratio of
(a) ultimate stress to working stress (b) working stress to ultimate stress
(c) breaking stress to ultimate stress (d) ultimate stress to breaking stress

478. The factor of safety is always more than unity.
(a) Correct (b) Incorrect

479. In compression test, the fracture in cast iron specimen would occur along
(a) the axis of load (b) an oblique plane
(c) at right angles to the axis of specimen (d) would not occur

480. Fatigue test is carried out for
(a) stresses varying between two limits of equal value, but of opposite sign
(b) stresses varying between two limits of unequal value, but of opposite sign
(c) stresses varying between two limits of unequal value but of same sign
(d) all of the above

ANSWERS

1.	(b)	2.	(d)	3.	(d)	4.	(d)	5.	(b)	6.	(a)
7.	(c)	8.	(d)	9.	(a)	10.	(b)	11.	(b)	12.	(b)
13.	(d)	14.	(a)	15.	(b)	16.	(d)	17.	(c)	18.	(d)
19.	(a)	20.	(b)	21.	(b)	22.	(b)	23.	(c)	24.	(c)
25.	(b)	26.	(d)	27.	(c)	28.	(a)	29.	(c)	30.	(a)
31.	(c)	32.	(b)	33.	(c)	34.	(d)	35.	(d)	36.	(a)
37.	(c)	38.	(b)	39.	(a)	40.	(b)	41.	(b)	42.	(d)
43.	(a)	44.	(d)	45.	(a)	46.	(b)	47.	(d)	48.	(b)
49.	(a)	50.	(a)	51.	(b)	52.	(c)	53.	(c)	54.	(d)
55.	(d)	56.	(a)	57.	(c)	58.	(c)	59.	(d)	60.	(b)
61.	(a)	62.	(a)	63.	(a)	64.	(c)	65.	(c)	66.	(c)
67.	(b)	68.	(d)	69.	(b)	70.	(c)	71.	(d)	72.	(c)
73.	(C), (D) (B), (A), (E)			74.	(c)	75.	(a)	76.	(b)	77.	(a)
78.	(a)	79.	(c)	80.	(b)	81.	(a)	82.	(a)	83.	(b)
84.	(b)	85.	(a)	86.	(a)	87.	(b)	88.	(d)	89.	(d)
90.	(a)	91.	(b)	92.	(a)	93.	(b)	94.	(a)	95.	(d)
96.	(a)	97.	(b)	98.	(c)	99.	(a)	100.	(c)	101.	(c)
102.	(c)	103.	(d)	104.	(b)	105.	(d)	106.	(a)	107.	(d)
108.	(c)	109.	(b)	110.	(b)	111.	(a)	112.	(c)	113.	(a)
114.	(a)	115.	(a)	116.	(a)	117.	(d)	118.	(d)	119.	(b)
120.	(a)	121.	(d)	122.	(c)	123.	(b)	124.	(b)	125.	(d)

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126. (c) 127. (d) 128. (b) 129. (c) 130. (b) 131. (d)
132. (b) 133. (b) 134. (a) 135. (b) 136. (c) 137. (a)
138. (a) 139. (a) 140. (b) 141. (a) 142. (a) 143. (c)
144. (b) 145. (b) 146. (a) 147. (b) 148. (c) 149. (a)
150. (b) 151. (c) 152. (a) 153. (d) 154. (a) 155. (a)
156. (c) 157. (d) 158. (b) 159. (d) 160. (a) 161. (c)
162. (d) 163. (a) 164. (a) 165. (b) 166. (a) 167. (a)
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174. (a) 175. (b) 176. (a) 177. (a) 178. (b) 179. (d)
180. (c) 181. (d) 182. (b) 183. (c) 184. (d) 185. (a)
186. (a) 187. (d) 188. (a) 189. (b) 190. (D), (A), (B), (C)
191. (c) 192. (c) 193. (c) 194. (d) 195. (c) 196. (a)
197. (d) 198. (b) 199. (a) 200. (c) 201. (b) 202. (a)
203. (c) 204. (b) 205. (a) 206. (a) 207. (b) 208. (a)
209. (d) 210. (b) 211. (d) 212. (c) 213. (d) 214. (c)
215. (b) 216. (a) 217. (a) 218. (d) 219. (a) 220. (b)
221. (d) 222. (d) 223. (a) 224. (d) 225. (a) 226. (d)
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245. (b) 246. (b) 247. (c) 248. (a) 249. (a) 250. (b)
251. (a) 252. (b) 253. (b) 254. (d) 255. (b) 256. (a)
257. (c) 258. (b) 259. (c) 260. (d) 261. (a) 262. (c)
263. (c) 264. (b) 265. (b) 266. (d) 267. (b) 268. (C),(A),
(E), (D), (B), (F) 269. (b) 270. (c) 271. (a) 272. (c)
273. (b) 274. (c) 275. (a) 276. (b) 277. (c) 278. (c)
279. (b) 280. (b) 281. (d) 282. (c) 283. (b) 284. (c)
285. (c) 286. (a) 287. (b) 288. (d) 289. (a) 290. (d)
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297. (c) 298. (a) 299. (c) 300. (a) 301. (a) 302. (b)
303. (b) 304. (b) 305. (a) 306. (a) 307. (b) 308. (c)
309. (c) 310. (b) 311. (b) 312. (b) 313. (c) 314. (c)
315. (d) 316. (d) 317. (a) 318. (d) 319. (c) 320. (c)
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327. (c) 328. (a) 329. (c) 330. (a) 331. (d) 332. (a)
333. (b) 334. (b) 335. (a) 336. (b) 337. (c) 338. (b)
339. (a) 340. (b) 341. (b) 342. (c) 343. (d) 344. (d)
345. (b) 346. (a) 347. (b) 348. (c) 349. (d) 350. (b)

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351. (*d*)	352. (*b*)	353. (*a*)	354. (*b*)	355. (*c*)	356. (*c*)
357. (*a*)	358. (*a*)	359. (*c*)	360. (*c*)	361. (*c*)	362. (*b*)
363. (*d*)	364. (*b*)	365. (*b*)	366. (*a*)	367. (*b*)	368. (*c*)
369. (*a*)	370. (*a*)	371. (*d*)	372. (*d*)	373. (*a*)	374. (*c*)
375. (*b*)	376. (*a*)	377. (*d*)	378. (*b*)	379. (*c*)	380. (*c*)
381. (*a*)	382. (*c*)	383. (*d*)	384. (*d*)	385. (*b*)	386. (*a*)
387. (*b*)	388. (*b*)	389. (*d*)	390. (*a*)	391. (*c*)	392. (*a*)
393. (*c*)	394. (*c*)	395. (*d*)	396. (*a*)	397. (*c*)	398. (*a*)
399. (*b*)	400. (*d*)	401. (*b*)	402. (*d*)	403. (*d*)	404. (*a*)
405. (*d*)	406. (*a*)	407. (*c*)	408. (*b*)	409. (*c*)	410. (*c*)
411. (*a*)	412. (*b*)	413. (*d*)	414. (*c*)	415. (*b*)	416. (*a*)
417. (*d*)	418. (*a*)	419. (*a*)	420. (*b*)	421. (*b*)	422. (*d*)
423. (*b*)	424. (*a*)	425. (*a*)	426. (*d*)	427. (*b*)	428. (*c*)
429. (*a*)	430. (*b*)	431. (*c*)	432. (*c*)	433. (*c*)	434. (*d*)
435. (*b*)	436. (*b*)	437. (*d*)	438. (*a*)	439. (*b*)	440. (*b*)
441. (*b*)	442. (*d*)	443. (*a*)	444. (*a*)	445. (*b*)	446. (*b*)
447. (*b*)	448. (*c*)	449. (*a*)	450. (*c*)	451. (*a*)	452. (*b*)
453. (*c*)	454. (*a*)	455. (*a*)	456. (*b*)	457. (*d*)	458. (*b*)
459. (*b*)	460. (*a*)	461. (*a*)	462. (*c*)	463. (*a*)	464. (*b*)
465. (*c*)	466. (*c*)	467. (*c*)	468. (*b*)	469. (*a*)	470. (*a*)
471. (*b*)	472. (*c*)	473. (*b*)	474. (*a*)	475. (*a*)	476. (*b*)
477. (*a*)	478. (*a*)	479. (*b*)	480. (*d*)		

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Hydraulic Machines

4.1 Introduction

The subject '*Hydraulic Machines*' may be defined as that branch of Engineering - science which deals with the machines run by water under some head or raising the water to higher levels.

4.2 Impact of Jets

The following relations are important :

(*a*) Force exerted by a jet of water impinging normally on a fixed plate,

$$*F_X = \frac{waV^2}{g} \text{ (in newton)}$$

where w = Specific weight of water in N / m^3,
a = Cross-sectional area of jet in m^2, and
V = Velocity of jet in m / s.

(*b*) Force exerted by a jet of water impinging normally (*i.e.* perpendicular) on a fixed plate inclined at an angle θ (as shown in Fig. 4.1) is

$$F_N = \frac{waV^2}{g} \times \sin\theta$$

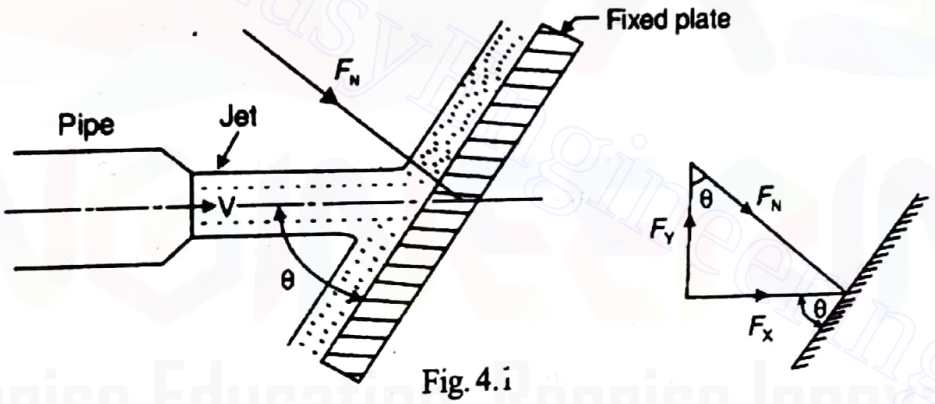

Fig. 4.1

Force exerted by the jet in the direction of flow,

$$F_X = F_N \sin\theta = \frac{waV^2}{g} \times \sin^2\theta$$

and force exerted by the jet in a direction normal to flow,

$$F_Y = F_N \cos\theta = \frac{waV^2}{g} \times \sin\theta\cos\theta$$

$$= \frac{waV^2}{2g} \times \sin 2\theta \quad \ldots (\because 2\sin\theta\cos\theta = \sin 2\theta)$$

(*c*) When a jet of water enters and leaves the curved fixed plate or vane tangentially, then the force of the jet along normal to the plate

$$= \frac{waV^2}{g}(\cos\alpha + \cos\beta)$$

*This equation may be written as

$F_X = \rho a V^2$ (in newton)

where ρ = Mass density of water in kg/m^3 = w / g

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where α and β = Inlet and outlet angles of the jet respectively.

(*d*) Force exerted by a jet of water impinging normally on a plate which due to the impact of jet, moves in the direction of jet with a velocity v is

$$= \frac{wa}{g}(V - v)^2$$

(*e*) When a jet of water enters and leaves a moving curved vane, then the force of jet in the direction of motion of the vane is

$$= \frac{waV}{g}(V_w - V_{w1})$$

where V_w and V_{w1} = Velocity of whirl at inlet and outlet respectively.

4.3 Hydraulic Turbines

A hydraulic turbine is a machine which converts the hydraulic energy into mechanical energy. The hydraulic turbines are also known as *water turbines*. Following two types of hydraulic turbines are important.

1. Impulse turbine; and 2. Reaction turbine

In an *impulse turbine*, the total energy at the inlet of a turbine is only kinetic energy. The pressure of water both at entering and leaving the vanes is atmospheric. It is used for high head of water. A Pelton wheel is a tangential flow impulse turbine.

In a *reaction-turbine*, the total energy at the inlet of a turbine is kinetic energy as well as pressure energy. It is used for low head of water. The Francis and Kaplan turbines are inward flow and axial flow reaction turbines respectively.

4.4 Impulse Turbines

The following important points may be noted for impulse turbines :

(*a*) The hydraulic efficiency of an impulse turbine is the ratio of the workdone on the wheel to the energy of the jet.

(*b*) The hydraulic efficiency of an impulse turbine is maximum when the velocity of wheel is one-half the velocity of jet of water at inlet.

(*c*) The maximum hydraulic efficiency of an impulse turbine is given by

$$\eta_{max} = \frac{1 + \cos\phi}{2}$$

where ϕ = Angle of blade tip at outlet.

(*d*) The mechanical efficiency of an impulse turbine is the ratio of the actual work available at the turbine to the energy imparted to the wheel.

(*e*) The overall efficiency of an impulse turbine is the ratio of the actual power produced by the turbine to the energy actually supplied by the turbine.

(*f*) The width of the bucket for a Pelton wheel is generally five times the diameter of jet.

(*g*) The depth of the bucket for a Pelton wheel is generally 1.2 times the diameter of jet.

(*h*) The number of buckets on the periphery of a Pelton wheel is given by $\left(\frac{D}{2d} + 15\right)$, where D is the pitch diameter of the wheel and d is the diameter of the jet.

(*i*) The ratio of D / d is called jet ratio.

(*j*) The maximum number of jets, generally, employed on Pelton wheel are six.

4.5 Reaction Turbines

The following important points may be noted for reaction turbines :

(*a*) In a reaction turbine, the water enters the wheel under pressure and flows over the vanes.

(*b*) The hydraulic efficiency of a reaction turbine is the ratio of the workdone on the wheel to the energy (or head of water) actually supplied to the turbine.

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(*c*) The overall efficiency of a reaction turbine is the ratio of the power produced by the turbine to the energy actually supplied by the turbine.

(*d*) A Kaplan turbine is an axial flow reaction turbine. The number of blades are generally 4 to 8 in a Kaplan turbine runner.

(*e*) A Francis turbine is an outward flow reaction turbine. The number of blades are generally 16 to 24 in a Francis turbine runner.

4.6 Draft Tube

The draft tube is a pipe of gradually increasing area used for discharging water from the exit of a reaction turbine. It is an integral part of mixed and axial flow turbines. Because of the draft tube, it is possible to have the pressure at runner outlet much below the atmospheric pressure.

The efficiency of a draft tube is defined as the ratio of net gain in pressure head to the velocity head at entrance of draft tube.

4.7 Specific Speed

The specific speed of a turbine is defined as the speed of an imaginary turbine, identical with the given turbine, which develops unit power under unit head. Mathematically, specific speed,

$$N_S = \frac{N\sqrt{P}}{H^{5/4}}$$

where P = Power, and H = Net head on turbine.

The specific speed plays an important role in the selection of a type of turbine. By knowing the specific speed of a turbine, the performance of the turbine can also be predicted.

4.8 Unit Speed, Unit Discharge and Unit Power

The unit speed is the speed of the turbine operating under one metre head. Mathematically,

unit speed, $$N_u = N/\sqrt{H}$$

The unit discharge is the discharge through a turbine when the head on the turbine is unity. Mathematically, unit discharge,

$$Q_u = Q/\sqrt{H}$$

The unit power is the power developed by a turbine when the head on the turbine is unity. Mathematically, unit power,

$$P_u = P/H^{3/2}$$

4.9 Cavitation

The formation, growth and collapse of vapour filled cavities or bubbles in a flowing liquid due to local fall in fluid pressure is called *cavitation*. The cavitation in a hydraulic machine affects in the following ways :

(*a*) It causes noise and vibration of various parts.

(*b*) It makes surface rough.

(*c*) It reduces the discharge of a turbine.

(*d*) It causes sudden drop in power output and efficiency.

The cavitation in reaction turbines can be avoided to a great extent by using the following methods:

(*a*) By installing the turbine below the tail race level.

(*b*) By using stainless steel runner of the turbine.

(*c*) By providing highly polished blades to the runner.

(*d*) By running the turbine runner to the designed speed.

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4.10 Centrifugal Pumps

A centrifugal pump is a machine which converts the kinetic energy of the water into pressure energy before the water leaves its casing. The flow of water leaving the impeller is free vortex. The impeller of a centrifugal pump may have volute casing, vortex casing and volute casing with guide blades.

The following important points may be noted for centrifugal pumps :

(*a*) The manometric head is the actual head of water against which a centrifugal pump has to work. It may be obtained by using the following relations, *i.e.*,

Manometric head = Workdone per kg of water – Losses within the impeller

= Energy per kg at outlet of impeller – Energy per kg at inlet of impeller

= Suction lift + Loss of head in suction pipe due to friction + Delivery lift + Loss of head in delivery pipe due to friction + Velocity head in the delivery pipe.

(*b*) The discharge (Q) of a centrifugal pump is given by

$$Q = \pi D.\, b.\, V_f$$

where D = Diameter of impeller at inlet,

b = Width of impeller at inlet, and

V_f = Velocity of flow at inlet.

(*c*) The manometric efficiency of a centrifugal pump is defined as the ratio of the manometric head to the energy supplied by the impeller.

(*d*) The mechanical efficiency of a centrifugal pump is defined as the ratio of energy available at the impeller to the energy supplied to the pump by the prime mover.

(*e*) The overall efficiency of a centrifugal pump is defined as the energy supplied to the pump to the energy available at the impeller.

(*f*) The efficiency of a centrifugal pump will the maximum when the blades are bent backward.

(*g*) The power required to drive a centrifugal pump is given by

$$P = \frac{w.Q.H_m}{\eta_o} \text{ (in kW)}$$

where w = Specific weight of water in kN/m^3,

Q = Discharge of the pump in m^3/s,

H_m = Manometric head in metres, and

η_o = Overall efficiency of the pump.

4.11 Multistage Centrifugal Pumps

The multistage centrifugal pumps are those which have two or more identical impellers mounted on the same shaft or on different shafts. They are used to produce high heads or to discharge a large quantity of liquid. In order to obtain a high head, a number of impellers are mounted in series or on the same shaft while to discharge a large quantity of liquid, the impellers are connected in parallel.

4.12 Specific Speed of Centrifugal Pump

The specific speed of a centrifugal pump is defined as the speed of an imaginary pump, identical with the given pump, which will discharge 1 litre of water, while it is being raised through a head of one metre. Mathematically, specific speed,

$$N_S = \frac{N\sqrt{Q}}{H_m^{3/4}}$$

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The ranges of specific speeds for different types of pumps are given in the following table.

Type of pump	Slow speed with radial flow at outlet	Medium speed with radial flow at outlet	High speed with radial flow at outlet	High speed with mixed flow at outlet	High speed with axial flow at outlet
Specific speed in r.p.m.	10 – 30	30 – 50	50 – 80	80 – 160	160 – 500

4.13 Net Positive Suction Head (NPSH)

The net positive suction head (NPSH) is defined as the difference between the net inlet head and the head corresponding to the vapour pressure of the liquid. It may be noted that when the pressure at the suction falls below the vapour pressure of the liquid, then cavitation will be formed.

4.14 Model Testing and Similarity of Pumps

In order to know the performance of the prototypes, the models of centrifugal pumps are tested.

When the ratio of all the corresponding linear dimensions of the model and the prototype are equal, then they are said to have *geometric similarity*. In other words, geometric similarity is said to exist between the model and the prototype, if both of them are identical in shape, but differ only in size.

When the ratio of corresponding velocities at corresponding points are equal, then the model and the prototype are said to have *kinematic similarity*.

When the ratio of corresponding forces acting at corresponding points are equal, then the model and the prototype are said to have *dynamic similarity*.

4.15 Reciprocating Pump

The reciprocating pump is a positive displacement pump as it discharges a definite quantity of liquid during the displacement of its piston or plunger which executes a reciprocating motion in a closely fitting cylinder. It is best suited for less discharge and higher heads.

The following important points may be noted for the reciprocating pump:

(*a*) Discharge through a reciprocating pump,

$Q = LAN / 60$ (in m^3 / s) ... (For single acting)

$= 2LAN / 60$ ... (For double acting)

where L = Length of the stroke in metres,

A = Cross-sectional area of the piston in m^2, and

N = Speed of the crank in r.p.m.

(*b*) Power required to drive a reciprocating pump

$= w Q (H_s + H_d)$ (in watts) ... (For single acting)

$= 2 w Q (H_s + H_d)$ (in watts) ... (For double acting)

where w = Weight density or specific weight of the liquid in N / m^3,

H_s = Suction head of the pump in metres, and

H_d = Delivery head of the pump in metres.

(*c*) The difference between the theoretical discharge and the actual discharge is called the *slip* of the pump.

(*d*) The slip of a reciprocating pump is negative when the suction pipe is long and delivery pipe is short and the pump is running at high speeds.

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4.16 Air Vessels

The air vessel, in a reciprocating pump, is a cast iron closed chamber having an opening at its base. These are fitted to the suction pipe and delivery pipe close to the cylinder of the pump. The vessels are used for the following purposes:

(*a*) To get continuous supply of liquid at a uniform rate.

(*b*) To save the power required to drive the pump. This is due to the fact that by using air vessels, the acceleration and friction heads are reduced. Thus the work is also reduced.

It may be noted that by fitting an air vessel to the reciprocating pump, the saving of work and subsequently the power is about 84.8 % in case of a single acting reciprocating pump and 39.2 % in case of double acting reciprocating pump.

4.17 Miscellaneous Hydraulic Machines

The following are the miscellaneous hydraulic machines:

(*a*) *Hydraulic press.* It is a device used to lift larger load by the application of a comparatively much smaller force. It is based on Pascal's law.

The efficiency of a hydraulic press is given by

$$\eta = \frac{W}{P} \times \frac{a}{A}$$

where W = Weight lifted by ram,

P = Force applied on plunger,

A = Area of ram, and

a = Area of plunger.

(*b*) *Hydraulic ram.* It is a device used to lift small quantity of water to a greater height when a large quantity of water is available at a smaller height. It works on the principle of water hammer.

(*c*) *Hydraulic accumulator.* It is a device used to store pressure energy which may be supplied to hydraulic machines such as presses, lifts and cranes.

(*d*) *Hydraulic intensifier.* It is device used to increase the intensity of pressure of water by means of energy available from a large quantity of water at a low pressure.

(*e*) *Hydraulic crane.* It is a device used to lift heavy loads. It is widely used in docks for loading and unloading ships, ware houses, foundry workshops and heavy industries.

(*f*) *Hydraulic lift.* It is a device used for carrying persons and loads from one floor to another, in a multistoreyed building.

OBJECTIVE TYPE QUESTIONS

1. The force exerted (in newton) by a jet of water impinging normally on a fixed plate is

(*a*) $\frac{waV}{2g}$ (*b*) $\frac{waV}{g}$ (*c*) $\frac{waV^2}{2g}$ (*d*) $\frac{waV^2}{g}$

where w = Specific weight of water in N / m^3,

a = Cross-sectional area of jet in m^2, and

V = Velocity of jet in m / s.

2. The force exerted by a jet of water (in a direction normal to flow) impinging on a fixed plate inclined at an angle θ with the jet is

(*a*) $\frac{waV}{2g} \times \sin\theta$ (*b*) $\frac{waV}{g} \times \sin\theta$ (*c*) $\frac{waV^2}{2g} \times \sin 2\theta$ (*d*) $\frac{waV^2}{g} \times \sin 2\theta$

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3. The force exerted by a jet of water impinging normally on a plate which is moving in the direction of jet with a velocity v is due to the impact of jet,

(a) $\frac{wa(V-v)}{2g}$ (b) $\frac{wa(V-v)}{g}$ (c) $\frac{wa(V-v)^2}{2g}$ (d) $\frac{wa(V-v)^2}{g}$

4. A jet of water enters and leaves a fixed curved vane tangentially. The force of jet along perpendicular to the vane is zero.

(a) True (b) False

5. A jet of water enters and leaves a fixed curved vane tangentially. The force of the jet along normal to the vane is

(a) $\frac{waV^2}{g}(\cos\alpha+\cos\beta)$ (b) $\frac{waV^2}{g}(\cos\alpha-\cos\beta)$

(c) $\frac{waV^2}{g}(\sin\alpha+\sin\beta)$ (d) $\frac{waV^2}{g}(\sin\alpha-\sin\beta)$

where α and β = Inlet and outlet angles of the jet respectively.

6. A jet of water enters and leaves a moving curved vane. The force of jet in the direction of motion of the vane is

(a) $\frac{waV}{g}(V_w+V_{wl})$ (b) $\frac{waV}{g}(V_w-V_{wl})$

(c) $\frac{waV^2}{g}(V_w+V_{wl})$ (d) $\frac{waV^2}{g}(V_w-V_{wl})$

where V_w and V_{wl} = Velocities of whirl at inlet and outlet respectively.

7. The ratio of the normal force of jet of water on a plate inclined at an angle of 30° as compared to that when the plate is normal to jet, is

(a) $1/\sqrt{2}$ (b) 1 / 2 (c) 1 (d) $\sqrt{2}$

8. A jet of water is striking at the centre of a curved vane moving with a uniform velocity in the direction of jet. For the maximum efficiency, the vane velocity is ..... of the jet velocity

(a) one-half (b) one-third (c) two-third (d) three-fourth

9. The principle of jet propulsion is used in driving the ships and aeroplanes.

(a) Correct (b) Incorrect

10. A ship with jet propulsion draws water through inlet orifices at right angles to the direction of its motion. The propelling force of the jet is

(a) $\frac{waV_r}{g}(V_r+v)$ (b) $\frac{waV_r}{g}(V_r-v)$ (c) $\frac{waV_r}{g}(V_r+v)^2$ (d) $\frac{waV_r}{g}(V_r-v)^2$

where a = Area of the jet,

V_r = Relative velocity of the jet and ship = $V + v$,

v = Velocity of the ship, and

V = Velocity of the jet issuing from the ship.

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11. The efficiency of jet propulsion for a ship with inlet orifices at right angles to the direction of motion of ship is given by

(a) $\frac{2(V_r - v)v}{V_r^2}$ (b) $\frac{2(V_r + v)v}{V_r^2}$ (c) $\frac{(V_r - v)v}{V_r}$ (d) $\frac{(V_r + v)v}{V_r}$

12. The efficiency of jet propulsion for a ship with inlet orifices at right angles to the direction of motion of ship, will be maximum when the relative velocity of the jet and ship is equal to twice the velocity of the ship.

(a) Yes (b) No

13. The maximum efficiency of jet propulsion of a ship with inlet orifices at right angles to the direction of motion of ship, is

(a) 40% (b) 50% (c) 60% (d) 80%

14. The water in a jet propelled boat is drawn through the openings facing the direction of motion of the boat. The efficiency of propulsion is given by

(a) $\frac{2v}{V_r - v}$ (b) $\frac{2v}{V_r + v}$ (c) $\frac{V}{V_r - v}$ (d) $\frac{V}{V_r + v}$

15. The undershot water wheels are those in which

(a) the wheel runs entirely by the weight of water

(b) the wheel runs entirely by the impulse of water

(c) the wheel runs partly by the weight of water and partly by the impulse of water

(d) none of the above

16. The breast water wheels are those in which the wheel runs partly by the weight of water and partly by the impulse of water.

(a) True (b) False

17. The overshot water wheels are those in which the wheel runs entirely by the ..... of water.

(a) weight (b) impulse

18. Which of the following statement is correct as regard to water wheels?

(a) They have slow speeds.

(b) They are suitable even for low water heads.

(c) They give constant efficiency, even if the discharge is not constant.

(d) all of the above

19. Braking jet in an impulse turbine is used

(a) to break the jet of water (b) to bring the runner to rest in a short time

(c) to change the direction of runner (d) none of these

20. Work done by a turbine ..... upon the weight of water flowing per second.

(a) depends (b) does not depend

21. A Pelton wheel is

(a) tangential flow impulse turbine (b) inward flow impulse turbine

(c) outward flow impulse turbine (d) inward flow reaction turbine

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22. In an impulse turbine, the jet of water impinges on the bucket with a low velocity and after flowing over the vanes, leaves with a high velocity.

(*a*) True (*b*) False

23. An impulse turbine is used for

(*a*) low head of water (*b*) high head of water

(*c*) medium head of water (*d*) high discharge

24. In an impulse turbine, the pressure of water both at entering and leaving the vanes, is atmospheric.

(*a*) Agree (*b*) Disagree

25. The head available at the inlet of the turbine is known as net or effective head.

(*a*) Correct (*b*) Incorrect

26. The gross or total head of the turbine is the ..... of the water levels at the head race and tail race.

(*a*) sum (*b*) difference (*c*) product

27. If H_g is the gross or total head and h_f is the head lost due to friction, then net or effective head (H) is given by

(*a*) $H = H_g / h_f$ (*b*) $H = H_g \times h_f$ (*c*) $H = H_g + h_f$ (*d*) $H = H_g - h_f$

28. The hydraulic efficiency of an impulse turbine is the

(*a*) ratio of the actual power produced by the turbine to the energy actually supplied by the turbine

(*b*) ratio of the actual work available at the turbine to the energy imparted to the wheel

(*c*) ratio of the work done on the wheel to the energy of the jet

(*d*) none of the above

29. The mechanical efficiency of an impulse turbine is

(*a*) ratio of the actual power produced by the turbine to the energy actually supplied by the turbine

(*b*) ratio of the actual work available at the turbine to the energy imparted to the wheel

(*c*) ratio of the work done on the wheel to the energy of the jet

(*d*) none of the above

30. The overall efficiency of an impulse turbine is the ratio of the actual power produced by the turbine to the energy actually supplied by the turbine.

(*a*) Yes (*b*) No

31. The hydraulic efficiency of an impulse turbine is maximum when velocity of wheel is ..... of the jet velocity,

(*a*) one-fourth (*b*) one-half (*c*) three-fourth (*d*) double

32. The maximum hydraulic efficiency of an impulse turbine is

(*a*) $\frac{1+\cos\phi}{2}$ (*b*) $\frac{1-\cos\phi}{2}$ (*c*) $\frac{1+\sin\phi}{2}$ (*d*) $\frac{1-\sin\phi}{2}$

where ϕ = Angle of blade tip at outlet.

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33. The relation between hydraulic efficiency (η_h), mechanical efficiency (η_m) and overall efficiency (η_o) is

(a) $\eta_h = \eta_o \times \eta_m$ (b) $\eta_m = \eta_o \times \eta_h$

(c) $\eta_o = \eta_h \times \eta_m$ (d) none of these

34. The overall efficiency for a Pelton wheel lies between

(a) 0.50 to 0.65 (b) 0.65 to 0.75 (c) 0.75 to 0.85 (d) 0.85 to 0.90

35. A double overhung Pelton wheel has

(a) two jets (b) two runners (c) four jets (d) four runners

36. The width of the bucket for a Pelton wheel is generally..... the diameter of jet.

(a) double (b) three times (c) four times (d) five times

37. The depth of the bucket for a Pelton wheel is generally..... the diameter of jet.

(a) equal to (b) 1.2 times (c) 1.8 times (d) double

38. The jet ratio is defined as the ratio of the

(a) diameter of jet to the diameter of Pelton wheel

(b) velocity of jet to the velocity of Pelton wheel

(c) diameter of Pelton wheel to the diameter of jet

(d) velocity of Pelton wheel to the velocity of jet

39. Which of the following is not an impulse turbine?

(a) Girad turbine (b) Turgo turbine (c) Pelton wheel (d) Kaplan turbine

40. The number of buckets on the periphery of a Pelton wheel is given by

(a) $\frac{D}{2d}+5$ (b) $\frac{D}{2d}+10$ (c) $\frac{D}{2d}+15$ (d) $\frac{D}{2d}+20$

41. The maximum number of jets, generally, employed in an impulse turbine without jet interference are

(a) two (b) four (c) six (d) eight

42. In a reaction turbine, the water enters the wheel under pressure and flows over the vanes.

(a) Correct (b) Incorrect

43. In a reaction turbine, the pressure head of water, while flowing over the vanes, is converted into kinetic head before leaving the wheel.

(a) Agree (b) Disagree

44. The function of guide vanes in a reaction turbine is to

(a) allow the water to enter the runner without shock

(b) allow the water to flow over them, without forming eddies

(c) allow the required quantity of water to enter the turbine

(d) all of the above

45. In a reaction turbine, the draft tube is used

(a) to run the turbine full (b) to prevent air to enter the turbine

(c) to increase the head of water by an amount equal to the height of the runner outlet above the tail race

(d) to transport water to downstream

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46. If V_1 and V_2 are the velocities of water at inlet and outlet of the draft tube respectively, then the efficiency of a draft tube is

(a) $\frac{V_1 - V_2}{V_1}$ (b) $\frac{V_1^2 - V_2^2}{V_1^2}$ (c) $\frac{V_1}{V_1 - V_2}$ (d) $\frac{V_1^2}{V_1^2 - V_2^2}$

47. Which of the following statement is correct ?

(a) In an impulse turbine, the water impinges on the buckets with pressure energy.

(b) In a reaction turbine, the water glides over the moving vanes with kinetic energy.

(c) In an impulse turbine, the pressure of the flowing water remains unchanged and is equal to atmospheric pressure.

(d) In a reaction turbine, the pressure of the flowing water increases after gliding over the vanes.

48. In an inward flow reaction turbine

(a) the water flows parallel to the axis of the wheel

(b) the water enters at the centre of the wheel and then flows towards the outer periphery of the wheel

(c) the water enters the wheel at the outer periphery and then flows towards the centre of the wheel

(d) the flow of water is partly radial and partly axial

49. In an axial flow reaction turbine, the water flows..... to the axis of the wheel.

(a) parallel (b) perpendicular

50. In an outward flow reaction turbine

(a) the water flows parallel to the axis of the wheel

(b) the water enters at the centre of the wheel and then flows towards the outer periphery of the wheel

(c) the water enters the wheel at the outer periphery and then flows towards the centre of the wheel

(d) the flow of water is partly radial and partly axial

51. In a mixed flow reaction turbine, the flow of water is partly radial and partly axial.

(a) Correct (b) Incorrect

52. The hydraulic efficiency of a reaction turbine, is the ratio of

(a) power produced by the turbine to the energy actually supplied by the turbine

(b) actual work available at the turbine to energy imparted to the wheel

(c) workdone on the wheel to the energy (or head of water) actually supplied to the turbine

(d) none of the above

53. The ratio of actual work available at the turbine to the energy imparted to the wheel is known as ..... efficiency.

(a) hydraulic (b) mechanical (c) overall

54. A Francis turbine is an outward flow reaction turbine.

(a) True (b) False

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55. The overall efficiency of a reaction turbine is the ratio of
(*a*) power produced by the turbine to the energy actually supplied by the turbine
(*b*) actual work available at the turbine to the energy imparted to the wheel
(*c*) workdone on the wheel to the energy (or head of water) actually supplied to the turbine
(*d*) none of the above

56. A Kaplan turbine is an axial flow reaction turbine.
(*a*) Correct (*b*) Incorrect

57. In a Francis turbine runner, the number of blades are generally between
(*a*) 2 to 4 (*b*) 4 to 8 (*c*) 8 to 16 (*d*) 16 to 24

58. In a Kaplan turbine runner, the number of blades are generally between
(*a*) 2 to 4 (*b*) 4 to 8 (*c*) 8 to 16 (*d*) 16 to 24

59. Which of the following is not a reaction turbine?
(*a*) Furneyron turbine (*b*) Jonval turbine (*c*) Thomson's turbine (*d*) Pelton wheel

60. The Furneyron turbine is ..... reaction turbine.
(*a*) an axial flow (*b*) an inward flow (*c*) an outward flow (*d*) a mixed flow

61. The Thomson's turbine is ..... reaction turbine.
(*a*) an axial flow (*b*) an inward flow (*c*) an outward flow (*d*) a mixed flo

62. In a Francis turbine, the pressure at inlet is .....that at outlet.
(*a*) less than (*b*) more than

63. The flow ratio of Francis turbine is defined as the ratio of the
(*a*) velocity of flow at inlet to the theoretical jet velocity
(*b*) theoretical velocity of jet to the velocity of flow at inlet
(*c*) velocity of runner at inlet to the velocity of flow at inlet
(*d*) none of the above

64. The flow ratio in case of Francis turbine varies from
(*a*) 0.15 to 0.3 (*b*) 0.4 to 0.5 (*c*) 0.6 to 0.9 (*d*) 1 to 1.5

65. The speed ratio of a Francis turbine is defined as the ratio of the theoretical jet velocity to the peripheral speed at inlet.
(*a*) Yes (*b*) No

66. The power produced by the reaction turbine is ..... to the head of water.
(*a*) directly proportional (*b*) inversely proportional

67. The speed ratio in case of Francis turbine varies from
(*a*) 0.15 to 0.3 (*b*) 0.4 to 0.5 (*c*) 0.6 to 0.9 (*d*) 1 to 1.5

68. If the Francis turbine is run below 50 percent head for a long period, it will not only lose its efficiency but also the cavitation danger will become more serious.
(*a*) Agree (*b*) Disagree

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68. The runaway speed of a hydraulic turbine is the speed
(a) at full load
(b) at which there will be no damage to the runner
(c) corresponding to maximum overload permissible
(d) at which the turbine will run freely without load

70. The power developed by a turbine is
(a) directly proportional to $H^{1/2}$ (b) inversely proportional to $H^{1/2}$
(c) directly proportional to $H^{3/2}$ (d) inversely proportional to $H^{3/2}$
where H = Head of water under which the turbine is working.

71. The unit power developed by a turbine is
(a) $\frac{P}{\sqrt{H}}$ (b) $\frac{P}{H}$ (c) $\frac{P}{H^{3/2}}$ (d) $\frac{P}{H^2}$
where P = Power developed by the turbine under a head of water (H).

72. The speed of a turbine runner is
(a) directly proportional to $H^{1/2}$ (b) inversely proportional to $H^{1/2}$
(c) directly proportional to $H^{3/2}$ (d) inversely proportional to $H^{3/2}$

73. The discharge through a turbine is
(a) directly proportional to $H^{1/2}$ (b) inversely proportional to $H^{1/2}$
(c) directly proportional to $H^{3/2}$ (d) inversely proportional to $H^{3/2}$

74. The unit speed of the turbine runner is
(a) $\frac{N}{\sqrt{H}}$ (b) $\frac{N}{H}$ (c) $\frac{N}{H^{3/2}}$ (d) $\frac{N}{H^2}$

75. The unit discharge through the turbine is
(a) $\frac{Q}{\sqrt{H}}$ (b) $\frac{Q}{H}$ (c) $\frac{Q}{H^{3/2}}$ (d) $\frac{Q}{H^2}$

76. The specific speed of a turbine is given by the equation
(a) $\frac{N\sqrt{P}}{H^{3/2}}$ (b) $\frac{N\sqrt{P}}{H^2}$ (c) $\frac{N\sqrt{P}}{H^{5/4}}$ (d) $\frac{N\sqrt{P}}{H^3}$

77. A Pelton wheel with one nozzle is preferred for a specific speed between 35 to 60 r.p.m.
(a) True (b) False

78. A Pelton wheel develops 1750 kW under a head of 100 metres while running at 200 r.p.m. and discharging 2500 litres of water per second. The unit power of the wheel is
(a) 0.25 kW (b) 0.75 kW (c) 1.75 kW (d) 3.75 kW

79. In the above question, the unit speed of the wheel is
(a) 10 r.p.m. (b) 20 r.p.m. (c) 40 r.p.m. (d) 80 r.p.m.

80. In Q. No. 78, the unit discharge of wheel is
(a) 0.25 m^3/s (b) 0.5 m^3/s (c) 1.5 m^3/s (d) 2.5 m^3/s

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81. The speed of an imaginary turbine, identical with the given turbine, which will develop a unit power under a unit head, is known as
(a) normal speed (b) unit speed (c) specific speed (d) none of these

82. A turbine develops 10 000 kW under a head of 25 metres at 135 r.p.m. Its specific speed is
(a) 175.4 r.p.m. (b) 215.5 r.p.m. (c) 241.5 r.p.m. (d) 275.4 r.p.m.

83. Which of the following turbine is preferred for a specific speed of 60 to 300 r.p.m.?
(a) Pelton wheel (b) Francis turbine (c) Kaplan turbine (d) none of these

84. A Kaplan turbine is preferred for a specific speed of 300 to 1000 r.p.m.
(a) Yes (b) No

85. Which of the following turbine is preferred for 0 to 25 m head of water?
(a) Pelton wheel (b) Kaplan turbine (c) Francis turbine (d) none of these

86. A Francis turbine is used when the available head of water is
(a) 0 to 25 m (b) 25 m to 250 m (c) above 250 m (d) none of these

87. For 450 m head of water, ... shall be used.
(a) Pelton wheel (b) Kaplan turbine (c) Francis turbine (d) none of these

88. A turbine is required to develop 1500 kW at 300 r.p.m. under a head of 150 m. Which of the following turbine should be used ?
(a) Pelton wheel with one nozzle (b) Pelton wheel with two or more nozzles
(c) Kaplan turbine (d) Francis turbine

89. A draft tube is used with impulse turbines.
(a) Yes (b) No

90. A Pelton wheel working under a constant head and discharge, has maximum efficiency when the speed ratio is
(a) 0.26 (b) 0.36 (c) 0.46 (d) 0.56

91. The efficiency of a Pelton wheel working under constant head ..... with the increase in power.
(a) remains same (b) increases (c) decreases

92. The discharge through a reaction turbine ..... with the increase in unit speed.
(a) remains same (b) increases (c) decreases

93. The efficiency of a reaction turbine for a given head ..... with the increase in speed.
(a) decreases (b) increases

94. The cavitation in a hydraulic machine is mainly due to
(a) low velocity (b) high velocity (c) low pressure (d) high pressure

95. The cavitation in a hydraulic machine
(a) causes noise and vibration of various parts
(b) reduces the discharge of a turbine
(c) causes sudden drop in power output and efficiency
(d) all of the above

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96. The cavitation in reaction turbines is avoided, to a great extent by
(a) installing the turbine below the tail race level
(b) using stainless steel runner of the turbine
(c) providing highly polished blades to the runner
(d) all of the above

97. The specific speed of a hydraulic turbine depends upon
(a) speed and power developed
(b) discharge and power developed
(c) speed and head of water
(d) speed, power developed and head of water

98. Which of the following statement is wrong ?
(a) The reaction turbines are used for low head and high discharge.
(b) The angle of taper on draft tube is less than 8°.
(c) An impulse turbine is generally fitted slightly above the tail race.
(d) A Francis turbine is an impulse turbine.

99. The specific speed of a turbine is the speed of an imaginary turbine, identical with the given turbine, which
(a) delivers unit discharge under unit head
(b) delivers unit discharge under unit speed
(c) develops unit power under unit head
(d) develops unit power under unit speed

100. Match the correct answer from *Group B* for the given statements in *Group A*.

Group A	*Group B*
(a) Velocity of sound in a fluid is	(A) $\frac{waV^2}{g}$
(b) When Mach number is 4, the flow is	(B) $\sqrt{K/\rho}$
(c) Thickness of boundary layer in a laminar flow is	(C) $\frac{5x}{\sqrt{R_{NX}}}$
(d) Force exerted by a jet of water impinging normally on a fixed plate is	(D) super-sonic

101. In a centrifugal pump, the water enters the impeller ..... and leaves the vanes axially.
(a) axially
(b) radially

102. The action of a centrifugal pump is that of a reversed reaction turbine.
(a) Correct
(b) Incorrect

103. The impeller of a centrifugal pump may have
(a) volute casing
(b) volute casing with guide blades
(c) vortex casing
(d) any one of these

104. In the casing of a centrifugal pump, the kinetic energy of the water is converted into pressure energy before the water leaves the casing.
(a) True
(b) False

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106. Manometric head, in case of a centrifugal pump, is equal to
(a) Suction lift + Loss of head in suction pipe due to friction + Delivery lift + Loss of head in delivery pipe due to friction + Velocity head in the delivery pipe
(b) Workdone per kN of water – Losses within the impeller
(c) Energy per kN at outlet of impeller – Energy per kN at inlet of impeller
(d) all of the above

107. In a centrifugal pump, the regulating valve is provided on the
(a) casing (b) delivery pipe (c) suction pipe (d) impeller

108. Manometric head is the actual head of water against which a centrifugal pump has to work.
(a) Right (b) Wrong

109. The static head of a centrifugal pump is equal to the ..... of suction head and delivery head.
(a) product (b) difference (c) sum

110. Mechanical efficiency of a centrifugal pump is the ratio of
(a) energy available at the impeller to the energy supplied to the pump by the prime mover
(b) actual workdone by the pump to the energy supplied to the pump by the prime mover
(c) energy supplied to the pump to the energy available at the impeller
(d) manometric head to the energy supplied by the impeller per kN of water

111. Overall efficiency of a centrifugal pump is the ratio of
(a) energy available at the impeller to the energy supplied to the pump by the prime mover
(b) actual workdone by the pump to the energy supplied to the pump by the prime mover
(c) energy supplied to the pump to the energy available at the impeller
(d) manometric head to the energy supplied by the impeller per kN of water

112. The ratio of quantity of liquid discharged per second from the pump to the quantity of liquid passing per second through the impeller is known as
(a) manometric efficiency (b) mechanical efficiency
(c) overall efficiency (d) volumetric efficiency

113. Discharge (Q) of a centrifugal pump is given by
(a) $Q = \pi.D.V_f$ (b) $Q = \pi.b.V_f$ (c) $Q = \pi.D.b.V_f$ (d) $Q = D.b.V_f$

where D = Diameter of impeller at inlet,
b = Width of impeller at inlet, and
V_f = Velocity of flow at inlet.

114. Power required (in watts) to drive a centrifugal pump is
(a) $\frac{w.H_m}{Q \times \eta_o}$ (b) $\frac{w.Q.H_m}{\eta_o}$ (c) $\frac{w.Q}{H_m \times \eta_o}$ (d) $\frac{w.Q \times \eta_o}{H_m}$

where H_m = Manometric head in metres,
w = Specific weight in N / m^3,
Q = Discharge of the pump in m^3 / s, and
η_o = Overall efficiency of the pump.

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114. The efficiency of a centrifugal pump will be maximum when the blades are bent backward.
(a) Yes (b) No

115. Multi-stage centrifugal pumps are used to
(a) give high discharge (b) produce high heads
(c) pump viscous fluids (d) all of these

116. Which of the following statement is correct ?
(a) The centrifugal pump is suitable for large discharge and smaller heads.
(b) The centrifugal pump requires less floor area and simple foundation as compared to reciprocating pump.
(c) The efficiency of centrifugal pump is less as compared to reciprocating pump.
(d) all of the above

117. A centrifugal pump will start delivering liquid only when the pressure rise in the impeller is equal to the
(a) kinetic head (b) velocity head (c) manometric head (d) static head

118. A reciprocating pump is suitable for less discharge and higher heads.
(a) True (b) False

119. A reciprocating pump is also called a ..... displacement pump.
(a) positive (b) negative

120. The discharge of a double acting reciprocating pump is
(a) $L.A.N$ (b) $2\,L.A.N$ (c) $\frac{L.A.N}{60}$ (d) $\frac{2\,L.A.N}{60}$

where L = Length of stroke,
A = Cross-sectional area of piston, and
N = Speed of crank in r.p.m.

121. Slip of a reciprocating pump is defined as the
(a) ratio of actual discharge to the theoretical discharge
(b) sum of actual discharge and the theoretical discharge
(c) difference of theoretical discharge and the actual discharge
(d) product of theoretical discharge and the actual discharge

122. Slip of a reciprocating pump is negative, when
(a) suction pipe is short and pump is running at low speeds
(b) delivery pipe is long and pump is running at high speeds
(c) suction pipe is short and delivery pipe is long and the pump is running at low speeds
(d) suction pipe is long and delivery pipe is short and the pump is running at high speeds

123. Head developed by a centrifugal pump is
(a) proportional to diameter of impeller
(b) proportional to speed of impeller
(c) proportional to diameter and speed of impeller
(d) none of the above

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124. Theoretical power required (in watts) to drive a reciprocating pump is

(*a*) wQH_s (*b*) wQH_d (*c*) $wQ(H_s - H_d)$ (*d*) $wQ(H_s + H_d)$

where w = Specific weight of liquid to be pumped in N/m^3,
Q = Discharge of the pump in m^3/s,
H_s = Suction head in metres, and
H_d = Delivery head in metres.

125. In a mixed flow centrifugal pump, the flow through the impeller is a combination of radial and axial flows.

(*a*) Correct (*b*) Incorrect

126. The air vessel, in a reciprocating pump, is a cast iron closed chamber having an opening at its base.

(*a*) Agree (*b*) Disagree

127. In a reciprocating pump, air vessels are fitted to the suction pipe and delivery pipe close to the cylinder of the pump.

(*a*) True (*b*) False

128. In a reciprocating pump, air vessels are used to

(*a*) smoothen the flow (*b*) reduce suction head
(*c*) increase delivery head (*d*) reduce acceleration head

129. By fitting an air vessel to the reciprocating pump, there is always a saving of work done and subsequently saving of power. This saving in case of a single acting reciprocating pump is

(*a*) 39.2% (*b*) 48.8% (*c*) 84.8% (*d*) 88.4%

130. In the above question, the saving in case of a double acting reciprocating pump is

(*a*) 39.2% (*b*) 48.8% (*c*) 84.8% (*d*) 88.4%

131. Discharge of a centrifugal pump is

(*a*) directly proportional to N (*b*) inversely proportional to N
(*c*) directly proportional to N^2 (*d*) inversely proportional to N^2

where N = Speed of the pump impeller.

132. Power required to drive a centrifugal pump is ..... proportional to N^3.

(*a*) directly (*b*) inversely

133. Delivery head of a centrifugal pump is

(*a*) directly proportional to N (*b*) inversely proportional to N
(*c*) directly proportional to N^2 (*d*) inversely proportional to N^2

134. Discharge of a centrifugal pump is

(*a*) directly proportional to diameter of its impeller
(*b*) inversely proportional to diameter of its impeller
(*c*) directly proportional to (diameter)^2 of its impeller
(*d*) inversely proportional to (diameter)^2 of its impeller

135. Delivery head of water of a centrifugal pump is inversely proportional to diameter of its impeller.

(*a*) Yes (*b*) No

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136. Power required to drive a centrifugal pump is directly proportional to ..... of its impeller.

(a) diameter (b) square of diameter

(c) cube of diameter (d) fourth power of diameter

137. The specific speed of a centrifugal pump may be defined as the speed of an imaginary pump, identical with the given pump, which will discharge one litre of water, while it is being raised through a head of one metre.

(a) True (b) False

138. The specific speed (N_S) of a centrifugal pump is given by

(a) $\frac{N\sqrt{Q}}{H^{2/3}}$ (b) $\frac{N\sqrt{Q}}{H^{3/4}}$ (c) $\frac{N\sqrt{Q}}{H}$ (d) $\frac{N\sqrt{Q}}{H^{5/4}}$

139. The specific speed of a centrifugal pump, delivering 750 litres of water per second against a head of 15 metres at 725 r.p.m., is

(a) 24.8 r.p.m. (b) 48.2 r.p.m. (c) 82.4 r.p.m. (d) 248 r.p.m.

140. The type of centrifugal pump preferred for a specific speed of 20 r.p.m. is

(a) slow speed pump with radial flow at outlet

(b) medium speed pump with radial flow at outlet

(c) high speed pump with radial flow at outlet

(d) high speed pump with axial flow at outlet

141. For centrifugal pump impeller, the maximum value of the vane exit angle is

(a) 10° to 15° (b) 15° to 20° (c) 20° to 25° (d) 25° to 30°

142. The specific speed from 160 to 500 r.p.m. of a centrifugal pump indicates that the pump is

(a) slow speed with radial flow at outlet (b) medium speed with radial flow at outlet

(c) high speed with radial flow at outlet (d) high speed with axial flow at outlet

143. If the net positive suction head (*NPSH*) requirement for the pump is not satisfied, then

(a) no flow will take place (b) cavitation will be formed

(c) efficiency will be low (d) excessive power will be consumed

144. When the speed of the pump increases, its net positive suction head (*NPSH*) requirement decreases.

(a) Agree (b) Disagree

145. Which of the following pump is suitable for small discharge and high heads?

(a) Centrifugal pump (b) Axial flow pump

(c) Mixed flow pump (d) Reciprocating pump

146. Which of the following pump is preferred for flood control and irrigation applications?

(a) Centrifugal pump (b) Axial flow pump

(c) Mixed flow pump (d) Reciprocating pump

147. The centrifugal pump preferred for a specific speed between 80 to 160 r.p.m. is

(a) slow speed with radial flow at outlet (b) medium speed with radial flow at outlet

(c) high speed with radial flow at outlet (d) high speed with mixed flow at outlet

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148. In order to avoid cavitation in centrifugal pumps
(a) the suction pressure should be high
(b) the delivery pressure should be high
(c) the suction pressure should be low
(d) the delivery pressure should be low

149. The discharge of a centrifugal pump working under constant head ..... with the speed
(a) increases
(b) decreases

150. The power of a centrifugal pump working under constant head and discharge increases with the speed.
(a) True
(b) False

151. Which of the following pump is generally used to pump highly viscous fluid?
(a) Centrifugal pump
(b) Reciprocating pump
(c) Air lift pump
(d) Screw pump

152. If the ratio of all the corresponding linear dimensions are equal, then the model and the prototype are said to have
(a) geometric similarity
(b) kinematic similarity
(c) dynamic similarity
(d) none of these

153. If the ratio of corresponding velocities at corresponding points are equal, then the model and the prototype are said to have dynamic similarity.
(a) Right
(b) Wrong

154. If the ratios of the corresponding forces acting at corresponding points are equal, then the model and the prototype are said to have.
(a) geometric similarity
(b) kinematic similarity
(c) dynamic similarity
(d) none of these

155. Geometric similarity is said to exist between the model and the prototype, if both of them
(a) have identical velocities
(b) are equal in size and shape
(c) are identical in shape, but differ only in size
(d) have identical forces

156. Dynamic similarity is said to exist between the model and the prototype, if both of them
(a) have identical velocities
(b) are equal in size and shape
(c) are identical in shape, but differ only in size
(d) none of the above

157. Kinematic similarity is said to exist between the model and the prototype, if both of them
(a) have identical velocities
(b) are equal in size and shape
(c) are identical in shape, but differ only in size
(d) have identical forces

158. Which type of the pump is different from others in the same group?
(a) Screw pump
(b) Gear pump
(c) Cam and piston pump
(d) Plunger pump

159. A hydraulic ram is a device used to
(a) store the energy of water
(b) increase the pressure of water
(c) to lift water from deep wells
(d) to lift small quantity of water to a greater height when a large quantity of water is available at a smaller height

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160. Which of the following pump is sucessfully used for lifting water to the boilers?

(a) Centrifugal pump (b) Reciprocating pump

(c) Jet pump (d) Air-lift pump

161. Which of the following pump is successfully used for lifting water from deep wells?

(a) Centrifugal pump (b) Reciprocating pump

(c) Jet pump (d) Air lift pump

162. Which of the following pump is successfully used for lifting water to the turbines?

(a) Centrifugal pump (b) Reciprocating pump

(c) Jet pump (d) Air lift pump

163. A hydraulic press is a device used

(a) to store pressure energy which may be supplied to a machine later on

(b) to increase the intensity of pressure of water by means of energy available from a large quantity of water at a low pressure

(c) to lift larger load by the application of a comparatively much smaller force

(d) all of the above

164. The efficiency of a hydraulic press is given by

(a) $\frac{W}{P} \times \frac{A}{a}$ (b) $\frac{P}{W} \times \frac{a}{A}$ (c) $\frac{W}{P} \times \frac{a}{A}$ (d) $\frac{P}{W} \times \frac{A}{a}$

where W = Weight lifted by ram, P = Force applied on plunger, A = Area of ram, and

a = Area of plunger.

165. The working of which of the following hydraulic units is based on Pascal's law?

(a) Air lift pump (b) Jet pump (c) Hydraulic coupling (d) Hydraulic press

166. A hydraulic accumulator is a device used to store ..... energy which may be supplied to a machine later on.

(a) strain (b) pressure (c) kinetic

167. The capacity of a hydraulic accumulator is generally specified as the maximum amount of energy stored.

(a) True (b) False

168. A hydraulic intensifier is a device used to increase the intensity of pressure of water by means of energy available from a large quantity of water at a low pressure.

(a) Right (b) Wrong

169. Which of the following hydraulic unit is used for transmitting increased or decreased torque to the driven shaft?

(a) Hydraulic ram (b) Hydraulic intensifier

(c) Hydraulic torque converter (d) Hydraulic accumulator

170. A hydraulic coupling belongs to the category of

(a) power absorbing machines (b) power developing machines

(c) energy transfer machines (d) energy generating machines

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ANSWERS

1.	(d)	2.	(c)	3.	(d)	4.	(b)	5.	(a)	6.	(b)			
7.	(b)	8.	(b)	9.	(a)	10.	(b)	11.	(a)	12.	(a)			
13.	(b)	14.	(b)	15.	(b)	16.	(a)	17.	(a)	18.	(d)			
19.	(b)	20.	(a)	21.	(a)	22.	(b)	23.	(b)	24.	(a)			
25.	(a)	26.	(b)	27.	(d)	28.	(c)	29.	(b)	30.	(a)			
31.	(b)	32.	(a)	33.	(c)	34.	(d)	35.	(b)	36.	(d)			
37.	(b)	38.	(c)	39.	(d)	40.	(c)	41.	(c)	42.	(a)			
43.	(b)	44.	(d)	45.	(c)	46.	(b)	47.	(c)	48.	(c)			
49.	(a)	50.	(b)	51.	(a)	52.	(c)	53.	(b)	54.	(b)			
55.	(a)	56.	(a)	57.	(d)	58.	(b)	59.	(d)	60.	(c)			
61.	(b)	62.	(b)	63.	(a)	64.	(a)	65.	(b)	66.	(a)			
67.	(c)	68.	(a)	69.	(d)	70.	(c)	71.	(c)	72.	(a)			
73.	(a)	74.	(a)	75.	(a)	76.	(c)	77.	(b)	78.	(c)			
79.	(b)	80.	(a)	81.	(c)	82.	(c)	83.	(b)	84.	(a)			
85.	(b)	86.	(b)	87.	(a)	88.	(a)	89.	(b)	90.	(c)			
91.	(b)	92.	(c)	93.	(a)	94.	(c)	95.	(d)	96.	(d)			
97.	(d)	98.	(d)	99.	(c)	100.	(B), (D), (C), (A)			101.	(b)			
102.	(a)	103.	(d)	104.	(a)	105.	(d)	106.	(b)	107.	(a)			
108.	(c)	109.	(a)	110.	(b)	111.	(d)	112.	(c)	113.	(b)			
114.	(a)	115.	(b)	116.	(d)	117.	(c)	118.	(a)	119.	(a)			
120.	(d)	121.	(c)	122.	(d)	123.	(c)	124.	(d)	125.	(a)			
126.	(a)	127.	(a)	128.	(d)	129.	(c)	130.	(a)	131.	(a)			
132.	(a)	133.	(c)	134.	(d)	135.	(b)	136.	(d)	137.	(a)			
138.	(b)	139.	(c)	140.	(a)	141.	(c)	142.	(d)	143.	(b)			
144.	(b)	145.	(d)	146.	(b)	147.	(d)	148.	(a)	149.	(a)			
150.	(a)	151.	(d)	152.	(a)	153.	(b)	154.	(c)	155.	(c)			
156.	(d)	157.	(a)	158.	(d)	159.	(d)	160.	(c)	161.	(d)			
162.	(c)	163.	(c)	164.	(c)	165.	(d)	166.	(b)	167.	(a)			
168.	(a)	169.	(c)	170.	(c)									

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3.1 Introduction

The word 'Hydraulics' has been derived from a Greek word 'Hudour' which means water. The subject 'Hydraulics' is that branch of Engineering - science which deals will water at rest or in motion. The subject 'Fluid Mechanics' is that branch of Engineering-science which deals with the behaviour of fluid under the conditions of rest and motion.

3.2 Important Terms Used in Hydraulics and Fluid Mechanics

The following are important terms used in Hydraulics and Fluid Mechanics :

1. *Density or mass density.* It is defined as the mass per unit volume of a liquid at a standard temperature and pressure. It is usually denoted by ρ (rho). It is expressed in kg / m^3. Mathematically density or mass density,

$$\rho = m / V$$

where m = Mass of the liquid, and

V = Volume of the liquid.

2. *Weight density or specific weight.* It is defined as the weight per unit volume of a liquid at a standard temperature and pressure. It is usually denoted by w. It is expressed in kN / m^3 or N / m^3 or N / mm^3. Mathematically, weight density or specific weight,

$$w = \rho.g$$

Note : For water, $w = 9.81$ kN / m^3 $= 9.81 \times 10^3$ N / m^3 $= 9.81 \times 10^{-6}$ N / mm^3.

3. *Specific volume.* It is defined as the volume per unit mass of the liquid. It is denoted by v. Mathematically, specific volume,

$$v = V / m = 1/\rho$$

4. *Specific gravity.* It is defined as the ratio of specific weight of a liquid to the specific weight of pure water at a standard temperature (4° C). It has no units.

Note : The specific gravity of pure water is taken as unity.

3.3 Properties of Liquid

The following properties of liquid are important from the subject point of view :

1. *Viscosity.* It is also known as **absolute viscosity* or *dynamic viscosity*. It is defined as the property of a liquid which offers resistance to the movement of one layer of liquid over another adjacent layer of liquid. The viscocity of a liquid is due to cohesion and interaction between particles.

2. *Kinematic viscosity.* It is defined as the ratio of dynamic viscosity to the density of liquid.

3. *Compressibility.* It is that property of a liquid by virtue of which liquids undergo a change in volume with the change in pressure. The compressibility is the reciprocal of bulk modulus of elasticity, which is defined as the ratio of compressive stress to volumetric strain.

* Refer also Art. 3.41

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4. *Surface tension.* It is that property of a liquid which enables it to resist tensile stress. It is denoted by σ (sigma). It is expressed in N / m.

5. *Capillarity.* It is defined as a phenomenon of rise or fall of a liquid surface in a small vertical tube held in a liquid relative to general level of the liquid. The height of rise or fall (h) in the tube is given by

$$h = \frac{4\sigma \cos\alpha}{wd}$$

where σ = Surface tension,

α = Angle of contact of the liquid surface,

w = Specific weight of liquid, and

d = Diameter of the capillary tube.

3.4 Pressure of a Liquid

When a liquid is contained in a vessel, it exerts force at all points on the sides and bottom of the vessel. The force per unit area is called *intensity of pressure*. Mathematically, intensity of pressure,

$$p = P / A$$

where P = Force acting on the liquid, and

A = Area on which the force acts.

The intensity of pressure at any point, in a liquid at rest is equal to the product of weight density of the liquid (w) and the *vertical height from the free surface of the liquid (h). Mathematically, intensity of pressure,

$$p = w \, . \, h$$

From this expression, we see that the intensity of pressure at any point, in a liquid, is directly proportional to depth of liquid from the surface.

The intensity of pressure may be expressed either in N / m^2, N / mm^2 or in metres of liquid or mm of liquid. It is also expressed in pascal (briefly written as Pa), such that

$$1\text{Pa} = 1\text{N} / \text{m}^2;\ 1\text{kPa} = 1\text{kN} / \text{m}^2 \text{ and } 1\text{MPa} = 1\text{MN} / \text{m}^2 = 1\text{N} / \text{mm}^2$$

3.5 Pascal's Law

According to Pascal's law, the intensity of pressure at any point in a fluid at rest is same in all directions.

3.6 Atmospheric Pressure, Gauge Pressure and Absolute Pressure

The atmospheric air exerts a normal pressure upon all surfaces with which it is in contact and it is known as *atmospheric pressure*. It is also known as *barometric pressure*. The atmospheric pressure at sea level (above absolute zero) is called standard atmospheric pressure and its value is given as follows :

Standard atmospheric pressure = 101.3 kN / m^2 or kPa (1kN / m^2 = 1kPa)

= 10.3 m of water

= 760 mm of Hg

The pressure measured with the help of a pressure gauge is known as *gauge pressure*, in which atmospheric pressure is taken as datum. All the pressure gauges record the difference between the

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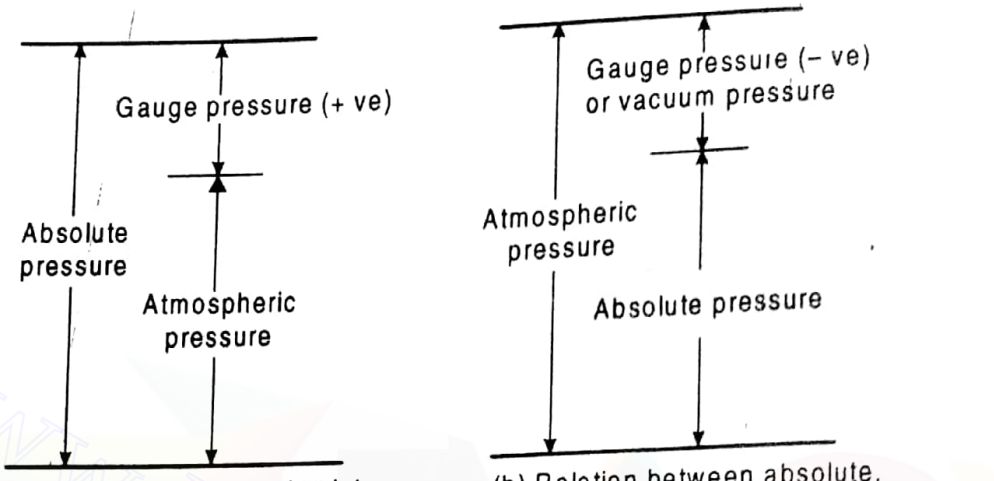
actual pressure and the atmospheric pressure. The actual pressure is known as *absolute pressure*. Mathematically

Absolute pressure = Atmospheric pressure + Gauge pressure (Positive)

This relation is used for pressures above atmospheric, *i.e.* for positive gauge pressure, as shown in Fig. 3.1 (*a*), For pressures below atmospheric, the gauge pressure will be negative. This negative gauge pressure is known as vacuum pressure. Therefore

Absolute pressure = Atmospheric pressure – Negative gauge pressure or vacuum pressure

This relation is shown in Fig 3.1 (*b*).



(a) Relation between absolute, atmospheric and gauge pressure.

(b) Relation between absolute, atmospheric and vacuum pressure.

Fig. 3.1

3.7 Measurement of Pressure

The pressure of a liquid may be measured by the manometers. These are the devices used for measuring the pressure at a point in a liquid by balancing the column of the liquid by the same or another column of liquid. The manometers are classified as follows:

1. Simple manometers such as piezometer and U-tube manometer.
2. Differential manometer.

A *Piezometer* is the simplest form of manometers used for measuring moderate pressures of liquids.

A *manometer* is used to measure

(*a*) High pressure of liquids,

(*b*) Vacuum pressures, and

(*c*) Pressure in pipes and channels.

A *differential manometer* is used to measure difference of pressures between two points in a pipe.

3.8 Total Pressure and Centre of Pressure

The total pressure is defined as the force exerted by a static fluid on a surface (either plane or curved) when the fluid comes in contact with the surface. This force is always normal to the surface.

The centre of pressure is defined as the point of application of the resultant pressure on the surface.

The total pressure and centre of pressure on the immersed surfaces are as follows :

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1. *Horizontally immersed surface.* The total pressure on a horizontally immersed surface, as shown in Fig. 3.2, is given by

$$P = w A.\bar{x}$$

where

w = Specific weight of the liquid,

A = Area of the immersed surface, and

$\bar{x}$ = Depth of the centre of gravity of the immersed surface from the liquid surface.

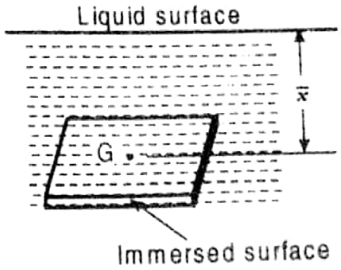

Fig. 3.2

The above expression holds good for all surfaces whether flat or curved.

2. *Vertically immersed surface.* The total pressure on a vertically immersed surface, as shown in Fig. 3.3 , is given by

$$P = w A.\bar{x}$$

and the depth of centre of pressure from the liquid surface,

$$\bar{h} = \frac{I_G}{A\bar{x}} + \bar{x}$$

where

A = Area of immersed surface,

$\bar{x}$ = Depth of centre of gravity of the immersed surface from the liquid surface, and

I_G = Moment of inertia of immersed surface about the horizontal axis through its centre of gravity.

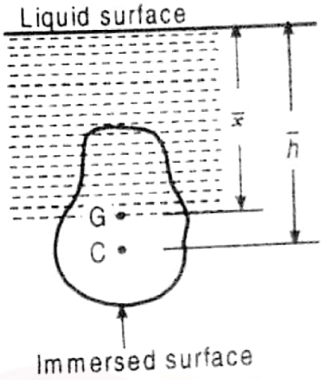

Fig. 3.3

3. *Inclined immersed surface.* The total pressure on an inclined surface, as shown in Fig. 3.4, is given by

$$P = w.A.\bar{x}$$

and the depth of centre of pressure from the liquid surface,

$$\bar{h} = \frac{I_G \sin^2\theta}{A\bar{x}} + \bar{x}$$

where

θ = Angle at which the immersed surface is inclined with the liquid surface.

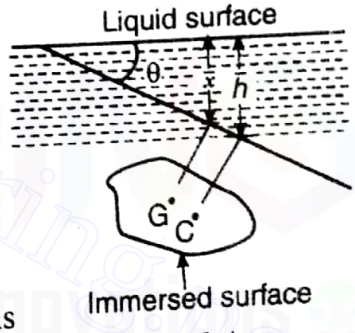

Fig. 3.4

4. *Curved immersed surface.* The total force on the curved surface, as shown in Fig. 3.5, is given by

$$P = \sqrt{(P_H)^2 + (P_V)^2}$$

and the direction of the resultant force on the curved surface with the horizontal is given by

$$\tan\theta = \frac{P_V}{P_H} \quad \text{or} \quad \theta = \tan^{-1}\left[\frac{P_V}{P_H}\right]$$

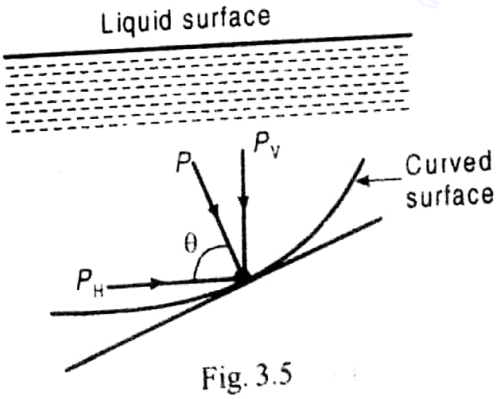

Fig. 3.5

where

P_H = Horizontal force on the curved surface and is equal to the total pressure on the projected area of the curved surface on the vertical plane, and

P_V = Vertical force on the curved surface and is equal to the weight of the liquid supported by the curved surface upto the liquid surface.

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3.9 Lock Gates

The lock gates are provided in navigation chambers to change the water level in a canal or river for navigation. There are two sets of gates, one set on either side of the chamber.

In a lock gate, the reaction between the two gates (R) is given by

$$R = \frac{P}{2 \sin \alpha}$$

where P = Resultant water pressure on the lock gate, and

α = Inclination of the gate with the normal to the side of the lock

3.10 Buoyancy

When a body is immersed wholly or partially in a liquid, it is lifted up by a force equal to the weight of liquid displaced by the body. This statement is known as *Archimede's principle.*

The tendency of a liquid to uplift an immersed body, because of the upward thrust of the liquid, is known as *buoyancy*. The force tending to lift up the body is called the force of buoyancy or *buoyant force* and it is equal to the weight of the liquid displaced. The point through which the buoyant force is supposed to act, is known as *centre of buoyancy.* It may be noted that

(*a*) If the force of buoyancy is more than the weight of the liquid displaced, then the body will float.

(*b*) If the force of buoyancy is less than the weight of the liquid displaced, then the body will sink down.

3.11 Equilibrium of Floating Bodies

The equilibrium of floating bodies is of the following three types:

1. *Stable equilibrium.* If a body floating in a liquid returns back to its original position, when given a small angular displacement, then the body is said to be in stable equilibrium.

2. *Unstable equilibrium.* If a body floating in a liquid does not return back to its original position and heels farther away when given a small angular displacement, then the body is said to be in unstable equilibrium.

3. *Neutral equilibrium.* If a body floating in a liquid occupies a new position and remains at rest in this new position, when given a small angular displacement, then the body is said to be in neutral equilibrium.

3.12 Metacentre and Metacentric Height

The *metacentre* may be defined as a point about which a floating body starts oscillating, when given a small angular displacement. It is denoted by M.

The *metacentric height* is the distance between the centre of gravity (G) of the floating body and the metacentre (M). Mathematically, metacentric height,

$$GM = \frac{I}{V} - BG = BM - BG$$

where I = Moment of inertia of the sectional area of the floating body at the water surface.

V = Volume of the body submerged in water, and

BG = Distance between the centre of buoyancy (B) and the centre of gravity (G).

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The conditions of equilibrium for a floating and submerged body are as follows :

S. No.	Equilibrium condition	Floating body	Submerged body
1.	Stable	M lies above G	B lies above G
2.	Unstable	M lies below G	B lies below G
3.	Neutral	M and G coincides	B and G coincides

The time of oscillation (T) of a floating body is given by

$$T = 2\pi\sqrt{\frac{k^2}{h.g}}$$

where
k = Radius of gyration of the floating body about its centre of gravity, and
h = Metacentric height of the floating body = GM

3.13 Fluid Kinematics

The Fluid Kinematics is that branch of Fluid Mechanics which deals with the study of velocity and acceleration of the fluid particles without taking into consideration any force or energy.

3.14 Rate of Discharge

The quantity of liquid flowing per second through a section of a pipe or a channel is called *discharge* and is measured in cumecs (m^3 / s). Mathematically, discharge,

$$Q = a\,v$$

where
a = Cross-sectional area of the pipe, and
v = Average velocity of the liquid.

It may noted that

(*a*) The velocity of the liquid is maximum at the centre of a pipe and is minimum near the walls.

(*b*) 1 m^3 = 1000 litres.

3.15 Equation of Continuity

If an incompressible liquid is continuously flowing through a pipe or a channel (whose cross - sectional area may or may not be constant), the quantity of liquid passing per second is the same at all sections. This is known as *equation of continuity* of a liquid flow. Mathematically,

$$Q_1 = Q_3 = Q_3 = \ldots\ldots \quad \text{or} \quad a_1 v_1 = a_2 v_2 = a_3 v_3 = \ldots\ldots$$

3.16 Types of Flows in a Pipe

The type of flow of a liquid depends upon the manner in which the particles unite and move. Though there are many types of flows, yet the following are important :

1. *Uniform flow.* A flow, in which the liquid particles at all sections of a pipe or channel have the same velocities, is called a uniform flow.

2. *Non-uniform flow.* A flow, in which the liquid particles at different sections of a pipe or channel have different velocities, is called a non-uniform flow.

3. *Streamline flow.* A flow, in which each liquid particle has a definite path and the paths of individual particles do not cross each other, is called a streamline flow.

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4. *Turbulent flow.* A flow, in which each liquid particle does not have a definite path and the paths of individual particles also cross each other, is called a turbulent flow.

5. *Steady flow.* A flow, in which the quantity of liquid flowing per second is constant, is called a steady flow. A steady flow may be uniform or non - uniform.

6. *Unsteady flow.* A flow, in which the quantity of liquid flowing per second is not constant, is called an unsteady flow.

7. *Compressible flow.* A flow, in which the volume of a fluid and its density changes during the flow, is called a compressible flow. All the gases are considered to have compressible flow.

8. *Incompressible flow.* A flow, in which the volume of a fluid and its density does not change during the flow, is called an incompressible flow. All the liquids are considered to have incompressible flow.

9. *Rotational flow.* A flow, in which the fluid particles also rotate (*i.e.* have some angular velocity) about their own axes while flowing, is called a rotational flow.

10. *Irrotational flow.* A flow, in which the fluid particles do not rotate about their own axes and retain their original orientations, is called an irrotational flow.

11. *One-dimensional flow.* A flow, in which the streamlines of its moving particles are represented by straight line, is called an one-dimensional flow.

12. *Two-dimensional flow.* A flow, whose streamlines of its moving particles are represented by a curve, is called a two-dimensional flow.

13. *Three - dimensional flow.* A flow, whose streamlines are represented in space *i.e.* along the three mutually perpendicular directions, is called a three - dimensional flow.

3.17 Dynamics of Fluid

The dynamics of fluid flow is defined as that branch of science which deals with the study of fluids in motion considering the forces which cause the flow.

3.18 Different Types of Energies or Head of a Liquid in Motion

The following are the three types of energies or head of flowing liquids:

1. *Potential energy or potential head.* It is due to the position above some suitable datum line. It is denoted by z.

2. *Kinetic energy or kinetic (or velocity) head.* It is due to the velocity of flowing liquid. Its value is given by $v^2 / 2g$, where v is the velocity of flow and g is the acceleration due to gravity.

3. *Pressure energy or pressure head.* It is due to the pressure of liquid. Its value is given by p / w, where p is the pressure in N / m^2 and w is the weight density of the liquid in N / m^3.

Note: The total energy or total head of a liquid particle in motion is given as follows :

Total energy, E = Potential energy + Kinetic energy + Pressure energy

and total head, H = Potential head + Kinetic head + Pressure head

3.19 Bernoulli's Equation

The Bernoulli's equation states that 'For a perfect incompressible liquid, flowing in a continuous stream, the total energy of a particle remains the same, while the particle moves from one point to another. Mathematically,

$$z_1 + \frac{v_1^2}{2g} + \frac{p_1}{w} = z_2 + \frac{v_2^2}{2g} + \frac{p_2}{w} = \text{Constant}$$

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The Bernoulli's equation is applied to venturimeter, orifice meter and pitot tube.

The Bernoulli's equation for real fluids is given by

$$\frac{p_1}{w} + \frac{v_1^2}{2g} + z_1 = \frac{p_2}{w} + \frac{v_1^2}{2g} + z_2 + h_L$$

where h_L = Loss of energy between sections 1 and 2.

3.20 Euler's Equation

The Euler's equation in the differential form for the motion of liquids is given as follows :

$$\frac{dp}{\rho} + g.dx + v.dv = 0$$

This equation is based on the following assumptions :

(*a*) The fluid is non - viscous.

(*b*) The fluid is homogeneous and incompressible.

(*c*) The flow is continuous, steady and along the streamline.

(*d*) The velocity of flow is uniform over the section.

Note: The Bernoulli's equation is obtained by integrating the above Euler's equation.

3.21 Venturimeter

It is an instrument used to measure the discharge of liquid flowing in a pipe. It consists of three parts, *i.e.*, the converging cone, the throat and the diverging cone. The length of the divergent cone is made about three to four times longer than that of the divergent cone in order to avoid tendency of breaking away the stream of liquid and to minimise frictional losses. It may be noted that

(*a*) The velocity of liquid at the throat is higher than that of inlet.

(*b*) The pressure of liquid at the throat is lower than that of inlet.

(*c*) The velocity and pressure of liquid flowing through the divergent portion decreases.

The discharge through a venturimeter is given by

$$Q = \frac{C_d\, a_1\, a_2}{\sqrt{a_1^2 - a_2^2}} \sqrt{2gh}$$

where C_d = Coefficient of discharge,

a_1 = Area at inlet,

a_2 = Area at throat, and

h = Venturi-head.

3.22 Orifice Meter and Pitot Tube

The orifice meter is a device (cheaper than venturimeter) used for measuring the discharge of the liquid flowing through a pipe. It works on the same principle as that of venturimeter.

The pitot tube is a small open tube bent at right angle. It is used to measure the velocity of flow at the required point in a pipe. It is determined by measuring the rise of liquid in a tube.

3.23 Momentum Equation

The momentum equation is based on the law of momentum or momentum principle which states

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that *'The net force acting on a mass of fluid is equal to the change in momentum of flow per unit time in that direction"* Mathematically, force acting on the fluid,

$$F = \frac{d(mv)}{dt}$$

where mv = Momentum.

The impulse - momentum equation is given by

$$F \times dt = d(mv)$$

It states that 'the impulse of a force (F) acting on a fluid mass (m) in a short interval of time (dt) is equal to the change of momentum [$d(mv)$] in the direction of force.

3.24 Orifice

The *orifice* is a small opening in the wall or base of a vessel through which the fluid flows. A *mouthpiece* is an attachment in the form of a small tube or pipe fixed to the orifice. Its length is usually two to three times the diameter of orifice. It is used to increase the amount of discharge.

3.25 Hydraulic Coefficients

The following are the hydraulic coefficients :

1. *Coefficient of contraction* (C_c). It is defined as the ratio of area of jet at *vena contracta (a_c) to the area of orifice (a).
2. *Coefficient of velocity* (C_v). It is defined as the ratio of the actual velocity of the jet at vena contracta (v) to the theoretical velocity (v_{th}).
3. *Coefficient of discharge* (C_d). It is defined as the ratio of the actual discharge through the orifice (Q) to the theoretical discharge (Q_{th}). The coefficient of discharge is equal to the product of C_c and C_v.
4. *Coefficient of resistance* (C_r). It is defined as the ratio of loss of head in the orifice to the head of water available at the exit of the orifice.

Note: The coefficient of velocity is determined experimentally by using the following relation, *i.e.*

$$C_v = \sqrt{\frac{x^2}{4yH}}$$

where x = Horizontal distance,

y = Vertical distance, and

H = Constant water head.

3.26 Important Expressions used in Orifices and Mouthpieces

The following are the important expressions used in orifices and mouthpieces :

(*a*) Discharge through a large rectangular orifice,

$$Q = \frac{2}{3} C_d . b \sqrt{2g} \left[H_2^{3/2} - H_1^{3/2} \right]$$

---

* The point at which the streamlines first become parallel is called *vena contracta*. The cross-sectional area of the jet at vena contrata is less than that of the orifice. The theoretical velocity of jet at vena contracta (v_{th}) is given by

$$v_{th} = \sqrt{2gH}$$

This expression is called *Torricelli's theorem*

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where C_d = Coefficient of discharge,
b = Breadth of the orifice,
H_1 = Height of the liquid above the top of the orifice, and
H_2 = Height of the liquid above the bottom of the orifice.

(*b*) Discharge through a wholly submerged orifice,

$$Q = C_d.b(H_2 - H_1)\sqrt{2gH}$$

where H_1 = Height of water (on the upstream side) above the top of the orifice,
H_2 = Height of water (on the downstream side) above the bottom of the orifice, and
H = Difference between two water levels on either side of the orifice.

(*c*) Time required to empty the tank completely through an orifice at the bottom,

$$T = \frac{2A\sqrt{H_1}}{C_d.a\sqrt{2g}}$$

(*d*) Time required to empty the hemispherical tank through an orifice at the bottom,

$$T = \frac{14\pi R^{5/2}}{15 C_d.a\sqrt{2g}}$$

where R = Radius of hemispherical tank.

(*e*) Discharge through an external mouthpiece,

$$Q = 0.855\ a\sqrt{2gH}$$

where a = Cross-sectional area of the mouthpiece, and
H = Height of liquid above the mouthpiece.

(*f*) Discharge through the internal mouthpiece when it is running free,

$$Q = 0.5a\sqrt{2gH}$$

(*g*) Discharge through the internal mouthpiece when it is running full,

$$Q = 0.707\,a\sqrt{2gH}$$

Notes: 1. The re-entrant or Borda's mouthpiece is an internal mouthpiece.

2. If the jet of liquid after contraction does not touch the sides of the mouthpieces, then the mouth piece,is said to be running free. In this case, the length of mouthpiece is equal to diameter of the orifice.

3. If the jet of liquid after contraction expands and fills up the whole mouthpiece, then the mouthpiece is said to be running full. In this case, the length of mouthpiece is more than three times the diameter of orifice.

3.27 Notches and Weirs

A *notch* may be defined as an opening provided in the side of a tank or vessel such that the liquid surface in the tank is below the top edge of the opening. It is generally made of a metallic plate. It is used for measuring the rate of flow of a liquid through a small channel or a tank.

A *weir* may be defined as any regular obstruction in an open channel over which the flow takes place. It is made of masonry or concrete. It is used for measuring the rate of flow of water in rivers or streams.

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3.28 Important Expressions used in Notches and Weirs

The following are the important expressions used in notches and weirs.

(*a*) Discharge over a rectangular notch or weir,

$$Q = \frac{2}{3} C_d . b \sqrt{2g} . H^{3/2}$$

where b = Width of notch or weir, and

H = Height of liquid above the sill of the notch.

(*b*) Discharge over a triangular notch or weir,

$$Q = \frac{8}{15} C_d \sqrt{2g} . \tan\left(\frac{\theta}{2}\right) H^{5/2}$$

For a right angled V-notch, $\theta = 90°$.

(*c*) Discharge over a trapezoidal notch or weir (also called Cippoletti weir) is equal to the sum of discharge over a rectangular notch or weir and the discharge over a triangular notch or weir.

(*d*) Discharge over a rectangular weir, according to Francis formula is given by

$$Q = \frac{2}{3} C_d \ (L - 0.1n H) \sqrt{2g} \ H^{3/2}$$

where n = Number of end contractions.

(*e*) Maximum discharge over a broad crested weir,

$$Q_{max} = 1.71 \, C_d . L . H^{3/2}$$

Notes : 1. A weir is said to be a *broad crested weir,* if the width of the crest of the weir is more than h height of water above the weir crest.

2. A weir is said to be a *narrow crested weir*, if the width of the crest of the weir is less than h height of water above the weir crest.

3. When the water level on the downstream side of a weir is above the top surface of a weir, th weir is known as *submerged* or *drowned weir.*

4. A weir, generally, used as a spillway of a dam is *Ogee weir*.

5. It has been observed that whenever water is flowing over a rectangular weir, having no end con tions, the nappe (*i.e.*, the sheet of water flowing over the weir) touches the side walls of the channel. A flowing over the weir, the nappe falls away from the weir, thus creating a space beneath the water. In su case, some air is trapped beneath the weir.

6. If the atmospheric pressure exists beneath the nappe, it is then known as *free nappe*.

7. If the pressure below the nappe is negative, it is then called a *depressed nappe*.

8. Sometimes, no air is left below the water and the nappe adheres or clings to the downstream si of the weir. Such a nappe is called *clinging nappe* or an *adhering nappe*.

3.29 Pipes and Channels

A pipe is a closed conduit (generally of circular section) which is used for carrying fluids unde pressure. The fluid completely fills the cross-section of the pipe. When the pipe is partially full o liquid, it then behaves like an *open channel.*

3.30 Loss of Head due to Friction in Pipe

According to Darcy's formula, the loss of head due to friction in the pipe (h_f) is given by

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$$h_f = \frac{4 f l v^2}{2g.d}$$

where
f = Darcy's coefficient,
l = Length of pipe,
v = Mean velocity of liquid in pipe, and
d = Diameter of pipe.

The major loss of head or energy is due to friction. The minor loss of head includes the following cases :

(*a*) Loss of head due to sudden enlargement,

$$h_e = \frac{(v_1 - v_2)^2}{2g}$$

(*b*) Loss of head due to sudden contraction,

$$h_c = \frac{v_2^2}{2g}\left[\frac{1}{C_c} - 1\right]^2$$

where
C_c = Coefficient of contraction.

(*c*) Loss of head at the inlet of a pipe,

$$h_i = 0.5 \times \frac{v^2}{2g}$$

(*d*) Loss of head at the outlet of a pipe,

$$h_o = \frac{v^2}{2g}$$

3.31 Hydraulic Gradient and Total Energy Lines

The line representing the sum of pressure head (p/w) and potential head or datum head (z) with respect to some reference line is hydraulic gradient line (H.G.L).

The line representing the sum of pressure head (p/w), datum head (z) and velocity head $(v^2/2g)$ with respect to some reference line is known as total energy line (T.G.L).

3.32 Pipes in Series or Compound Pipes

Figure 3.6 shows a system of pipes in series.

The difference of water level in the two tanks A and B is given by

$$H = \frac{4 f_1 l_1 v_1^2}{2g d_1} + \frac{4 f_2 l_2 v_2^2}{2g d_2} + \frac{4 f_3 l_3 v_3^2}{2g d_3}$$

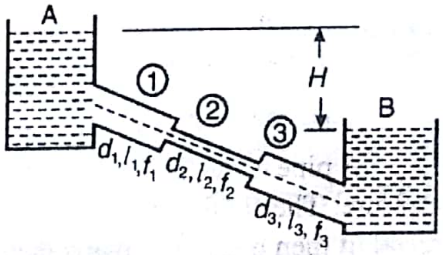

Fig. 3.6

If $f_1 = f_2 = f_3 = f$, then

$$H = \frac{4f}{2g}\left[\frac{l_1 v_1^2}{d_1} + \frac{l_2 v_2^2}{d_2} + \frac{l_3 v_3^2}{d_3}\right]$$

If a compound pipe is to be replaced by a pipe of uniform diameter (known as equivalent pipe),

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then the loss of head and discharge of both the pipes should be same. The uniform diameter (d) of the equivalent pipe may be obtained from the following relation:

$$\frac{l}{d^5} = \frac{l_1}{d_1^5} + \frac{l_2}{d_2^5} + \frac{l_3}{d_3^5}$$

where l = Length of the equivalent pipe = $l_1 + l_2 + l_3$

3.33 Pipes in Parallel

Figure 3.7 shows a system of pipes in parallel. In such a case

(*a*) The rate of discharge in the main pipe is equal to the sum of discharges in each of the parallel pipes, *i.e.*

$$Q = Q_1 + Q_2$$

(*b*) The loss of head in each pipe is same, *i.e.*

$$h_{f1} = h_{f2} \text{ or } \frac{4 f_1 l_1 v_1^2}{2 g d_1} = \frac{4 f_2 l_2 v_2^2}{2 g d_2}$$

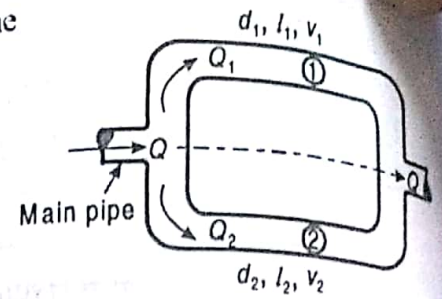

Fig. 3.7

3.34 Syphon

A syphon is a long bent pipe used to connect two reservoirs at different levels intervened by a high ridge. The highest point of the syphon is called the *summit*. An air vessel is provided at the summit in order to avoid interruption in the flow.

3.35 Power Transmitted through the Pipe

The power transmitted (in watts) through the pipe

= Weight of water flowing in N / s × Head of water in m

The power transmitted will be maximum when the head lost in friction is equal to one-third of the total supply head.

The maximum efficiency of transmission through a pipe is 66.67 percent.

3.36 Flow through Nozzle at the end of a Pipe

A nozzle is a tapering mouthpiece which is fitted to the end of a water pipe line to discharge water at a high velocity. A nozzle is generally made of convergent shape. The power transmitted through the nozzle is maximum when the head lost due to friction in the pipe is one-third of the total supply head at the inlet of the pipe. The diameter of the nozzle (d) for maximum transmission of power is given by

$$d = \left[\frac{D^5}{8 f l}\right]^{1/4}$$

where D = Diameter of pipe,

f = Darcy's coefficient of friction for pipe, and

l = Length of pipe.

3.37 Water Hammer

When a liquid flowing through a long pipe is suddenly brought to rest by closing the valve at the end of a pipe, then a pressure wave of high intensity is produced behind the valve. This pressure wave of high intensity has the effect of hammering action on the walls of the pipe. This phenomenon is known as *water hammer* or *hammer blow*.

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The magnitude of water hammer depends upon

(*a*) The length of pipe line,

(*b*) The elastic properties of the pipe material,

(*c*) The elastic properties of the liquid flowing through the pipe, and

(*d*) The speed at which the valve is closed.

3.38 Flow Through Open Channels

According to Chezy formula, the mean velocity of liquid,

$$v = C\sqrt{m.i}$$

and discharge,

$$Q = A.v = AC\sqrt{m.i}$$

where

C = Chezy's constant.

A = Area of flow,

m = Hydraulic mean depth = $\dfrac{\text{Area of flow } (A)}{\text{Wetted perimeter } (P)}$,

= $d/4$, for circular pipe

$$i = \frac{h_f}{l} = \text{Loss of head per unit length of pipe.}$$

According to Manning's formula, discharge through an open channel,

$$Q = A.\,M\,m^{2/3}\,i^{1/2}$$

where

M = Manning's constant.

3.39 Most Economical Section of a Channel

A channel is said to be most economical if

(*a*) It gives maximum discharge for a given cross -sectional area and bed shape,

(*b*) It has minimum wetted perimeter, and

(*c*) It involves lesser excavation for the designed amount of discharge.

The following points are worthnoting :

1. The most economical section of a rectangular channel is one which has hydraulic radius equal to half the depth of flow.

2. The most economical section of a trapezoidal channel is one which has hydraulic mean depth equal to half the depth of flow.

3. The most economical section of a triangular channel is one which has its sloping sides at an angle of 45° with the vertical.

4. The discharge through a channel of rectangular section is maximum when its breadth is twice the depth.

5. The discharge through a channel of trapezoidal section is maximum when the sloping side is equal to half the width at the top.

6. The discharge through a channel of circular section is maximum when the depth of water is equal to 0.95 times the diameter of the circular channel.

7. The velocity through a channel of circular section is maximum when the depth of water is equal to 0.81 times the diameter of circular channel.

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8. The depth of water in a channel corresponding to the minimum specific energy is known as *critical depth.*

9. If the depth of water in an open channel is less than the critical depth, then the flow is known as *torrential flow.*

10. If the depth of water in an open channel is greater than the critical depth, then the flow is called *tranquil flow.*

3.40 Vortex Flow

When a cylindrical vessel, containing some liquid, is rotated about its vertical axis, the liquid surface is depressed down at the axis of its rotation and rises up near the walls of the vessel on all sides. This type of flow is known as *vortex flow.* It is of the following two types:

1. *Forced vortex flow.* In this type of flow, the vessel containing the liquid is forced to rotate about the fixed vertical axis with the help of some external torque.

2. *Free vortex flow.* In this type of flow, the liquid particles describe circular paths about a fixed vertical axis, without any external torque acting on the particles. The flow of water through the hole in the bottom of a wash basin is an example of free vortex flow.

The following important points may be noted for vortex flow :

(*a*) When a cylindrical vessel containing liquid is revolved, the surface of the liquid takes the shape of a paraboloid.

(*b*) The rise of liquid along the walls of a revolving cylinder about the initial level is same as the depression of the liquid at the axis of rotation.

(*c*) The total pressure on the bottom of a closed cylindrical vessel completely filled up with a liquid is equal to the sum of the total centrifugal pressure and the weight of the liquid in the vessel.

(*d*) The total pressure (P) on the top of a closed cylindrical vessel of radius (r) completely filled up with a liquid of specific weight (w) and rotating at ω rad / s about its vertical axis is given by

$$P = \frac{\pi w \omega^2 r^2}{4g}$$

(*e*) The increase in pressure at the outer edge of a drum of radius (r) completely filled up liquid of mass density (ρ) and rotating at ω rad / s is $\frac{\rho \omega^2 r^2}{2}$.

(*f*) The tangential velocity (v) of the water element having a free vortex is inversely proportional to its distance from the centre.

3.41 Viscous Flow

We have already discussed in Art. 3.3 that viscosity (also called absolute or dynamic viscosity) is the property of a liquid which offers resistance to the movement of one layer of liquid over another adjacent layer of liquid. In other words, viscosity is the property of a liquid which controls its rate of flow. The viscosity of a liquid is due to cohesion and interaction between particles.

In S. I. units, the unit of viscosity is N- s / m^2 and in C. G. S. units, it is expressed in poise, such that

$$1 \text{ poise} = 0.1 \text{ N - s / m}^2$$

We have also discussed in Art. 3.3 that the ratio of dynamic viscosity to the density of the liquid is called *kinematic viscosity.* In S. I. units, the unit of kinematic viscosity is m^2/s and in C. G. S. units, it is expressed in stoke, such that

$$1 \text{ stoke} = 1 \text{ cm}^2 / \text{s} = 10^{-4} \text{ m}^2 / \text{s}$$

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3.42 Newton's Law of Viscosity

According to Newton's law of viscosity, the shear stress on a layer of a fluid is directly proportional to the rate of shear strain.

The following important points may be noted for viscous flow :

(*a*) A fluid which has no viscosity is known as an *ideal fluid.*

(*b*) A fluid which has a viscosity is known as a *real fluid.*

(*c*) A fluid whose viscosity does not change with the rate of deformation or shear strain is known as *Newtonian fluid.*

(*d*) A fluid whose viscosity changes with the rate of deformation or shear strain is known as *Non - Newtonian fluid.*

(*e*) A flow in which the viscosity of fluid is dominating over the inertia forces, is called *laminar flow*. It takes place at very low velocities.

(*f*) A flow in which the inertia force is dominating over the viscosity, is called *turbulent flow.* It takes place at high velocities.

(*g*) The velocity at which the flow changes from the laminar flow to the turbulent flow, is called *critical velocity.* It is of two types, *i.e.*, lower critical velocity and higher critical velocity. The velocity at which the laminar flow stops, is known as *lower critical velocity*, while the velocity at which the turbulent flow starts, is known as *higher critical velocity.*

(*h*) The ratio of the inertia force to the viscous force is called *Reynold's number*. The flow in a pipe is laminar when Reynold's number is less than 2000 and flow is turbulent when Reynold's number is more than 2800. But when Reynold's number is between 2000 and 2800, the flow is neither laminar nor turbulent.

(*i*) The velocity corresponding to Reynold's number of 2000, is called lower critical velocity and the velocity corresponding to Reynold's number of 2800, is called higher critical velocity.

(*j*) The loss of head due to viscosity for laminar flow in pipe is

$$H_L = \frac{32\,\mu v l}{w d^2}$$

where μ = Viscosity of the liquid,

v = Velocity of the liquid in the pipe,

l = Length of pipe,

d = Diameter of pipe, and

w = Specific weight of flowing liquid.

(*k*) The loss of head due to friction in a pipe of uniform diameter in which a viscous flow is taking place is $16 / R_N$, where R_N is Reynold's number.

3.43 Viscous Resistance

Though the theory of viscosity has a number of applications, yet the viscous resistance on bearings is important. The following points may be noted for viscous resistance:

(*a*) Torque required to overcome viscous resistance of footstep bearing is

$$T = \frac{\pi^2 \mu N R^4}{60 t}$$

where μ = Viscosity of the oil,

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N = Speed of the shaft,

R = Radius of the shaft, and

t = Thickness of the oil film.

(*b*) Torque required to overcome viscous resistance of a collar bearing is

$$T = \frac{\pi^2 \mu N}{60t}\left[(R_1)^4 - (R_2)^4\right]$$

where R_1 and R_2 = External and internal radius of collar.

(*c*) The coefficient of viscosity may be found out, experimentally, by the following methods:

(*i*) Capillary tube method;

(*ii*) Orifice type viscometer;

(*iii*) Rotating cylinder method; and

(*iv*) Falling sphere method.

(*d*) The coefficient of viscosity (in poises), according to the method of orifice type viscometer, is

$$\mu = \left[0.0022\, t - \frac{1.8}{t}\right] \times \text{Sp.gr.of liquid}$$

3.44 Compressible Flow of Fluids

We have already discussed that for an incompressible fluid flow, the total quantity of flow at different sections of a pipe is same, *i.e.*

$$Q = a_1 v_1 = a_2 v_2 = a_3 v_3 = \ldots.$$

But in a compressible fluid flow, the mass of fluid flowing through any section of the pipe is same, *i.e.*,

$$m_1 = m_2 = m_3 = \ldots.$$

$$\therefore \quad a_1 v_1 \rho_1 = a_2 v_2 \rho_2 = a_3 v_3 \rho_3 = \ldots.$$

or $$a_1 v_1 w_1 = a_2 v_2 w_2 = a_3 v_3 w_3 = \ldots. \quad \ldots(\because w = \rho g)$$

3.45 Velocity of Sound Wave

The velocity of sound in a fluid is given by

$$C = \sqrt{K/\rho}$$

where K = Bulk modulus, and

ρ = Density of the fluid.

3.46 Mach Number and its Importance

The ratio of velocity of fluid, in an undisturbed stream, to the velocity of sound wave, is known as *Mach number*. It gives us an important information about the type of flow. In general, the flow of a fluid is divided into the following four types depending upon the Mach number.

(*a*) When the Mach number is less than unity, the flow is called a *sub-sonic flow*.

(*b*) When the Mach number is equal to unity, the flow is called a *sonic flow*.

(*c*) When the Mach number is between 1 and 6, the flow is called a *supersonic flow*.

(*d*) When the Mach number is more than 6, the flow is called *hypersonic flow*.

3.47 Stagnation Point

A point in the flow, where the velocity of fluid is zero, is called a stagnation point.

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3.48 Flow Around Immersed Bodies

We see that when a solid body is held in the path of a moving fluid and is completely immersed in it, the body will be subjected to some pressure or force. Conversely, if a body is moved with a uniform velocity through a fluid at rest, it offers some resistance to the moving body or the body has to exert some force to maintain its steady movement.

According to *Newton's law of resistance*, the force exerted by a moving fluid on an immersed body is directly proportional to the rate of change of momentum due to the presence of the body.

The following points may be noted for the flow around immersed bodies:

(*a*) Whenever a plate is held immersed at some angle with the direction of the flow of the liquid, it is subjected to some pressure. The component of this pressure, in the direction of the flow of the liquid, is known as *drag* and the component of this pressure at right angles to the direction of the flow of the liquid is known as *lift*.

(*b*) According to Prandtl – Blassius relation, the thickness of boundary layer in laminar flow is

$$\delta_{lam} = \frac{5x}{\sqrt{R_{NX}}}$$

and thickness of boundary layer in a turbulent flow,

$$\delta_{tur} = \frac{0.377x}{(R_{NX})^{1/5}}$$

where x = Distance between the leading edge of the body and the section where thickness of boundary layer is required, and

R_{NX} = Reynold's number at a distance x from the leading edge.

3.49 Types of Forces Present in a Moving Liquid

The important forces present in a moving liquid are as follows :

(*a*) *Inertia force.* It is the product of mass and aceleration of the flowing liquid.

(*b*) *Viscous force.* It is the product of shear stress due to viscosity and the cross-sectional area of flow.

(*c*) *Gravity force.* It is the product of mass and acceleration due to gravity of a flowing liquid.

(*d*) *Surface tension force.* It is the product of surface tension per unit length and length of the surface of flowing liquid.

(*e*) *Pressure force.* It is the product of intensity of pressure and the area of a flowing liquid.

(*f*) *Elastic force.* It is the product of elastic stress and the area of a flowing liquid.

3.50 Dimensionless Numbers

The important dimensionless numbers are as follows :

(*a*) *Reynold's number.* It is the ratio of the inertia force to the viscous force.

(*b*) *Froude's number.* It is the ratio of the inertia force to the gravity force.

(*c*) *Weber's number.* It is the ratio of the inertia force to the surface tension force.

(*d*) *Euler's number.* It is the ratio of the inertia force to the pressure force.

(*e*) *Mach's number or Cauchy's number.* It is the ratio of the inertia force to the elastic force.

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OBJECTIVE TYPE QUESTIONS

1. The mass per unit volume of a liquid at a standard temperature and pressure is called
   (*a*) specific weight (*b*) mass density (*c*) specific gravity (*d*) none of these
2. The volume per unit mass of a liquid is called specific volume.
   (*a*) Yes (*b*) No
3. The weight per unit volume of a liquid at a standard temperature and pressure is called
   (*a*) specific weight (*b*) mass density (*c*) specific gravity (*d*) none of these
4. The specific weight of water in S.I. units is taken as
   (*a*) 9.81 kN/m^3 (*b*) 9.81×10^3 N/m^3 (*c*) 9.81×10^{-6} N/mm^3 (*d*) any one of these
5. The ratio of specific weight of a liquid to the specific weight of pure water at a standard temperature is called
   (*a*) density of liquid (*b*) specific gravity of liquid
   (*c*) compressibility of liquid (*d*) surface tension of liquid
6. The specific gravity has no units.
   (*a*) Agree (*b*) Disagree
7. The specific gravity of water is taken as
   (*a*) 0.001 (*b*) 0.01 (*c*) 0.1 (*d*) 1
8. The specific weight of sea water is ..... that of pure water.
   (*a*) same as (*b*) less than (*c*) more than
9. The density of a liquid in kg / m^3 is numerically equal to its specific gravity.
   (*a*) True (*b*) False
10. The specific weight is also known as weight density.
    (*a*) Correct (*b*) Incorrect
11. The mass of 2.5 m^3 of a certain liquid is 2 tonnes. Its mass density is
    (*a*) 200 kg / m^3 (*b*) 400 kg / m^3 (*c*) 600 kg / m^3 (*d*) 800 kg / m^3
12. The specific gravity of an oil whose specific weight is 7.85 kN / m^3, is
    (*a*) 0.8 (*b*) 1 (*c*) 1.2 (*d*) 1.6
13. A vessel of 4 m^3 contains an oil which weighs 30 kN. The specific weight of the oil is
    (*a*) 4.5 kN/m^3 (*b*) 6 kN/m^3 (*c*) 7.5 kN/m^3 (*d*) 10 kN/m^3
14. The property of a liquid which offers resistance to the movement of one layer of liquid over another adjacent layer of liquid, is called
    (*a*) surface tension (*b*) compressibility (*c*) capillarity (*d*) viscosity
15. Kinematic viscosity is the product of dynamic viscosity and the density of the liquid.
    (*a*) Yes (*b*) No
16. The force per unit length is the unit of
    (*a*) surface tension (*b*) compressibility (*c*) capillarity (*d*) viscosity
17. The variation in the volume of a liquid with the variation of pressure is called its
    (*a*) surface tension (*b*) compressibility (*c*) capillarity (*d*) viscosity

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18. The property of a liquid which enables it to resist tensile stress is called its surface tension.

(*a*) Agree (*b*) Disagree

19. When a tube of smaller diameter is dipped in water, the water rises in the tube due to viscosity of water.

(*a*) True (*b*) False

20. When a tube of smaller diameter is dipped in water, the water rises in the tube with an upward ..... surface.

(*a*) concave (*b*) convex

21. A glass tube of smaller diameter is used while performing an experiment for the capillary rise of water because

(*a*) it is easier to see through the glass tube

(*b*) glass tube is cheaper than a metallic tube

(*c*) it is not possible to conduct this experiment with any other tube

(*d*) all of the above

22. The mercuty does not wet the glass. This is due to the property of the liquid known as

(*a*) cohesion (*b*) adhesion (*c*) viscosity (*d*) surface tension

23. With an increase in size of tube, the rise or depression of liquid in the tube due to surface tension will

(*a*) decrease (*b*) increase

(*c*) remain unchanged (*d*) depend upon the characteristics of liquid

24. A glass tube of small diameter (d) is dipped in fluid. The height of rise or fall in the tube is given by

(*a*) $\frac{4wd}{\sigma \cos \alpha}$ (*b*) $\frac{\sigma \cos \alpha}{4wd}$ (*c*) $\frac{4\sigma \cos \alpha}{wd}$ (*d*) $\frac{wd}{4\sigma \cos \alpha}$

where w = Specific weight of liquid,

α = Angle of contact of the liquid surface, and

σ = Surface tension.

25. In the manufacturing of lead shots, the property of surface tension is utilised.

(*a*) Agree (*b*) Disagree

26. The surface tension of mercury at normal temperature is ..... that of water.

(*a*) same as (*b*) lower than (*c*) higher than

27. The unit of surface tension is

(*a*) N / m (*b*) N/m^2 (*c*) N/m^3 (*d*) N-m

28. The viscosity of a liquid is due to cohesion of its particles.

(*a*) Correct (*b*) Incorrect

29. The viscosity of a liquid ..... its rate of flow through a hole in a vessel.

(*a*) effects (*b*) does not effect

30. The viscosity of water is ..... than that of mercury.

(*a*) higher (*b*) lower

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31. Falling drops of water become spheres due to the property of
(a) surface tension of water (b) compressibility of water
(c) capillarity of water (d) viscosity of water

32. The intensity of pressure at any point, in a liquid, is
(a) directly proportional to the area of the vessel containing liquid
(b) directly proportional to the depth of liquid from the surface
(c) directly proportional to the length of the vessel containing liquid
(d) inversely proportional to the depth of liquid from the surface

33. The pressure intensity in kN/m^2 (or kPa) at any point in a liquid is
(a) w (b) wh (c) w / h (d) h / w
where w = Specific weight of liquid, and
h = Depth of liquid from the surface.

34. The pressure at a point 4 m below the free surface of water is
(a) 19.24 kPa (b) 29.24 kPa (c) 39.24 kPa (d) 49.24 kPa

35. The height of a water column equivalent to a pressure of 0.15 MPa is
(a) 15.3 m (b) 25.3 m (c) 35.3 m (d) 45.3 m

36. The intensity of pressure at any point, in a liquid, is ..... to the depth of liquid from the surface.
(a) equal (b) directly proportional (c) inversely proportional

37. According to Pascal's law, the intensity of pressure at any point in a fluid at rest is the same in all directions.
(a) Agree (b) Disagree

38. Water is ..... liquid.
(a) a compressible (b) an incompressible

39. The pressure measured with the help of a pressure gauge is called
(a) atmospheric pressure (b) gauge pressure
(c) absolute pressure (d) mean pressure

40. The atmospheric pressure at sea level is
(a) $103\ kN/m^2$ (b) 10.3 m of water (c) 760 mm of mercury (d) all of these

41. The density of air is same at different heights.
(a) Correct (b) Incorrect

42. When the pressure intensity at a point is more than the local atmospheric pressure, then the difference of these two pressures is called
(a) gauge pressure (b) absolute pressure
(c) positive gauge pressure (d) vacuum pressure

43. When the pressure intensity at a point is less than the local atmospheric pressure, then the difference of these two pressures is called vacuum pressure.
(a) Agree (b) Disagree

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44. The vacuum pressure is always the negative gauge pressure.
(a) Yes (b) No

45. The absolute pressure is equal to
(a) gauge pressure + atmospheric pressure (b) gauge pressure – atmospheric pressure
(c) atmospheric pressure – gauge pressure (d) gauge pressure – vacuum pressure

46. The pressure less than atmospheric pressure is known as
(a) suction pressure (b) vacuum pressure
(c) negative gauge pressure (d) all of these

47. Gauge pressure at a point is equal to the absolute pressure ..... the atmospheric pressure.
(a) plus (b) minus

48. The pressure of a liquid measured with the help of a piezometer tube is
(a) vacuum pressure (b) gauge pressure
(c) absolute pressure (d) atmospheric pressure

49. The vacuum pressure can be measured with the help of a piezometer tube.
(a) True (b) False

50. The pressure measured with the help of a piezometer tube is in
(a) N/mm^2 (b) N/m^2 (c) head of liquid (d) all of these

51. A piezometer tube is used only for measuring
(a) low pressure (b) high pressure
(c) moderate pressure (d) vacuum pressure

52. The liquid used in manometers should have
(a) low density (b) high density
(c) low surface tension (d) high surface tension

53. A manometer is used to measure
(a) atmospheric pressure (b) pressure in pipes and channels
(c) pressure in venturimeter
(d) difference of pressures between two points in a pipe

54. A manometer is used to measure
(a) low pressure (b) moderate pressure
(c) high pressure (d) atomospheric pressure

55. A manometer can be used to measure vacuum pressures.
(a) Agree (b) disagree

56. A differential manometer is used to measure
(a) atmospheric pressure (b) pressure in pipes and channels
(c) pressure in venturimeter
(d) difference of pressures between two points in a pipe

57. The intensity of pressure on an immersed surface ..... with the increase in depth.
(a) does not change (b) increases (c) decreases

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58. The total pressure on a horizontally immersed surface is

(*a*) wA (*b*) $w\bar{x}$ (*c*) $wA\bar{x}$ (*d*) $\frac{wA}{\bar{x}}$

where w = Specific weight of the liquid,

A = Area of the immersed surface, and

$\bar{x}$ = Depth of the centre of gravity of the immersed surface from the liquid surface.

59. The total pressure on an immersed surface inclined at an angle θ with the liquid surface is

(*a*) wA (*b*) $w\bar{x}$ (*c*) $wA\bar{x}$ (*d*) $\frac{wA\bar{x}}{\sin\theta}$

60. The point at which the resultant pressure on an immersed surface acts, is known as

(*a*) centre of gravity (*b*) centre of depth

(*c*) centre of pressure (*d*) centre of immersed surface

61. The centre of pressure acts ..... the centre of gravity of immersed surface.

(*a*) at (*b*) above (*c*) below

62. The depth of centre of pressure ($\bar{h}$) for a vertically immersed surface from the liquid surface is given by

(*a*) $\frac{I_G}{A\bar{x}} - \bar{x}$ (*b*) $\frac{I_G}{\bar{x}} - A\bar{x}$ (*c*) $\frac{A\bar{x}}{I_G} + \bar{x}$ (*d*) $\frac{I_G}{A\bar{x}} + \bar{x}$

where I_G = Moment of inertia of the immersed surface about horizontal axis through its centre of gravity,

A = Area of immersed surface, and

$\bar{x}$ = Depth of centre of gravity of the immersed surface from the liquid surface.

63. The centre of pressure for a vertically immersed surface lies at a distance equal to ..... the centre of gravity.

(*a*) $\frac{I_G}{A\bar{x}}$ below (*b*) $\frac{I_G}{A\bar{x}}$ above (*c*) $\frac{A\bar{x}}{I_G}$ below (*d*) $\frac{A\bar{x}}{I_G}$ above

64. A vertically immersed surface is shown in Fig. 3.8. The distance of its centre of pressure from the water surface is

(*a*) $\frac{bd^2}{12} + \bar{x}$ (*b*) $\frac{d^2}{12\bar{x}} + \bar{x}$

(*c*) $\frac{b^2}{12} + \bar{x}$ (*d*) $\frac{d^2}{12} + \bar{x}$

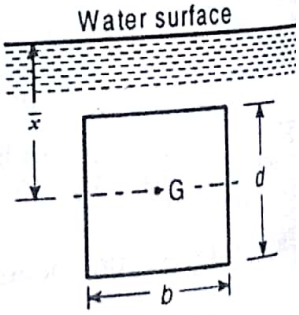

Fig. 3.8

65. The depth of centre of pressure for an immersed surface inclined at an angle θ with the liquid surface lies at a distance equal to ..... the centre of gravity.

(*a*) $\frac{I_G \sin^2\theta}{A\bar{x}}$ below (*b*) $\frac{I_G \sin^2\theta}{A\bar{x}}$ above (*c*) $\frac{I_G \sin\theta}{A\bar{x}}$ below (*d*) $\frac{I_G \sin\theta}{A\bar{x}}$ above

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66. A vertical wall is subjected to a pressure due to one kind of liquid, on one of its sides. The total pressure on the wall per unit length is

(*a*) wH (*b*) $wH/2$ (*c*) $wH^2/2$ (*d*) $wH^2/3$

where w = Specific weight of liquid, and
H = Height of liquid.

67. A water tank contains 1.3 m deep water. The pressure exerted by the water per metre length of the tank is

(*a*) 2.89 kN (*b*) 8.29 kN (*c*) 9.28 kN (*d*) 28.9 kN

68. A vertical wall is subjected to a pressure due to one kind of liquid, on one of its sides. The total pressure on the wall acts at a distance ..... from the liquid surface.

(*a*) $H/3$ (*b*) $H/2$ (*c*) $2H/3$ (*d*) $3H/4$

69. A vertical wall is subjected to a pressure due to one kind of liquid, on one of its sides. Which of the following statement is correct?

(*a*) The pressure on the wall at the liquid level is minimum.

(*b*) The pressure on the bottom of the wall is maximum.

(*c*) The pressure on the wall at the liquid level is zero, and on the bottom of the wall is maximum.

(*d*) The pressure on the bottom of the wall is zero.

70. When a vertical wall is subjected to pressures due to liquid on both sides, the resultant pressure is the ..... of the two pressures.

(*a*) sum (*b*) difference (*c*) arithmatic mean (*d*) geometric mean

71. In a lockgate, the reaction between two gates is

(*a*) $\frac{P}{\sin\alpha}$ (*b*) $\frac{2P}{\sin\alpha}$ (*c*) $\frac{P}{2\sin\alpha}$ (*d*) $\frac{P}{\sin\alpha/2}$

where P = Resultant pressure on the lock gate, and
α = Inclination of the gate with the normal to the side of the lock.

72. The water pressure per metre length on a vertical masonry wall of dam is

(*a*) $wH/2$ (*b*) wH (*c*) $wH^2/2$ (*d*) $wH^2/4$

where w = Specific weight of the liquid, and
H = Height of the liquid.

73. Match the correct answer from *Group B* for the statements given in *Group A*

Group A	*Group B*
(*a*) The weight per unit volume of a liquid is	(*A*) N/m
(*b*) The unit of surface tension is	(*B*) wh
(*c*) The unit of pressure is	(*C*) specific weight
(*d*) The pressure intensity at any point in a liquid is	(*D*) N/m^2

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74. The stability of a dam is checked for
(a) tension at the base
(b) overturning of the wall or dam
(c) sliding of the wall or dam
(d) all of these

75. When a body is placed over a liquid, it is subjected to gravitational force and upthrust of the liquid.
(a) True
(b) False

76. When a body is placed over a liquid, it will sink down if
(a) gravitational force is equal to the upthrust of the liquid
(b) gravitational force is less than the upthrust of the liquid
(c) gravitational force is more than the upthrust of the liquid
(d) none of the above

77. When a body is placed over a liquid, it will float if
(a) gravitational force is equal to the upthrust of the liquid
(b) gravitational force is less than the upthrust of the liquid
(c) gravitational force is more than the upthrust of the liquid
(d) none of the above

78. When a body is immersed wholly or partially in a liquid, it is lifted up by a force equal to the weight of liquid displaced by the body. This statement is called
(a) Pascal's law
(b) Archimede's principle
(c) principle of floatation
(d) Bernoulli's theorem

79. The tendency of a liquid to uplift a submerged body, because of the upward thrust of the liquid, is known as buoyancy.
(a) Agree
(b) Disagree

80. The force of buoyancy is always ..... the weight of the liquid displaced by the body.
(a) equal to
(b) less than
(c) more than

81. The body will float if the force of buoyancy is ..... the weight of the liquid displaced.
(a) equal to
(b) less than
(c) more than

82. The body will sink down if the force of buoyancy is ..... the weight of the liquid displaced.
(a) equal to
(b) less than
(c) more than

83. The centre of gravity of the volume of the liquid displaced is called
(a) centre of pressure
(b) centre of buoyancy
(c) metacentre
(d) none of these

84. The centre of buoyancy is the centre of area of the immersed body.
(a) Correct
(b) Incorrect

85. The buoyancy depends upon the
(a) weight of the liquid displaced
(b) pressure with which the liquid is displaced
(c) viscosity of the liquid
(d) compressibility of the liquid

86. A uniform body 3 m long, 2 m wide and 1 m deep floats in water. If the depth of immersion is 0.6 m, then the weight of the body is
(a) 3.53 kN
(b) 33.5 kN
(c) 35.3 kN
(d) none of these

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87. When a body, floating in a liquid, is given a small angular displacement, it starts oscillating about a point known as

(*a*) centre of pressure (*b*) centre of gravity (*c*) centre of buoyancy (*d*) metacentre

88. The metacentric height is the distance between the

(*a*) centre of gravity of the floating body and the centre of buoyancy

(*b*) centre of gravity of the floating body and the metacentre

(*c*) metacentre and centre of buoyancy

(*d*) original centre of buoyancy and new centre of buoyancy

89. The line of action of the force of buoyancy acts through the centre of gravity of the volume of the liquid displaced.

(*a*) True (*b*) False

90. The metacentric heights of two floating bodies *A* and *B* are 1 m and 1.5 m respectively. Select the correct statement.

(*a*) The bodies *A* and *B* have equal stability (*b*) The body *A* is more stable than body *B*

(*c*) The body *B* is more stable than body *A* (*d*) The bodies *A* and *B* are unstable

91. If a body floating in a liquid returns back to its original position, when given a small angular displacement, the body is said to be in

(*a*) neutral equilibrium (*b*) stable equilibrium

(*c*) unstable equilibrium (*d*) none of these

92. If a body floating in a liquid does not return back to its original position, and heels farther away when given a small angular displacement, the body is said to be in neutral equilibrium.

(*a*) Yes (*b*) No

93. If a body floating in a liquid occupies a new position and remains at rest in this new position, when given a small angular displacement, The body is said to be in ..... equilibrium.

(*a*) neutral (*b*) stable (*c*) unstable

94. A body floating in a liquid is said to be in neutral equilibrium, if its metacentre

(*a*) coincides with its centre of gravity

(*b*) lies above its centre of gravity

(*c*) lies below its centre of gravity

(*d*) lies between the centre of buoyancy and centre of gravity

95. A body floating in a liquid is said to be in a stable equilibrium, if its metacentre coincides with its centre of gravity.

(*a*) True (*b*) False

96. A body floating in a liquid is said to be not in equilibrium if its metacentre lies below its centre of gravity.

(*a*) Agree (*b*) Disagree

97. A submerged body is said to be in a stable equilibrium, if its centre of gravity ..... the centre of buoyancy.

(*a*) coincides with (*b*) lies below (*c*) lies above

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98. The time of oscillation (T) of a floating body is given by

(*a*) $2\pi\sqrt{\frac{k^2}{h.g}}$ (*b*) $2\pi\sqrt{\frac{h.g}{k^2}}$ (*c*) $\frac{1}{2\pi}\sqrt{\frac{k^2}{h.g}}$ (*d*) $\frac{1}{2\pi}\sqrt{\frac{h.g}{k^2}}$

where k = Radius of gyration of the floating body about its centre of gravity, and

h = Metacentric height of the floating body.

99. The metacentric height of a ship is 0.6 m and the radius of gyration is 4 m. The time of rolling of a ship is

(*a*) 4.1s (*b*) 5.2 s (*c*) 10.4 s (*d*) 14.1 s

100. The quantity of a liquid flowing per second through a section of a pipe or a channel is called discharge and is measured in cumecs (m^3/s).

(*a*) True (*b*) False

101. One cubic metre of water weighs

(*a*) 100 litres (*b*) 250 litres (*c*) 500 litres (*d*) 1000 litres

102. One litre of water occupies a volume of

(*a*) 100 cm^3 (*b*) 250 cm^3 (*c*) 500 cm^3 (*d*) 1000 cm^3

103. When a liquid is flowing through a pipe, the velocity of the liquid is

(*a*) maximum at the centre and minimum near the walls

(*b*) minimum at the centre and maximum near the walls

(*c*) zero at the centre and maximum near the walls

(*d*) maximum at the centre and zero near the walls

104. If an incompressible liquid is continuously flowing through a pipe, the quantity of liquid passing per second is different at different sections.

(*a*) True (*b*) False

105. The imaginary line drawn in the fluid in such a way that the tangent to any point gives the direction of motion at that point, is known as

(*a*) path line (*b*) stream line (*c*) steak line (*d*) potential line

106. The flow in a pipe or channel is said to be uniform when

(*a*) the liquid particles at all sectons have the same velocities

(*b*) the liquid particles at different sections have different velocities

(*c*) the quantity of liquid flowing per second is constant

(*d*) each liquid particle has a definite path

107. The flow in a pipe or channel is said to be non-uniform when

(*a*) the liquid particles at all sections have the same velocities

(*b*) the liquid particles at different sections have different velocities

(*c*) the quantity of liquid flowing per second is constant

(*d*) each liquid particle has a definite path

108. A flow in which each liquid particle has a definite path, and the paths of individual particles do not cross each other, is called

(*a*) steady flow (*b*) uniform flow (*c*) streamline flow (*d*) turbulent flow

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109. A flow in which each liquid particle does not have a definite path and the paths of individual particles also cross each other, is called turbulent flow.

(*a*) Agree (*b*) Disagree

110. A flow in which the quantity of liquid flowing per second is constant, is called ..... flow.

(*a*) steady (*b*) streamline (*c*) turbulent (*d*) unsteady

111. A flow in which the quantity of liquid flowing per second is not constant, is called

(*a*) streamline flow (*b*) turbulent flow (*c*) steady flow (*d*) unsteady flow

12. Which of the following statement is correct ?

(*a*) In a compressible flow, the volume of the flowing liquid changes during the flow.

(*b*) A flow in which the volume of the flowing liquid does not change, is called incompressible flow.

(*c*) When the particles rotate about their own axes while flowing, the flow is said to be rotational flow.

(*d*) all of the above

13. According to equation of continuity,

(*a*) $w_1a_1 = w_2a_2$ (*b*) $w_1v_1 = w_2v_2$ (*c*) $a_1v_1 = a_2v_2$ (*d*) $a_1 / v_1 = a_2 / v_2$

14. A flow through a long pipe at constant rate is called

(*a*) steady uniform flow (*b*) steady non-uniform flow

(*c*) unsteady uniform flow (*d*) unsteady non-uniform flow

15. A flow through a long pipe at decreasing rate is called ..... uniform flow.

(*a*) steady (*b*) unsteady

16. A flow through an expanding tube at constant rate is called

(*a*) steady uniform flow (*b*) steady non-uniform flow

(*c*) unsteady uniform flow (*d*) unsteady non-uniform flow

17. A flow through an expanding tube at increasing rate is called unsteady non-uniform flow.

(*a*) Yes (*b*) No

18. A flow whose streamline is represented by a curve, is called

(*a*) one-dimensional flow (*b*) two-dimensional flow

(*c*) three-dimensional flow (*d*) four-dimensional flow

19. A flow in which the volume of a fluid and its density does not change during the flow is alled ..... flow.

(*a*) incompressible (*b*) compressible

20. All the gases are considered to have compressible flow and all the liquids are considered to ave incompressible flow.

(*a*) Correct (*b*) Incorrect

21. A flow whose streamline is represented by a straight line, is called ..... dimensional flow.

(*a*) one (*b*) two (*c*) three (*d*) four

22. In one dimensional flow, the flow

(*a*) is steady and uniform (*b*) takes place in straight line

(*c*) takes place in curve (*d*) takes place in one direction

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123. In two dimensional flow, the flow does not take place in a curve.

(*a*) True (*b*) False

124. The total energy of a liquid particle in motion is equal to

(*a*) pressure energy + kinetic energy + potential energy

(*b*) pressure energy – (kinetic energy + potential energy)

(*c*) potential energy – (pressure energy + kinetic energy

(*d*) kinetic energy – (pressure energy + potential energy)

125. The total head of a liquid particle in motion is equal to

(*a*) pressure head + kinetic head + potential head

(*b*) pressure head – (kinetic head + potential head)

(*c*) potential head – (pressure head + kinetic head)

(*d*) kinetic head – (pressure head + potential head)

126. For a perfect incompressible liquid, flowing in a continuous stream, the total energy of a particle remains the same, while the particle moves from one point to another. This statement is called

(*a*) continuity equation (*b*) Bernoulli's equation

(*c*) Pascal's law (*d*) Archimede's principle

127. According to Bernoulli's equation

(*a*) $Z + \frac{p}{w} + \frac{v^2}{2g} = \text{constant}$ (*b*) $Z + \frac{p}{w} - \frac{v^2}{2g} = \text{constant}$

(*c*) $Z - \frac{p}{w} + \frac{v^2}{2g} = \text{constant}$ (*d*) $Z - \frac{p}{w} - \frac{v^2}{2g} = \text{constant}$

128. Euler's equation in the differential form for the motion of liquids is given by

(*a*) $\frac{dp}{\rho} + g.dz + v.dv = 0$ (*b*) $\frac{dp}{\rho} - g.dz + v.dv = 0$

(*c*) $\rho.dp + g.dz + v.dv = 0$ (*c*) $\rho.dp - g.dz + v.dv = 0$

129. The Bernoulli's equation is based on the assumption that

(*a*) there is no loss of energy of the liquid flowing

(*b*) the velocity of flow is uniform across any cross-section of the pipe

(*c*) no force except gravity acts on the fluid

(*d*) all of the above

130. The Euler's equation for the motion of liquids is based upon the assumption that

(*a*) the fluid is non - viscous, homogeneous and incompressible

(*b*) the velocity of flow is uniform over the section

(*c*) the flow is continuous, steady and along the stream line

(*d*) all of the above

131. Bernoulli's equation is applied to

(*a*) venturimeter (*b*) orifice meter (*c*) pitot tube (*d*) all of these

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132. Barometer is used to measure

(*a*) velocity of liquid (*b*) atmospheric pressure

(*c*) pressure in pipes and channels

(*d*) difference of pressure between two points in a pipe

133. Venturimeter is used to

(*a*) measure the velocity of a flowing liquid

(*b*) measure the pressure of a flowing liquid

(*c*) measure the discharge of liquid flowing in a pipe

(*d*) measure the pressure difference of liquid flowing between two points in a pipe line

134. The length of the divergent cone in a venturimeter is ..... that of the convergent cone.

(*a*) equal to (*b*) double (*c*) three to four times (*d*) five to six times

135. In a venturimeter, the velocity of liquid at throat is ..... than at inlet.

(*a*) higher (*b*) lower

136. The pressure of liquid at throat in a venturimeter is ..... than that at inlet.

(*a*) higher (*b*) lower

137. The velocity of the liquid flowing through the divergent portion of a venturimeter

(*a*) remains constant (*b*) increases

(*c*) decreases (*d*) depends upon mass of liquid

138. In order to avoid tendency of separation at throat in a venturimeter, the ratio of the diameter at throat to the diameter of pipe should be

(*a*) $\frac{1}{16}$ to $\frac{1}{8}$ (*b*) $\frac{1}{8}$ to $\frac{1}{4}$ (*c*) $\frac{1}{4}$ to $\frac{1}{3}$ (*d*) $\frac{1}{3}$ to $\frac{1}{2}$

139. The pressure of the liquid flowing through the divergent portion of a venturimeter

(*a*) remains constant (*b*) increases

(*c*) decreases (*d*) depends upon mass of liquid

140. The divergent portion of a venturimeter is made longer than convergent portion in order to

(*a*) avoid the tendency of breaking away the stream of liquid

(*b*) to minimise frictional losses

(*c*) both (*a*) and (*b*) (*d*) none of these

141. The discharge through a venturimeter is given by

(*a*) $\frac{C_d \sqrt{a_1^2 - a_2^2}}{a_1 a_2} \sqrt{2gh}$ (*b*) $\frac{C_d\, a_1 a_2}{\sqrt{a_1^2 - a_2^2}} \sqrt{2gh}$

(*c*) $\frac{C_d\,(a_1 - a_2)}{a_1 + a_2} \sqrt{2gh}$ (*d*) $\frac{C_d \sqrt{a_1 a_2}}{a_1 + a_2} \sqrt{2gh}$

where C_d = Coefficient of discharge,

a_1 = Area at inlet,

a_2 = Area at throat, and

h = Venturi - head.

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142. In order to measure the flow with a venturimeter, it is installed in
(*a*) horizontal line
(*b*) inclined line with flow upwards
(*c*) inclined line with flow downwards
(*d*) any direction and in any location

143. A pitot tube is used to measure the
(*a*) velocity of flow at the required point in a pipe
(*b*) pressure difference between two points in a pipe
(*c*) total pressure of liquid flowing in a pipe
(*d*) discharge through a pipe

144. When the venturimeter is inclined, then for a given flow it will show ..... reading.
(*a*) same (*b*) more (*c*) less

145. If a pitot tube is placed with its nose upstream, downstream or sideways, the reading will be the same in every case.
(*a*) True (*b*) False

146. Coefficient of contraction is the ratio of
(*a*) actual velocity of jet at vena contracta to the theoretical velocity
(*b*) loss of head in the orifice to the head of water available at the exit of the orifice
(*c*) actual discharge through an orifice to the theoretical discharge
(*d*) area of jet at vena contracta to the area of orifice

147. Coefficient of resistance is the ratio of
(*a*) actual velocity of jet at vena contracta to the theoretical velocity
(*b*) area of jet at vena contracta to the area of orifice
(*c*) loss of head in the orifice to the head of water available at the exit of the orifice
(*d*) actual discharge through an orifice to the theoretical discharge

148. A jet of water discharging from a 40 mm diameter orifice has a diameter of 32 mm at its vena contracta. The coefficient of contraction is
(*a*) 0.46 (*b*) 0.64 (*c*) 0.78 (*d*) 0.87

149. The coefficient of discharge is the ratio of theoretical discharge to the actual discharge through an orifice.
(*a*) True (*b*) False

150. Coefficient of velocity is defined as the ratio of
(*a*) actual velocity of jet at vena contracta to the theoretical velocity
(*b*) area of jet at vena contracta to the area of orifice
(*c*) actual discharge through an orifice to the theoretical discharge
(*d*) none of the above

151. The theoretical velocity of jet at vena contracta is
(*a*) $2gH$ (*b*) $H\sqrt{2g}$ (*c*) $2g\sqrt{H}$ (*d*) $\sqrt{2gH}$
where H = Head of water at vena contracta.

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152. Coefficient of discharge C_d is equal to

(*a*) $C_c \times C_v$ (*b*) $C_c \times C_r$ (*c*) $C_v \times C_r$ (*d*) C_c / C_r

where C_c = Coefficient of contraction,

C_v = Coefficient of velocity, and

C_r = Coefficient of resistance.

153. An average value of coefficient of velocity is

(*a*) 0.62 (*b*) 0.76 (*c*) 0.84 (*d*) 0.97

154. The value of coefficient of velocity for a sharp edged orifice ..... with the head of water.

(*a*) decreases (*b*) increases

155. The value of coefficient of discharge is ..... the value of coefficient of velocity.

(*a*) less than (*b*) same as (*c*) more than

156. The coefficient of velocity is determined experimentally by using the relation

(*a*) $C_v = \sqrt{\frac{y^2}{4xH}}$ (*b*) $C_v = \sqrt{\frac{x^2}{4yH}}$ (*c*) $C_v = \sqrt{\frac{4xH}{y^2}}$ (*d*) $C_v = \sqrt{\frac{4yH}{x^2}}$

157. Which of the following statement is wrong?

(*a*) A flow whose streamline is represented by a curve, is called two dimensional flow.

(*b*) The total energy of a liquid particle is the sum of potential energy, kinetic energy and pressure energy.

(*c*) The length of divergent portion in a venturimeter is equal to the convergent portion.

(*d*) A pitot tube is used to measure the velocity of flow at the required point in a pipe.

158. An orifice is said to be large, if

(*a*) the size of orifice is large (*b*) the velocity of flow is large

(*c*) the available head of liquid is more than 5 times the height of orifice

(*d*) the available head of liquid is less than 5 times the height of orifice

159. The velocity of liquid flowing through an orifice varies with the available head of the liquid.

(*a*) Agree (*b*) Disagree

160. The discharge through a small rectangular orifice is given by

(*a*) $Q = C_d \times a \times \sqrt{2gh}$ (*b*) $Q = \frac{2}{3} C_d \times a \times h$

(*c*) $Q = \frac{C_d \times a}{\sqrt{2gh}}$ (*d*) $Q = \frac{3C_d \times a}{\sqrt{2h}}$

where C_d = Coefficient of discharge for the orifice,

a = Cross-sectional area of the orifice,

h = Height of the liquid above the centre of the orifice.

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161. The discharge through a large rectangular orifice is given by

(a) $Q = \frac{2}{3} C_d \times b\sqrt{2g}\,(H_2 - H_1)$

(b) $Q = \frac{2}{3} C_d \times b\sqrt{2g}\left(H_2^{1/2} - H_1^{1/2}\right)$

(c) $Q = \frac{2}{3} C_d \times b\sqrt{2g}\left(H_2^{3/2} - H_1^{3/2}\right)$

(d) $Q = \frac{2}{3} C_d \times b\sqrt{2g}\left(H_2^{2} - H_1^{2}\right)$

where H_1 = Height of the liquid above the top of the orifice,

H_2 = Height of the liquid above the bottom of the orifice,

b = Breadth of the orifice, and

C_d = Coefficient of discharge.

162. The discharge through a wholly drowned orifice is given by

(a) $Q = C_d \times b H_1 \sqrt{2gH}$

(b) $Q = C_d \times b H_2 \sqrt{2gH}$

(c) $Q = C_d \times b\,(H_2 - H_1)\sqrt{2gH}$

(d) $Q = C_d \times b H \sqrt{2gH}$

where H_1 = Height of water (on the upstream side) above the top of the orifice,

H_2 = Height of water (on the downstream side) above the bottom of the orifice, and

H = Difference between two water levels on either side of the orifice.

163. A tank of uniform cross-sectional area (A) containing liquid upto height (H_1) has an orifice of cross-sectional area (a) at its bottom. The time required to bring the liquid level from H_1 to H_2 will be

(a) $\frac{2A\sqrt{H_1}}{C_d \times a\sqrt{2g}}$

(b) $\frac{2A\sqrt{H_2}}{C_d \times a\sqrt{2g}}$

(c) $\frac{2A\left(\sqrt{H_1} - \sqrt{H_2}\right)}{C_d \times a\sqrt{2g}}$

(d) $\frac{2A\left(H_1^{3/2} - H_2^{3/2}\right)}{C_d \times a\sqrt{2g}}$

164. A tank of uniform cross-sectional area (A) containing liquid upto height (H_1) has an orifice of cross-sectional area (a) at its bottom. The time required to empty the tank completely will be

(a) $\frac{2A\sqrt{H_1}}{C_d \times a\sqrt{2g}}$

(b) $\frac{2AH_1}{C_d \times a\sqrt{2g}}$

(c) $\frac{2AH_1^{3/2}}{C_d \times a\sqrt{2g}}$

(d) $\frac{2AH_1^{2}}{C_d \times a\sqrt{2g}}$

165. If the value of coefficient of discharge increases, the discharge through the orifice decreases

(a) True

(b) False

166. A hemispherical tank of radius (R) containing liquid upto height (H_1) has an orifice of cross sectional area (a) at its bottom. The time required to lower the level of liquid from (H_1) to (H_2) will b

(a) $\frac{\pi}{C_d \times a\sqrt{2g}}\left[\frac{2}{3} R\left(H_1^{3/2} - H_2^{3/2}\right) - \frac{1}{5}\left(H_1^{5/2} - H_2^{5/2}\right)\right]$

(b) $\frac{2\pi}{C_d \times a\sqrt{2g}}\left[\frac{2}{3} R\left(H_2^{3/2} - H_1^{3/2}\right) - \frac{1}{5}\left(H_2^{5/2} - H_1^{5/2}\right)\right]$

(c) $\frac{2\pi}{C_d \times a\sqrt{2g}}\left[\frac{2}{3} R^2\left(H_1^{3/2} - H_2^{3/2}\right) - \frac{1}{5}\left(H_1^{5/2} - H_2^{5/2}\right)\right]$

(d) none of the above

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167. A hemispherical tank of radius (R) has an orifice of cross-sectional area (a) at its bottom and is full of liquid. The time required to empty the tank completely is

(a) $\frac{14\pi R^{1/2}}{15 C_d \times a\sqrt{2g}}$ (b) $\frac{14\pi R^{3/2}}{15 C_d \times a\sqrt{2g}}$ (c) $\frac{14\pi R^{5/2}}{15 C_d \times a\sqrt{2g}}$ (d) $\frac{14\pi R^{7/2}}{15 C_d \times a\sqrt{2g}}$

168. A pipe of length more than double the diameter of orifice fitted externally or internally to the orifice is called a

(a) notch (b) weir (c) mouthpiece (d) nozzle

169. In a short cylindrical external mouthpiece, the vena contracta occurs at a distance ..... the diameter of the orifice from the outlet of orifice.

(a) equal to (b) one-fourth (c) one-third (d) one-half

170. The length AB of a pipe ABC in which the liquid is flowing has diameter (d_1) and is suddenly enlarged to diameter (d_2) at B which is constant for the length BC. The loss of head due to sudden enlargement is

(a) $\frac{(v_1 - v_2)^2}{g}$ (b) $\frac{v_1^2 - v_2^2}{g}$ (c) $\frac{(v_1 - v_2)^2}{2g}$ (d) $\frac{v_1^2 - v_2^2}{2g}$

171. The length AB of a pipe ABC in which the liquid is flowing has diameter (d_1) and is suddenly contracted to diameter (d_2) at B which is constant for the length BC. The loss of head due to sudden contraction, assuming coefficient of contraction as 0.62, is

(a) $\frac{v_1^2}{2g}$ (b) $\frac{v_2^2}{2g}$ (c) $\frac{0.5 v_1^2}{2g}$ (d) $\frac{0.375 v_2^2}{2g}$

172. The loss of head at entrance in a pipe is

(a) $\frac{v^2}{2g}$ (b) $\frac{0.5 v^2}{2g}$ (c) $\frac{0.375 v^2}{2g}$ (d) $\frac{0.75 v^2}{2g}$

where v = Velocity of liquid in the pipe.

173. The loss of head due to an obstruction in a pipe is twice the loss of head at its entrance.

(a) Agree (b) Disagree

174. The loss of head at exit of a pipe is

(a) $\frac{v^2}{2g}$ (b) $\frac{0.5 v^2}{2g}$ (c) $\frac{0.375 v^2}{2g}$ (d) $\frac{0.75 v^2}{2g}$

175. The discharge through an external mouthpiece is given by

(a) $0.855\, a\sqrt{2gH}$ (b) $1.855\, aH\sqrt{2g}$

(c) $1.585\, a\sqrt{2gH}$ (d) $5.85\, aH\sqrt{2g}$

where a = Cross-sectional area of the mouthpiece, and

H = Height of liquid above the mouthpiece.

176. The coefficient of discharge for an external mouthpiece depends upon

(a) velocity of liquid (b) pressure of liquid

(c) area of mouthpiece (d) length of mouthpiece

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177. Re-entrant or Borda's mouthpiece is an ..... mouthpiece.

(*a*) internal (*b*) external

178. In an internal mouthpiece, if the jet after contraction does not touch the sides of the mouthpiece, then the mouthpiece is said to be

(*a*) running full (*b*) running free

(*c*) partially running full (*d*) partially running free

179. In an internal mouthpiece, if the jet after contraction expands and fills up the whole mouthpiece, then the mouthpiece is said to be running free.

(*a*) True (*b*) False

180. An internal mouthpiece is said to be running ..... if the length of the mouthpiece is more than three times the diameter of the orifice.

(*a*) free (*b*) partially (*c*) full

181. The coefficient of discharge in case of internal mouthpiece is ..... that of external mouthpiece.

(*a*) less than (*b*) more than

182. The coefficient of discharge for an external mouthpiece is

(*a*) 0.375 (*b*) 0.5 (*c*) 0.707 (*d*) 0.855

183. An internal mouthpiece is said to be running free if the length of the mouthpiece is ..... the diameter of the orifice.

(*a*) less than twice (*b*) more than twice

(*c*) less than three times (*d*) more than three times

184. When an internal mouthpiece is running free, the discharge through the mouthpiece is

(*a*) $0.5 a\sqrt{2gH}$ (*b*) $0.707 a\sqrt{2gH}$

(*c*) $0.855 a\sqrt{2gH}$ (*d*) $a\sqrt{2gH}$

where a = Area of mouthpiece, and

H = Height of liquid above the mouthpiece.

185. When an internal mouthpiece is running full, the discharge through the mouthpiece is twice the discharge when it is running free.

(*a*) Right (*b*) Wrong

186. The discharge through a convergent mouthpiece is ..... the discharge through an internal mouthpiece of the same diameter and head of water.

(*a*) equal to (*b*) one-half (*c*) three fourth (*d*) double

187. In an external mouthpiece, the absolute pressure head at vena contracta is ..... the atmospheric pressure head by an amount equal to 0.89 times the height of the liquid, above the vena contracta.

(*a*) less than (*b*) more than

188. In an internal mouthpiece, the absolute pressure head at vena contracta is ..... the atmospheric pressure head by an amount equal to height of the liquid above the vena contracta.

(*a*) less than (*b*) more than

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189. In an external or internal mouthpiece, the absolute pressure head at vena contracta is zero when atmospheric pressure head is 10.3 m of water.

(*a*) Correct (*b*) Incorrect

190. In a convergent mouthpiece, the absolute pressure head at vena contracta is the same as that of the atmosphere.

(*a*) True (*b*) False

191. In a convergent - divergent mouthpiece, the ratio of areas at outlet (*i.e.* divergence) and at vena contracta (*i.e.*, convergence) of the mouthpiece is

(*a*) $\frac{a}{a_c} = \sqrt{\frac{H_a - H_c}{H}}$ (*b*) $\frac{a}{a_c} = \sqrt{\frac{H}{H_a - H_c}}$

(*c*) $\frac{a}{a_c} = \sqrt{1 + \frac{H_a - H_c}{H}}$ (*d*) $\frac{a}{a_c} = \sqrt{1 + \frac{H}{H_a - H_c}}$

where a and a_c = Areas of mouthpiece at outlet and vena contracta respectively,
H_a = Atmospheric pressure head,
H_c = Absolute pressure head at vena contracta, and
H = Height of liquid above mouthpiece.

192. An opening in the side of a tank or vessel such that the liquid surface with the tank is below the top edge of the opening, is called

(*a*) weir (*b*) notch (*c*) orifice (*d*) none of these

193. A notch is, usually, made of a metallic plate.

(*a*) Correct (*b*) Incorrect

194. A notch is used to measure ..... of liquids.

(*a*) pressure (*b*) discharge (*c*) velocity (*d*) volume

195. The discharge over a rectangular notch is

(*a*) $\frac{2}{3} C_d \times b\sqrt{2gH}$ (*b*) $\frac{2}{3} C_d \times b\sqrt{2g} \times H$

(*c*) $\frac{2}{3} C_d \times b\sqrt{2g} \times H^{3/2}$ (*d*) $\frac{2}{3} C_d \times b\sqrt{2g} \times H^2$

where b = Width of notch, and
H = Height of liquid, above the sill of the notch.

196. The discharge over a right angled notch is

(*a*) $\frac{8}{15} C_d \sqrt{2g} \times H$ (*b*) $\frac{8}{15} C_d \sqrt{2g} \times H^{3/2}$

(*c*) $\frac{8}{15} C_d \sqrt{2g} \times H^2$ (*d*) $\frac{8}{15} C_d \sqrt{2g} \times H^{5/2}$

where H = Height of liquid above the apex of notch.

197. If the coefficient of discharge is 0.6, then the discharge over a right angled notch is

(*a*) $0.417\, H^{5/2}$ (*b*) $1.417\, H^{5/2}$ (*c*) $4.171\, H^{5/2}$ (*d*) $7.141\, H^{5/2}$

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198. The discharge over a rectangular notch is
(a) inversely proportional to $H^{3/2}$ (b) directly proportional to $H^{3/2}$
(c) inversely proportional to $H^{5/2}$ (d) directly proportional to $H^{5/2}$

199. The discharge over a triangular notch is
(a) inversely proportional to $H^{3/2}$ (b) directly proportional to $H^{3/2}$
(c) inversely proportional to $H^{5/2}$ (d) directly proportional to $H^{5/2}$

200. The discharge over the trapezoidal notch is equal to the discharge over the rectangular notch ..... the discharge over the triangular notch.
(a) plus (b) minus

201. The error in discharge (dQ/Q) to the error in measurement of head (dH/H) over a rectangular notch is given by
(a) $\frac{dQ}{Q} = \frac{1}{2} \times \frac{dH}{H}$ (b) $\frac{dQ}{Q} = \frac{3}{4} \times \frac{dH}{H}$ (c) $\frac{dQ}{Q} = \frac{dH}{H}$ (d) $\frac{dQ}{Q} = \frac{3}{2} \times \frac{dH}{H}$

202. The error in discharge (dQ/Q) to the error in measurement of head (dH/H) over a triangular notch is given by
(a) $\frac{dQ}{Q} = \frac{3}{2} \times \frac{dH}{H}$ (b) $\frac{dQ}{Q} = 2 \times \frac{dH}{H}$ (c) $\frac{dQ}{Q} = \frac{5}{2} \times \frac{dH}{H}$ (d) $3 \times \frac{dH}{H}$

203. An error of 1% in measuring head over the crest of the notch (H) will produce an error of ..... in discharge over a triangular notch,
(a) 1% (b) 1.5% (c) 2% (d) 2.5%

204. An error of 1% in measuring head over the apex of the notch (H) will produce an error of ..... in discharge over a triangular notch.
(a) 1% (b) 1.5% (c) 2% (d) 2.5%

205. A structure used to dam up a stream or river over which the water flows is called
(a) orifice (b) notch (c) weir (d) dam

206. The difference between the notch and weir is that the notch is of bigger size and the weir is of a smaller size.
(a) Agree (b) Disagree

207. A weir is usually made of masonry or concrete.
(a) Yes (b) No

208. The sheet of water flowing over a notch or a weir is known as
(a) sill or crest (b) nappe or vein (c) orifice (d) none of t

209. The top of the weir over which the water flows is known as
(a) sill or crest (b) nappe or vein (c) orifice (d) none of t

210. The length of a liquid stream while flowing over a weir ..... at the ends of the sill.
(a) expands (b) does not change (c) contracts

211. According to Francis formula, the discharge over a rectangular weir is
(a) $\frac{2}{3} C_d (L - nH)\sqrt{2gH}$ (b) $\frac{2}{3} C_d (L - 0.1nH)\sqrt{2g}H^{3/2}$
(c) $\frac{2}{3} C_d (L - nH)\sqrt{2g}H^2$ (d) $\frac{2}{3} C_d (L - 0.2nH)\sqrt{2g}H^{5/2}$
where n = Number of end contractions.

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212. When the coefficient of discharge (C_d) is 0.623, then the general equation for discharge over a rectangular weir is

(*a*) $1.84\,(L-0.1\,nH)\,H^{3/2}$ (*b*) $1.84\,(L-nH)\,H^{2}$

(*c*) $1.84\,(L-0.1nH)\,H^{5/2}$ (*d*) $1.84\,(L-nH)\,H^{3}$

213. When the end contractions of the weir are suppressed, then number of end contractions (n) are taken as zero

(*a*) Agree (*b*) Disagree

214. According to Bazin's formula, the discharge over a rectangular weir is $mL\sqrt{2g}\times H^{3/2}$, where m is equal to

(*a*) $0.405+\dfrac{0.003}{H}$ (*b*) $0.003+\dfrac{0.405}{H}$ (*c*) $0.405+\dfrac{H}{0.003}$ (*d*) $0.003+\dfrac{H}{0.405}$

215. According to Bazin, the coefficient of discharge varies with the height of water over the sill of a weir.

(*a*) Correct (*b*) Incorrect

216. The Cippoletti weir is a ..... weir.

(*a*) rectangular (*b*) triangular (*c*) trapezoidal (*d*) circular

217. The Francis formula for the discharge over Cippoletti weir is

(*a*) $1.84\,L\,H^{1/2}$ (*b*) $1.84\,LH$ (*c*) $1.84\,LH^{3/2}$ (*d*) $1.84\,LH^{5/2}$

218. The discharge over a rectangular weir, considering the velocity of approach, is

(*a*) $\dfrac{2}{3}C_d\times L\sqrt{2g}\,[H_1-H_a]$ (*b*) $\dfrac{2}{3}C_d\times L\sqrt{2g}\left[H_1^{3/2}-H_a^{3/2}\right]$

(*c*) $\dfrac{2}{3}C_d\times L\sqrt{2g}\left[H_1^{2}-H_a^{2}\right]$ (*d*) $\dfrac{2}{3}C_d\times L\sqrt{2g}\left[H_1^{5/2}-H_a^{5/2}\right]$

where H_1 = Total height of water above the weir $= H + H_a$

H = Height of water, over the crest of the weir, and

H_a = Height of water, due to velocity of approach.

219. A weir is said to be narrow-crested weir, if the width of the crest of the weir is ..... half the height of water above the weir crest.

(*a*) equal to (*b*) less than (*c*) more than

220. A weir is said to be broad crested weir. if the width of the crest of the weir is ..... half the height of water above the weir crest.

(*a*) equal to (*b*) less than (*c*) more than

221. In a broad-crested weir, the discharge is maximum if the head of water on the downstream side of weir is ..... the head of water on the upstream side of weir.

(*a*) equal to (*b*) one-third (*c*) two-third (*d*) three-fourth

222. The maximum discharge over a broad crested weir is

(*a*) $0.384\,C_d\times L\times H^{1/2}$ (*b*) $0.384\,C_d\times L\times H^{3/2}$

(*c*) $1.71\,C_d\times L\times H^{1/2}$ (*d*) $1.71\,C_d\times L\times H^{3/2}$

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223. In a sharp-crested weir, the thickness of the weir is kept less than half of the height of water above the crest of the weir.

(*a*) True (*b*) False

224. A weir, generally, used as a spillway of a dam is

(*a*) narrow crested weir (*b*) broad crested weir

(*c*) Ogee weir (*d*) submerged weir

225. The formula for discharge over a sharp-crested weir and Ogee weir is same as that of a rectangular weir.

(*a*) Agree (*b*) Disagree

226. When the water level on the downstream side of a weir is above the top surface of a weir, the weir is known as

(*a*) narrow-crested weir (*b*) broad-crested weir

(*c*) Ogee weir (*d*) submerged weir

227. In a free nappe,

(*a*) the pressure below the nappe is atmospheric

(*b*) the pressure below the nappe is negative

(*c*) the pressure above the nappe is atmospheric

(*d*) the pressure above the nappe is negative

228. In a depressed nappe

(*a*) the pressure below the nappe is atmospheric

(*b*) the pressure below the nappe is negative

(*c*) the pressure above the nappe is atmospheric

(*d*) the pressure above the nappe is negative

229. The discharge of a depressed nappe is 6 to 7 percent ..... that of a free nappe.

(*a*) less than (*b*) more than

230. The discharge through a siphon spillway is

(*a*) $C_d \times a\sqrt{2gH}$ (*b*) $C_d \times a\sqrt{2g} \times H^{3/2}$

(*c*) $C_d \times a\sqrt{2g} \times H^2$ (*d*) $C_d \times a\sqrt{2g} \times H^{5/2}$

231. The frictional resistance of a pipe varies approximately with ..... of the liquid.

(*a*) pressure (*b*) velocity

(*c*) square of velocity (*d*) cube of velocity

232. According to Darcy's formula, the loss of head due to friction in the pipe is

(*a*) $\frac{f l v^2}{2gd}$ (*b*) $\frac{f l v^2}{gd}$ (*c*) $\frac{3 f l v^2}{2gd}$ (*d*) $\frac{4 f l v^2}{2gd}$

where f = Darcy's coefficient,

l = Length of pipe,

v = Velocity of liquid in pipe, and

d = Diameter of pi

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233. The hydraulic mean depth or the hydraulic radius is the ratio of

(*a*) area of flow and wetted perimeter (*b*) wetted perimeter and diameter of pipe

(*c*) velocity of flow and area of flow (*d*) none of these

234. The hydraulic mean depth for a circular pipe of diameter (*d*) is

(*a*) $d/6$ (*b*) $d/4$ (*c*) $d/2$ (*d*) d

235. The hydraulic gradient line is always parallel to the centre line of the pipe.

(*a*) Correct (*b*) Incorrect

236. The hydraulic gradient line may be above or below the centre line of the pipe.

(*a*) True (*b*) False

237. The total energy line lies over the hydraulic gradient line by an amount equal to the

(*a*) pressure head (*b*) velocity head

(*c*) pressure head + velocity head (*d*) pressure head – velocity head

238. The hydraulic gradient line lies over the centre line of the pipe by an amount equal to the

(*a*) pressure head (*b*) velocity head

(*c*) pressure head + velocity head (*d*) pressure head – velocity head

239. The total energy line lies over the centre line of the pipe by an amount equal to

(*a*) pressure head (*b*) velocity head

(*c*) pressure head + velocity head (*d*) pressure head – velocity head

240. The efficiency of power transmission through pipe is

(*a*) $\frac{H - h_f}{H}$ (*b*) $\frac{H}{H - h_f}$ (*c*) $\frac{H + h_f}{H}$ (*d*) $\frac{H}{H + h_f}$

where H = Total supply head, and

h_f = Head lost due to friction in the pipe.

241. The power transmitted through a pipe is

(*a*) $w \times Q \times H$ (*b*) $w \times Q \times h_f$

(*c*) $w \times Q \left(H - h_f\right)$ (*d*) $w \times Q \left(H + h_f\right)$

where w = Specific weight in N / m^3, and

Q = Discharge in m^3 / s.

242. The power transmitted through the pipe is maximum when the head lost due to friction is equal to

(*a*) one-fourth of the total supply head (*b*) one-third of the total supply head

(*c*) one-half of the total supply head (*d*) two-third of the total supply head

243. The maximum efficiency of transmission through a pipe is

(*a*) 50% (*b*) 56.7% (*c*) 66.67% (*d*) 76.66%

244. A compound pipe is required to be replaced by a new pipe. The two pipes are said to be equivalent, if

(*a*) length of both the pipes is same (*b*) diameter of both the pipes is same

(*c*) loss of head and discharge of both the pipes is same

(*d*) loss of head and velocity of flow in both the pipes is same

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245. Select the wrong statement

(*a*) An equivalent pipe is treated as an ordinary pipe for all calculations

(*b*) The length of an equivalent pipe is equal to that of a compound pipe

(*c*) The discharge through an equivalent pipe is equal to that of a compound pipe

(*d*) The diameter of an equivalent pipe is equal to that of a compound pipe

246. When the pipes are in series, the total head loss is equal to the sum of the head loss in each pipe.

(*a*) Yes (*b*) No

247. A compound pipe of diameter d_1, d_2 and d_3 having lengths l_1, l_2 and l_3 is to be replaced by an equivalent pipe of uniform diameter d and of the same length (l) as that of the compound pipe. The size of the equivalent pipe is given by

(*a*) $\frac{l}{d^2} = \frac{l_1}{d_1^2} + \frac{l_2}{d_2^2} + \frac{l_3}{d_3^2}$ (*b*) $\frac{l}{d^3} = \frac{l_1}{d_1^3} + \frac{l_2}{d_2^3} + \frac{l_3}{d_3^3}$

(*c*) $\frac{l}{d^4} = \frac{l_1}{d_1^4} + \frac{l_2}{d_2^4} + \frac{l_3}{d_3^4}$ (*d*) $\frac{l}{d^5} = \frac{l_1}{d_1^5} + \frac{l_2}{d_2^5} + \frac{l_3}{d_3^5}$

248. In case of flow through parallel pipes,

(*a*) the head loss for all the pipes is same

(*b*) the total discharge is equal to the sum of discharges in the various pipes

(*c*) the total head loss is the sum of head losses in the various pipes

(*d*) all of the above

249. The siphon will work satisfactorily, if the minimum pressure in the pipe is ..... vapour pressure of liquid.

(*a*) equal to (*b*) less than (*c*) more than

250. A siphon is used to connect two reservoirs at different levels intervened by a high ridge.

(*a*) True (*b*) False

251. An air vessel is provided at the summit in a syphon to

(*a*) avoid interruption in the flow (*b*) increase discharge

(*c*) increase velocity (*d*) maintain pressure difference

252. A nozzle is generally made of

(*a*) cylindrical shape (*b*) convergent shape

(*c*) divergent shape (*d*) convergent-divergent shape

253. A nozzle placed at the end of a water pipe line discharges water at a

(*a*) low pressure (*b*) high pressure (*c*) low velocity (*d*) high velocity

254. The power transmitted through the nozzle is maximum when the head lost due to friction in the pipe is ..... of the total supply head.

(*a*) one-half (*b*) one-third (*c*) two-third

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255. The diameter of the nozzle (d) for maximum transmission of power is given by

(a) $d = \left(\frac{D^5}{8fl}\right)^{1/2}$ (b) $d = \left(\frac{D^5}{8fl}\right)^{1/3}$ (c) $d = \left(\frac{D^5}{8fl}\right)^{1/4}$ (d) $d = \left(\frac{D^5}{8fl}\right)^{1/5}$

where D = Diameter of pipe,
f = Darcy's coefficient of friction for pipe, and
l = Length of pipe.

256. The water hammer in pipes occurs due to sudden change in the velocity of flowing liquid.

(a) Agree (b) Disagree

257. The magnitude of water hammer depends upon the

(a) elastic properties of the pipe material
(b) elastic properties of the liquid flowing through the pipe
(c) speed at which the valve is closed
(d) all of the above

258. The pressure of fluid due to hammer blow is

(a) directly proportional to density of fluid
(b) inversely proportional to density of fluid
(c) directly proportional to (density)$^{1/2}$ of fluid
(d) inversely proportional to (density)$^{1/2}$ of fluid

259. The hammer blow in pipes occurs when

(a) there is excessive leakage in the pipe
(b) the pipe bursts under high pressure of fluid
(c) the flow of fluid through the pipe is suddenly brought to rest by closing of the valve
(d) the flow of fluid through the pipe is gradually brought to rest by closing of the valve

260. The purpose of a surge tank is

(a) to control the pressure variations due to rapid changes in the pipe line flow
(b) to eliminate water hammer possibilities
(c) to regulate flow of water to turbines by providing necessary retarding head of water
(d) all of the above

261. The velocity of flow is same at all points in the cross-section of a channel.

(a) True (b) False

262. According to Chezy's formula, the discharge through an open channel is

(a) $A\sqrt{m \times i}$ (b) $C\sqrt{m \times i}$ (c) $AC\sqrt{m \times i}$ (d) $mi\sqrt{A \times C}$

where A = Area of flow,
C = Chezy's constant,
m = Hydraulic mean depth, and
i = Uniform slope in bed.

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263. According to Manning's formula, the discharge through an open channel is

(a) $A \times M \times m^{1/2} \times i^{2/3}$ (b) $A \times M \times m^{2/3} \times i^{1/2}$

(c) $A^{1/2} \times M^{2/3} \times m \times i$ (d) $A^{2/3} \times M^{1/3} \times m \times i$

where M = Manning's constant.

264. When the flow in an open channel is gradually varied, the flow is said to be

(a) steady uniform flow (b) steady non-uniform flow

(c) unsteady uniform flow (d) unsteady non-uniform flow

265. A channel is said to be of most economical cross-section, if

(a) it gives maximum discharge for a given cross-sectional area and bed slope

(b) it has minimum wetted perimeter

(c) it involves lesser excavation for the designed amount of discharge

(d) all of the above

266. The discharge through a channel of rectangular section will be maximum, if

(a) its depth is twice the breadth (b) its breadth is twice the depth

(c) its depth is thrice the breadth (d) its breadth is thrice the depth

267. The most economical section of a rectangular channel is one which has hydraulic mean depth or hydraulic radius equal to

(a) half the depth (b) half the breadth

(c) twice the depth (d) twice the breadth

268. The discharge through a channel of trapezoidal section is maximum when

(a) width of channel at the top is equal to twice the width at the bottom

(b) depth of channel is equal to the width at the bottom

(c) the sloping side is equal to half the width at the top

(d) the sloping side is equal to the width at the bottom

269. The most economical section of a trapezoidal channel is one which has hydraulic mean depth equal to

(a) $\frac{1}{2}$ depth (b) $\frac{1}{2}$ breadth (c) $\frac{1}{2}$ sloping side (d) $\frac{1}{4}$ (depth + breadth)

270. The discharge through a channel of circular section will be maximum when the depth of water is ..... the diameter of the circular channel.

(a) 0.34 times (b) 0.67 times (c) 0.81 times (d) 0.95 times

271. The velocity through a channel of circular section will be maximum when the depth of water is ..... the diameter of the circular channel.

(a) 0.34 times (b) 0.67 times (c) 0.81 times (d) 0.95 times

272. The highest efficiency is obtained with a channel of ..... section.

(a) circular (b) square (c) rectangular (d) trapezoidal

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273. In open channels, the specific energy is the

(*a*) total energy per unit discharge

(*b*) total energy measured with respect to the datum passing through the bottom of the channel

(*c*) total energy measured above the horizontal datum

(*d*) kinetic energy plotted above the free surface of water

274. The depth of water in a channel corresponding to the minimum specific energy is known as critical depth.

(*a*) Agree (*b*) Disagree

275. The critical depth for a channel is given by

(*a*) $\left(\frac{q}{g}\right)^{1/2}$ (*b*) $\left(\frac{q^2}{g}\right)^{1/3}$ (*c*) $\left(\frac{q^3}{g}\right)^{1/4}$ (*d*) $\left(\frac{q^4}{g}\right)^{1/5}$

where q = Unit discharge (discharge per unit width) through the channel.

276. If the depth of water in an open channel is greater than the critical depth, the flow is called

(*a*) critical flow (*b*) turbulent flow (*c*) tranquil flow (*d*) torrential flow

277. If the depth of water in an open channel is less than the critical depth, the flow is called

(*a*) critical flow (*b*) turbulent flow (*c*) tranquil flow (*d*) torrential flow

278. The flow at critical depth in an open channel is called torrential flow.

(*a*) Yes (*b*) No

279. The discharge in an open channel corresponding to critical depth is

(*a*) zero (*b*) minimum (*c*) maximum

280. The most efficient section of a channel is

(*a*) triangular (*b*) rectangular (*c*) square (*d*) trapezoidal

281. The rise, in water level, which occurs during the transformation of the unstable shooting flow to the stable streaming flow is called hydraulic jump.

(*a*) Yes (*b*) No

282. The critical depth meter is used to measure

(*a*) velocity of flow in an open channel (*b*) depth of flow in an open channel

(*c*) hydraulic jump (*d*) depth of channel

283. In a venturiflume, the flow takes place at

(*a*) atmospheric pressure (*b*) gauge pressure

(*c*) absolute pressure (*d*) none of these

284. A venturiflume is a flumed structure constructed across a channel by restricting its width.

(*a*) True (*b*) False

285. A structure whose width is ..... the width of the channel, is called a flumed structure.

(*a*) less than (*b*) more than

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286. A venturiflume is used to measure

(*a*) pressure of liquid

(*b*) discharge of liquid

(*c*) pressure difference between two points in a channel

(*d*) pressure difference between two points in a pipe

287. The coefficient of venturiflume, generally, lies between

(*a*) 0.3 to 0.45 (*b*) 0.50 to 0.75 (*c*) 0.75 to 0.95 (*d*) 0.95 to 1.0

288. When a cylindrical vessel, containing some liquid, is rotated about its vertical axis, the liquid surface is depressed down at the axis of its rotation and rises up near the walls of the vessel on all sides. This type of flow is known as

(*a*) steady flow (*b*) turbulent flow (*c*) vortex flow (*d*) uniform flow

289. The rise of liquid along the walls of a revolving cylinder about the initial level is ..... the depression of the liquid at the axis of rotation.

(*a*) same as (*b*) less than (*c*) more than

290. When a cylindrical vessel containing liquid is revolved about its vertical axis at a constant angular velocity, the pressure

(*a*) varies as the square of the radial distance

(*b*) increases linearly as its radial distance

(*c*) increases as the square of the radial distance

(*d*) decreases as the square of the radial distance

291. When a cylindrical vessel containing liquid is revolved, the surface of the liquid takes the shape of

(*a*) a triangle (*b*) a paraboloid (*c*) an ellipse (*d*) none of these

292. The total pressure on the top of a closed cylindrical vessel competely filled up with a liquid is

(*a*) directly proportional to $(\text{radius})^2$ (*b*) inversely proportional to $(\text{radius})^2$

(*c*) directly proportional to $(\text{radius})^4$ (*d*) inversely proportional to $(\text{radius})^4$

293. The total pressure on the bottom of a closed cylindrical vessel completely filled up with a liquid is the sum of the total centrifugal pressure and the weight of the liquid in the vessel.

(*a*) Correct (*b*) Incorrect

294. The flow of water through the hole in the bottom of a wash basin is an example of

(*a*) steady flow (*b*) uniform flow (*c*) free vortex (*d*) forced vortex

295. The total pressure on the top of a closed cylindrical vessel of radius (r) completely filled up with liquid of specific weight (w) and rotating at (ω) rad / s about its vertical axis, is

(*a*) $\frac{\pi w \omega^2 r^2}{4g}$ (*b*) $\frac{\pi w \omega^2 r^3}{4g}$ (*c*) $\frac{\pi w \omega^2 r^4}{4g}$ (*d*) $\frac{\pi w \omega^2 r^2}{2g}$

296. The increase in pressure at the outer edge of a drum of radius (r) completely filled up with liquid of density (ρ) and rotating at (ω) rad / s is

(*a*) $\rho \omega^2 r^2$ (*b*) $2\rho \omega^2 r^2$ (*c*) $\frac{\rho \omega^2 r^2}{2}$ (*d*) $\frac{\rho \omega^2 r^2}{4}$

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297. The tangential velocity of the water element having a free vortex is

(*a*) directly proportional to its distance from the centre

(*b*) inversely proportional to its distance from the centre

(*c*) directly proportional to its (distance)^2 from the centre

(*d*) inversely proportional to its (distance)^2 from the centre

298. When a cylindrical vessel of radius (r) containing liquid is revolved about its vertical axis ω rad / s, then depth of parabola which the liquid assumes is

(*a*) $\frac{\omega . r}{2g}$ (*b*) $\frac{\omega^2 . r^2}{2g}$ (*c*) $\frac{\omega . r}{4g}$ (*d*) $\frac{\omega^2 . r^2}{4g}$

299. In the above question, if the angular velocity ω is doubled, then the depth of parabola will be

(*a*) halved (*b*) two times (*c*) four times (*d*) eight times

300. In Q. No. **298,** if the angular velocity ω is halved and radius of vessel is doubled, then the depth of parabola will remain same.

(*a*) Correct (*b*) Incorrect

301. The property of a liquid which controls its rate of flow is called viscosity.

(*a*) True (*b*) False

302. According to Newton's law of viscosity, the shear stress on a layer of a fluid is ..... to the rate of shear strain.

(*a*) equal to (*b*) directly proportional

(*c*) inversely proportional

303. A thick liquid like a syrup has a ..... viscosity than a light liquid like water.

(*a*) lesser (*b*) greater

304. The shear stress between the two liquid layers is ..... proportional to the distance between two layers.

(*a*) directly (*b*) indirectly

305. Newton's law of viscosity is a relationship between

(*a*) pressure, velocity and temperature (*b*) shear stress and rate of shear strain

(*c*) shear stress and velocity (*d*) rate of shear strain and temperature

306. The unit of dynamic viscosity in S.I. units is

(*a*) N-m / s^2 (*b*) N-s / m^2 (*c*) poise (*d*) stoke

307. Poise is the unit of viscosity in C.G.S. system of units.

(*a*) Agree (*b*) Disagree

308. One poise is equal to

(*a*) 0.1 N-s / m^2 (*b*) 1N-s / m^2 (*c*) 10 N-s / m^2 (*d*) 100 N-s / m^2

309. The kinematic viscosity is the

(*a*) ratio of absolute viscosity to the density of the liquid

(*b*) ratio of density of the liquid to the absolute viscosity

(*c*) product of absolute viscosity and density of the liquid

(*d*) product of absolute viscosity and mass of the liquid

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310. Stoke is the unit of
(*a*) kinematic viscosity in C. G. S. units (*b*) kinematic viscosity in M. K. S. units
(*c*) dynamic viscosity in M. K. S. units (*d*) dynamic viscosity in S. I. units

311. One stoke is equal to
(*a*) 10^{-2} m^2 / s (*b*) 10^{-3} m^2 / s
(*c*) 10^{-4} m^2 / s (*d*) 10^{-6} m^2 / s

312. The unit of kinematic viscosity in S. I. units is
(*a*) N-m / s (*b*) N-s / m^2 (*c*) m^2 / s (*d*) N - m

313. The viscosity of water at 20° C is
(*a*) one stoke (*b*) one centistroke (*c*) one poise (*d*) one centipoise

314. The kinematic viscosity of an oil (in stokes) whose specific gravity is 0.95 and viscosity 0.01 poise, is
(*a*) 0.0116 stoke (*b*) 0.116 stoke (*c*) 0.0611 stoke (*d*) 0.611 stoke

315. The dynamic viscosity of the liquid ..... with rise in temperature.
(*a*) remain unaffected (*b*) increases (*c*) decreases

316. A fluid having no viscosity is known as
(*a*) real fluid (*b*) ideal fluid
(*c*) newtonian fluid (*d*) non-newtonian fluid

317. A fluid whose viscosity does not change with the rate of deformation or shear strain is known as
(*a*) real fluid (*b*) ideal fluid
(*c*) newtonian fluid (*d*) non-newtonian fluid.

318. A fluid whose viscosity changes with the rate of deformation or shear strain is known as non newtonian fluid.
(*a*) True (*b*) False

319. A fluid which obeys the Newton's law of viscosity is termed as
(*a*) real fluid (*b*) ideal fluid
(*c*) newtonian fluid (*d*) non-newtonian fluid

320. Water is a ..... fluid.
(*a*) real (*b*) ideal (*c*) newtonian (*d*) non-newtonian

321. An ideal fluid is frictionless and incompressible.
(*a*) Correct (*b*) Incorrect

322. The shear stress-strain graph for a newtonian fluid is a
(*a*) straight line (*b*) parabolic curve (*c*) hyperbolic curve (*d*) elliptical

323. The shear stress-strain graph for a non-newtonian fluid is a curve.
(*a*) Correct (*b*) Incorrect

324. The dynamic viscosity of gases ..... with rise in temperature.
(*a*) remain unaffected (*b*) increases (*c*) decreases

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325. A flow in which the viscosity of fluid is dominating over the inertia force is called
(a) steady flow (b) unsteady flow (c) laminar flow (d) turbulent flow

326. A flow in which..... force is dominating over the viscosity is called turbulent flow.
(a) elastic (b) surface tension (c) viscous (d) inertia

327. Laminar flow ..... place at very low velocities.
(a) takes (b) does not take

328. Turbulent flow takes place at high velocities.
(a) Agree (b) Disagree

329. The velocity at which the flow changes from laminar flow to turbulent flow is called
(a) critical velocity (b) velocity of approach
(c) sub-sonic velocity (d) super-sonic velocity

330. Which of the following is an example of laminar flow?
(a) Under ground flow (b) Flow past tiny bodies
(c) Flow of oil in measuring instruments (d) all of these

331. The velocity at which the laminar flow stops, is known as
(a) velocity of approach (b) lower critical velocity
(c) higher critical velocity (d) none of these

332. The velocity at which the turbulent flow starts is known as higher critical velocity.
(a) Yes (b) No

333. Reynold's number is the ratio of the inertia force to the
(a) surface tension force (b) viscous force
(c) gravity force (d) elastic force

334. The flow in a pipe is laminar, when Reynold number is less than 2000.
(a) True (b) False

335. The flow in a pipe is turbulent when Reynold number is
(a) less than 2000 (b) between 2000 and 2800
(c) more than 2800 (d) none of these

336. The flow in a pipe is neither laminar nor turbulent when Reynold number is
(a) less than 2000 (b) between 2000 and 2800
(c) more than 2800 (d) none of these

337. The velocity corresponding to Reynold number of 2000 is called
(a) sub-sonic velocity (b) super-sonic velocity
(c) lower critical velocity (d) higher critical velocity

338. The velocity corresponding to Reynold number of 2800, is called
(a) sub-sonic velocity (b) super-sonic velocity
(c) lower critical velocity (d) higher critical velocity

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339. The loss of head due to viscosity for laminar flow in pipes is

(*a*) $\frac{4\mu v l}{w d^2}$ (*b*) $\frac{8\mu v l}{w d^2}$ (*c*) $\frac{16\mu v l}{w d^2}$ (*d*) $\frac{32\mu v l}{w d^2}$

where d = Diameter of pipe,

l = Length of pipe,

v = Velocity of the liquid in the pipe,

μ = Viscosity of the liquid, and

w = Specific weight of the flowing liquid.

340. The loss of head due to friction in a pipe of uniform diameter in which a viscous flow is taking place, is

(*a*) $1 / R_N$ (*b*) $4 / R_N$ (*c*) $16 / R_N$ (*d*) $64 / R_N$

where R_N = Reynold number.

341. The loss of pressure head in case of laminar flow is proportional to

(*a*) velocity (*b*) $(\text{velocity})^2$ (*c*) $(\text{velocity})^3$ (*d*) $(\text{velocity})^4$

342. A moving fluid mass may be brought to a static equilibrium position, by aplying an imaginary inertia force of the same magnitude as that of the accelerating force but in the opposite direction. This statement is called

(*a*) Pascal's law (*b*) Archimede's principle

(*c*) D-Alembert's principle (*d*) none of these

343. The D-Alembert's principle is used for changing the dynamic equilibrium of a fluid mass, into a static equilibrium.

(*a*) Agree (*b*) Disagree

344. When a tank containing liquid moves with an acceleration in the horizontal direction, then the free surface of the liquid

(*a*) remains horizontal (*b*) becomes curved

(*c*) falls on the front end (*d*) falls on the back end

345. An open tank containing liquid is made to move from rest with a uniform acceleration. The angle θ which the free surface of liquid makes with the horizontal is such that

(*a*) $\tan\theta = a / g$ (*b*) $\tan\theta = 2a / g$ (*c*) $\tan\theta = a / 2g$ (*d*) $\tan\theta = a^2 / 2g$

where a = Horizontal acceleration of the tank, and

g = Acceleration due to gravity.

346. An open tank containing liquid is moving with an acceleration on an inclined plane. The inclination of the free surface of the liquid will be ..... to the acceleration of the tank.

(*a*) equal to (*b*) directly proportional

(*c*) inversely prcportional

347. A closed tank is completely filled with an oil. If it is made to move with a horizontal acceleration, then the pressure at the back end will be more than that at the front end.

(*a*) Correct (*b*) Incorrect

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348. The torque required to overcome viscous resistance of a footstep bearing is

(a) $\frac{\mu \pi^2 NR}{60t}$ (b) $\frac{\mu \pi^2 NR^2}{60t}$ (c) $\frac{\mu \pi^2 NR^3}{60t}$ (d) $\frac{\mu \pi^2 NR^4}{60t}$

where μ = Viscosity of the oil,
N = Speed of the shaft,
R = Radius of the shaft, and
t = Thickness of the oil film.

349. The power absorbed (in watts) in overcoming the viscous resistance of a footstep bearing is

(a) $\frac{\mu \pi^3 N^2 R^2}{1800t}$ (b) $\frac{\mu \pi^3 N^2 R^4}{1800t}$ (c) $\frac{\mu \pi^3 N^2 R^2}{3600t}$ (d) $\frac{\mu \pi^3 N^2 R^4}{3600t}$

350. The torque required to overcome viscous resistance of a collar bearing is

(a) $\frac{\mu \pi^2 N}{60t}(R_1 - R_2)$ (b) $\frac{\mu \pi^2 N}{60t}(R_1^2 - R_2^2)$

(c) $\frac{\mu \pi^2 N}{60t}(R_1^3 - R_2^3)$ (d) $\frac{\mu \pi^2 N}{60t}(R_1^4 - R_2^4)$

where R_1 and R_2 = External and internal radius of collar.

351. In a footstep bearing, if the speed of the shaft is doubled, then the torque required to overcome the viscous resistance will be

(a) double (b) four times (c) eight times (d) sixteen times

352. In a footstep bearing, if the radius of the shaft is doubled, then the torque required to overcome the viscous resistance will be

(a) double (b) four times (c) eight times (d) sixteen times

353. The coefficient of viscosity may be determined by

(a) capillary tube method (b) orifice type viscometer
(c) rotating cylinder method (d) all of these

354. The coefficient of viscosity (in poises) is given by

$$\mu = \left(0.0022\, t - \frac{1.8}{t}\right) \times \text{sp.gr.of liquid}$$

This equation is used to determine the viscosity of liquids by

(a) capillary tube method (b) orifice type viscometer
(c) rotating cylinder method (d) falling sphere method

355. Bulk modulus of a fluid is the ratio of

(a) shear stress to shear strain
(b) increase in volume to the viscosity of fluid
(c) increase in pressure to the volumetric strain
(d) critical velocity to the viscosity of fluid

356. Bulk modulus of a fluid ..... as the pressure increases.

(a) remains same (b) decreases (c) increases

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357. The volume of a fluid ..... as the pressure increases.
(*a*) remains same (*b*) decreases (*c*) increases

358. The specific weight of compressible fluids does not remain constant.
(*a*) True (*b*) False

359. The pressure of air ..... with the increase of height from the surface of the earth.
(*a*) does not change (*b*) decreases (*c*) increases

360. The celerity (velocity) of a pressure wave in a fluid is given by
(*a*) $\sqrt{K.\rho}$ (*b*) $\sqrt{K/\rho}$ (*c*) $\sqrt{\rho/K}$ (*d*) $K.\rho$

where K = Bulk modulus, and
ρ = Density of the fluid.

361. The ratio of velocity of fluid in an undisturbed stream to the velocity of sound wave is known as Mach number.
(*a*) Yes (*b*) No

362. When the Mach number is less than unity, the flow is called
(*a*) sub-sonic flow (*b*) sonic flow
(*c*) super-sonic flow (*d*) hyper-sonic flow

363. When the Mach number is equal to unity, the flow is called sonic flow.
(*a*) True (*b*) False

364. When the Mach number is between ..... the flow is called super-sonic flow.
(*a*) 1 and 2.5 (*b*) 2.5 and 4 (*c*) 4 and 6 (*d*) 1 and 6

365. When the Mach number is more than 6, the flow is called
(*a*) sub-sonic flow (*b*) sonic flow
(*c*) super-sonic flow (*d*) hyper-sonic flow

366. A flow is called sub-sonic, if the Mach number is
(*a*) less than unity (*b*) unity
(*c*) between 1 and 6 (*d*) more than 6

367. A flow is called sonic, if the Mach number is unity.
(*a*) Agree (*b*) Disagree

368. A flow is called super-sonic if the
(*a*) velocity of flow is very high (*b*) discharge is difficult to measure
(*c*) Mach number is between 1and 6 (*d*) none of these

369. A flow is called hyper-sonic, if the Mach number is
(*a*) less than unity (*b*) unity (*c*) between 1 and 6 (*d*) none of these

370. A point, in a compressible flow where the velocity of fluid is zero, is called
(*a*) critical point (*b*) vena contracta (*c*) stagnation point (*d*) none of these

371. The pressure at a stagnation point is always low.
(*a*) Agree (*b*) Disagree

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372. When a plate is immersed in a liquid parallel to the flow, it will be subjected to a pressure..... that if the same plate is immersed perpendicular to the flow.

(*a*) less than (*b*) more than

373. The force exerted by a moving fluid on an immersed body is directly proportional to the rate of change of momentum due to the presence of the body. This statement is called

(*a*) Newton's law of motion (*b*) Newton's law of cooling

(*c*) Newton's law of viscosity (*d*) Newton's law of resistance

374. The Newton's law of resistance is based on the assumption that the

(*a*) planes of the body are completely smooth

(*b*) space around the body is completely filled with the fluid

(*c*) fluid particles do not exert any influence on one another

(*d*) all of the above

375. Whenever a plate is held immersed at some angle with the direction of flow of the liquid, it is subjected to some pressure. The component of this pressure, in the direction of flow of the liquid, is known as

(*a*) lift (*b*) drag (*c*) stagnation pressure (*d*) bulk modulus

376. Whenever a plate is held immersed at some angle with the direction of flow of the liquid, it is subjected to some pressure. The component of this pressure, at right angles to the direction of flow of the liquid is known as lift.

(*a*) True (*b*) False

377. According to Prandtl-Blassius relation, the thickness of boundary layer in laminar flow is

(*a*) $\frac{5x}{\sqrt{R_{NX}}}$ (*b*) $\frac{5.835x}{\sqrt{R_{NX}}}$ (*c*) $\frac{0.377x}{(R_{NX})^{1/5}}$ (*d*) $\frac{5.377x}{(R_{NX})^{1/5}}$

where x = Distance between the leading edge of the body and the section where thickness of boundary layer is required, and

R_{NX} = Reynold's number at a distance x from the leading edge.

378. According to Prandtl-Blassius relation, the thickness of boundary layer in a turbulent flow is

(*a*) $\frac{5x}{\sqrt{R_{NX}}}$ (*b*) $\frac{5.835}{\sqrt{R_{NX}}}$ (*c*) $\frac{0.377x}{(R_{NX})^{1/5}}$ (*d*) $\frac{5.377x}{(R_{NX})^{1/5}}$

379. The separation of flow occurs when the hydrodynamic boundary layer thickness is reduced to zero.

(*a*) Agree (*b*) Disagree

380. The force present in a moving liquid is

(*a*) inertia force (*b*) viscous force (*c*) gravity force (*d*) all of these

381. The product of mass and accelaration of flowing liquid is called

(*a*) inertia force (*b*) viscous force (*c*) gravity force (*d*) pressure force

382. Viscous force is the ..... of shear stress due to viscosity and cross-sectional area of flow.

(*a*) sum (*b*) different (*c*) product (*d*) ratio

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383. Surface tension force is the product of surface tension per unit length and cross-sectional area of flow.

(*a*) Correct (*b*) Incorrect

384. The ratio of the inertia force to the viscous force is called

(*a*) Reynold's number (*b*) Froude's number (*c*) Weber's number (*d*) Euler's number

385. The Reynold's number of a ship is ..... to its velocity and length.

(*a*) directly proportional (*b*) inversely proportional

386. The ratio of the inertia force to the gravity force is called Froud's number.

(*a*) Agree (*b*) Disagree

387. The ratio of the inertia force to the ..... is called Euler's number.

(*a*) pressure force (*b*) elastic force

(*c*) surface tension force (*d*) viscous force

388. The ratio of the inertia force to the surface tension force is called Weber's number.

(*a*) Correct (*b*) Incorrect

389. The ratio of the inertia force to the elastic force is called

(*a*) Reynold's number (*b*) Froude's number (*c*) Weber's number (*d*) Mach number

390. Froude's number is the ratio of inertia force to

(*a*) pressure force (*b*) elastic force

(*c*) gravity force (*d*) surface tension force

391. Select the correct statement

(*a*) Weber's number is the ratio of inertia force to elastic force.

(*b*) Weber's number is the ratio of gravity force to surface tension force.

(*c*) Weber's number is the ratio of viscous force to pressure force.

(*d*) Weber's number is the ratio of inertia force to surface tension force.

392. Euler's number is the ratio of ..... force to pressure force.

(*a*) inertia (*b*) gravity (*c*) viscous

393. The reciprocal of Euler's number is called Newton number.

(*a*) Yes (*b*) No

394. Reynold's number is the ratio of inertia force to

(*a*) pressure force (*b*) elastic force (*c*) gravity force (*d*) viscous force

395. The value of bulk modulus of a fluid is required to determine

(*a*) Reynold's number (*b*) Froude's number (*c*) Mach number (*d*) Euler's number

ANSWERS

1. (*b*)	**2.** (*a*)	**3.** (*a*)	**4.** (*d*)	**5.** (*b*)	**6.** (*a*)
7. (*d*)	**8.** (*c*)	**9.** (*a*)	**10.** (*a*)	**11.** (*d*)	**12.** (*a*)
13. (*c*)	**14.** (*d*)	**15.** (*b*)	**16.** (*a*)	**17.** (*b*)	**18.** (*a*)
19. (*b*)	**20.** (*a*)	**21.** (*a*)	**22.** (*d*)	**23.** (*a*)	**24.** (*c*)
25. (*a*)	**26.** (*c*)	**27.** (*a*)	**28.** (*a*)	**29.** (*a*)	**30.** (*a*)

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31. (a)	32. (b)	33. (b)	34. (c)	35. (a)	36. (b)
37. (a)	38. (b)	39. (b)	40. (d)	41. (b)	42. (c)
43. (a)	44. (a)	45. (a)	46. (d)	47. (b)	48. (b)
49. (b)	50. (c)	51. (c)	52. (d)	53. (b)	54. (c)
55. (a)	56. (d)	57. (b)	58. (c)	59. (c)	60. (c)
61. (c)	62. (d)	63. (a)	64. (b)	65. (a)	66. (c)
67. (b)	68. (c)	69. (c)	70. (b)	71. (c)	72. (c)
73. (C), (A), (D), (B)		74. (d)	75. (a)	76. (c)	77. (b)
78. (b)	79. (a)	80. (a)	81. (c)	82. (b)	83. (b)
84. (a)	85. (a)	86. (c)	87. (d)	88. (b)	89. (a)
90. (c)	91. (b)	92. (b)	93. (a)	94. (a)	95. (b)
96. (a)	97. (b)	98. (a)	99. (c)	100. (a)	101. (d)
102. (d)	103. (a)	104. (b)	105. (b)	106. (a)	107. (b)
108. (c)	109. (a)	110. (a)	111. (d)	112. (d)	113. (c)
114. (a)	115. (b)	116. (b)	117. (a)	118. (b)	119. (a)
120. (a)	121. (a)	122. (b)	123. (b)	124. (a)	125. (a)
126. (b)	127. (a)	128. (a)	129. (d)	130. (d)	131. (d)
132. (b)	133. (c)	134. (c)	135. (a)	136. (b)	137. (c)
138. (d)	139. (c)	140. (c)	141. (b)	142. (d)	143. (a)
144. (a)	145. (b)	146. (d)	147. (c)	148. (b)	149. (b)
150. (a)	151. (d)	152. (a)	153. (d)	154. (b)	155. (a)
156. (b)	157. (c)	158. (d)	159. (a)	160. (a)	161. (c)
162. (c)	163. (c)	164. (a)	165. (b)	166. (c)	167. (c)
168. (c)	169. (b)	170. (c)	171. (d)	172. (b)	173. (a)
174. (a)	175. (a)	176. (d)	177. (a)	178. (b)	179. (b)
180. (c)	181. (a)	182. (d)	183. (c)	184. (a)	185. (b)
186. (d)	187. (a)	188. (a)	189. (a)	190. (a)	191. (c)
192. (b)	193. (a)	194. (b)	195. (c)	196. (d)	197. (b)
198. (b)	199. (d)	200. (a)	201. (d)	202. (c)	203. (b)
204. (d)	205. (c)	206. (b)	207. (a)	208. (b)	209. (a)
210. (c)	211. (b)	212. (a)	213. (a)	214. (a)	215. (a)
216. (c)	217. (c)	218. (b)	219. (b)	220. (c)	221. (c)
222. (d)	223. (a)	224. (c)	225. (a)	226. (d)	227. (a)
228. (b)	229. (b)	230. (a)	231. (c)	232. (d)	233. (a)
234. (b)	235. (b)	236. (b)	237. (b)	238. (a)	239. (c)
240. (a)	241. (c)	242. (b)	243. (c)	244. (c)	245. (d)
246. (a)	247. (d)	248. (a), (b)	249. (c)	250. (a)	251. (a)
252. (b)	253. (d)	254. (b)	255. (c)	256. (a)	257. (d)

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258.	(c)	259.	(c)	260.	(d)	261.	(b)	262. (c) 263. (b)
264.	(b)	265.	(d)	266.	(b)	267.	(a)	268. (c) 269. (a)
270.	(d)	271.	(c)	272.	(d)	273.	(b)	274. (a) 275. (b)
276.	(c)	277.	(d)	278.	(b)	279.	(c)	280. (d) 281. (a)
282.	(c)	283.	(a)	284.	(a)	285.	(a)	286. (b) 287. (d)
288.	(c)	289.	(a)	290.	(a)	291.	(b)	292. (c) 293. (a)
294.	(c)	295.	(c)	296.	(c)	297.	(b)	298. (b) 299. (c)
300.	(a)	301.	(a)	302.	(b)	303.	(b)	304. (b) 305. (b)
306.	(b)	307.	(a)	308.	(a)	309.	(a)	310. (a) 311. (c)
312.	(c)	313.	(d)	314.	(a)	315.	(c)	316. (b) 317. (c)
318.	(a)	319.	(c)	320.	(c)	321.	(a)	322. (a) 323. (a)
324.	(b)	325.	(c)	326.	(d)	327.	(a)	328. (a) 329. (a)
330.	(d)	331.	(b)	332.	(a)	333.	(b)	334. (a) 335. (c)
336.	(b)	337.	(c)	338.	(d)	339.	(d)	340. (c) 341. (a)
342.	(c)	343.	(a)	344.	(c)	345.	(a)	346. (b) 347. (a)
348.	(d)	349.	(b)	350.	(d)	351.	(a)	352. (d) 353. (d)
354.	(b)	355.	(c)	356.	(c)	357.	(b)	358. (a) 359. (b)
360.	(b)	361.	(a)	362.	(a)	363.	(a)	364. (d) 365. (d)
366.	(a)	367.	(a)	368.	(c)	369.	(d)	370. (c) 371. (b)
372.	(a)	373.	(d)	374.	(d)	375.	(b)	376. (a) 377. (a)
378.	(c)	379.	(a)	380.	(d)	381.	(a)	382. (c) 383. (b)
384.	(a)	385.	(a)	386.	(a)	387.	(a)	388. (a) 389. (d)
390.	(c)	391.	(d)	392.	(a)	393.	(a)	394. (d) 395. (c)

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5

Surveying

5.1 Introduction

The art of determining relative positions of objects on the surface of the earth by taking measurements in the horizontal and vertical planes, is called *surveying*. The surveying may primarily be divided into the following two classes :

1. *Plane surveying*. The surveys in which the curvature of earth is not taken into consideration are known as plane surveys. These surveys extend over small areas. The degree of accuracy obtained in this type of surveying is comparatively low. Generally areas less than 250 km^2 are treated as plane. When the surveys extend over limited areas, the difference in length between the arc and the subtended chord for any two points on the surface of the earth is only about 0.1 m for a distance of 18.2 km, 0.3 m for 54.3 km and 0.5 m for 91 km. Similarly, the difference between the sum of the angles of a spherical triangle on the earth's surface and that of the angles of the corresponding plane triangle is only one second for every 195.5 km^2 of area.

2. *Geodetic surveying*. The surveys in which the curvature of earth is taken into consideration are known as geodetic surveys (also called trigonometrical surveying). These surveys extend over large areas (more than 250 km^2) and where the degree of accuracy required is great.

5.2 General Classification of Surveys

The surveys may be classified in different ways as follows :

1. *According to the instrument used.* The surveys, according to the instrument used are chain survey, compass survey, plane table survey, theodolite survey etc.

2. *According to the purpose of survey.* The surveys, according to the purpose are mine survey, geological survey, archaeological survey and military survey.

3. *According to the method employed.* The surveys, according to the method employed are triangulation survey and traverse survey.

4. *According to the place of work.* The surveys, according to the place of work are land survey, hydrographical or marine survey and aerial survey.

The land survey may be further sub-divided into the following classes :

(*a*) *Topographical survey.* This survey is carried out for determining the natural features of the country such as hills, valleys, rivers, lakes, woods and nallahs etc. It is also used for artificial objects such as canals, railways, roads, towns and villages etc.

(*b*) *Cadastral survey.* This survey is performed to determine the additional details such as boundaries of fields, houses and other property.

(*c*) *City survey.* This survey is performed in connection with town planning schemes such as drainage, water supply etc. and for laying out plots, roads, streets etc.

(*d*) *Engineering survey.* This survey is performed for determining and for collecting data for the design of engineering works such as roads, railways, reservoirs or works in connection with water supply, sewerage etc. The engineering survey may be further sub-divided into the following classes:

(*i*) *Reconnaissance surveys* for determining the feasibility and rough cost of scheme.

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(*ii*) *Preliminary surveys* for collecting more precise data to choose the best location for the work.

(*iii*) *Location surveys* for setting out the work on the ground.

5.3 Principles of Surveying

The following are the two fundamental principles of surveying which should be kept in view while determining the relative position of points on the surface of the earth.

1. To work from whole to the part. The working from whole to the part is done in surveying in order to ensure that errors and mistakes of one portion do not affect the remaining portion.

2. To fix the positions of new stations by at least two independent processes. The new stations are fixed from points already fixed by linear measurements, angular measurements or by both linear and angular measurements.

5.4 Scales

The drawings of objects are not usually made full sized. It is generally necessary to draw them to a convenient scale. The ratio of the distance on the map or drawing to the corresponding distance on the ground is called *representative fraction (R.F.)*. For example, when 1 cm on a map represents 10 m on the ground, then the representative fraction of the scale is 1/1000.

The scales may be plain scale, diagonal scale, comparative scale, shrunk scale and vernier scale.

A *plain scale* is used to read only two dimensions such as metres and decimetres.

A *diagonal scale* is used to read three dimensions such as metres, decimetres and centimetres.

A *comparative scale* has a common representative fraction but read in different measures.

The *vernier scale* is used for measuring fractional parts of the smallest division of the main scale. It consists essentially of a small scale called the vernier scale which moves with its graduated edge along the graduated edge of a long fixed scale called the main or primary scale. The readings with a simple vernier can be taken in one direction only. There are two types of verniers *i.e.* direct vernier and retrograde vernier.

In a *direct vernier*, the smallest division of a vernier is shorter than the smallest division of its primary scale. In a *retrograde vernier*, the smallest division of a vernier is longer than the smallest division of its primary scale.

The ratio of the smallest division on the main scale to the number of divisions on the vernier is called *least count of the vernier.* For example, if x is the smallest division on the main scale and n are the number of divisions on the vernier, then the least count of the vernier is x/n.

Note : If by chance measurements are taken with a wrong scale, then the true measurements may be found by using the following relations :

1. $$\text{True length} = \frac{\text{Wrong scale}}{\text{Correct scale}} \times \text{Measured length}$$

2. $$\text{True area} = \frac{\text{Wrong scale}}{\text{Correct scale}} \times \text{Calculated area}$$

By the scale is meant its R.F.

5.5 Measurement of Distance

There are two main methods of determining distance *i.e.* direct and indirect or computative. The direct method includes the use of chain, tape and other instrument and is very accurate. In indirect method, the distances are obtained by calculations as in tacheometry, telemetry or triangulation.

The following are various methods used for measuring distance by direct method, but the method to be used depends largely upon the degree of accuracy required.

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1. *Pacing.* It consists in walking over a distance and counting the number of paces. The average length of a pace is 80 cm. This method is chiefly used for reconnaissance surveys, for the preparation of military plans and for locating details in small-scale mapping.

An instrument known as *Passometer* may be used for counting the number of paces. It is like a pocket watch in size and appearance which automatically records the number of paces taken in pacing a given distance.

2. *Instrumental method.* Some instruments like Pedometer, speedometer, odometer, perambulator may be used to find the distance approximately. The speedometer gives better results than pacing provided the route is smooth as along a highway. The odometer can be attached to the wheel of a vehicle such as a carriage, cart, bicycle etc. in order to measure the distance travelled.

3. *Judging distance.* This is a very rough method of determining distances. It is used in estimating distance of details in reconnaissance survey.

4. *Time measurement.* The distances are also roughly determined by knowing the average time taken per km by a person at walk or a horse at trot and the total time taken to cover that distance.

5. *Chaining.* The method of measuring distance with the help of a chain or tape is called chaining. It is the most accurate and common method of measuring distance.

Note : In all chaining operations, two men (called chain men) are required. The chain man at the forward end of the chain is called the *leader* while the chain man at the rear end of the chain is known as *follower.*

5.6 Instruments Used for Chaining

The following instruments are used while chaining :

(*a*) *Chain.* It is composed of a 100 or 150 pieces of galvanised mild steel wire 4 mm (8 SWG) in diameter called links. There are two main kind of surveying chains *i.e.* metric surveying chains and non-metric surveying chains. The 20 m and 30 m surveying chains have been prescribed by Indian standards.

(*b*) *Arrows.* Each chain is accompanied with 10 arrows. They are also called marking or chaining pins and are used to mark the end of each chain during the process of chaining. The arrows are made of good quality hardened and tempered steel wire 4 mm (8 SWG) in diameter and 400 mm in length.

(*c*) *Tapes.* The measuring tapes, according to the material used, are classified as cloth or linen tape, metallic tape, steel tape and invar tape. Since invar is an alloy of steel (64 %) and nickel (36 %) and possesses a very low coefficient of thermal expansion, therefore, the invar tape is generally used for accurate measurement of distance.

(*d*) *Ranging rods.* The ranging rods are used for marking the positions of stations conspicuously and for ranging straight lines. The ranging may be direct and indirect. The *direct ranging* is possible only when the end stations are mutually intervisible. The *indirect ranging* is resorted to when the ends of a line are not intervisible due to high ground or a hill intervening.

(*e*) *Line ranger.* It is a small reflecting instrument used for fixing intermediate points on the chain lines.

5.7 Error in Length due to Incorrect Chain

It may be noted that the distance measured with the chain or tape of incorrect lenght will not be correct. The correct distance can be calculated from the following relations :

$$\text{Correct or true distance} = \frac{L'}{L} \times \text{Measured distance}$$

where L' = Incorrect length of a chain or tape, and

L = Correct length of a chain or tape.

Notes : 1. When the chain used is *too long*, then the measured distance is *too short*, *i.e.* less than its true distance. Consequently, the error is *negative* and the correction is *positive.*

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2. When the cahin used is *too short*, then the measured distance is *too great*, i.e. greater than its distance. Therefore, the error is *positive* and the correction is *negative*.

3. The true area and true volume may be determined by the following relations :

(*a*) $\text{True area} = \left(\frac{L'}{L}\right)^2 \times \text{Measured area}$

(*b*) $\text{True volume} = \left(\frac{L'}{L}\right)^3 \times \text{Measured volume}$

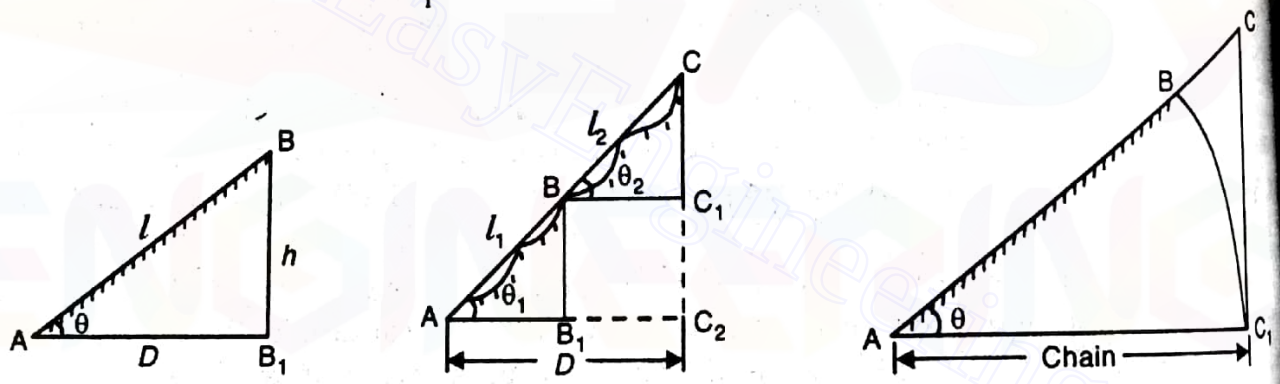
5.8 Chaining on Sloping Ground

In surveying, the distance required for plotting purposes are the horizontal distances. If ground is sloping, the horizontal distances are obtained either directly or indirectly. In the *direct method* (commonly known as *stepping method*), horizontal distances are directly measured on ground by the process of stepping which consists in measuring the line in short horizontal lengths. This method is more convenient and gives better results while measuring horizontal distance down the hill.

The *indirect method* is more accurate and rapid when the slope of the ground is long and gentle. In this method, the various slopes are measured by a clinometer (usually by Abney level) and the difference in elevation between successive points is determined by a level or hand level. Knowing the angle of slope of the ground and the slope distance, the horizontal distances may be computed by any one of following three methods :

First method [Refer Fig. 5.1 (*a*)]. Knowing the sloping distance (l) and the angle of slope (θ), the horizontal distance AB_1 is given by

$$AB_1 = D = l \cos \theta$$



(*a*) (*b*) (*c*)

Fig. 5.1

If the slope of the ground is not regular, but is made up of varying inclinations as shown in Fig. 5.1 (*b*), then the horizontal distance AC_2 is given by

$$AC_2 = D = AB_1 + B_1C_2 + \ldots = AB_1 + BC_1 + \ldots = l_1 \cos \theta_1 + l_2 \cos \theta_2 = \Sigma l \cos$$

Second method. If the difference in elevation (h) in Fig. 5.1 (*a*) between the ends of the slope is determined by any levelling instrument, then horizontal distance,

$$AB_1 = D = \sqrt{l^2 - h^2}$$

Third method. If only the distance between the ends of a line is required, the horizontal distance may be determined after the chaining is completed. If, however, a number of intermediate points have to be located, a correction may be applied in the field at every chain length. The correction may be calculated as follows [Refer Fig. 5.1 (*c*)].

$$AC_1 = AB = 1 \text{ chain} = 100 \text{ links}$$

$$AC = 100 \sec \theta \text{ links}$$

$$\therefore \quad BC = AC - AB = 100 (\sec \theta - 1) \text{ links}$$

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The amount 100 (sec θ – 1) is known as *hypotenusal allowance*. This indirect method in which the correction for hypotenusal allowance is applied to each chain length is usually employed in route surveys.

5.9 Correction for Slope

The horizontal distances can also be determined by applying negative corrections to the distance measured along the slope. The following are the formulae for corrections :

1. *Correction for slope if the vertical distance between the first and last point (h) is known.* Refer Fig. 5.2.

Correction to the slope distance,

$$C_h = B_1C_1 = AC_1 - AB_1$$
$$= AB - AB_1 \quad (\because AC_1 = AB)$$
$$= l - D$$
$$= l - \sqrt{l^2 - h^2} \quad \text{(Exact)}$$
$$= l - l\left[1 - \frac{h^2}{2l^2} - \frac{h^4}{8l^4} - .....\right]$$
$$= \frac{h^2}{2l} \quad \text{(Approx.)} \quad \text{...[Neglecting higher powers of } l\text{]}$$

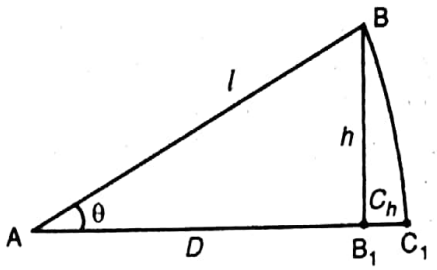

Fig. 5.2

The correction is to be subtracted from the slope distance in order to obtain its horizontal equivalent.

2. *Correction for slope when the angle of slope of the ground (θ) is known.*

When the angle of slope of the ground is measured with great precision such as with a theodolite, then correction for slope should be determined by the exact formula as given below :

From Fig. 5.2, we find that

$$C_h = B_1C_1 = AC_1 - AB_1 = l - l\cos\theta = l(1 - \cos\theta)$$

5.10 Errors in Chaining

The errors in chaining are of the following three types :

1. *Instrumental errors*. These errors are due to faulty adjustments or imperfections of the instruments such as chain or tape may be too long or too short etc.

2. *Natural errors*. These errors arise due to variations in the phenomenon of nature such as temperature etc.

3. *Personal errors*. These errors are classified as compensating errors and cumulative errors.

The *compensating errors* are those which occur in either direction and tend to compensate at the end. These errors do not affect the survey work seriously.

The *cumulative errors* are those which occur in one direction only and go on accumulating. These errors have a serious effect on the accuracy of survey work.

The errors in chaining are regarded as *positive* (making the measured length more than the actual) or *negative* (making the measured length less than the actual).

Note : The compensating and cumulating errors that occur in chaining are proportional to $\sqrt{L}$, and L respectively where L is the length of line.

5.11 Tape Correction

Since the tape is not used in the field under standard conditions of temperature, pull etc. therefore, it is necessary to apply the following corrections to the measured length of a line in order to obtain its true length.

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1. Correction for absolute length,

$$C_a = \frac{L \times c}{l}$$

where L = Measured length of a line,
l = Nominal length of a tape, and
c = Correction to the tape length.

The correction may be *positive* or *negative* depending upon the correction required by the tape.

2. Correction for temperature,

$$C_t = \alpha (T_m - T_o) L \text{ (in m)}$$

where α = Coefficient of thermal expansion,
T_m = Mean temperature during measurement,
T_o = Temperature at which tape is standardised, and
L = Measured length in m.

The sign for correction is *plus* or *minus* according as T_m is greater or less than T_o.

3. Correction for pull (or tension),

$$C_p = \frac{(P - P_o) L}{A.E} \text{ (in m)}$$

where P = Pull applied during measurement in N,
P_o = Pull at which the tape is standardised in N,
L = Measured length in m,
A = Cross-sectional area of the tape in m^2, and
E = Modulus of elasticity of the tape material in N/m^2.

The correction may be *positive* or *negative* according as P is greater or less th

4. Correction for sag,

$$C_s = \frac{w^2 L^2}{24 P^2}$$

where w = Weight of the tape in N/m,
L = Length of tape in m, and
P = Pull applied in N.

Note : The tension at which the effects of pull and sag for a tape are neutralised, is known as *normal tension.*

5. Correction for slope or vertical alignment,

$$C_v = \frac{h^2}{2l}$$

where h = Difference in height between the ends of the slope, and
l = Length of the slope.

If the slopes are given in terms of vertical angles, then

$$C_v = 2l \sin^2 \frac{\theta}{2}$$

where θ = Angle of the slope.

This correction is always subtractive from the measured length.

5.12 Chain Surveying

It is the system of surveying in which the sides of the various triangles are measured directly the field and no angular measurements are taken. The simplest kind of surveying is the chain surveyi

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and is most suitable when the

(*a*) ground is fairly level and open with simple detail,

(*b*) plans are required on a large scale, and

(*c*) area to be surveyed is small.

The principle of surveying is triangulation. It consists of the arrangement of framework of triangles because a triangle is the only simple plane figure, which can be plotted from the lengths of its sides measured in the field. Since an equilateral triangle can be more accurately plotted than an obtuse angled triangle, therefore, the triangles formed in a chain survey should be nearly equilateral as possible. Such triangles are known as *well conditioned* or *well shaped triangles*. In a well conditioned triangle, no angle should be less than 30° and greater than 120°.

The terms commonly used in chain surveying are as follows :

1. *Base line*. The longest of the chain lines used in making a survey is generally regarded as a base line. It fixes up the directions of all other lines as on the base line is built up the framework of a survey.

2. *Check line*. A line joining the apex of a triangle to some fixed point on the opposite side or a line joining some fixed points on any two sides of a triangle. A check line is measured to check the accuracy of framework.

3. *Tie line*. A line joining some fixed points (termed as tie stations) on the main survey lines. A tie line usually fulfils a dual purpose, *i.e.* it checks the accuracy of the framework and enables the surveyor to locate the interior details which are far away from the main chain lines.

4. *Offsets*. The lateral measurements (*i.e.* the distance measured from the chain lines) to the objects right or left of the chain lines are called offsets. The offsets may be perpendicular or oblique. In the strict sense, offsets are always taken at right angles to the survey line. They are also called perpendicular or right angled offsets. The measurements which are not made at right angles to the survey line are called oblique offsets or tie-line offsets.

The offsets, according to its length, may be short or long. Generally, the offsets are called short when they are less than 15 m in length and long when their length is more than 15 m.

The accuracy required in laying down the perpendicular offsets and in measuring them depends upon the scale of plotting, length of the offset, and the importance of the object to which the offset is taken.

5.13 Instruments for Setting Out Right Angles

The following instruments may be used for setting out right angles at a given point on the line and for finding the foot of perpendicular from a given point to a line.

1. *Cross staff*. There are three forms of cross staff, namely, open cross staff, French cross staff and the adjustable cross staff. Since the open cross staff is light and strong, therefore, it is more commonly used for setting out an offset at a right angle. The French cross staff is used for setting out an offset at an angle of 45° and the adjustable cross staff is used for setting out an offset at any angle.

2. *Optical square*. It is more accurate than the cross staff and is used for setting out accurately the long offsets. It is a small compact hand instrument based upon the principle of reflection. The other instruments belonging to a class of reflecting instrument are line ranger, box sextant and a prismatic compass.

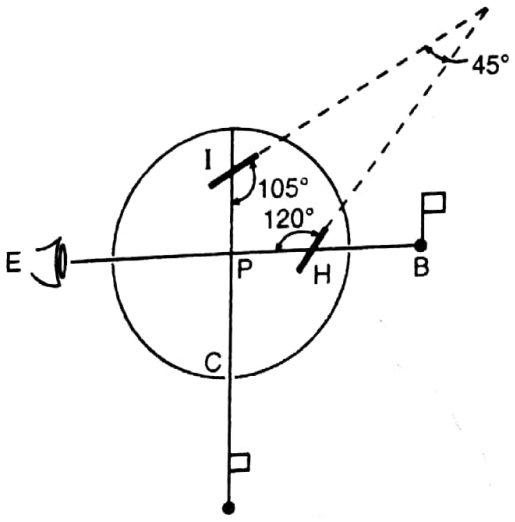

Fig. 5.3

Fig. 5.3 shows the sectional plan of the important

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parts of the optical square. *H* and *I* are two mirrors placed at an angle of 45° to each other. The mirror *H*, called the *horizon glass*, is half silverd and half unsilvered. The mirror *I*, known as *index glass*, is wholly silvered.

The principle underlying the construction of reflecting instruments may be stated as "If there are two plane mirrors whose reflecting surfaces make a given angle with each other and if the ray of light is reflected successively from both of them, then the angle between the first incident ray and last reflected ray is twice the angle between the two mirrors". In case of an optical square, the angle between the first incident ray and the last reflected ray is 90°.

5.14 Obstacles in Chaining

The various obstacles or obstructions such as woods, hills, ponds, rivers, buildings etc. are continually met with in chaining. The various obstacles may be classed as follows :

1. Those which can be chained across but cannot be seen across, *i.e.* chaining free, vision obstructed such as a rising ground or a hill intervening.
2. Those which can be seen across but cannot be chained across, *i.e.* chaining obstructed but vision free such as a pond, plantations, tank, river etc.
3. Those which can neither be seen across nor be chained across, *i.e.* chaining and vision both obstructed such as a building.

5.15 Traverse Surveying

A traverse surveying is one in which the framework consists of a series of connected lines whose lengths are measured with a chain or tape and the directions are determined with an angular instrument. The instruments commonly used for the measurement of angles are a compass and a theodolite. Sometimes, a box sextant is also used.

The direction of a survey line may be defined either by the horizontal angle between the line and the line adjacent to it or by the angle (called the bearing) between the fixed line of reference (called the meridian) and the line. The reference direction employed in surveying may be a true or geographical meridian, a magnetic meridian or an arbitrary or assumed meridian.

The *true* or *geographical meridian* is a line in which the plane passing through the given point and the north and south poles intersects the surface of the earth. The direction of a true meridian is invariable. The true meridians through the various stations are not parallel, but converge to the poles. However, for ordinary small surveys, they are assumed to be parallel to each other. The horizontal angle between the true meridian and a line is called *true bearing* of the line. It is also known as *azimuth*.

The *magnetic meridian* is the direction indicated by a freely suspended and properly balanced magnetic needle, unaffected by local attractive forces. The angle which the line makes with the magnetic meridian is called a magnetic bearing of the line or simply bearing of the line.

The *arbitrary* or *assumed meridian* is usually the direction from a survey station to some well defined permanent object or the first line of a survey. The angle between this meridian and a line is known as arbitrary or assumed bearing of the line.

5.16 Designation of Bearings

The following two systems are commonly used to express the bearings :

1. Whole circle system; and 2. Quadrantal system.

In the *whole circle system*, the bearing of a line is always measured clockwise from the north point of the reference meridian towards the line right round the circle. The angle thus measured is called the *whole circle bearing* (W.C.B.). It may have any value between 0° and 360°. The bearing observed with a prismatic compass or a theodolite are the whole circle bearings.

In the *quadrantal system*, the bearing of a line is measured clockwise or anticlockwise from

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the north point or the south point whichever is nearer the line, towards the east or west. In this system, the bearing is reckoned from 0° to 90° in each quadrant. The bearings observed with a surveyor's compass are the quadrantal bearings.

5.17 Reduced Bearings

When the whole circle bearing of a line exceeds 90°, it must be reduced to the corresponding angle less than 90°, which has the same numerical values of the trigonometrical functions. This angle is known as the *reduced bearing* (*R.B.*). In order to obtain the reduced bearings from the whole circle bearings of the lines, the following table may be used :

Table 5.1. Rule for reduced bearings (R.B.)

Case	*W.C.B between*	*Rule for R.B.*	*Quadrant*
I	0° and 90°	= W.C.B.	N-E
II	90° and 180°	= 180° – W.C.B.	S-E
III	180° and 270°	= W.C.B. – 180°	S-W
IV	270° and 360°	= 360° – W.C.B.	N-W

5.18 Fore and Back Bearings

Every line has two bearings, one observed at each end of the line. The bearing of a line in the direction of the progress of survey is called *fore* or *forward bearing* (F.B.), while its bearing in the opposite direction is known as the *back* or *reverse bearing* (B.B). It may be noted that the fore and back bearings of a line differ exactly by 180°. In the whole circle bearing system, the back bearing of a line may be obtained from the fore bearing by using the following relation :

$$\text{Back bearing} = \text{Fore bearing} \pm 180°$$

When the fore bearing is less than 180°, then use *plus* sign and when it exceeds 180°, then use *minus* sign.

In the quadrantal system, the fore and back bearings are numerically equal but with opposite letters. For example, if the fore bearing of a line is N40°25′E, then the back bearing of the line is S40°25′W.

5.19 Local Attraction, Dip and Magnetic Declination

The *magnetic needle is seriously deflected from its normal position when it is under the influence of external attractive forces (called the sources of local attraction). Such a disturbing influence is known as *local attraction*. The term is also used to denote the amount of deviation of the needle from its normal position.

If the needle is perfectly balanced before magnetisation, it remains in horizotnal position. But it will not remain in the same position after it is magnetised, on account of the magnetic influence of the earth. It will be inclined downwards towards the pole. This inclination of the needle with the horizontal is known as *dip* of the needle. The amount of dip is not constant, but varies in different parts of the earth. It is 0° at the equator and 90° at the magnetic poles.

The magnetic meridian at a place does not coincide with the true meridian at that place except in few places. The horizontal angle which the magnetic meridian makes with the true meridian is known as *magnetic declination* or simply declination of the needle.

5.20 Theodolite Traversing

The theodolite is the most intricate and accurate instrument used for measuring horizontal and vertical angles. The theodolites are primarily classified as follows :

1. Transit, and 2. Non-transit

A theodolite is called a *transit theodolite*, when its telescope can be transited *i.e.* revolved through

* The magnetic needle is an essential part of the various forms of compass.

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In a *non-transit theodolite*, the telescope cannot be transited. These types of theodolites have now become obsolete. The theodolites are also classified as vernier theodolites and micrometer theodolites, according as the vernier or micrometer is fitted to read the graduated circle. The following terms should be well understood when manipulating a transit theodolite :

(*a*) *Centering.* It means setting the theodolite exactly over a station mark. It can be done by means of a plumb bob.

(*b*) *Transiting.* It is also called *plunging* or *reversing*. It is the process of turning the telescope of a theodolite over its supporting axis (horizontal axis) through 180° in a vertical plane thus bringing it upside down making it point exactly in opposite direction.

(*c*) *Line of collimation.* It is also known as *line of sight*. It is an imaginary line joining the point of intersection of the cross-hairs of the diaphragm and the optical centre of the object glass and its continuation. The line of collimation must be at right angles to the horizontal axis.

(*d*) *Axis of telescope.* It is a line joining the optical centre of the object glass and the centre of the eye piece. The axis of telescope must be parallel to the line of collimation.

(*e*) *Axis of level or bubble tube.* It is the straight line trangential to the longitudinal curve of the level tube at the centre of the tube. The axis of bubble tube must be perpendicular to the vertical axis.

5.21 Surveying Telescope

The telescope of a theodolite may be of the following two types : 1. External focussing; and 2. Internal focussing.

The first type is used in older type of theodolites while the latter is used in modren instruments. It is mounted near its centre on a horizontal axis at right angles to the main longitudinal axis of the telescope.

The principal parts of a telescope are the body, the object glass or objective, the eye-piece, and the diaphragm. The body consists of two tubes one of which slides within the other. The object glass or objective is invariably a compound lens consisting of an outer double convex lens of hard crown glass and an inner concave-convex lens of dense flint glass. The eye-piece magnifies both the image and the cross-hairs. A non-erecting or inverting eye piece is most commonly used for surveying telescopes. The diaphragm consists of a brass ring called the cross-hair ring carrying-cross hairs. It is held nearer to the eye-piece.

Notes : 1. The real image of an object formed by the objective must lie in the plane of the cross-hairs. When the image formed does not lie in the plane of cross-hairs, then the parallex should be removed. It is done by focussing the eye-piece, and by focussing the object glass.

2. The object of focussing the eye-piece is to make the cross-hairs distinct and clear. The object of focussing the object glass is to bring the image of the object formed in the plane of the cross hairs.

5.22 Measurement of Horizontal Angles, Direct Angles, Deflection Angles and Vertical Angles

The following three methods are used to measure horizontal angles :

1. Ordinary method, 2. Repetition method, and 3. Reiteration method.

In order to measure a horizontal angle more accurately, a method of repetition is used. The method of reiteration is another method of measuring horizontal angles with high precision. It is less tedious and is generally preferred when several angles are to be measured at a particular station.

An angle measured clockwise from the proceeding survey line to the following survey line is called a *direct angle*. The direct angles may have any value between 0° and 360°.

An angle made by a survey line with the prolongation of the proceeding line is called a *deflection angle*. It is equal to the difference between the included angle and 180°. The deflection angles may have any value between 0° and 180°. The method of measuring deflection angles is more commonly used in railways and highway works.

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An angle between the inclined line of sight and the horizontal is called a *vertical angle.*

5.23 Traverse Survey with a Theodolite

In theodolite traversing, the field work consisting of reconnaissance, selection of stations, marking and locating stations, running of survey lines, locating the details and booking of field notes is almost the same as for compass traversing. The traverse may be open or closed like the compass or plane table traverses.

A theodolite is used for determining the relative directions of the lines of the traverse and a steel tape is generally used for linear measurements. The methods by which the relative directions of the lines of a traverse may be determined are as follows :

1. By the measurement of angles between successive lines.
2. By the direct observation of bearings of the survey lines.

The first method is generally used for long traverses and where high precision is required, while the second method is used for short traverses where high precision is not required and for topographical surveys.

5.24 Traverse Computations

In survey work, after the field work is over, the position of different points are plotted on a plan with reference to two lines which are respectively parallel and perpendicular to the meridian. If the length and bearing of a line are known, its projections on the line parallel to the meridian and on the line perpendicular to it may be obtained.

These projections are called *latitude* and *departure* of the line respectively. The latitude of the line may, therefore, be defined as the distance measured parallel to the meridian (North and South line) while the departure may be defined as the distance measured parallel to the line perpendicular to the meridian (East and West line).

Latitude (L) when measured upward or northward is called *northing* and assumed to be positive. When the latitude is measured downward or southward, it is called *southing* and assumed to be negative.

Similarly, departure (D) when measured rightward or eastward is called *easting* and assumed to be positive. When the departure is measured leftward or westward, it is called *westing* and assumed to the negative.

In order to find the latitude of a line, multiply the length of the line by the *cosine* of its reduced bearing, and in order to find its departure, multiply the length of the line by the *sine* of its reduced bearing (see Fig. 5.4).

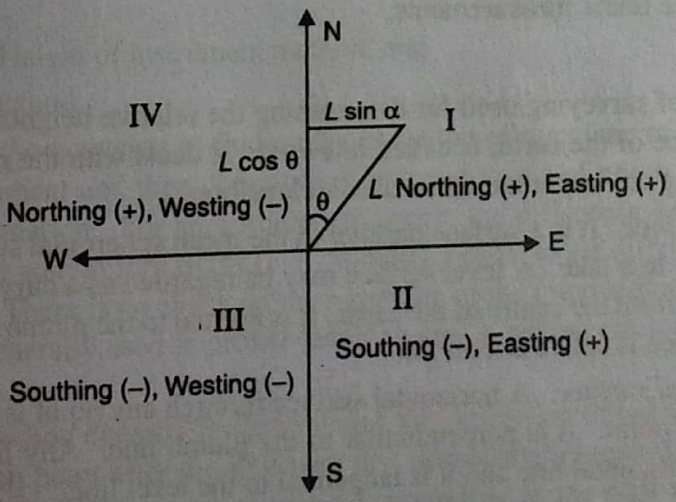

Fig. 5.4

If L is the length of the line and θ is its reduced bearing, then

Latitude of the line $= L \cos \theta$

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Departure of the line $= L \sin \theta$

$\therefore$ Length of the line $= \sqrt{(\text{Latitude})^2 + (\text{Departure})^2}$

$=$ Latitude $\times$ secant of reduced bearing

$=$ Departure $\times$ cosecant of reduced bearing

The reduced bearing of a line determines the sign of its latitude and departure, the first letter *N* or *S* of the bearing defines sign of latitude and the last one *E* or *W*, the sign of departure. If the bearing of a line is given as W.C.B., then the following table may be used to determine the signs of latitude and departure.

Table 5.2. Signs of latitude and departure.

W.C.B. between	*Quadrant*	*Sign of*	
		Latitude	*Departure*
0° and 90°	I (N-E)	+	+
90° and 180°	II (S-E)	−	+
180° and 270°	III (S-W)	−	−
270° and 360°	IV (N-W)	+	−

The latitude and departure of any point with reference to the preceding are called *consecutive co-ordinates* of the point, while the co-ordinates of any point with reference to a common origin are known as *independent coordinates* of the point. The independent coordinates are also known as *total latitude* and *total departure* of the point.

5.25 Balancing the Traverse

It is the process of adjusting the latitudes and departures by applying corrections to them in such a way that the algebraic sum of the latitudes, and that of the departure should be each equal to zero, *i.e.* the sum of the northings should be exactly equal to the sum of the southings and the sum of the easting should be exactly equal to the sum of the westings. The following rules may be used for finding the corrections to balance the survey :

1. *Bowditch's rule.* It is also known as *compass rule.* This rule is used to balance the traverse when the angular and linear measurements are equally precise. It is most commonly used in traverse adjustment.

2. *Transit rule.* This rule is used to balance the traverse when the angular measurements are more precise than the linear measurements.

5.26 Levelling

The method of surveying used for determining the relative heights or elevations of points or objects on the surface of the earth, is called *levelling*. It deals with the measurements in a vertical plane. The following are important terms used in levelling.

(*a*) *Level surface.* It is a surface parallel to the mean spheroidal surface of the earth, *e.g.* the surface of still water in a lake. A level surface may be regarded as a curved surface, every point of which is equidistant from the centre of the earth. It is normal to the plumb line at all points. Any line lying in a level surface is called a *level line.*

(*b*) *Horizontal surface.* A horizontal surface through any point is a surface tangential to the level surface at that point. It is perpendicular to the plumb line. Any line lying in the horizontal surface is called a horizontal line and it is tangential to the level line.

(*c*) *Vertical surface.* A vertical surface through any point is a surface normal to the level surface at that point. Any line lying in the vertical surface is called a vertical line and is normal to the level line.

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(*d*) *Datum surface or line.* It is an arbitrary surface or line from which the elevation of points are measured and compared.

(*e*) *Elevation of a point.* It is a vertical distance above or below the datum. It is also known as reduced level (R.L.). The elevation of a point is positive or negative according as the point lies above or below the datum.

(*f*) *Bench mark.* It is a fixed reference point of known elevation. It may be noted that levelling should always commence from a permanent bench mark and end on a permanent bench mark.

(*g*) *Backsight (B.S.) or Backsight reading.* It is a staff reading taken on a point of known elevation (or reduced level) as on a bench mark or a change point. It is the first staff reading taken after the level is set up and levelled. It is also called a *plus sight.*

(*h*) *Fore sight (F.S.) or fore sight reading.* It is a staff reading taken on a point whose elevation (or reduced level) is to be determined as on a change point. It is the last staff reading taken before shifting of the level to another position. It is also called a *minus sight.*

(*i*) *Intermediate sight (I.S.) or intermediate sight reading.* It is any other staff reading taken on a point of unknown elevation (or reduced level) from the same set up of the level. All sights taken between the back sight and fore sight are intermediate sights.

(*j*) *Change point.* It is point denoting the shifting of the level. It is a point on which the fore and back sights are taken.

(*k*) *Station.* It is a point whose elevation is to be determined. It may be noted that it is a point where the staff is held and the reading taken during the process of levelling.

(*l*) *Height of instrument (H.I.).* It is the elevation (or reduced level) of the plane of collimation (or plane of sight) when the instrument is correctly levelled. It is equal to the reduced level of bench mark plus the back sight.

5.27 Simple and Differential Levelling

When it is required to find the difference in elevation between two points, both of which are visible from a single position of the level, then method of simple levelling is used.

When the two points are too far apart, the difference in elevation between them is too great and there are obtacles between them, then a method of differential levelling is used to find the difference in elevation between them.

5.28 Reduction of Levels

The following are two methods of working out the reduced levels of points from the staff readings taken in the field :

1. Collimation or Height of instrument method, and
2. Rise and Fall method.

The *collimation method* consists in finding the elevation of the plane of collimation (H.I.) for evey set up of the instrument and then obtaining of reduced levels of points with reference to the respective plane of collimation. For an arithmetical check, the difference between the sum of the back sights (B.S.) and the sum of fore sights (F.S.) should be equal to the difference between the first and last reduced levels. There is no check on the reduction of the intermediate reduced levels. The collimation method is generally used in profile levelling and in setting out levels for constructional work.

The *rise and fall method* consists in determining the difference of level between consecutive points by comparing each point after the first with that immediately preceeding it. The difference between their staff readings indicates a rise or a fall according as the staff reading at the point is smaller or greater than that at the preceding point. The reduced level of each point is then found by adding rise or subtracting fall to or from the reduced level of the preceding point. The rise and fall method provides complete check on intermediate reduced level in addition to back sights and fore

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sights. This method is used for differential levelling and other precise levelling operations.

5.29 Contouring

A contour or a contour line may be defined as a line joining the points having the same elevation above the datumn surface. The process of tracing contour lines on the surface of the earth is called *contouring* and the maps upon which these lines are drawn are called *contour maps*.

The constant vertical distance between any two consecutive contours is called the *contour interval* and the horizontal distance between any two adjacent contours is termed as the *horizontal equivalent* and depends upon the slope of the ground. The contour interval depends upon the nature of the ground, scale of the map, purpose and extent of the survey. The contour interval of any survey is inversely proportional to the scale of the map and it should be constant throughout the survey.

The following are important characteristics of contours :

1. All points in a contour line have the same elevation.
2. When the contour lines are widely separated, it indicates a *flat ground* and when they are close together, it indicates a *steep ground*.
3. When the contour lines are uniformly spaced, it indicates a uniform slope and when they are straight, parallel and equally spaced, it indicated a plane surface.
4. A series of closed contour lines on the map indicates a *hill*, if the higher values are inside.
5. A series of closed contour lines on the map indicates a *depression*, if the higher values are outside.
6. The contour lines cross ridge or valley lines at right angles. If the higher values are inside the bend or loop in the contour, it indicates a *ridge* and if the higher values are outside the bend, it indicates a *valley*.
7. When the contour lines merge or cross one another on map, it indicates an *overhanging cliff*.
8. When several contours coincide and the horizontal equivalent becomes zero, it indicates a *vertical cliff*.

5.30 Methods of Contouring

There are mainly two methods of locating contours, *i.e.* direct method and indirect method.

In the *direct method*, the contours to be located are directly traced out in the field by locating and making a number of points on each contour. The direct method by radial lines is suitable for small areas where a single point in the centre can command the whole area.

In the *indirect method*, the points located and surveyed are not necessarily on the contour lines, but the *spot levels are taken along the series of lines laid out over the area. This method of contouring is also known as contouring by spot levels. This method is cheaper, quicker and less tedious as compared with direct method. The following three methods are mainly used :

(*a*) By squares, (*b*) By cross-sections, and (*c*) By tacheometer.

The cross-section method is most suitable for survey of long narrow strips such as a road, railway, canal etc. The tacheometric method is particularly suitable when a contoured map of a hill is required. The spacing of cross-sections in a hilly country is usually 20 m.

5.31 Interpolation of Contours

The process of spacing the contours proportionally between the plotted ground points is termed as *interpolation of contours*. There are three methods of interpolation, *i.e.* by estimation, by arithmetical calculation, and by graphical method. Out of these three methods, the arithmetical calculation is best method and is used for small areas where accurate results are necessary.

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* Spot level means the reduced level of a point on the surface of the ground.

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5.32 Plane Table Surveying

The method of surveying in which the field work and plotting are done simultaneously, is called *plane tabling*. It is commonly employed for small and medium scale mapping of comparatively large areas where great accuracy is not the main consideration such as for topographical surveys. It is less costly than a theodolite survey. It is particularly advantageous in magnetic areas. It is not suitable for work in a wet climate. In plane table surveying, the equipment essentially consists of a drawing board mounted on a tripod and a straight edge called an alidade. The alidade is available in two forms *i.e.* plain alidade and telescopic alidade. The telescopic alidade is used to measure horizontal and vertical distances directly.

In order to set up a plane table at a station, the following three operations are performed :

1. *Levelling*. It is the operation of setting up the plane table over a station point and at a convenient height. The legs of the tripod are spread well apart and fixed firmly to the ground. The levelling is done by means of levelling screws or by simply adjusting the legs.

2. *Centering*. It is the operation in which the plane table is so placed over the station on the ground that the point on the paper corresponding to the station occupied is exactly over the station on the ground. This may be done by means of plumbing fork or U-frame.

3. *Orientation*. It is the operation in which the plane table is turned so that all the lines on the paper are parallel to the corresponding lines on the ground.

5.33 Methods of Plane Tabling

The following are four methods of surveying with the plane table :

1. *Radiation*. In this method, the point is located on plan by drawing a ray from the plane table station to the point, and plotting to scale along the ray the distance measured from the station to the point. The method is suitable for plotting of small areas which can be commanded from a single station. It is chiefly used for locating the details from stations, which have been previously established by other method of surveying.

2. *Intersection*. In this method, the point is fixed on plan by the intersection of the rays drawn from the two instrument stations. The method is commonly employed for locating the distant and inaccessible points, locating the broken boundaries, and the point which may be used subsequently as the instrument stations.

3. *Traversing*. This method is similar to that of compass or transit traversing. It is used for running survey lines between stations which have been previously fixed by other method of surveying to locate topographical details. It is also suitable for the survey of roads, rivers etc.

4. *Resection*. This method is used for establishing the instrument stations only. After mixing the stations, the details are located either by radiation or intersection.

5.34 Two Point Problem and Three Point Problem

The *two point problem* consists in locating the position on the plan of the station occupied by the plane table, by means of observations to two well defined points, which are visible from the instrument station and whose positions have been already plotted on the plan.

The *three point problem* consists in locating on the plan the position of the instrument station on the ground by means of observations to three well defined points whose positions have been already plotted on the plan.

5.35 Curves

The curves are regular bends provided in the lines of communication like roads, railways etc. The circular curves are classificd as follows :

1. Simple curve, 2. Compound curve, 3. Reverse (or serpentine) curve and 4. Deviation curve.

A *simple curve* consists of a single arc of a circle connecting two straights. It has radius of the same magnitude throughout.

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A *compound curve* consists of two or more simple curves having different radii bending in the same direction and lying on the same side of the common tangent. Their centres lie on the same side of the curve.

A *reverse or serpentine curve* is made up of two arcs having equal or different radii bending in opposite directions with a common tangent at their junction. Their centres lie on the opposite sides of the curve.

A *deviation curve* is simply a combination of two reverse curves.

5.36 Transition Curves

A non-circular curve of varying radius introduced between a straight and a circular curve for the purpose of giving easy changes of direction of a route is called a *transition* or *easement curve*. The object of introducing a transition curve at each end of the circular curve is as follows :

(*a*) to obtain a gradual increase of curvature from zero at the tangent point to the specified quantity at the junction of the transition curve with the circular curve.

(*b*) to provide a satisfactory means of obtaining a gradual increase of super-elevation from zero on the tangent point to the specified amount on the main circular curve.

(*c*) to accomplish gradually the transition from the tangent to the circular curve and from the circular curve to the tangent.

A transition curve when inserted between the tangent and the circular curve should meet the tangent line as well as the circular curve tangentially. The rate of increase of curvature along the transition curve should be the same as that of increase of super-elevation.

The following three types of transition curves are in common use :

(*i*) cubic parabola, (*ii*) cubical spiral, and (*iii*) lemniscate.

The first two types are used on railways and highways both while third one is used on highways only.

5.37 Tacheometric Surveying

A branch of surveying in which the horizontal and vertical distances of point are obtained by angular observations with a tacheometer is called *tacheometric surveying*. A tacheometer, in a general sense, is a transit theodolite having a stadia telescope filled with two horizontal hairs called stadia hairs in addition to the usual cross hair. The principle of tacheometry is mainly used for locating contours, for hydrographic surveys, for filling in detail in topographic surveys and for location surveys for roads, railways, etc. It is also sometimes employed for small surveys in which elevations are not determined.

In the stadia system of tacheometry, though there are two methods of surveying *i.e.* fixed hair method and the movable method, yet the former is commonly used. In the fixed hair method, the distance between the stadia hairs is fixed. When a staff is sighted through the telescope, a certain length of staff is intercepted by the stadia lines and from this value of staff intercept, the distance from the instrument to the staff is determined. The staff intercept varies with its distance from the instrument. It may be noted that the horizontal distance (D) form the vertical axis of the instrument to the staff is given by :

$$D = \frac{f}{i} \times S + (f + d)$$

where

f = Focal length of the object glass,

i = Interval between stadia lines,

S = Staff intercept, and

d = Horizontal distance from optical centre to the vertical axis of the tacheometer.

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In the above equation, (f/i) is called the *multiplying constant* of the tacheometer whose value is, generally, kept as 100 while $(f+d)$ is called *additive constant* and its value varies from 30 cm to 45 cm. When an additional convex lens (known as anallatic lens) is provided in the telescope of a tacheometer, the additive constant is zero.

5.38 Computation of Areas

The calculation of areas forms an important part of land surveying. By the term 'area' is meant the area of a tract of land as projected upon a horizontal plane and not the actual area of the surface of the land. The following rules may be applied for finding the areas enclosed between the adjacent survey lines and the curved boundaries :

1. *Mid-ordinate rule.* According to this rule , the total sum of the ordinates at the mid-points of each division multiplied by the common distance between the ordinates gives the required area.

2. *Average ordinate rule.* According to this rule, the average of the ordinates multiplied by the length of the base line, gives the required area.

3. *Trapezoidal rule.* This rule may be stated as follows :

'To the sum of the first and the last ordinates, add twice the sum of the intermediate ordinates. The total sum thus obtained is multiplied by the common distance between the ordinates. One-half of this product gives the required area'.

4. *Simpson's rule.* This rule may be stated as follows :

'To the sum of the first and last ordinates, add twice the sum of the remaining odd ordinates and four times the sum of all the even ordinates. The total sum thus obtained is multiplied by one-third of the common distance between the ordinates and the result gives the required area.'

OBJECTIVE TYPE QUESTIONS

1. In plane surveying,

(*a*) the curvature of the earth is taken into consideration

(*b*) the curvature of the earth is not taken into consideration

(*c*) the surveys extend over small areas (*d*) the surveys extend over large areas

2. In geodetic surveying, the curvature of the earth is taken into consideration.

(*a*) Agree (*b*) Disagree

3. The curvature of the earth is taken into consideration if the limit of survey is

(*a*) 50 to 100 km^2 (*b*) 100 to 200 km^2

(*c*) 200 to 250 km^2 (*d*) more than 250 km^2

4. The difference is length between the arc and the subtended chord on the surface of the earth for a distance of 18.2 km is only

(*a*) 10 mm (*b*) 30 mm (*c*) 50 mm (*d*) 100 mm

5. The difference between the sum of the angles of a spherical triangle on the earth's surface and the angles of the corresponding plane triangle for every 195.5 km^2 of area is only

(*a*) 1 second (*b*) 5 second (*c*) 10 second (*d*) 15 second

6. In order to determine the natural features such as valleys, rivers, lakes etc., the surveying preferred is

(*a*) city surveying (*b*) location surveying

(*c*) cadastral surveying (*d*) topographical surveying

7. The reconnaissance surveying is carried out to determine the artificial features such as roads, railways, canals, buildings etc.

(*a*) True (*b*) False

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8. The surveying used to determine additional details such as boundaries of fields, is called
(a) city surveying (b) location surveying
(c) cadastral surveying (d) topographical surveying

9. The fundamental principle of surveying is to work from the
(a) whole to the part (b) part to the whole
(c) lower level to higher level (d) higher level to lower level

10. The working from whole to the part is done in surveying in order to ensure that
(a) survey work is completed more quickly (b) number of errors is minimum
(c) plotting is done more quickly
(d) errors and mistakes of one portion do not affect the remaining portion

11. The representative fraction of the scale is the ratio of the distance on the map or drawing to the corresponding distance on the ground.
(a) Yes (b) No

12. When 1 cm on a map represents 10 m on the ground, the representative fraction of the scale is
(a) 1/10 (b) 1/100 (c) 1/1000 (d) 1/10000

13. The representative fraction 1/2500 means that the scale is
(a) 1 cm = 0.25 m (b) 1 cm = 2.5 m (c) 1 cm = 25 m (d) 1 cm = 250 m

14. A plain scale is used to read
(a) one dimension (b) two dimensions (c) three dimensions (d) all of these

15. A diagonal scale is used to read ..... dimensions.
(a) two (b) three (c) four

16. A scale which has a common representative fraction, but read in different measures, is called a
(a) plain scale (b) diagonal scale (c) shrunk scale (d) comparative scale

17. A scale used for measuring fractional parts of the smallest division of the main scale is known as vernier scale.
(a) Correct (b) Incorrect

18. In a direct vernier, the smallest division of a vernier is ..... the smallest division of its primary scale
(a) equal to (b) shorter than (c) longer than

19. In a retrograde vernier, the smallest division of a vernier is ..... the smallest division of its primary scale.
(a) equal to (b) shorter than (c) longer than

20. With a simple vernier, readings can be taken in one direction only.
(a) Yes (b) No

21. Measurements taken with a wrong scale can be corrected by using the relation
(a) True length = $\frac{\text{Correct scale}}{\text{Wrong scale}} \times$ Measured length
(b) True length = $\left(\frac{\text{Correct scale}}{\text{Wrong scale}}\right)^2 \times$ Measured length
(c) True length = $\left(\frac{\text{Correct scale}}{\text{Wrong scale}}\right)^3 \times$ Measured length
(d) None of the above

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22. If x is the smallest division on the main scale and n are the number of divisions on the vernier, then the least count of the vernier is
(a) $x + n$ (b) $x - n$ (c) $x \times n$ (d) x / n

23. An average length of a pace is
(a) 60 cm (b) 80 cm (c) 100 cm (d) 120 cm

24. The method of measuring distance by pacing is chiefly used in
(a) reconnaissance surveys (b) preliminary surveys
(c) location surveys (d) all of these

25. A metallic tape is made of an alloy of nickel and steel.
(a) True (b) False

26. An invar tape is generally used for accurate measurement of distance because it possesses ..... coefficient of thermal expansion.
(a) zero (b) low (c) high

27. The instrument attached to the wheel of a vehicle in order to measure the distance travelled, is called
(a) passometer (b) pedometer (c) odometer (d) speedometer

28. It is more convenient and gives better results while measuring horizontal distance ..... by stepping method.
(a) down the hill (b) up the hill (c) in plane areas

29. Which of the following statement is correct ?
(a) The line ranger is used for fixing intermediate points on the chain lines.
(b) The indirect ranging is resorted to when the ends of a line are not intervisible due to high ground.
(c) The chainman at the forward end of the chain is called leader.
(d) all of the above

30. The correction to be applied to each 30 m chain for a line measured along a slope of θ is
(a) $30 (1 - \sin \theta)$ (b) $30 (1 - \cos \theta)$ (c) $30 (1 - \tan \theta)$ (d) $30 (1 - \cot \theta)$

31. Direct ranging is possible only when the end stations are
(a) close to each other (b) not more than 100 m apart
(c) mutually intervisible (d) located at highest points in the sea

32. The error in measured length due to incorrect holding of chain is
(a) compensating error (b) cumulative error (c) instrumental error (d) negative error

33. When the length of chain used in measuring distance is shorter than the standard length, the error in measured distance will be compensating error.
(a) Right (b) Wrong

34. When the length of chain used in measuring distance is longer than the standard length, the error in measured distance will be
(a) positive error (b) negative error
(c) compensating error (d) none of these

35. If a chain is used at a temperature ..... the temperature at which it was calibrated, the error in measured length is positive.
(a) equal to (b) lower than (c) higher than

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36. If a chain is used at a temperature ..... the temperature at which it was calibrated, the error in measured length is negative.
(a) equal to (b) lower than (c) higher than

37. The error in measured length due to sag of chain or tape is known as
(a) positive error (b) negative error
(c) compensating error (d) instrumental error

38. When the measured length is less than the actual length, the error is known as
(a) positive error (b) negative error
(c) compensating error (d) instrumental error

39. The positive error makes the measured distance ..... the actual distance.
(a) less than (b) more than

40. Which of the following statement is correct ?
(a) The error in measured length due to bad ranging is compensating error.
(b) If the chain used in measuring a distance is too short, the error is positive error.
(c) The error in measured length due to careless holding of chain is cumulative error.
(d) When the pull applied while measuring with a tape, is more than the standard pull for that tape, the error in measured length is positive.

41. The correction to the measured length will be negative when the chain is held on the ground sloping upwards.
(a) Yes (b) No

42. When (h) is the difference in heights between the extremities of a chain length (l), then the correction for slope required is
(a) h/l (b) h^2/l (c) $h^2/2l$ (d) $h/2l$

43. When the length of a chain along a slope of θ is (l), the correction for slope required is
(a) $l \sin^2\left(\frac{\theta}{2}\right)$ (b) $l \cos^2\left(\frac{\theta}{2}\right)$ (c) $2l \sin^2\left(\frac{\theta}{2}\right)$ (d) $2l \cos^2\left(\frac{\theta}{2}\right)$

44. Cumulative errors that occur in chaining are proportional to
(a) L (b) $\sqrt{L}$ (c) $1/L$ (d) $1/\sqrt{L}$
where L = Length of the line.

45. Compensating errors that occur in chaining are proportional to
(a) L (b) $\sqrt{L}$ (c) $1/L$ (d) $1/\sqrt{L}$
where L = Length of the line.

46. When a tape of length (L) and weight (w) N/m is stretched at its ends with a pull (P) N, then the correction for sag required is
(a) $\frac{wL}{24P}$ (b) $\frac{w^2L^2}{24P^2}$ (c) $\frac{w^3L^3}{24P^3}$ (d) $\frac{w^4L^4}{24P^4}$

47. The tension, at which the effects of pull and sag for a tape are neutralised, is known as
(a) initial tension (b) absolute tension (c) surface tension (d) normal tension

48. When a chain of designated length L and actual length L' is used for measuring a line, the true length of the line will be
(a) $\frac{L}{L'} \times$ measured length (b) $\frac{L'}{L} \times$ measured length
(c) $(L' - L) \times$ measured length (d) $(L' + L) \times$ measured length

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49. The longest of the chain lines used in making a survey is generally regarded as a base line.
(a) Agree (b) Disagree

50. A line joining the apex of a triangle to some fixed point on the opposite side is called a
(a) check line (b) tie line (c) base line (d) none of these

51. A line joining some fixed points on the main survey lines, is called a
(a) check line (b) tie line (c) base line (d) none of these

52. A base line in a chain survey
(a) checks the accuracy of the framework
(b) enables the surveyor to locate the interior details which are far away from the main chain lines
(c) fixes up the directions of all other lines
(d) all of the above

53. A plumb bob is required
(a) when measuring distances along slopes in a hilly country
(b) for accurate centering of a theodolite over a station mark
(c) for testing the verticality of ranging poles
(d) all of the above

54. Chain surveying is most suitable when
(a) area to be surveyed is small
(b) ground is fairly level and open with simple details
(c) plans are required on a large scale
(d) all of the above

55. Chain surveying consists of the arrangement of framework of triangles because a triangle is the ly simple plane figure which can be plotted uniquely if ..... of the triangle are known.
(a) three sides (b) three angles
(c) one side and two angles (d) one angle and two sides

56. In a well conditioned triangle, no angle should be less than
(a) 30° (b) 40° (c) 50° (d) 60°

57. A check line in a chain surveying
(a) checks the accuracy of the framework
(b) enables the surveyor to locate the interior details which are far away from the main chain lines
(c) fixes up the directions of all other lines
(d) all of the above

58. A tie line in a chain surveying
(a) checks the accuracy of the framework
(b) enables the surveyor to locate the interior details which are far away from the main chain lines
(c) fixes up the directions of all other lines
(d) all of the above

59. When the position of a point is to be located accurately by a perpendicular offset, the direction f perpendicular is set out by means of
(a) theodolite (b) optical square (c) dumpy level (d) planimeter

60. When the position of a point is to be fixed most accurately, it should be located by oblique ffsets.
(a) True (b) False

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61. The accuracy in laying down the perpendicular offsets and in measuring them depends upon
(a) scale of plotting (b) length of offset
(c) importance of the object (d) all of these

62. When the length of offset is 20 m, it is called ..... offset.
(a) short (b) long

63. The limiting length of the offset is ..... when its perpendicular direction is set out by eye.
(a) 5 m (b) 10 m (c) 15 m (d) 20 m

64. The instrument used for setting out an offset at a right angle, is called
(a) open cross-staff (b) french cross-staff
(c) adjustable cross-staff (d) optical square

65. In a field book, the booking is commenced at the bottom of a page and worked upwards.
(a) True (b) False

66. The adjustable cross-staff is used for setting out an offset
(a) at an angle of 45° (b) at an angle of 60° (c) at a right angle (d) at any angle

67. For setting out an offset at an angle of 45°, ... cross-staff is used.
(a) open (b) french (c) adjustable

68. A French cross-staff has a magnetic compass at the top.
(a) Right (b) Wrong

69. An open cross-staff is commonly used for setting out
(a) short offsets (b) long offsets (c) oblique offsets (d) none of these

70. An optical square is used for the same purpose as the cross-staff, but it is more accurate.
(a) Yes (b) No

71. The angle of intersection of the horizon glass and index glass in an optical square is
(a) 30° (b) 45° (c) 60° (d) 75°

72. The horizon glass in an optical square is
(a) wholly silvered (b) wholly unsilvered
(c) one-fourth silvered and three-fourth unsilvered
(d) half silvered and half unsilvered

73. The index glass in an optical square is
(a) wholly silvered (b) wholly unsilvered
(c) one-fourth silvered and three-fourth unsilvered
(d) half silvered and half unsilvered

74. The optical square is used to measure angles by
(a) refraction (b) reflection
(c) double refraction (d) double reflection

75. The instrument, belonging to a class of reflecting instrument, is
(a) line ranger (b) box sextent (c) prismatic compass (d) all of these

76. In an optical square, the angle between the first incident ray and the last reflected ray is
(a) 60° (b) 90° (c) 120° (d) 150°

77. When the object lies on the left hand side of the chain line, then while taking offset with an optical square, it is held in
(a) left hand upside down (b) right hand upside down
(c) left hand upright (d) right hand upright

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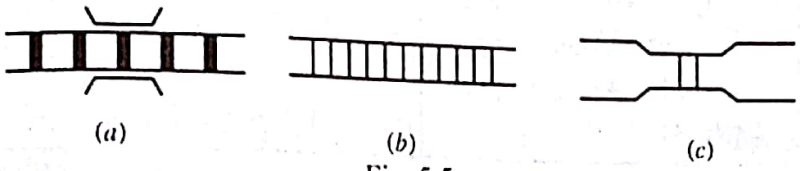
78. The angle between the reflecting surfaces of a prism square is
(a) 30° (b) 45° (c) 60° (d) 75°

79. The obstacle, which obstructs vision but not chaining, is a
(a) river (b) pond (c) hill (d) all of these

80. The obstacle, which obstructs chaining but not vision, is a
(a) river (b) hill (c) rising ground (d) all of these

81. The building is an example of obstacle in which chaining and vision are both obstructed.
(a) Correct (b) Incorrect

82. The conventional symbol, as shown in Fig. 5.5 (a), represents a
(a) road bridge (b) railway bridge (c) canal with lock (d) none of these



(a) (b) (c)

Fig. 5.5

83. The conventional symbol, as shown in Fig. 5.5 (b), represents a ..... railway line.
(a) single (b) double

84. The conventional symbol, as shown in Fig. 5.5 (c), represents a
(a) road bridge (b) railway bridge (c) canal with lock (d) none of these

85. In a prismatic compass, the zero of the graduated ring is located at
(a) north end (b) south end (c) east end (d) west end

86. The true or geographical meridians through the various stations
(a) are parallel (b) converge to the poles
(c) converge from north pole to south pole (d) converge from south pole to north pole

87. The direction of a true meridian at a station is invariable.
(a) Right (b) Wrong

88. The line in which the plane passing through the given point and the north and south poles intersects the surface of the earth, is called
(a) arbitrary meridian (b) magnetic meridian (c) true meridian (d) none of these

89. In a whole circle system, the bearing of a line is measured
(a) always clockwise from the south point of the reference meridian towards the line right round the circle
(b) clockwise or anticlockwise from the east or west whichever is nearer the line towards north or south
(c) clockwise or anticlockwise from the north or south whichever is nearer the line towards east or west
(d) none of the above

90. In a quadrantal system, the bearing of a line is measured
(a) always clockwise from the south point of the reference meridian towards the line right round the circle
(b) clockwise or anticlockwise from the east or west whichever is nearer the line towards north or south
(c) clockwise or anticlockwise from the north or south whichever is nearer the line towards east or west
(d) none of the above

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91. The bearing observed with a prismatic compass is ..... of a line.
(a) whole circle bearing (b) quadrantal bearing

92. The bearing observed with a surveyor's compass is ..... of a line.
(a) whole circle bearing (b) quadrantal bearing

93. In a whole circle bearing system, $S\ 25°\ 15'\ E$ corresponds to
(a) $115°\ 15'$ (b) $154°\ 45'$ (c) $205°\ 15'$ (d) $334°\ 45'$

94. The whole circle bearing is given in *Group A*. Match the correct answer from Group B quadrantal bearing system.

Group A	Group B
(a) $62°\ 20'$	(A) $S\ 35°\ 45'\ W$
(b) $148°\ 15'$	(B) $N\ 46°\ 45'\ W$
(c) $215°\ 45'$	(C) $S\ 31°\ 45'\ E$
(d) $313°\ 15'$	(D) $N\ 62°\ 20'\ E$

95. In a whole circle bearing system $N\ 25°\ 15'\ W$ corresponds to
(a) $115°\ 15'$ (b) $154°\ 45'$ (c) $205°\ 15'$ (d) $334°\ 45'$

96. The bearing of a line in the direction of the progress of survey is called back bearing.
(a) Yes (b) No

97. If the fore bearing of a line is $36°\ 15'$, its back bearing will be
(a) $36°\ 15'$ (b) $126°\ 15'$ (c) $143°\ 45'$ (d) $216°\ 15'$

98. If the fore bearing of a line is ....., its back bearing will be $36°\ 15'$.
(a) $36°\ 15'$ (b) $126°\ 15'$ (c) $143°\ 45'$ (d) $216°\ 15'$

99. If the fore bearing of a line is $N\ 26°\ 35'\ W$, its back bearing will be
(a) $S\ 26°\ 35'\ E$ (b) $S\ 26°\ 35'\ W$ (c) $N\ 26°\ 35'\ E$ (d) $N\ 53°\ 25'\ W$

100. When the whole circle bearing of two lines AB and AC are 115° and 41° respectively, then included angle BAC will be
(a) 41° (b) 74° (c) 115° (d) 156°

101. The horizontal angle between the true meridian and a survey line is called
(a) magnetic bearing (b) azimuth (c) dip (d) magnetic declination

102. The horizontal angle between the true meridian and magnetic meridian is known as
(a) true bearing (b) dip (c) local attraction (d) magnetic declination

103. Due to the magnetic influence of the earth, the magnetic needle of the prismatic compass may be inclined downward towards the pole. This inclination of the needle with the horizontal is known as
(a) true bearing (b) dip (c) local attraction (d) magnetic declination

104. At the equator, the amount of dip is
(a) 0° (b) 45° (c) 60° (d) 90°

105. At the magnetic poles, the amount of dip is
(a) 0° (b) 45° (c) 60° (d) 90°

106. Which of the following statement is wrong ?
(a) The magnetic meridian coincides with the true meridian at all the places.
(b) The magnetic meridian does not vary from place to place on the earth's surface.
(c) The magnetic declination at a place is constant.
(d) all of the above

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107. The lines of earth's magnetic field run from
(a) south to north (b) north to south (c) east to west (d) west to east

108. In order to fix up the directions of the survey lines in the compass survey, the horizontal angle between the survey line and a fixed line of reference is measured. This fixed line reference is the magnetic meridian.
(a) True (b) False

109. The lines passing through points at which the magnetic declination is equal at a given time are called
(a) isogonic lines (b) agonic lines (c) isoclinic lines (d) none of these

110. The diurnal variation of the magnetic needle is ..... near the equator.
(a) more (b) less

111. In high latitudes, the diurnal variation of the magnetic needle is greater.
(a) Agree (b) Disagree

112. The diurnal variation of the magnetic needle is more in ..... at the same place.
(a) summer than winter (b) winter than summer

113. When the magnetic bearing of the sun at noon is 185° 20′, the magnetic declination will be
(a) 5° 20′ east (b) 5° 20′ west (c) 5° 20′ north (d) 5° 20′ south

114. When the magnetic declination is 5° 20′ east, the magnetic bearing of the sun at noon will be
(a) 95° 20′ (b) 174° 40′ (c) 185° 20′ (d) 354° 40′

115. The magnetic bearing of a line is 55° 30′ and the magnetic declination is 4° 30′ west. The true bearing of a line will be
(a) 30° (b) 34° 30 (c) 49° (d) 51°

116. The magnetic bearing of a line is *S* 35° 30′ *E* and the magnetic declination is 4° 10′ east. The true bearing of a line will be
(a) *S* 31° 30′ *E* (b) *S* 31° 30′ *W* (c) *S* 39° 50′ *E* (d) *S* 39° 50′ *W*

117. When the magnetic declination is negative, the magnetic meridian is towards the west of true meridian.
(a) Correct (b) Incorrect

118. The theodolite is an instrument used for measuring very accurately
(a) horizontal angles only (b) vertical angles only
(c) horizontal and vertical angles (d) linear measurements

119. The process of turning the telescope of a theodolite over its supporting axis through 180° in a vertical plane, is called
(a) transiting (b) reversing (c) plunging (d) any one of these

120. An imaginary line joining the point of intersection of the cross-hairs of the diaphragm and the optical centre of the object glass, is known as
(a) fundamental line (b) axis of telescope
(c) axis of level tube (d) line of collimation

121. A line joining the optical centre of the object glass and the centre of the eye piece, is known as
(a) fundamental line (b) axis of telescope
(c) axis of level tube (d) line of collimation

122. The axis of bubble tube must be perpendicular to the vertical axis.
(a) Right (b) Wrong

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123. The line of collimation must be parallel to the horizontal axis.
(a) Yes (b) No

124. The axis of telescope level must be ..... to the line of collimation.
(a) parallel (b) perpendicular

125. In the surveying telescopes, cross hairs are fitted in
(a) centre of the telescope (b) optical centre of the eye piece
(c) front of the eye piece (d) front of the objective

126. In the surveying telescope, diaphragm is held
(a) inside the eye piece (b) inside the objective
(c) nearer to the eye piece (d) nearer to the objective

127. The image formed by the objective in the plane of cross hairs is
(a) real and straight (b) real and inverted
(c) virtual and straight (d) virtual and inverted

128. An imaginary line tangential to the longitudinal curve of the level at the centre of the t called
(a) horizontal axis (b) vertical axis
(c) axis of the level tube (d) line of collimation

129. An axis about which the telescope can be rotated in a horizontal plane, is called
(a) horizontal axis (b) vertical axis
(c) axis of the level tube (d) line of collimation

130. The real image of an object formed by the objective must lie at the centre of telescope.
(a) Agree (b) Disagree

131. When the image formed by the objective is not situated in the plane of cross-hairs,
(a) the cross-hairs should be adjusted (b) the eye-piece should be focussed
(c) the objective should be focussed (d) the parallex should be removed

132. When the cross-hairs are not clearly visible,
(a) the cross-hairs should be adjusted (b) the eye-piece should be focussed
(c) the objective should be focussed (d) the parallex should be removed

133. For removing the parallex,
(a) the eye-piece should be focussed for distinct vision of cross-haris
(b) the image of the object should be brought in the plane of cross-hairs
(c) either (a) or (b) (d) both (a) and (b)

134. The capacity of a telescope of producing a sharp image is called its
(a) definition (b) brightness (c) sensitivity (d) magnificati

135. The brightness of the image ..... the magnifying power.
(a) is directly proportional to (b) is inversely proportional to
(c) varies directly as the square of (d) varies inversely as the square of

136. The image produced by the telescope will be dull, if it has ..... magnification.
(a) low (b) high

137. A low magnification of a telescope produces ..... image.
(a) dull (b) bright

138. If the definition of a telescope is poor, it will produce a clear and distinct image.
(a) True (b) False

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139. The ratio of the focal length of the objective to that of an eye-piece of a telescope is called its
(a) definition (b) brightness (c) sensitivity (d) magnification

140. The power of a telescope to form distinguishable images of objects separated by small angular distance is called its
(a) definition (b) brightness (c) sensitivity (d) resolving power

141. The magnification of a telescope is the ratio of the angle subtended at the eye by the virtual image of the object to that subtended by the object.
(a) Correct (b) Incorrect

142. The angle of field of the telescope
(a) is independent of the size of the object galss
(b) increases as the size of the eye piece increases
(c) decreases as the distance between eye piece and object increases
(d) all of the above

143. The capability of showing small angular movements of the level tube vertically, is called its ensitivity.
(a) Right (b) Wrong

144. In order to measure a horizontal angle more accurately than a vernier, a
(a) method of repitition is used (b) method of reiteration is used
(c) method of deflection angles is used (d) method of double observations is used

145. In measuring horizontal angles, the theodolite should be turned
(a) clockwise from the forward station to the back station
(b) clockwise from the back station to the forward station
(c) anticlockwise from the forward station to the back station
(d) anticlockwise from the back station to the forward station

146. The method of reiteration of measuring horizontal angles is generally preferred when several ngles are to be measured at a particular station.
(a) Yes (b) No

147. An angle made by a survey line with the prolongation of the proceeding line, is known as
(a) direct angle (b) vertical angle (c) horizontal angle (d) deflection angle

148. A deflection angle in a traverse is equal to the
(a) difference between the included angle and 180°
(b) difference between 360° and the included angle
(c) sum of the included angle and 180°
(d) none of the above

149. The deflection angle may have any value between
(a) 0° and 45° (b) 0° and 90° (c) 0° and 120° (d) 0° and 180°

150. An angle measured clockwise from the proceeding survey line to the following survey line is called
(a) direct angle (b) vertical angle (c) horizontal angle (d) deflection angle

151. The deflection angle may be directly obtained by setting the instrument to read ..... on back station.
(a) 0° (b) 90° (c) 180° (d) 270°

152. The direct angles may have any value between
(a) 0° and 90° (b) 0° and 120° (c) 0° and 180° (d) 0° and 360°

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153. In railway and highway works, the method of measuring the ..... is generally emplo
(a) direct angles (b) deflection angles

154. An angle between the inclined line of sight and the horizontal is called
(a) direct angle (b) vertical angle (c) horizontal angle (d) deflection a

155. Generally, the deflection angle is measured twice, once with the telescope normal and with the telescope reversed.
(a) True (b) False

156. In locating the details of an object whose direct measurement is not possible due to obstruction, the method used is
(a) by angles and distances from the same station
(b) by angle from one station and distance from the other station
(c) by distance from two different stations
(d) by angles from two different stations

157. In locating the details of inaccessible objects visible atleast from transit stations, the me used is
(a) by angles and distances from the same station
(b) by angle from one station and distance from the other station
(c) by distances from two different stations
(d) none of the above

158. The traversing by the method of deflection angles is chiefly used in
(a) canals (b) highways (c) railways (d) all of these

159. In precision theodolite traverse for roads and railways, the angular error of closure should exceed
(a) $15''\sqrt{N}$ (b) $30''\sqrt{N}$ (c) $45''\sqrt{N}$ (d) $1'\sqrt{N}$
where N = Number of angles.

160. The projection of a traverse line on a line perpendicular to the meridian is known as
(a) latitude of the line (b) departure of the line
(c) bearing of the line (d) co-ordinate of the line

161. Which of the following statement is wrong ?
(a) The distance measured parallel to the north-south line is called latitude of the line.
(b) The distance measured parallel to the east-west line is called departure of the line.
(c) The latitude is positive when measured downward or southward.
(d) The departure is negative when measured to the left or westward.

162. The projection of a traverse line on a line parallel to the meridian is known as ..... of the li
(a) latitude (b) departure (c) bearing

163. In any closed traverse, if the survey work is correct, then
(a) the algebraic sum of latitudes should be equal to zero
(b) the algebraic sum of departures should be equal to zero
(c) the sum of northings should be equal to the sum of southings
(d) all of the above

164. The latitude of a traverse line is obtained by multiplying its length with the cosine of its reduc bearing.
(a) Correct (b) Incorrect

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165. The departure of a traverse line is obtained by multiplying its length with the tangent of its reduced bearing.
(a) Agree (b) Disagree

166. When the whole circle bearing of a traverse line is between 90° and 180°, then
(a) the latitude is positive and departure is negative
(b) the departure is positive and latitude is negative
(c) both the latitude and departure are positive
(d) both the latitude and departure are negative

167. The latitude and departure of a traverse line are both positive when the whole circle bearing of the line lies in the
(a) first quadrant (b) second quadrant (c) third quadrant (d) fourth quadrant

168. When the latitudes and departures are so adjusted that the algebraic sum of the latitudes and departures are equal to zero, the operation is called
(a) balancing the latitude (b) balancing the departure
(c) balancing the traverse (d) none of these

169. When the angular and linear measurements are equally precise in traversing, the balancing of a traverse is done by
(a) transit rule (b) empirical rule (c) Bowditch's rule (d) any one of these

170. When the angular measurements of a traverse are more precise than the linear measurements, the balancing of a traverse is done by
(a) transit rule (b) empirical rule (c) Bowditch's rule (d) any one of these

171. The length of a traverse line (L) may be obtained by
(a) $L = \sqrt{(\text{Latitude})^2 \times (\text{Departure})^2}$ (b) L = Latitude × secant of reduced bearing
(c) L = Departure × cosecant of reduced bearing
(d) any one of the above

172. The distance by which the last point of the traverse falls short to coincide with the starting point is called the closing error.
(a) Right (b) Wrong

173. The method of surveying used for determining the relative height of points on the surface of the earth is called
(a) levelling (b) simple levelling
(c) longitudinal levelling (d) differential levelling

174. A surface which is normal to the direction of gravity at all points, as indicated by a plumb line, is known as
(a) datum surface (b) level surface (c) horizontal surface (d) vertical surface

175. An arbitrary surface with reference to which the elevation of points are measured and compared, is called
(a) datum surface (b) level surface (c) horizontal surface (d) vertical surface

176. A line normal to the plumb line at all points is known as
(a) horizontal line (b) vertical line
(c) level line (d) line of collimation

177. A vertical line at any point is a line normal to the level surface at that point.
(a) Yes (b) No

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178. The vertical distance above or below the datum is called
(*a*) reduced level of the point (*b*) elevation of the point
(*c*) height of the instrument (*d*) either (*a*) or (*b*)

179. The height of instrument is the height of the centre of the telescope above the ground where level is set up.
(*a*) True (*b*) False

180. Match the correct answer from *Group B* for the statements given in *Group A*.

Group A	*Group B*
(*a*) The first staff reading taken after setting up the instrument, is called	(*A*) positive
(*b*) The last staff reading taken before moving the instrument, is called	(*B*) station point
(*c*) When the point is above the datum, the reduced level of the point will be	(*C*) back sight
(*d*) A point on which the staff is held, is called	(*D*) fore sight

181. A back sight indicates the ..... of the instrument.
(*a*) shifting (*b*) setting up (*c*) height

182. The point on which the instrument is set up, is called station point.
(*a*) True (*b*) False

183. A fixed point of reference of known elevation is called
(*a*) change point (*b*) station point (*c*) bench mark (*d*) datum

184. An imaginary line tangential to the longitudinal curve of the bubble tube at its middle poi called
(*a*) axis of telescope (*b*) axis of level tube
(*c*) level line (*d*) line of collimation

185. A staff reading taken on a bench mark or a point of known elevation is called
(*a*) fore sight reading (*b*) back sight reading
(*c*) intermediate sight (*d*) any one of these

186. A staff reading taken on a point whose elevation is to be determined as on a change poi called
(*a*) fore sight reading (*b*) back sight reading
(*c*) intermediate sight (*d*) none of these

187. The line of collimation should be ..... when staff readings are being taken
(*a*) vertical (*b*) horizontal

188. To find the true difference of level between two points, the level should be kept
(*a*) at either of the two points (*b*) exactly midway between the two poi
(*c*) at any point on the line joining the two points
(*d*) none of the above

189. For accurate work, the lengths of back sight and fore sight are kept unequal.
(*a*) Agree (*b*) Disagree

190. The reduced level of the plane of collimation is ..... height of instrument.
(*a*) equal to (*b*) less than (*c*) greater than

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191. The height of instrument is equal to
(a) reduced level of bench mark + back sight
(b) reduced level of bench mark + fore sight
(c) reduced level of bench mark + intermediate sight
(d) back sight + fore sight

192. The levelling should always commence from a temporary bench mak and end on a permanent bench mark.
(a) Correct (b) Incorrect

193. A method of differential levelling is used in order to find the difference in elevation between two points when
(a) they are too far apart (b) there are obstacles between them
(c) the difference in elevation between them is too great
(d) all of the above

194. The collimation method for obtaining the reduced levels of points does not provide a check on
(a) fore sights (b) back sights
(c) change points (d) intermediate sights

195. The rise and fall method for obtaining the reduced levels of points provides a check on
(a) fore sights only (b) back sights only
(c) intermediate sights only (d) all of these

196. It is required to find the difference in elevation between two points *A* and *B*. During levelling, it is found that the staff reading at *B* is more than the staff reading at *A*. It indicates that the point *A* is ..... the point *B*.
(a) higher than (b) lower than

197. Collimation method is used in
(a) profile levelling (b) differential levelling
(c) check levelling (d) both (a) and (b)

198. Rise and fall method is used in.
(a) profile levelling (b) differential levelling
(c) check levelling (d) none of these

199. The method of levelling in which the heights of mountains are found by observing the temperature at which water boils is known as
(a) barometric levelling (b) reciprocal levelling
(c) longitudinal levelling (d) hypometry

200. Which of the following statement is correct ?
(a) In levelling, the effect of curvature is to decrease the staff reading.
(b) The effect of refraction in levelling is to increase the staff reading.
(c) The combined effect of curvature and refraction in levelling is to increase the staff reading.
(d) all of the above

201. In levelling, the effect of refraction varies with the atmospheric conditions.
(a) Yes (b) No

202. When the effect of curvature is taken into account in levelling, the true staff reading is obtained by ..... the correction of curvature from the observed staff reading.
(a) adding (b) subtracting

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203. In levelling, the effect of refraction may be taken as ..... of that due to curvature.
(a) one-half (b) one-third (c) one-fifth (d) one-seventh

204. When the effect of refraction is taken into account in levelling, the true staff reading is obtained by subtracting the correction for refraction from the observed staff reading.
(a) Right (b) Wrong

205. In levelling, the correction for curvature (in metres) is equal
(a) $0.00785\ D^2$ (b) $0.0785\ D^2$ (c) $0.0112\ D^2$ (d) $0.0673\ D^2$
where D = Distance from the level to the staff reading in kilometres.

206. In levelling, the correction for combined curvature and refraction (in metres) is equal to
(a) $0.00785\ D^2$ (b) $0.0785\ D^2$ (c) $0.0112\ D^2$ (d) $0.0673\ D^2$

207. The error which is not completely eliminated in reciprocal levelling, is
(a) error due to curvature (b) error due to refraction
(c) error due to non-adjustment of the line of collimation
(d) error due to non-adjustment of bubble tube

208. The line joining the points having the same elevation above the datum surface, is called a
(a) contour surface (b) contour line (c) contour interval (d) contour gradient

209. The contour interval depends upon the
(a) nature of the ground (b) scale of map
(c) purpose and extent of survey (d) all of these

210. The vertical distance between any two consecutive contours is called
(a) vertical equivalent (b) horizontal equivalent
(c) contour interval (d) contour gradient

211. The horizontal distance between any two consecutive contours is called
(a) vertical equivalent (b) horizontal equivalent
(c) contour interval (d) contour gradient

212. The contour interval of any survey is inversely proportional to the scale of the map.
(a) Agree (b) Disagree

213. The contour interval ..... throughout the survey.
(a) should be constant (b) need not be constant

214. The contour lines can cross one another on map only in the case of
(a) a vertical cliff (b) a valley (c) a ridge (d) an overhanging cliff

215. When several contours coincide, it indicates
(a) a vertical cliff (b) a valley (c) a ridge (d) a saddle

216. Which of the following statement is wrong ?
(a) A series of closed contour lines on the map indicates a depression if the higher values are inside.
(b) A series of closed contour lines on a plane indicates a hill if the higher values are outside
(c) The uniformly spaced contour lines indicates a plane surface.
(d) all of the above

217. Contour lines cross ridge or valley lines at
(a) 30° (b) 45° (c) 60° (d) 90°

218. The points on a contour gradient will have the same elevation.
(a) True (b) False

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219. The reduced level of a point on the ground is called
(a) spot level (b) spot height (c) either (a) or (b) (d) none of these

220. In route surveys, the most suitable method of contouring is
(a) by squares (b) by radial lines (c) by cross-sections (d) by tacheometer

221. The tacheometric method of contouring is particularly suitable
(a) when a contoured map of hill is required (b) when the area is not very extensive
(c) in surveys of roads or railways (d) all of these

222. The spacing of cross-sections in a hilly country is usually
(a) 5 m (b) 10 m (c) 15 m (d) 20 m

223. In indirect method of contouring, the best method of interpolation of contours is
(a) by graphical method (b) by estimation
(c) by arithmetical calculation (d) all of these

224. The method of surveying in which field work and plotting work are done simultaneously, is called
(a) compass surveying (b) levelling (c) plane tabling (d) chain surveying

225. In plane tabling, the instrument used to measure horizontal and vertical distances directly, is known as
(a) plane alidade (b) telescopic alidade (c) tacheometer (d) clinometer

226. The plane table surveying is
(a) most suitable for preparing small-scale maps
(b) particularly advantageous in magnetic areas
(c) less costly than a theodolite survey
(d) all of the above

227. In plane table surveying, field work is recorded in a field book to be plotted afterwards.
(a) Agree (b) Disagree

228. The operation of turning the table so that all the lines on the paper are parallel to the corresponding lines on the ground, is called
(a) levelling (b) centering (c) setting (d) orientation

229. The plotting of small areas which can be commanded from a single station, is usually done on the plane table by the method of
(a) radiation (b) intersection (c) traversing (d) resection

230. The method of intersection in plane tabling is commonly used for
(a) locating the distant and inaccessible points
(b) locating the broken boundaries
(c) locating the points which may be used subsequently as the instrument stations
(d) all of the above

231. The method of plane tabling commonly used for establishing the instrument stations only, is a
(a) method of radiation (b) method of intersection
(c) method of traversing (d) method of resection

232. According to Lehman's rule of plane tabling
(a) the distance to the point sought from each of the three rays is proportional to the distance of the three known points from the instrument station
(b) when the instrument station is outside the great circle, the point sought is always on the same side of the ray drawn to the most distant point as the intersection of the other two rays
(c) when looking in the direction of the reference points, the point sought is on the same side of each of the three rays
(d) all of the above

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233. The strength of 'fix' of a plane table from three known points is good if the ..... than the other two stations.
(a) nearer (b) farther

234. The strength of 'fix' of a plane table from three known points is poor if the instrument sta is near the great circle.
(a) Correct (b) Incorrect

235. A reverse curve consists of
(a) a single curve of a circle connecting two straights
(b) two arcs of different radii bending in the same direction
(c) two arcs of equal radii bending in the same direction
(d) two arcs of equal or different radii bending in the opposite directions

236. A compound curve consists of two arcs of equal radii bending in the same direction.
(a) Right (b) Wrong

237. When the centres of the arcs lie on the opposite sides of the common tangent at the junctio the two curves, it is known as a
(a) simple curve (b) vertical curve (c) compound curve (d) reverse curv

238. A simple circular cruve is designated by the
(a) radius of the curve (b) cruvature of the curve
(c) angle subtended at the centre by a chord of any length
(d) angle subtended at the centre by a chord of particular length

239. The degree of the curve is the angle subtended by a chord of ..... length.
(a) 15 m (b) 20 m (c) 25 m (d) 30 m

240. When R is the radius of the curve (in metres), D is the degree of curve (in degrees) and len of the chord is 30 m, then the relation between R and D is
(a) $R = 1520/D$ (b) $R = 1720/D$ (c) $R = 4500/D$ (d) $R = 5400/D$

241. The angle between the back tangent and forward tangent of a curve is known as
(a) deflection angle (b) central angle (c) angle of intersection (d) none of thes

242. The angle by which the forward tangent deflects from the back tangent of a curve is calle
(a) deflection angle (b) central angle (c) angle of intersection (d) none of thes

243. A deflection angle is
(a) less than 90° (b) more than 90° but less than 180°
(c) equal to the difference between the angle of intersection and 180°
(d) equal to the difference between the angle of intersection and 360°

244. The length of peg interval for flat curves is
(a) 15 m (b) 20 m (c) 25 m (d) 30 m

245. When the length of a chord is less than the peg interval, it is known as
(a) small chord (b) short chord (c) sub-chord (d) normal chor

246. The total length of the curve is equal to
(a) $\pi R \phi$ (b) $\frac{\pi R \phi}{90}$ (c) $\frac{\pi R \phi}{180}$ (d) $\frac{\pi R \phi}{360}$
where R = Radius of the curve, and
ϕ = Deflection angle.

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247. The length of a long chord is equal to

(a) $R \sin \phi$ (b) $R \cos \phi$ (c) $2R \sin \frac{\phi}{2}$ (d) $2R \cos \frac{\phi}{2}$

248. The distance between the midpoint of the long chord and the mid-point of the curve, is equal to

(a) $R(1 - \sin \phi)$ (b) $R(1 - \cos \phi)$ (c) $R\left(1 - \frac{\sin \phi}{2}\right)$ (d) $R\left(1 - \frac{\cos \phi}{2}\right)$

249. The deflection angle for any chord is equal to the deflection angle for the proceeding chord minus the tangential angle for that chord.

(a) Yes (b) No

250. When the curve is to be set out over a rough ground, the method used is

(a) Rankine's method (b) two theodolite method
(c) tacheometric method (d) either (b) or (c)

251. Two theodolite method of setting out a curve involves

(a) linear measurements only (b) angular measurements only
(c) both linear and angular measurements (d) none of these

252. In tacheometric method of setting out a curve, no chain or tape is used.

(a) True (b) False

253. A curve of varying radius is known as

(a) simple curve (b) compound curve
(c) reverse curve (d) transition cruve

254. The object of introducing a transition curve at each end of the circular curve is

(a) to obtain a gradual increase of curvature from zero at the tangent point to the specified quantity at the junction of the transition curve with the circular curve
(b) to provide a satisfactory means of obtaining a gradual increase of super-elevation from zero on the tangent point to the specified amount on the main circular curve
(c) to accomplish gradually the transition from the tangent to the circular curve and from the circular curve to the tangent
(d) all of the above

255. A transition curve when inserted between the tangent and the circular curve

(a) should meet the original straight tangentially
(b) should meet the circular curve tangentially
(c) the rate of increase of curvature along the transition curve should be same as that of increase of super-elevation
(d) all of the above

256. The amount of super-elevation on railways is equal to

(a) gv^2/GR (b) Gv^2/gR (c) GR/gv^2 (d) gR/Gv^2

where G = Distance between the centres of the rails in metres,
R = Radius of the curve in metres, and
v = Speed of the vehicle in m/s.

257. In the above question, the expression v^2/gR is called

(a) radial acceleration (b) centrifugal force (c) centrifugal ratio (d) super-elevation

258. The magnitude of super-elevation depends upon the speed of the vehicle and the radius of the curve.

(a) Correct (b) Incorrect

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259. The fundamental requirement of the spiral curve is that its radius of curvature at any point shall vary inversely as the distance from the beginning of the curve.
(*a*) Agree (*b*) Disagree

260. The curve used for ideal transition curve is a
(*a*) cubic parabola (*b*) clothoid spiral (*c*) cubic spiral (*d*) lemniscate

261. The perpendicular offset from a tangent to the junction of transition curve and circular curve is equal to
(*a*) $L/6R$ (*b*) $L/24R$ (*c*) $L^2/6R$ (*d*) $L^2/24R$
where L = Length of the transition curve, and
R = Radius of the circular curve.

262. The shift of a curve is equal to
(*a*) $L/6R$ (*b*) $L/24R$ (*c*) $L^2/6R$ (*d*) $L^2/24R$

263. The shift of a curve is ..... the perpendicular offset from a tangent to the junction transition curve and circular curve.
(*a*) equal to (*b*) one-half (*c*) one-third (*d*) one-fourth

264. When the sight distance (S) is equal to the length of the vertical curve ($2l$) joining two gradients $+g_1\%$ and $-g_2\%$, then the height of the apex is equal to
(*a*) $\dfrac{(g_1 - g_2)l}{400}$ (*b*) $\dfrac{S - l}{400}(g_1 - g_2)$ (*c*) $\dfrac{(g_1 - g_2)S^2}{1600l}$ (*d*) $\dfrac{(g_1 - g_2)S}{800l}$

265. The autogenous curve of an automobile corresponds to a
(*a*) cubic parabola (*b*) clothoid spiral (*c*) true spiral (*d*) lemniscate

266. The polar equation for a lemniscate curve is
(*a*) $l = k\sqrt{\sin\alpha}$ (*b*) $l = k\sqrt{\sin 2\alpha}$ (*c*) $l = k\sqrt{\cos\alpha}$ (*d*) $l = k\sqrt{\cos}$
where α = Polar deflection angle of any point on the lemniscate curve.

267. A lemniscate curve between the tangents is transitional throughout, if the polar deflection angle of its apex is equal to
(*a*) $\phi/3$ (*b*) $\phi/4$ (*c*) $\phi/5$ (*d*) $\phi/6$
where ϕ = Deflection angle.

268. In a lemniscate curve, the angle between the tangent at the end of the polar ray and the tangent at the commencement of the curve (*i.e.* straight) is ..... the angle between the polar ray and straight.
(*a*) equal to (*b*) double (*c*) three times (*d*) four times

269. A branch of surveying in which the horizontal and vertical distances of points are obtained instrumental observations, is known as
(*a*) chain surveying (*b*) plane table surveying
(*c*) tacheometric surveying (*d*) hydrographic surveying

270. A stadia telescope, in a tacheometer, is fitted with
(*a*) two additional vretical hairs (*b*) two additional horizontal hairs
(*c*) cross hairs only (*d*) all of these

271. The principle of tacheometry is used
(*a*) for locating contours (*b*) on hydrographic surveys
(*c*) for filling in detail in topographic surveys (*d*) all of these

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272. When a staff is sighted through the telescope, a certain length of staff is intercepted by the stadia lines. The staff intercept varies with the distance at which the staff is held.
(a) Yes (b) No

273. The multiplying constant for the tacheometer is
(a) f/i (b) i/f (c) f/d (d) $f+d$
where f = Focal length of the objective,
i = Interval between the stadia lines or hairs, and
d = Horizontal distance from the optical centre to the vertical axis of the tacheometer.

274. The additive constant for the tacheometer is
(a) f/i (b) i/f (c) f/d (d) $f+d$

275. The multiplying constant for the tacheometer is, generally, kept as
(a) 20 (b) 40 (c) 60 (d) 100

276. The value of additive constant for the tacheometer varies from
(a) 0 to 15 cm (b) 15 to 30 cm (c) 30 to 45 cm (d) 45 to 60 cm

277. When the anallatic lens is provided in the telescope of a tacheometer, the additive constant is zero.
(a) Agree (b) Disagree

278. To the sum of the first and last ordinates, add twice the sum of the intermediate ordinates. The total sum thus obtained is multiplied by the common distance between the ordinates. One-half of this product gives the required area. This rule of finding the area is called
(a) mid-ordinate rule (b) trapezoidal rule
(c) average ordinate rule (d) Simpson's rule

279. To the sum of the first and last ordinates, add twice the sum of the remaining odd ordinates and four times the sum of all the even ordinates. The total sum thus obtained is multiplied by one-third of the common distance between the ordinates and the result gives the required area. This rule of finding the area is called
(a) mid-ordinate rule (b) trapezoidal rule
(c) average ordinate rule (d) Simpson's rule

280. The area of any irregular figure can be calculated accurately with the help of a planimeter.
(a) True (b) False

ANSWERS

1. (b), (c)	2. (a)	3. (d)	4. (a)	5. (a)	6. (d)
7. (b)	8. (c)	9. (a)	10. (d)	11. (a)	12. (c)
13. (c)	14. (b)	15. (b)	16. (d)	17. (a)	18. (b)
19. (c)	20. (a)	21. (d)	22. (d)	23. (b)	24. (a)
25. (b)	26. (b)	27. (c)	28. (a)	29. (d)	30. (b)
31. (c)	32. (a)	33. (b)	34. (b)	35. (b)	36. (c)
37. (a)	38. (b)	39. (b)	40. (b)	41. (a)	42. (c)
43. (c)	44. (a)	45. (b)	46. (b)	47. (d)	48. (b)
49. (a)	50. (a)	51. (b)	52. (c)	53. (d)	54. (d)
55. (a)	56. (a)	57. (a)	58. (b)	59. (b)	60. (b)
61. (d)	62. (b)	63. (c)	64. (a)	65. (a)	66. (d)
67. (b)	68. (b)	69. (b)	70. (a)	71. (b)	72. (d)

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73. (a) 74. (b) 75. (d) 76. (b) 77. (d) 78. (b)
79. (c) 80. (a) 81. (a) 82. (b) 83. (a) 84. (c)
85. (b) 86. (b) 87. (a) 88. (c) 89. (d) 90. (c)
91. (a) 92. (b) 93. (b) 94. (D), (C), (A), (B) 95. (d)
96. (b) 97. (d) 98. (d) 99. (a) 100. (b) 101. (b)
102. (d) 103. (b) 104. (a) 105. (d) 106. (d) 107. (b)
108. (a) 109. (a) 110. (b) 111. (a) 112. (a) 113. (b)
114. (d) 115. (d) 116. (a) 117. (a) 118. (c) 119. (d)
120. (d) 121. (b) 122. (a) 123. (b) 124. (a) 125. (c)
126. (c) 127. (b) 128. (c) 129. (b) 130. (b) 131. (c)
132. (b) 133. (d) 134. (a) 135. (d) 136. (b) 137. (b)
138. (b) 139. (d) 140. (d) 141. (a) 142. (d) 143. (a)
144. (a) 145. (b) 146. (a) 147. (d) 148. (a) 149. (d)
150. (a) 151. (a) 152. (d) 153. (b) 154. (b) 155. (a)
156. (b) 157. (d) 158. (d) 159. (d) 160. (b) 161. (c)
162. (a) 163. (d) 164. (a) 165. (b) 166. (b) 167. (a)
168. (c) 169. (c) 170. (a) 171. (d) 172. (a) 173. (a)
174. (b) 175. (a) 176. (c) 177. (a) 178. (d) 179. (b)
180. (C), (D), (A), (B) 181. (b) 182. (b) 183. (c) 184. (b)
185. (b) 186. (a) 187. (b) 188. (b) 189. (a) 190. (a)
191. (a) 192. (b) 193. (d) 194. (d) 195. (d) 196. (a)
197. (a) 198. (b), (c) 199. (d) 200. (c) 201. (a) 202. (b)
203. (d) 204. (b) 205. (b) 206. (d) 207. (b) 208. (b)
209. (d) 210. (c) 211. (b) 212. (a) 213. (a) 214. (d)
215. (a) 216. (d) 217. (d) 218. (b) 219. (c) 220. (c)
221. (a) 222. (d) 223. (c) 224. (c) 225. (b) 226. (d)
227. (b) 228. (d) 229. (a) 230. (d) 231. (d) 232. (d)
233. (a) 234. (a) 235. (d) 236. (b) 237. (d) 238. (d)
239. (d) 240. (b) 241. (c) 242. (a) 243. (c) 244. (d)
245. (c) 246. (c) 247. (c) 248. (d) 249. (b) 250. (d)
251. (b) 252. (a) 253. (d) 254. (d) 255. (d) 256. (b)
257. (c) 258. (a) 259. (a) 260. (d) 261. (c) 262. (d)
263. (d) 264. (a) 265. (d) 266. (b) 267. (d) 268. (c)
269. (c) 270. (b), (c) 271. (d) 272. (a) 273. (a) 274. (d)
275. (d) 276. (c) 277. (a) 278. (b) 279. (d) 280. (a)

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6

Building Materials

6.1 Introduction

The building materials include stones, bricks, lime, cement, concrete, mortar and timber. These materials are discussed, in brief, as follows :

6.2 Stones

The stones are derived from rocks which form the earth's crust and have no definite shape or chemical composition but are mixtures of two or more minerals. The rocks from which stones are obtained may be classified in the following three groups :

1. *Geological classification.* Geologically, the rocks are classified into three types as follows :

(*a*) *Igneous rocks.* The igneous rocks are formed due to the solidification of molten mass laying below or above the earth surface. It has a crystalline glossy or fused texture.

(*b*) *Sedimentary rocks.* The sedimentary rocks are formed due to gradual deposition of materials like sand, clay etc., generally by setting water. These are also called stratified because these rocks are formed in layers. Limestone and sandstone belong to this category of rocks.

(*c*) *Metamorphic rocks.* The metamorphic rocks are formed due to alteration of original structure under heat and excessive pressure. Marble is an example of metamorphic rock.

2. *Physical classification.* Physically, the rocks are classified as follows :

(*a*) *Stratified rocks.* The stratified rocks are those which exhibit distinct layers which can be separated. The limestone, slate and sandstone are examples of stratified rocks.

(*b*) *Unstratified rocks.* The unstratified rocks are those which do not show any sign of strata and cannot be easily split into slabs. The granite and marble are examples of unstratified rocks.

3. *Chemical classification.* Chemically, the rocks are classified as follows :

(*a*) *Silicious rocks.* The silicious rocks are those which contain silica as the main constituent. The granite, quartzite, gneiss are examples of silicious rocks.

(*b*) *Argillaceous rocks.* The argillaceous rocks are those which contain clay or alumina as the main constituent. The slate, laterite, Kaoline are the examples of argillaceous rocks.

(*c*) *Calcarious rocks.* The calcarious rocks are those which contain lime or calcium carbonate as the main constituent. The limestone and marble are the examples of calcarious rocks.

6.3 Important Building Stones

The following are important building stones, their composition, properties and uses :

1. *Granite.* It is an igneous rock. It is mainly composed of quartz, *felspar and mica. Its specific gravity is 2.64 and compressive strength varies from 70 to 130 MN/m^2. Its colour depends upon that of felspar which may be brown, grey, green and pink. A fine grained granite offers high resistance to weathering. It can be easily polished and worked. It is used for exterior facing of buildings.

* Felspar is a silicate of aluminium with varying amounts of potash, soda or lime.

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2. *Slate.* It is an argillaceous rock. It is mainly composed of alumina mixed with sand or carbonate of lime. Its specific gravity is 2.8 and compressive strength varies from 60 to 70 MN/m^2. It has grey or dark blue colour. A good slate is hard, tough and fine grained. It is suitable for use in cisterns. The slate in the form of tiles is used as an excellent roof covering material.

3. *Gneiss.* It is a silicious rock. It is mainly composed of quartz and felspar. It is more easily worked than granite. It is a good material for street paving.

4. *Sandstone.* It is a sedimentary rock of silicious variety. It is mainly composed of quartz, lime and silica. Its specific gravity is 2.65 to 2.95 and compressive strength varies from 35 to 40 MN/m^2. Its usual colours are white, grey, brown, pink etc. The fine grained stones are strong and durable. It is suitable for ashlar work, mouldings, carvings etc.

5. *Limestone.* It is a sedimentary rock of calcarious variety. Its specific gravity is 2.6. It is available in brown, yellow and dark grey colours. It is used in large quantities in blast furnaces. It may be used as stone masonry for walls.

6. *Marble.* It is a metamorphic rock of calcarious variety. Its specific gravity is 2.7 and it is available in many colours. It is very hard and takes a fine polish. It is used for carving and decoration work.

7. *Kankar.* It is an impure limestone containing 30% of alumina and silica. The hard kankar is used for foundations of buildings.

8. *Laterite.* It is a sandy claystone containing high percentage of iron oxide. It has a porous and cellular structure. Its specific gravity, varies from 2 to 2.2. The laterite blocks are suitable as building stones whereas nodular laterite proves a very good road metal.

9. *Moorum.* It is a decomposed laterite and has deep brown or red colour. It is used in surfacing fancy paths and garden walks.

10. *Quartzite.* It is a silicious sandstone which has been subjected to metamorphic action. It is strong and durable. It is used as a road metal or railway ballast or in concrete.

6.4 Bricks

The brick is the most commonly used building material and used for constructing walls, columns, roofs, paving floors etc. A good brick clay contains 20 to 30 percent of alumina, 50 to 60 percent of silica and the remaining constituents are lime, magnesia, sodium, potassium, manganese and iron oxide. It may be noted that

1. The excess of alumina in the clay makes the brick crack and warp on drying.
2. The excess of silica in the clay makes the brick brittle and weak.
3. The excess of lime in the clay causes the bricks to melt and distort during burning.
4. The alkaline salt present in the bricks, absorb moisture from air which on drying leaves powder deposit on the brick. This effect is known as *efflorescence.* It is also caused if the clay used for making bricks contain pyrite and the water used for pugging the clay contain gypsum.

6.5 Manufacture of Bricks

The manufacture of bricks consist of the following four major operations :

1. *Preparation of brick clay.* First of all, the earth is dug out in clear weather and cleaned of stones, pebbles, grits, vegetable matter etc. The earth after digging out is left to atmospheric action for few weeks. This process is known as *weathering.* It is found that 1.5 to 2.5 cum of earth required for moulding 1000 bricks. The clay is then tempered in pug-mills.

Note : The process of mixing clay, water and other ingredients to make bricks is known as *kneading.*

2. *Moulding bricks.* After preparing the clay, the moulding of bricks is carried out either by hand or by machine. In hand moulding, the bricks are moulded by hand *i.e.* manually. It is preferred where manpower is cheap and readily available. The hand moulding may be done either on ground

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on table and accordingly these are termed as ground moulding or table moulding.

The bricks are moulded in machine, when large number of bricks are to be manufactured in a short time. The machine moulding may be performed either by plastic method or dry process method.

Note : The hand made bricks are superior to machine made bricks for facing purposes.

3. *Drying of bricks.* After the bricks are moulded, they are dried. The drying of bricks may be natural or artificial. In natural drying, the moulded bricks are kept in the sun for a day or two so that they become sufficiently hard to be handled safely. These bricks are now arranged in rows on their edges on a slightly raised ground called *hacks*. A little space for free circulation of air is kept for each brick. The air and sun dried bricks are adequately strong and durable. If the bricks are not properly dried before they are burnt, they may get cracked and distorted during the burning process.

The artificial drying is used when bricks are required on a large scale and at a rapid rate.

4. *Burning of bricks.* The burning of dry bricks is done either in a clamp or in a kiln. In India, both clamp and kiln burning are practised. It may be noted that the average out-turn of first class bricks in clamp burning is about 60% whereas for kiln burning it is about 80 to 90%.

Notes : 1. The burning of bricks in kilns is complete within 24 hours.

2. The bricks should be burnt at a temperature from 1000°C to 1200°C.

3. The bricks after burning in kilns require about 12 days to cool down for unloading.

6.6 Classification of Bricks

The bricks are classified as under :

1. *First class bricks.* These bricks are well burnt having smooth and even surface with perfect rectangular shape and uniform reddish colour. These bricks should not absorb water more than 20 percent of its own dry weight after 24 hours immersion in water. It should have a minimum crushing strength of 10.5 MN/m^2.

2. *Second class bricks.* These bricks are slightly over burnt having rough surface and not perfectly rectangular in shape. These bricks should not absorb water more than 22 percent of its own dry weight after 24 hours immersion in water.

3. *Third class bricks.* These bricks are not properly burnt (under burnt) in the kiln and hence these are soft and can be easily broken. These bricks should not absorb water more than 25 percent of its own dry weight after 24 hours immersion in water.

4. *Jhama bricks.* These bricks are over burnt with irregular shape. These bricks are dark bluish in colour.

Notes : 1. The standard size of bricks are 19 cm × 9 cm × 4 cm or 19 cm × 9 cm × 9 cm

2. The specific gravity of bricks is about 2.

3. The number of bricks required for one cubic metre of brick masonry are 550.

6.7 Special Bricks

The special bricks differ from the commonly used building bricks with respect to their shape, specifications and special purpose for which they are made. Following are some of the special bricks :

1. *Squint bricks.* These bricks are used in construction of acute and obtuse squint quoins.

2. *Paving bricks.* These bricks are extensively used for street pavements, stable floors, garden walls etc.

3. *Round bricks.* These bricks are used for circular pillars.

4. *Perforated and Hollow bricks.* These bricks are used for partition walls or panel walls in multi-storeyed buildings.

5. *Refractory bricks.* A good refractory brick should have the capability of withstanding high temperature and low coefficient of expansion and contraction. Following are the three types of

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refractory bricks :

(*a*) Acid bricks (Fire bricks and silica bricks),

(*b*) Basic bricks (Magnesite bricks, dolomite bricks and bauxite bricks), and

(*c*) Neutral bricks (Chrome bricks, chrome-magnesite bricks and spinel bricks).

6.8 Building Tiles

The building tiles are thin slabs of brick clay, burnt in kiln. The various types of tiles are flooring tiles, roofing tiles (*i.e.* pot tiles, *pan tiles and flat tiles), wall tiles, drain tiles and glazed earthenware tiles.

6.9 Lime

The lime is calcium oxide (CaO) obtained by calcination of limestone (white chalk), kankar and other calcarious substances. It is not found in nature in the free state.

It is used as a matrix for concrete, for plastering walls, ceiling etc, for improving soil for agricultural purposes and in the production of glass. It is also used as a flux in the manufacture of steel, and in the manufacture of paints.

6.10 Types of Lime

The lime is available in the following types :

1. *Quick lime.* It is the lime obtained after the calcination of pure limestone. It is amorphous and highly caustic having no affinity for carbonic acid.

2. *Slaked lime or hydrated lime.* It is the lime formed by the absorption of water by quick lime. The process of chemical combination of quick lime with required quantity of water is known as *slaking*.

3. *Fat or rich lime.* It is the lime which has high calcium oxide (about 95%) content and can set and become hard only in the presence of carbon dioxide from atmosphere. This type of lime is perfectly white in colour. It has high plasticity. It slakes rapidly with considerable evolution of heat and its volume increases two to three times of its original volume during slaking. It takes very long time to develop adequate strength. It is commonly used for white washing and plastering walls.

4. *Hydraulic lime.* It is the lime which has small quantities of silica, alumina and iron oxide which are in chemical combination with calcium oxide. It can set and become hard even in the absence of carbon dioxide and can set under water.

The hydraulic lime, depending upon the percentage of clayey impurities in the form of silica, alumina and iron oxide, are classified into the following three groups :

(*a*) Feebly hydraulic lime - 5 to 10%;

(*b*) Moderately hydraulic lime - 10 to 25%; and

(*c*) Eminently hydraulic lime - 25 to 30%.

5. *Poor or lean lime.* It is the lime which contains more than 30% of clayey impurities in the form of silica, alumina and iron oxide. Since the mortar made from this type of lime is of poor quality, therefore it is used for inferior type of work.

6.11 Cement

The word 'cement' usually means *portland cement* used in civil engineering works which set well under water, hardens quickly and attains strength. Cement differs from lime by the property that it does not slake but sets readily and acquires more strength on setting. The setting power of cement is more than that of lime but cement is similar in many respects to a good quality hydraulic lime. The

* The pan tiles are similar to pot tiles, but are less curved. The pan tiles are comparatively heavier, stronger and durable than curved tiles.

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various constituents of a *Portland cement are as follows :

Lime - 63%; Silica - 22%; Alumina - 6%; Iron oxide - 3%; Magnesium oxide - 2.5%; Sulphur trioxide - 1.5%; Loss on ignition - 1.5%; Alkalies - 0.5%.

The lime, silica, and iron oxide imparts strength to cement, while alumina gives quick setting property. The alkalies when in excess, causes efflorescence and magnesium oxide and sulphur trioxide are not desirable in excess amounts.

The **manufacture of cement consists of grinding the raw materials (calcareous and argillaceous stones containing silica, alumina and iron oxide) and mixing them intimately in a certain proportion. It is then burnt in a large rotary kiln at a temperature of about 1500°C, when the material sinters and partially fuses into balls known as *clinker*. The clinker is cooled and ground to fine powder with some gypsum added, and the resulting product is the commercial Portland cement. The calcium sulphate in the form of gypsum (usually 1 to 3%) is added in order to lengthen the initial setting time of cement.

The cement clinkers consist of the following major compounds :

Tricalcium silicate (4%); Dicalcium silicate (32%); Tricalcium aluminate (10.5%) and Tetra-calcium alumino ferrite (9%).

The setting and hardening of cement paste is mainly due to ***the hydration and hydrolysis of these compounds. It may be noted that greater the percentage of tricalcium silicate in the cement, the better will be the cement. The tricalcium aluminate and tetracalcium alumino ferrite compounds are responsible for the initial setting of cement.

6.12 Testing of Portland Cement

The following important tests are carried out for normal setting of Portland cement :

1. *Fineness test.* This test is conducted to check the proper grinding of cement. The fineness of cement is tested either by sieve method or air permeability method.

The percentage of residue left after sieving good Portland cement in 90 micron IS (Indian standard) sieve should not exceed 10%.

A good Portland cement should not have specific surface less than 2250 cm^2/g of cement, if found by air permeability method.

2. *Consistency test.* This test is conducted to determine the percentage of water required for preparing cement pastes of standard consistency. The consistency test is performed with the help of Vicat's apparatus which determines the initial and final setting time and normal consistency of cement.

Notes : (*a*) The initial setting time of ordinary and rapid hardening cement should not be less than 30 minutes.

(*b*) The final setting time of ordinary and rapid hardening cement should not be more than 10 hours.

(*c*) The normal consistency of Portland cement is about 25%.

3. *Soundness test.* This test is carried out to detect the presence of uncombined lime and magnesia in cement which causes the expansion of cement. The soundness of cement is tested with *Le Chatelier apparatus*. According to Indian standard specifications, the expansion should not exceed 10 mm for any type of Portland cement.

4. *Tensile strength test.* This test is carried out on standard briquettes made of a good Portland cement and standard sand mortar (in 1 : 3 ratio) to determine the tensile strength of cement.

The average tensile strength after 3 and 7 days of curing should not be less than 2 N/mm^2 and 2.5 N/mm^2 respectively.

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* See also Chapter 13 on Concrete Technology.

** The wet process or dry process may be employed for the manufacture of cement.

*** The rate of hydration and hydrolysis of cement depends upon its fineness.

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5. *Compressive strength test.* This test is carried out on standard cubes made of a good Portland cement and standard sand mortar (in 1 : 3 ratio) to determine the compressive strength of the cement. According to Indian standard specifications, the average compressive strength for three cubes should not be less than 11.5 N/mm^2 and 17.5 N/mm^2 after 3 and 7 days of curing respectively.

6.13 Mortar and Concrete

The *mortar* is a paste made by mixing lime, surkhi and water; lime, sand and water; and cement, sand and water. The lime and cement are the binding materials whereas sand and surkhi prevent shrinkage and cracks in setting and give strength to the mortar. The mortar used in concrete is called matrix. It may be noted that the mortar made with coarse sand is stronger than the one made with fine sand.

The *concrete* is a mixture of cement, sand, brick or stone ballast and water, which when placed in forms and allowed to cure, becomes hard like stone. It is much stronger in compression than in tension. In order to enable it to resist tensile streses, it is reinforced or strengthened with steel in the form of steel bars or wire netting etc. The concrete so obtained is called *reinforced concrete.*

Notes : 1. The workability and durability of cement concrete is usually improved by increasing the quantity of cement.
2. The maximum water cement ratio for durable concrete is 0.8.
3. The density of concrete increases with the increase in size of aggregate.
4. The shrinkage of concrete is directly proportional to the contents of cement and water at the time of mixing. It increases with the increase in the percentage of cement.
5. The shrinkage of ordinary concrete is about 0.3 to 0.6 mm / m.
6. The coefficient of linear expansion of concrete is almost the same as that of steel.

6.14 Timber

It is the wood suitable for building or engineering purposes and it is applied to trees measuring not less than 0.6 m in girth. The cross-section of an exogenous tree is shown in Fig. 6.1. The important parts are as follows :

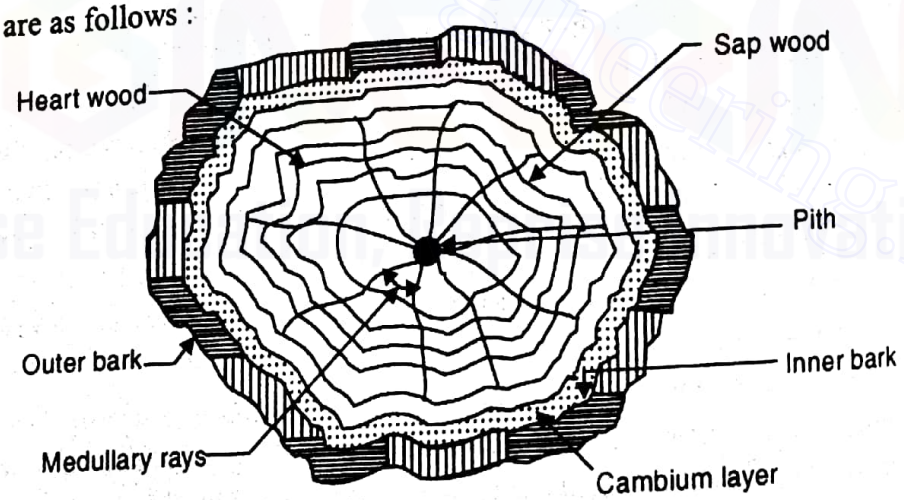

Fig. 6.1

(*a*) *Pith.* It is the inner most central portion or core of the tree.

(*b*) *Annular rings.* These are the concentric circles or rings of woody fibre around the pith.

(*c*) *Heart wood.* It consists of the inner annular rings around the pith.

(*d*) *Sapwood.* It consists of the outer annular rings between the heart wood and cambium layer.

(*e*) *Cambium layer.* It is a thin layer just below the bark and not converted to sap wood yet.

(*f*) *Medullary rays.* These are thin radial fibres extending from the pith to cambium layer.

(*g*) *Inner bark.* It is the inner skin or layer covering the cambium layer.

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(*h*) *Outer bark.* It is the outermost cover or skin of stem.

6.15 Seasoning of Timber

The process of drying timber or removing moisture or sap, present in a freshly felled tree, is called *seasoning of timber*. The following two methods are commonly used for seasoning of timber.

1. *Natural seasoning or Air seasoning.* This method of seasoning the wood is simple and cheep, but it is very slow. It requires about 60 to 90 days for soft wood.
2. *Artificial seasoning or Kiln seasoning.* It is the quickest method of wood seasoning and keeps the moisture contents under control. The seasoning by this method, generally, takes four to five days under normal conditions.

6.16 Defects in Timber

The following are the most common defects in timber :

1. *Heart shake.* This defect usually occurs in over matured trees and is caused due to shrinkage of the heartwood.
2. *Star shake.* This defect is mostly caused by severe frost or by severe heat of the sun. It is mostly confined to sap wood.
3. *Cup shake or Ring shake.* This defect is caused by strong winds which sway the tree or due to excessive frost which affects the moisture present in the tree when it is still young.
4. *Knot.* This defect is caused by the roots of small branches of the tree which as embedded in the stem with the formation of circular rings at right angles to those of the stem. The knot may be *live knot* or *dead knot.*
5. *Foxiness.* This defect is caused due to over maturity and unventilated storage of the wood during its transit.
6. *Honey combing.* This defect is caused during seasoning of timber.
7. *Dry rot.* This defect is caused by fungus.
8. *Wet rot.* This defect is caused by alternating drying and wetting of the timber.

6.17 Paints

The paints are coatings of fluid materials applied over the surfaces of timber and metals as protective coatings and to improve their appearance. The paint commonly used for engineering purposes is an oil paint. It is a fluid paste prepared by dissolving a base into a vehicle along with a colouring pigment. The bases used in oil paints are white lead, zinc white, red lead, iron oxide, titanium white and lithophone (a mixture of zinc sulphide and borytes). The base in oil paint is added to hide the surface to be painted. The vehicles used are linseed oil, poppy oil, nut oil, tung oil etc. It acts as a binder for the base and the pigment. The colouring pigments include black, blue, brown etc. The other ingredients of an oil paint are solvent or thinner, drier and inert filler. The solvent or thinner (turpentine oil, naptha petroleum spirit etc.) is added to the paint to modify the consistency of the paint, to make its application easy and smooth. The drier (litharge, lead acetate, manganese sulphate etc.) enables the paint to dry quickly. The inert filler (powdered chalk, charcoal, silica, gypsum etc.) are used to make the paint economical and of desired quality.

The different types of paints are oil paint, aluminium paint, bronze paint, asbestos paint, cellulose paint, cement paint, enamel paint, emulsion paint, silicate paint, casein paint, plastic paint and synthetic rubber paint.

6.18 Varnishes

The varnish is a homogeneous mixture of natural or synthetic resin in a particular solvent. The commonly used resins are copal, amber, lac or shellac, dammer etc. and the solvents are linseed oil, turpentine oil, methylated spirit or alcohol. A drier (litharge) is also added to help in quick drying of varnish. The varnishes are of the following two types :

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(*a*) Oil varnishes, and (*b*) Spirit varnishes.

The *oil varnish* is a homogeneous solution of one or more resins in a drying oil (linseed oil) and a volatile solvent (turpentine oil) and drier.

The *spirit varnish* is obtained by dissolving the resin (lac or shellac) in a volatile solvent (methylated spirit)

6.19 Lacquers

A lacquer is a solution made by dissolving nitrocellulose, resin and plasticizer in a solvent with or without the colouring pigments. In a lacquer, nitrocellulose provides toughness and resistance to abrasion. The resins (such as alkyd, copal, dammer, ester, gum etc.) increase adhesion and hardness. The plasticizer (castor oil) is added to improve elasticity and plasticity. The solvent is usually a mixture of ketone, alcohol and a hydrocarbon.

6.20 Distempers

The distemper is made by mixing a dry pigment (chalk or whiting) with clean water and ordinary size. It is used on plastered surfaces not exposed to weather.

OBJECTIVE TYPE QUESTIONS

1. The rocks formed due to solidification of molten mass laying below or above the earth surface are called

(*a*) aqueous rocks
(*b*) sedimentary rocks
(*c*) metamorphic rocks
(*d*) igneous rocks

2. The sedimentary rocks are formed due to

(*a*) solidification of molten mass lying below or above the earth surface
(*b*) gradual deposition of materials like sand, clay, etc., generally by setting water
(*c*) alteration of original structure under heat and excessive pressure
(*d*) none of the above

3. The rocks formed due to alteration of original structure under heat and excessive pressure are called metamorphic rocks.

(*a*) Agree
(*b*) Disagree

4. Granite is an example of

(*a*) aqueous rocks
(*b*) sedimentary rocks
(*c*) metamorphic rocks
(*d*) igneous rocks

5. Igneous rock has

(*a*) crystalline, glossy or fused texture
(*b*) foliated structure which is hard and durable
(*c*) layers of different composition, colour and structure
(*d*) none of the above

6. Laterite is chemically classified as

(*a*) calcareous rock
(*b*) argillaceous rock
(*c*) silicious rock
(*d*) metamorphic rock

7. The calcareous rocks have ..... as the main constituent.

(*a*) lime or calcium carbonate
(*b*) clay or alumina

8. Gneiss is chemically classified as

(*a*) calcareous rock
(*b*) argillaceous rock
(*c*) silicious rock
(*d*) none of these

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9. Which of the following is an example of agrillaceous rock ?
(a) Kaolin (b) Slate (c) Laterite (d) all of these

10. Which of the following is an example of silicious rock ?
(a) Granite (b) Gneiss
(c) Quartzite (d) all of these

11. Limestone is physically classified as ..... rock.
(a) stratified (b) unstratified

12. Moorum is a decomposed laterite and has deep brown or red colour.
(a) Yes (b) No

13. Marble is an example of
(a) aqueous rock (b) metamorphic rock
(c) sedimentary rock (d) igneous rock

14. Slate in the form of tiles is used
(a) for paving (b) as road metal
(c) as an excellent roof covering material (d) for the manufacture of cement

15. Granite is mainly composed of
(a) quartz and mica (b) felspar and mica
(c) quartz and felspar (d) quartz, felspar and mica

16. Sandstone consists of
(a) quartz and lime (b) quartz and silica
(c) quartz, lime and silica (d) silica, lime and alumina

17. Marble contains mostly lime and silica.
(a) True (b) False

18. The compressive strength of granite is
(a) 50 to 70 MN/m^2 (b) 70 to 130 MN/m^2
(c) 130 to 170 MN/m^2 (d) 170 to 200 MN/m^2

19. In order to dry the quarry sap of a freshly quarried stone, it should be exposed to open air for period of
(a) one month (b) four months
(c) six to twelve months (d) two years

20. A good building stone is one which does not absorb more than ..... of its weight of ater after one day's immersion.
(a) 5% (b) 10% (c) 15% (d) 25%

21. The specific gravity of stone should not, in any case, be less than
(a) 1 (b) 1.5 (c) 2 (d) 2.5

22. Which of the following statements is wrong ?
(a) A stone with large percentage of quartz is very soft.
(b) Quartz has a greasy lustre.
(c) Felspar is a silicate of aluminium with varying amounts of potash, soda or lime.
(d) all of these

23. Siliceous rocks have alumina or clay as their major constituent.
(a) Yes (b) No

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24. Argillaceous rocks have their main constituent as
(a) carbonates of lime (b) clay or alumina
(c) silica or sand (d) all of these

25. The colour of granite is
(a) grey (b) green (c) brown (d) all of these

26. A fine-grained granite
(a) offers higher resistance to weathering (b) can be easily polished and worked
(c) is used for exterior facing of buildings (d) all of these

27. A limestone found in seams of great thickness in non-crystalline texture with earthy appearan is called
(a) granular limestone (b) compact limestone
(c) magnesium limestone (d) kankar

28. A limestone containing about 30% of alumina and silica is called
(a) granular limestone (b) compact limestone
(c) magnesium limestone (d) kankar

29. The compressive strength of sandstone is
(a) 40 MN/m^2 (b) 55 MN/m^2 (c) 65 MN/m^2 (d) 80 MN/m^2

30. The specific gravity of sandstone is
(a) 1.1 to 1.8 (b) 1.8 to 2.65 (c) 2.65 to 2.95 (d) 2.95 to 3.4

31. The silicious sandstone which has been subjected to metamorphic action, is called
(a) moorum (b) laterite (c) quartzite (d) dolomite

32. For railway ballast, the stone should be
(a) soft with a uniform texture (b) hard, heavy, strong and durable
(c) hard, tough, resistant to abrasion and durable
(d) hard, dense, durable, tough and easily workable

33. The quarrying of stone by the method of wedging is successfully carried out in
(a) sandstones (b) limestones (c) marbles (d) all of these

34. When quarrying is to be done in hard stone and compact rocks, the usual method of quarrying
(a) by wedging (b) by channelling machine
(c) by blasting (d) all of these

35. The compressive strength of felspar is ..... quartz.
(a) equal to (b) less than (c) more than

36. The most powerful explosive used in blasting is
(a) blasting power (b) dynamite (c) gun cotton (d) cordite

37. Gun cotton is made by saturating cotton with nitric acid.
(a) Agree (b) Disagree

38. The dressing of stone is done
(a) immediately after quarrying (b) after seasoning
(c) after three months of quarrying (d) just before building

39. The crushing strength of a stone depends upon its
(a) texture (b) specific gravity (c) workability (d) both (a) and (

40. For the construction of retaining walls, a ..... stone must be used.
(a) soft (b) hard (c) heavy

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41. The attrition test on stones is performed
   (*a*) to determine the crushing strength of the stone
   (*b*) for assessing the resistance of stone to the sun, rain, wind etc.
   (*c*) to ascertain the stability of the stone when exposed to acid fumes
   (*d*) for determining the rate of wear of stone due to grinding action under traffic

42. The stone used for the construction of curved or ornamental work should be soft.
   (*a*) Right (*b*) Wrong

43. A first class brick should not absorb water more than ..... of its own dry weight after 24 hours immersion in cold water.
   (*a*) 10% (*b*) 15% (*c*) 20% (*d*) 25%

44. The brick earth is derived by the disintegration of ..... rocks.
   (*a*) igneous (*b*) metamorphic

45. The principal constituent of every kind of brick earth is alumina.
   (*a*) True (*b*) False

46. A first class brick should have a minimum crushing strength of
   (*a*) 7 MN/m^2 (*b*) 10.5 MN/m^2 (*c*) 12.5 MN/m^2 (*d*) 14 MN/m^2

47. The percentage of alumina in a good brick clay should vary from
   (*a*) 20 to 30% (*b*) 30 to 40% (*c*) 40 to 50% (*d*) 50 to 60%

48. The percentage of silica in a good brick clay should vary from
   (*a*) 20 to 30% (*b*) 30 to 40% (*c*) 40 to 50% (*d*) 50 to 60%

49. Excess of alumina in the clay
   (*a*) makes the brick brittle and weak
   (*b*) makes the brick crack and warp on drying
   (*c*) changes colour of the brick from red to yellow
   (*d*) improves impermeability and durability of the brick

50. Excess of silica in the clay
   (*a*) makes the brick brittle and weak
   (*b*) makes the brick crack and wrap on drying
   (*c*) changes the colour of the brick from red to yellow
   (*d*) improves impermeability and durability of the brick

51. The colour of brick depends upon the amount of iron oxide present in the clay.
   (*a*) Correct (*b*) Incorrect

52. Which of the following constituent, when present in excess quantity in clay causes the bricks to melt and distort during burning ?
   (*a*) Alumina (*b*) Silica (*c*) Lime (*d*) Alkalies

53. The alkaline salt present in the bricks, absorbs moisture from the air which on drying
   (*a*) leaves pores and makes the bricks porous (*b*) leaves high powder deposit on the brick
   (*c*) makes the bricks brittle and weak (*d*) all of these

54. The standard size of a masonry brick is 20 cm × 10 cm × 10 cm.
   (*a*) Agree (*b*) Disagree

55. The size of mould for bricks should be ..... the specified size of the bricks.
   (*a*) equal to (*b*) smaller than (*c*) larger than

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56. Efflorescence is caused if
(a) the alkaline salt is present in the bricks
(b) the clay used for making bricks contain pyrite
(c) the water used for pugging the clay contains gypsum
(d) all of the above

57. The good clay for making bricks is
(a) unweathered clay (b) weathered clay (c) silted soil (d) black cotton soil

58. The process of mixing clay, water and other ingredients to make bricks, is known as
(a) tempering (b) pugging (c) kneading (d) moulding

59. The hand made bricks are ..... to machine made bricks for facing purposes.
(a) superior (b) inferior

60. The bricks after moulding should be dried in
(a) open air (b) sun for 3 to 8 days
(c) air for 3 to 8 days but not in sun (d) hot air for 3 days

61. The natural drying of bricks is also called hack drying.
(a) True (b) False

62. The indentation marks left on bricks during the process of moulding, are known as
(a) fillets (b) frogs (c) projections (d) marks

63. The frog of a brick is normally made on its
(a) longer face (b) shorter face (c) bottom face (d) top face

64. The average out-turn of first class bricks in clamp burning is about
(a) 50% (b) 60% (c) 70% (d) 80%

65. The average out-turn of first class bricks in kiln burning is
(a) 50 to 60% (b) 60 to 70% (c) 70 to 80% (d) 80 to 90%

66. The burning of bricks in kilns is complete within ..... hours.
(a) 12 (b) 24 (c) 48 (d) 96

67. The bricks after burning in kilns require about ..... days to cool down for unloading.
(a) 4 (b) 8 (c) 10 (d) 12

68. The bricks should be burnt at temperature from
(a) 300°C to 500°C (b) 500°C to 700°C
(c) 700°C to 1000°C (d) 1000°C to 1200°C

69. The type of brick suitable for panal walls for multi-storeyed buildings is
(a) hollow bricks (b) perforated bricks
(c) either (a) or (b) (d) none of these

70. The compressive strength of second class bricks should not be less than
(a) 7.5 MN/m^2 (b) 9 MN/m^2 (c) 10.5 MN/m^2 (d) 12 MN/m^2

71. Jhama bricks are
(a) well burnt having smooth and even surface
(b) slightly over burnt having rough surface
(c) under burnt and can be easily broken
(d) over burnt with irregular shape

72. The compressive strength of perforated bricks should not be less than
(a) 4 MN/m^2 (b) 5 MN/m^2 (c) 6 MN/m^2 (d) 7 MN/m^2

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73. The compressive strength of paving bricks should not be less than
(a) 20 MN/m^2 (b) 30 MN/m^2 (c) 40 MN/m^2 (d) 50 MN/m^2

74. The length of a curved tile varies from
(a) 10 to 12 cm (b) 12 to 15 cm (c) 15 to 20 cm (d) 20 to 22.5 cm

75. Which of the following statement is wrong ?
(a) The pan tiles are similar to pot tiles, but are less curved.
(b) The pan tiles are comparatively heavier, stronger and durable than curved tiles.
(c) The fire bricks are generally used for lining kilns.
(d) none of the above

76. For one cubic metre of brick masonry, the number of bricks required are
(a) 400 (b) 450 (c) 500 (d) 550

77. The dolomite bricks are
(a) ordinary bricks (b) acid refractory bricks
(c) basic refractory bricks (d) neutral refractory bricks

78. A good refractory brick should withstand high temperature. It should also have low coefficient of expansion and contraction.
(a) Yes (b) No

79. Lime is used
(a) as a matrix for concrete (b) for plastering walls, ceilings etc.
(c) for improving soil for agricultural purposes
(d) all of the above

80. Lime occurs in a free state in nature.
(a) True (b) False

81. Quick lime is a
(a) carbonate of lime (b) oxide of calcium
(c) product left immediately after the calcination of pure limestone
(d) lime quickly treated with water

82. The lime which consists almost entirely of calcium oxide, is called
(a) poor lime (b) rich lime (c) hydraulic lime (d) limestone

83. The lime which contains more than 30% of clayey impurities in the form of silica, alumina and iron oxide, is known as
(a) poor lime (b) rich lime (c) hydraulic line (d) limestone

84. Eminently hydraulic lime is one in which the percentage of silica, alumina and iron oxide is
(a) 5 to 10% (b) 10 to 25% (c) 25 to 30% (d) 30 to 40%

85. The hydraulic lime which resembles very much with Portland cement in its chemical composition is called
(a) feebly hydraulic lime (b) moderately hydraulic lime
(c) eminently hydraulic lime (d) none of these

86. Poor or lean lime
(a) slakes rapidly with considerable evolution of heat
(b) takes very long time to develop adequate strength
(c) has high plasticity
(d) none of the above

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87. Rich or fat lime
(*a*) slakes rapidly with considerable evolution of heat
(*b*) takes very long time to develop adequate strength
(*c*) has high plasticity
(*d*) all of these

88. The commonly used lime for works under water or in damp situations is
(*a*) fat lime
(*b*) lean lime
(*c*) feebly hydraulic lime
(*d*) eminently hydraulic lime

89. The slaking of moderately hydraulic lime is scarcely noticeable.
(*a*) Yes
(*b*) No

90. Which of the following statement is correct ?
(*a*) The fat lime swells two to three times of its original volume during slaking.
(*b*) The poor lime is of pure white colour.
(*c*) The feebly hydraulic lime slakes sluggishly.
(*d*) all of the above

91. The fuel generally used for burning limestone is
(*a*) coal (*b*) charcoal (*c*) firewood (*d*) any one of these

92. During the process of burning limestone, clay forms certain compound which
(*a*) gives hydraulic lime
(*b*) gives power of quick setting
(*c*) does not allow to be dissolved in the outside water when used in damp situations
(*d*) all of the above

93. The process of adding the required quantity of water to quick lime in order to convert it into hydrated lime, is known as
(*a*) calcination (*b*) hydration (*c*) slaking (*d*) quenching

94. The advantage of adding pozzolana (or surkhi) to lime is to
(*a*) reduce shrinkage
(*b*) increase resistance to cracking
(*c*) increase resistance to chemical attack
(*d*) all of these

95. The commonly used lime in white washing is
(*a*) quick lime (*b*) fat lime (*c*) lean lime (*d*) hydraulic lime

96. The lime mortar is made from
(*a*) quick lime (*b*) fat lime (*c*) lean lime (*d*) hydraulic lime

97. Match the correct answer from *Group B* for the statements given in *Group A*.

Group A	*Group B*
(*a*) Lime putty is obtained from	(*A*) quick lime
(*b*) Slaked lime is obtained from	(*B*) fat lime
(*c*) White lime is also called	(*C*) hydrated lime
(*d*) Lime produced by slaking burnt limestone is	(*D*) slaked lime

98. Quick lime on reaction with water gives
(*a*) hydraulic lime (*b*) slaked lime (*c*) hydrated lime (*d*) poor lime

99. Hydraulic lime generates ..... heat as compared to fat lime.
(*a*) same (*b*) less (*c*) more

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100. The constituent in lime which retard the slaking action and increase the rapidity of setting, is
(a) silica (b) sulphate (c) alkalies (d) alumina

101. The main constituent of a Portland cement is
(a) lime (b) alumina (c) iron oxide (d) alkalies

102. The silica in Portland cement should be
(a) 10 to 20% (b) 20 to 25% (c) 25 to 40% (d) 40 to 60%

103. The dry process of mixing is usually employed in the manufacture of Portland cement when the raw material is
(a) blast furnace slag (b) chalk (c) clay (d) all of these

104. The clinker is formed at a temperature of
(a) 500°C (b) 1000°C (c) 1200°C (d) 1500°C

105. The amount of gypsum, usually, added in the manufacture of cement is
(a) 0.1 to 0.5% (b) 0.5 to 1% (c) 1 to 3% (d) 3 to 5%

106. Gypsum is added in the manufacture of Portland cement
(a) while mixing the raw materials
(b) during burning in the rotary kiln
(c) at the beginning of grinding the clinker
(d) at the end of grinding the clinker into powder

107. Gypsum is added in the manufacture of Portland cement in order to
(a) shorten the setting time of cement (b) lengthen the setting time of cement
(c) decrease the burning temperature (d) decrease the grinding time

108. The cementing property in cement is mainly due to
(a) lime (b) silica (c) iron oxide (d) alumina

109. The setting and hardening of cement paste is mainly due to the hydration and hydrolysis of
(a) tri-calcium silicate (b) di-calcium silicate
(c) tri-calcium aluminate (d) all of these

110. The greater the percentage of tri-calcium silicate in the cement, the better will be the cement.
(a) Correct (b) Incorrect

111. The compound responsible for the initial setting of cement, is
(a) tri-calcium aluminate (b) tetra-calcium alumino ferrite
(c) both (a) and (b) (d) none of these

112. The ultimate strength of cement is provided by
(a) silica (b) di-calcium silicate
(c) tri-calcium silicate (d) tri-calcium aluminate

113. A good quality cement should have higher percentage of
(a) silica (b) free lime
(c) di-calcium silicate (d) tri-calcium silicate

114. The strength of white cement is ..... that of ordinary cement.
(a) equal to (b) less than (c) greater than

115. The percentage of the slag component of Portland-slag cement varies from
(a) 10 to 40% (b) 40 to 70% (c) 70 to 80% (d) 80 to 90%

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116. The rapid hardening Portland cement has a
(a) lower heat of hydration (b) higher heat of hydration
(c) lower shrinkage coefficient (d) higher shrinkage coefficient

117. The initial setting of cement is caused due to
(a) di-calcium silicate (b) tri-calcium silicate
(c) tri-calcium aluminate (d) tri-calcium alumino ferrite

118. The rapid hardening Portland cement is obtained by
(a) grinding the clinker to a high degree of fineness
(b) adding calcium sulphate to the mixture
(c) adding gypsum after grinding
(d) burning the mixture at a lower temperature

119. The fineness of cement is tested by
(a) air-permeability method (b) Le-chatelier method
(c) Vicat's apparatus (d) all of these

120. The soundness of cement is tested by
(a) air permeability method (b) Le-chatelier method
(c) Vicat's apparatus (d) all of these

121. Vicat's apparatus is used to determine the
(a) initial setting time of cement (b) final setting time of cement
(c) normal consistency of cement (d) all of these

122. A good Portland cement when tested for fineness, the percentage of residue left after sieving 90 micron IS sieve should not exceed 10 percent.
(a) True (b) False

123. Le-chatelier method is used to determine
(a) initial setting of cement (b) fineness of cement
(c) soundness of cement (d) normal consistency of cement

124. The expansion of cement should not exceed ..... for any type of Portland cement.
(a) 5 mm (b) 10 mm (c) 15 mm (d) 20 mm

125. The normal consistency of Portland cement is about
(a) 10% (b) 15% (c) 20% (d) 25%

126. The initial setting time of rapid hardening cement should not be less than
(a) 30 min (b) 1 hour (c) 4 hours (d) 8 hours

127. The final setting time of ordinary cement should not be more than
(a) 2 hours (b) 4 hours (c) 8 hours (d) 10 hours

128. The addition of pozzolana to Portland cement causes
(a) less heat of hydration (b) increase in shrinkage
(c) decrease in permeability (d) all of these

129. The rate of hydration and hydrolysis of cement depends upon its
(a) soundness (b) fineness (c) setting time (d) tensile strength

130. The compressive strength of ordinary cement is less than its tensile strength.
(a) Right (b) Wrong

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131. The percentage of the residue left after sieving good Portland cement in 90 micron sieve should not exceed
(a) 5% (b) 10% (c) 20% (d) 30%

132. The expansion in Portland cement can be tested by
(a) fineness test (b) soundness test
(c) setting time test (d) normal consistency test

133. The specific surface (in cm^2/g) of a good Portland cement should not be less than
(a) 500 (b) 1100 (c) 2250 (d) 3200

134. The expansion of Portland cement is caused by
(a) free lime (b) magnesia (c) silica (d) both (b) and (c)

135. The compressive strength of a good Portland cement and standard sand mortar after 3 days of curing should not be less than
(a) 7 MN/m^2 (b) 11.5 MN/m^2 (c) 17.5 MN/m^2 (d) 21 MN/m^2

136. The sand is mixed with lime mortar to
(a) reduce cost (b) reduce setting time
(c) improve strength (d) prevent shrinkage and cracking

137. Which of the following statement is correct ?
(a) The sand used for making mortar should be fine.
(b) The rounded grains of sand produce a strong mortar.
(c) The mortar made with coarse sand is stronger than the one made with fine stand.
(d) all of the above

138. For R.C.C. construction, the maximum size of coarse aggregate is limited to
(a) 10 mm (b) 15 mm (c) 20 mm (d) 25 mm

139. The bulking of sand ..... with addition of water upto about 5% by weight.
(a) increases (b) decreases

140. Concrete is strong in tension but weak in compression.
(a) True (b) False

141. Consolidation of concrete should proceed
(a) before mixing (b) before placing
(c) immediately after mixing (d) immediately after placing

142. The workability of cement concrete can be improved by
(a) increasing the quantity of cement
(b) increasing the proportion of coarse aggregate
(c) increasing the quantity of sand
(d) all of the above

143. The durability of concrete is proportional to
(a) sand content (b) water-cement ratio
(c) cement-aggregate ratio (d) aggregate-water ratio

144. The maximum water-cement ratio for durable concrete is
(a) 0.2 (b) 0.4 (c) 0.6 (d) 0.8

145. The durability of cement concrete is usually improved by
(a) increasing the quantity of coarse sand (b) increasing the quantity of cement
(c) decreasing the water-cement ratio (d) decreasing the proportion of fine aggregate

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146. The strength of cement concrete increases with
(a) increase in the size of aggregate
(b) increase in the temperature of water of curing
(c) increase in the size of aggregate
(d) all of the above

147. The density of concrete ..... with increase in the size of aggregate.
(a) does not change (b) increases (c) decreases

148. The strength of cement concrete is directly proportional to cement-water ratio.
(a) Agree (b) Disagree

149. The shrinkage of concrete
(a) is proportional to contents of cement
(b) is directly proportional to water contents at the time of mixing
(c) increases with increase in the percentage of concrete
(d) all of the above

150. The shrinkage of concrete ..... its bond strength.
(a) does not change (b) increases (c) decreases

151. The shrinkage of ordinary concrete is about
(a) 0.1 to 0.3 mm/m (b) 0.3 to 0.6 mm/m
(c) 0.6 to 1.2 mm/m (d) 1.2 to 2.1 mm/m

152. The coefficient of linear expansion of concrete is almost the same as that of steel.
(a) Correct (b) Incorrect

153. According to Indian standard specifications, the full strength of concrete is achieved after
(a) 7 days (b) 14 days (c) 21 days (d) 28 days

154. According to Indian standard specifications, the concrete should be cured under a humidity
(a) 30% (b) 50% (c) 70% (d) 90%

155. According to Indian standard specifications, the temperature for curing is
(a) 5°C (b) 10°C (c) 27°C (d) 42°C

156. The slump test of concrete is used to measure its
(a) consistency (b) tensile and compressive strength
(c) impact value (d) homogeneity

157. The central part of a tree is called
(a) heart wood (b) pith (c) sap wood (d) cambium lay

158. The thin radial fibres extending from the pith to the cambium layer is called medullary ray
(a) Yes (b) No

159. The defect caused due to over-maturity and unventilated storage of the wood during its tran is called
(a) knot (b) rind gall (c) foxiness (d) heart shake

160. The defect caused by imperfect seasoning, is called
(a) wet rot (b) dry rot
(c) honeycombing (d) cup shake

161. Seasoning of timber
(a) increases the weight of timber (b) improves strength properties of timber
(c) does not give dimensional stability (d) all of these

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162. The purpose of seasoning of timber is to
(a) change the direction of grains (b) remove voids
(c) reduce moisture content (d) all of these

163. The moisture content in timber for framework should not exceed
(a) 5% (b) 10% (c) 15% (d) 20%

164. The time required for air seasoning of soft wood is
(a) 15 to 30 days (b) 30 to 60 days (c) 60 to 90 days (d) 90 to 120 days

165. The time required for seasoning of timber in kiln seasoning is
(a) 2 to 5 days (b) 5 to 10 days (c) 10 to 20 days (d) 20 to 40 days

166. The timber whose thickness is less than 5 cm and the width exceeds 12 cm, is called a
(a) board (b) plank (c) batten (d) log

167. The strength of timber is maximum in the direction ..... to the grains.
(a) parallel (b) perpendicular

168. An assembled product made up of veneers and adhesives is called
(a) board (b) plank (c) plywood (d) batten

169. The thickness of five-ply sheet varies from
(a) 3 to 6 mm (b) 6 to 9 mm (c) 9 to 16 mm (d) 16 to 20 mm

170. The thickness of lamin boards vary from
(a) 5 to 12 mm (b) 12 to 15 mm (c) 12 to 25 mm (d) 25 to 30 mm

171. The wood generally used for railway sleepers is
(a) mango (b) kail (c) babul (d) deodar

172. The chief ingredient of a paint is
(a) alcohol (b) drier (c) oil (d) pigment

173. The liquid medium used in oil paints is
(a) thinner (b) alcohol (c) linseed oil (d) turpentine

174. The pigment in paints is mixed to give desired
(a) smoothness (b) colour (c) appearance (d) durability

175. The liquid part of the paint is called
(a) pigment (b) vehicle (c) solvent (d) drier

176. The liquid medium used in enamel paints is
(a) thinner (b) alcohol (c) turpentine (d) varnish

177. The metallic oxide used in the form of powder in a paint is called
(a) extender (b) base (c) vehicle (d) drier

178. The base in a paint is added to
(a) improve the quality of paint (b) make smooth surface
(c) hide the surface to be painted (d) all of these

179. The commonly base used in a paint is
(a) iron oxide (b) zinc oxide (c) titanium white (d) any one of these

180. The thinner used for oil paints is
(a) water (b) turpentine
(c) carbon tetrachloride (d) any one of these

181. Linseed oil in paint is used as a
(a) base (b) thinner (c) carrier (d) pigment

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182. Linseed oil is rapidly soluble in
(a) alcohol (b) turpentine (c) naptha (d) all of these

183. The commonly used extender in a paint is
(a) barium sulphate (b) gypsum (c) alcohol (d) any one of th

184. The drier in an oil paint should not be more than ..... (by volume).
(a) 5% (b) 10% (c) 15% (d) 20%

185. The commonly used solvent in oil paints is
(a) turpentine (b) naptha (c) either (a) or (b) (d) none of thes

186. The best primer used for structural steel work is
(a) white lead (b) red lead (c) zinc oxide (d) iron oxide

187. The vehicle used in bronze paints is usually
(a) linseed oil (b) naptha
(c) water (d) nitro-cellulose lacquer

188. Bituminous paint consists of bitumen dissolved in
(a) spirit (b) naptha (c) linseed oil (d) either (a) or

189. The bitumen paints are used for providing ..... surface.
(a) rough (b) smooth (c) protective

190. The commonly used cement in cement paints is
(a) white cement (b) Portland cement
(c) alumina cement (d) rapid hardening cement

191. The solvent used in cement paints is
(a) thinner (b) turpentine (c) water (d) spirit

192. Snocem is an oil paint.
(a) True (b) False

193. Enamel paint is made by adding
(a) white lead in varnish (b) bitumen in varnish
(c) white lead in lacquer (d) zinc white in spirit

194. The paint which has high reflective property is
(a) cellulose paint (b) casein paint (c) bronze paint (d) enamel paint

195. Which of the following paint is highly resistant to fire ?
(a) Cement paint (b) Asbestos paint (c) Aluminium paint (d) Enamel paint

196. Lacquer paints are more durable than enamel paints.
(a) Yes (b) No

197. Spirit varnish consists of
(a) spirit and wax (b) spirit and shellac
(c) turpentine, spirit and wax (d) turpentine, spirit and shellac

198. Distemper is used on
(a) brick walls (b) concrete surfaces
(c) plastered surfaces exposed to weather (d) plastered surfaces not exposed to weath

199. The base material for distemper is
(a) chalk (b) lime (c) clay (d) lime putty

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200. Which of the following statement is correct ?
(a) Stains used as paints have synthetic pigments.
(b) Stucco paints contain polyvinyl acetate.
(c) The solvent used in distempers is turpentine.
(d) all of the above

ANSWERS

1. (d) 2. (b) 3. (a) 4. (d) 5. (a) 6. (b)
7. (a) 8. (c) 9. (d) 10. (d) 11. (a) 12. (a)
13. (b) 14. (c) 15. (d) 16. (c) 17. (a) 18. (b)
19. (c) 20. (a) 21. (d) 22. (a) 23. (b) 24. (b)
25. (d) 26. (d) 27. (b) 28. (d) 29. (c) 30. (c)
31. (c) 32. (d) 33. (d) 34. (c) 35. (b) 36. (c)
37. (a) 38. (a) 39. (d) 40. (c) 41. (d) 42. (a)
43. (c) 44. (a) 45. (a) 46. (b) 47. (a) 48. (d)
49. (b) 50. (a) 51. (a) 52. (c) 53. (b) 54. (b)
55. (c) 56. (d) 57. (b) 58. (c) 59. (a) 60. (c)
61. (a) 62. (b) 63. (d) 64. (b) 65. (d) 66. (b)
67. (d) 68. (d) 69. (c) 70. (a) 71. (d) 72. (d)
73. (c) 74. (c) 75. (d) 76. (d) 77. (c) 78. (a)
79. (d) 80. (b) 81. (c) 82. (b) 83. (a) 84. (c)
85. (c) 86. (d) 87. (d) 88. (d) 89. (b) 90. (a)
91. (d) 92. (d) 93. (c) 94. (d) 95. (b) 96. (d)
97. (D), (A), (B), (C) 98. (b) 99. (b) 100. (b) 101. (a)
102. (b) 103. (a) 104. (d) 105. (c) 106. (d) 107. (b)
108. (a) 109. (d) 110. (a) 111. (c) 112. (b) 113. (d)
114. (b) 115. (b) 116. (b), (d) 117. (c) 118. (a) 119. (a)
120. (b) 121. (d) 122. (a) 123. (c) 124. (b) 125. (d)
126. (a) 127. (d) 128. (d) 129. (b) 130. (b) 131. (b)
132. (b) 133. (c) 134. (d) 135. (b) 136. (d) 137. (c)
138. (d) 139. (a) 140. (b) 141. (d) 142. (a) 143. (c)
144. (d) 145. (b) 146. (d) 147. (b) 148. (a) 149. (c)
150. (b) 151. (b) 152. (a) 153. (d) 154. (d) 155. (c)
156. (a) 157. (b) 158. (a) 159. (c) 160. (c) 161. (b)
162. (c) 163. (c) 164. (c) 165. (c) 166. (a) 167. (a)
168. (c) 169. (b) 170. (c) 171. (b) 172. (d) 173. (c)
174. (b) 175. (b) 176. (d) 177. (b) 178. (c) 179. (d)
180. (b) 181. (c) 182. (d) 183. (d) 184. (b) 185. (c)
186. (b) 187. (d) 188. (d) 189. (c) 190. (a) 191. (c)
192. (b) 193. (a) 194. (c) 195. (b) 196. (a) 197. (b)
198. (d) 199. (a) 200. (b)

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7 Irrigation Engineering

7.1 Introduction

The process of artificially supplying water to soil for raising crops is called *irrigation*. It is practically a science of planning and designing an efficient and economic irrigation system. It includes the engineering of controlling and harnessing the various natural sources of water by the construction of dams, canals and finally distributing the water to the agricultural fields.

The irrigation is necessary in an area where there is a scantly rainfall and where commercial crops require more water. It is also necessary where the rainfall is non-uniform and where there is a controlled water supply.

The irrigation water is said to be unsatisfactory, if it contains

1. Chemicals toxic to plants or to persons using plants as food.
2. Chemicals which react with the soil to produce unsatisfactory moisture characteristics.
3. Bacteria injurious to persons or animals eating plants irrigated with water.

The irrigation may be divided into the following two types :

(*a*) Lift irrigation; and (*b*) Surface irrigation or flow irrigation.

The method of irrigating the agricultural land by lifting water from the available at a lower level, is known as *lift irrigation*. The water for lift irrigation may be drawn from open wells or deep wells.

The method of irrigation in which water is supplied directly to soil surface from a channel located at higher elevation of the field, is known as *surface irrigation* or *flow irrigation*.

7.2 Classification of Soil Water

When water is spread over the soil either by irrigation or by rainfal, the water is absorbed by the pores of the soil. This water is termed as *soil water* or *soil moisture*. Following are the various types of soil water.

1. *Capillary water.* A part of water which exists in the porous space of the soil by molecular attraction, is known as capillary water. This water is a useful soil moisture for the growth of plants.
2. *Gravitational water.* A part of water which will move out of the soil, if proper drainage is provided, is known as gravitational water or superfluous water. This water is not useful for the plants as it flows out rapidly and it cannot be absorbed by the root zone.
3. *Hydroscopic water.* When an oven dried sample of soil is kept open in the atmosphere, it absorbs some amount of water. This water is known as hydroscopic water and cannot be extracted or absorbed by the root of the plants. So, at this stage, the growth of the plants is stopped and ultimately the plants are dead.

7.3 Terms used in Irrigation

The following terms are generally used in irrigation :

1. *Saturation capacity.* The amount of water required to fill up the pore spaces in soil particles by replacing all air held in pore spaces, is known as saturation capacity or total capacity or maximum holding capacity of the soil.

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2. *Field capacity.* The moisture content of the soil, after free drainage has removed most of the gravity water, is known as field capacity. The field capacity of a soil depends upon capillary tension in soil and porosity of soil.

3. *Permanent wilting point.* The water content at which plants can no longer extract sufficient water from the soil for its growth, is known as permanent wilting point.

4. *Available moisture.* The difference in water content of the soil between field capacity and permanent wilting is known as available moisture.

5. *Kor-watering.* The first watering given to the crop when it has grown a few centimetres is called kor-watering. The optimum depth of kor-watering is 19 cm for rice, 13.5 cm for wheat and 16.5 cm for sugarcane.

6. *Paleo (Paleva).* The first watering before sowing the crop is called paleo.

7. *Root zone depth.* The maximum depth in soil strata, in which the crop spreads its root system and derives water from the soil is called root zone depth.

8. *Overlap allowance.* The extent of water to be supplied for maturing a particular crop which extends from one season to another is called overlap allowance.

9. *Crop ratio.* The ratio of the areas of the two main crop seasons *e.g.*, Kharif and Rabi, is known as crop ratio.

10. *Intensity of irrigation.* The ratio of cultivated land for a particular crop to the total *culturable command area is called intensity of irrigation.

7.4 Base Period, Delta and Duty

The whole period of cultivation from the time when irrigation water is first supplied for preparation for the ground to its last watering before harvesting the crop is called *base period.* It is slightly less than the crop period. The crop period is defined as the time (in days) that crop takes from the instant of its sowing to that of its harvest.

The total depth of irrigation water required by a crop during the entire period the crop is in the field, is called *delta* of the crop.

The ratio between the area of a crop irrigated and the quantity of water required during its entire period of the growth is known as *duty.* The duty of irrigation water goes on increasing as the water flows. It depends upon many factors such as the type of crop, type of soil, climatic condition, method of irrigation etc.

The relation between base period, delta and duty is given by

$$\Delta = \frac{8.64B}{D}$$

where Δ = Delta in metres,

B = Base period in days, and

D = Duty in hectares / cumec.

7.5 Commanded Areas

The areas over which the canal irrigation water flows by gravity is known as *commanded area.* Following are the two types of command areas :

1. *Gross commanded area.* It is the total area which can be irrigated economically without considering the limitations of the quantity of available water.

2. *Culturable commanded area.* It is the area in which crop is grown at a particular time or crop season. The culturable commanded area may be of the following two categories :

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* Please refer Art. 7.5

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(*a*) *Culturable cultivated area.* It is the area within culturable commanded area where the cultivation has been actually done at present.

(*b*) *Culturable uncultivated area.* It is the area within culturable area where cultivation is possible but it is not being cultivated at present due to some reasons.

7.6 Methods of Distribution of Irrigation Water

Following are the various methods of distribution of irrigation water :

1. *Free flooding irrigation.* In this method, the field is divided into a small sized plots which are practically level. Water enters the field at its higher end and flows towards the lower end. It is stopped a little before it actually reaches a lower end. In this method, large quantity of water is wasted. This method is generally used in inundation irrigation system and where steep land is available.

2. *Check flooding irrigation.* In this method, the field is divided into a relatively level plots surrounded by checks or levees. The checks are generally 2 m to 3 m wide at the base and 25 cm to 30 cm high. In this method, large streams descharge water into the plots. This method is more suitable for permeable soil. It is used for crops which can stand inundation of water for sometimes.

3. *Border flooding irrigation.* In this method, the field is divided into a number of long parallel strips called borders, which are separated by low ridges. This method of irrigation is used for closed growing crops such as wheat, fodder etc. but not for rice crop.

4. *Furrow irrigation.* In this method, furrows are developed between the crop rows in the planting and cultivating processes. The size and shape of the furrow depends upon the spacing between the crop rows and the type of crops grown. This method is suitable for irrigating crops planted in rows.

5. *Sprinkler irrigation.* In this method, water is applied in the form of a spray as in ordinary rain. The sprinkler system consists of a system of perforated pipes which may be either fixed or revolving round a vertical shaft. Water is forced into these pipes which emerges in the form of a spray through the perforations and spreads on the field very evenly.

7.7 Consumptive Use of Water

The consumptive use of water by a crop is defined as the depth of water consumed by evaporation and transpiration during crop growth, including water consumed by accompanying weed growth. The value of consumptive use of water varies from crop to crop, time to time and even from place to place.

7.8 Hydrology

The science which deals with the occurrence, distribution and circulation of water is called *hydrology.* The study of hydrology is useful for the following :

1. For the proper design and operation of hydraulic structures.
2. For ascertaining flood flows expected at a spillway or highway culvert or in a city drainage system.
3. For ascertaining reservoir capacity to ensure adequate water for irrigation or municipal water supply during draughts.
4. For ascertaining the effect of reservoirs, levees, and other control works in flood flow in a stream.

Notes : (*a*) The science which deals with the physical features and conditions of water on the earth surface is called *hydrography.*

(*b*) The science which deals with the measurement of water is called *hydrometry.*

7.9 Hydrological Cycle

The water of the universe always changes from one state to another in a cyclic order under the influence of the sun. The water from the surface source like lakes, rivers, ocean etc. converts

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vapour by evaporation. These vapours get condensed due to the sudden fall in temperature and pressure and thus clouds are formed. These clouds again causes precipitation (*i.e.* rainfall). Some of the vapours are converted to ice at the peak of the mountains. The ice again melts in summer and flows as rivers to meet the sea or ocean. These processes of evaporation, precipitation and melting of ice go on continuously and thus a balance is maintained in the atmosphere. This earth's water circulatory system (from the stage of evaporation from ocean to the final return to the ocean) is called *hydrological cycle.*

If E is the evaporation, P is precipitation and R is run-off, then the hydrological cycle is expressed by the relation,

$$P = E + R$$

7.10 Hydrograph, Hyetograph

A graph showing variations of discharge (in cumec) with time (in hours or days), at a particular point of a stream, is known as *hydrograph*. The discharge is plotted as ordinate (Y-axis) and the time is plotted as abscissa (X-axis).

The hydrograph representing one cm of run off from a rainfall of some unit duration and specific area distribution is known as *unit hydrograph*. The concept of unit hydrograph was first given by L.K. Sherman in 1932.

The graphical representation of average rainfall and rainfall excess (*i.e.* rainfall minus infiltration) rates over specified areas during successive unit time intervals during a storm is called *hyetograph*.

7.11 Precipitation

We have already discussed that water goes on evaporation continuously from the water surfaces on earth (*e.g.* river, lake, sea, ocean, etc.) by the effect of sun. The water vapour goes on collecting in the atmosphere upto a certain limit. When this limit exceeds, the water vapours get condensed and there by cloud is formed. Ultimately droplets are formed and returned to earth in the form of rain, snowfall etc. This is known as *precipitation*.

Depending upon the various atmospheric conditions, the precipitation may be of the following types :

(*a*) *Cyclonic precipitation*. It results from lifting of air masses converging into low pressure area.

(*b*) *Convective precipitation*. It results from natural rising of warmer, lighter air in colder and denser surroundings.

(*c*) *Orographic precipitation*. It results from lifting of warm moisture-laden air masses due to topographic barriers.

Note : The amount of precipitation (rainfall) is generally measured by float type rain gauge.

7.12 Run-off and Catchment

The amount of water which flows over the surface of the earth after all the losses have taken place is called *run-off*.

A tract of land which contributes the above run-off into a stream or reservoir is called *catchment* and its area is known as *catchment area*.

The run-off is measured in terms of depth of water (*i.e.* cm) or in terms of discharge (*i.e.* cumecs).

The following are the factors affecting the run-off from a catchment :

1. Intensity of rainfall; 2. Soil characteristics of catchment; 3. Topography of the catchment; 4. Shape and size of catchment; 5. Geological condition of catchment; 6. Weather condition.

7.13 Estimation of Maximum Flood Discharge

The following empirical formulae may be adopted to compute the maximum flood discharge :

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1. *Dicken's formula.* According to Dicken's formula, the flood discharge (Q) in cumecs is given by

$$Q = CA^{3/4}$$

where C = Flood coefficient, and

A = Area of basin in sq. km.

The value of C is taken as 11.4 for Nothern India, 13.9 to 19.5 to Central India and 22.5 to 2 for Western Ghats.

2. *Ryve's formula.* According to Ryve's formula, for Madras catchments, the flood discharge (Q) in cumecs is given by

$$Q = CA^{2/3}$$

The value of C is taken as 6.75 for areas within 24 km from the coast, 8.45 for areas within 2 km to 161 km from the coast and 10.1 for limited areas near hills.

3. *Inglis formula.* According to Inglis formula, the flood discharge (Q) in cumecs is given b

$$Q = \frac{123\,A}{\sqrt{A + 10.4}}$$

This formula is used for estimating flood discharge for the catchments of former Bomba presidency.

4. *Nawab Jang Bahadur formula.* According to Nawab Jang Bahadur formula, for America catchments, the flood discharge (Q) in cumecs is given by

$$Q = CA^{\left(0.993 - \frac{1}{14}\log A\right)}$$

The value of C varies from 48 to 60.

5. *Fanning's formula.* According to Fanning's formula, the flood discharge (Q) in cumecs given by

$$Q = CA^{5/6}$$

6. *Fuller's formula.* According to Fuller's formula, the flood discharge (Q) is cumecs given by

$$Q = CA^{0.8}\,(1 + 0.8 \log T)\,(1 + 2.67\,A^{-0.3})$$

where T = Number of years in which maximum flood is considered.

7.14 Irrigation Canals

The canals used for irrigation purposes are called *irrigation canals*. The irrigations are ve important in increasing the crop production of the country. The irrigation canals are classified follows :

1. *Classification based upon the type of soil.* The canals depending upon the type of s may be alluvial canals and non-alluvial canals. The canals which pass through the *alluvial soil known as *alluvial canal.* The canal which pass through the non-alluvial (*i.e.* rock plain areas) so are called non-alluvial canals.

2. *Classification based upon the nature of water supply.* The canals depending upon t nature of water supply may be perennial or permanent canals and non-perennial or inundation cana The canals in which water flows throughout the year are known as *perennial* or *permanent cana* The canals in which water does not flow throughout the year (or water flows during monsoons) known as *non-perennial* or *inundation canals*.

3. *Classification based upon the funds available.* The canals depending upon the funds availa may be protective canals and productive canals. The canals which are constructed in the intrest of t

* The soil formed by the agency of water over a course of time is called *alluvial soil.*

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public and without any revenue expected, are called *protective canals*. The canals which are constructed for revenue are class *productive canals*.

7.15 Canal Alignment

The canal alignment should be such that it can irrigate maximum area. A canal may be aligned in the following three ways :

1. *Contour canal.* A canal which is aligned parallel to the contours of a country is called contour canal. It can irrigate only on one side of the canal *i.e.* low value contours side.

2. *Water-shed or ridge canal.* The canal which is aligned along the *water-shed line (or ridge line) is known as water-shed canal or ridge canal. The advantage of this type of canal is that it can irrigate the areas on both sides. The irrigation canals are generally aligned along water-shed.

3. *Side slope canal.* The canal which is aligned at right-angles to the contours of a country (*i.e.* along the side slope) is known as side slope canal. This canal runs approximately parallel to the natural drainage of a country. In a side slope canal, cross-drainage works are completely eliminated.

7.16 Layout of Canal System

The main components or construction works in a canal system in the correct sequence are as follows :

Canal head works, head regulator, main canal, branch canal, distributories (major and minor) and field channel or water courses.

The layout of a canal system is shown in Fig. 7.1

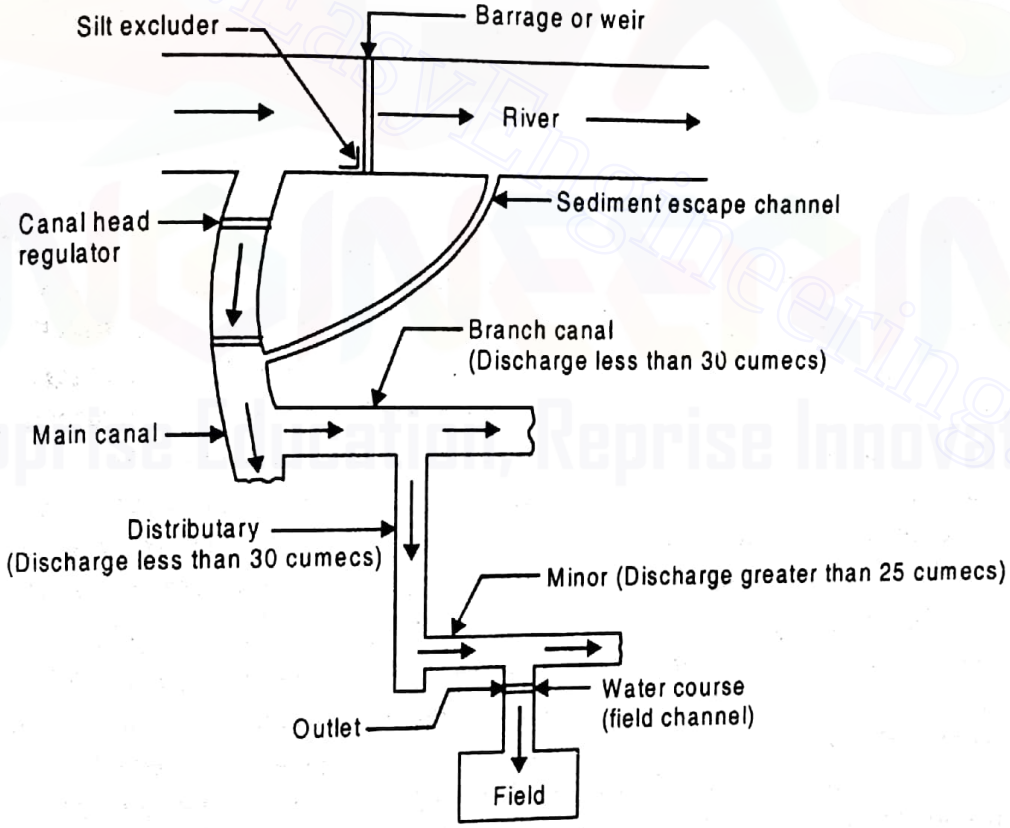

Fig. 7.1

7.17 Terms Relating to Canal Section

The following are different terms related to canal section :

1. *Berm.* The narrow strip of land at the ground level between the inner toe of the bank and top edge of the cutting, is known as berm. The berms provide additional strength to banks and thus

* Water-shed is the highest level line (*i.e.* ridge) in the area. The dividing line between the catchment area of two streams is called water-shed line.

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make it safe against breaches. A gap created in the bank of a canal is called a breach. The berms when fully formed have the following functions :

(*a*) They provide a bigger water way.

(*b*) They protect the bank from erosion because of wave action.

(*c*) They reduce the absorption losses and prevent leaks.

(*d*) They provide a scope for future widening of the canal.

(*e*) They bring the saturation line within the embankment.

2. *Free board.* The gap or margin of height, between full supply level (F.S.L.) and top of the bank, is called free board. It depends upon the size of canal, location of the canal and water surface fluctuations. The free board in a canal is provided for the following reasons :

(*a*) To keep a sufficient margin so that the canal water does not over top the bank in case of heavy rainfall or fluctuations in water supply.

(*b*) To keep the saturation gradient much below the top of the bank.

3. *Service road or inspection road.* The roadway provided either on one side (for branch canals) or on both sides of the canal bank (for main canal) for inspection and maintenance works is known as service road or inspection road. The width of the service road for branch canal varies from 3 to 4 metres and for main canal, the width varies from 4 to 6 m. The level of the service road is kept 0.4 to 0.8 m higher than full supply level (F.S.L.).

4. *Dowel or Dowla.* The raised portion provided on the canal side of the service road for the safety of the vehicles plying on it, is known as dowel or dowla. It is provided above the free supply level by a margin of free board. Practically, the dowels act as curbs on the side of road way towards the canal. The height of the dowel above the road level is 30 cm and the width at the top varies from 30 cm to 60 cm.

5. *Spoil bank.* The banks, constructed by the surplus excavated soil which may not be completely required from the construction of the banks, are known as spoil banks. The spoil banks are provided on one side or both sides of the canal bank depending upon the quantity of excess earth and the available space. These banks run parallel to the main bank. The construction of spoil bank is discontinued when the canal is to be connected with cross branch canals or distributaries.

6. *Borrow pits.* When the excavated earth for the construction of a canal is not sufficient for the earth work required for filling, then the extra earth required for the construction is taken from some pits which are known as borrow pits. These pits are dug in the adjoining lands.

The borrow pits may be inside or outside. The inside borrow pit should be excavated in the centre of the canal width and the maximum depth should be 1 metre. The width of the pit should not be less than half the width of the canal. The excavation of the inside pits should start from a distance of about 10 m from the toe of the big canal and 5 m for small canals.

Since outside pits create some inconvenience, therefore these are not preferred.

7. *Balancing depth.* When the quantity of excavated earth can be fully utilised by making the banks on both sides of the canal, then the cross-section of the canal is said be *economical section* or *balancing section*. The depth of cutting for that ideal condition is known as balancing depth. It is possible only when the canal section is partly in cutting and partly in filling. The cost of earth work will also be balanced.

7.18 Canal Lining

The laying of the impervious layer which protects the bed and sides of the canal is called *canal lining*. The lining of a canal assures economical water distribution, reduces possibility of breaching, prevents silting channel and increases available head for power generation. In a lined canal, the resistance to flow decreases and velocity of flow increases. It also decreases the maintenance of the canal. The lining of a canal is necessary for the following reasons :

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(*a*) to minimise the seepage losses through the bed and sides of the canal.
(*b*) to prevent scouring and erosion of bed and sides of the canal due to high velocity of flood water at the time of heavy rainfall.
(*c*) to increase the discharge in the canal section by increasing the velocity.
(*d*) to prevent water logging of area which takes place due to rise in ground water table.
(*e*) to prevent the growth of weeds along the bed and sides of the canal.
(*f*) to minimise the cost of maintenance of the canal.
(*g*) to increase the command area.

The canal lining may be of the following types, depending upon their properties :

1. *Cement concrete lining.* The cement concrete lining is widely accepted as the best impervious lining. It can resist the effect of scouring and erosion very efficiently. The velocity of flow may be kept above 2.5 m/s. It can eliminate completely the growth of weeds.

2. *Lime concrete lining.* This lining is preferred where hydraulic lime, surki and brick ballast are available in plenty along the course of the canal. This lining is less durable than cement concrete lining.

3. *Pre-cast concrete lining.* It consists of pre-cast concrete slabs of size 60 cm × 60 cm × 5 cm which are set along the canal bank and bed with cement mortar. This lining is recommended for the canal in full banking.

4. *Cement-mortar lining.* This lining is not durable unless protected suitably. A thickness of 2.5 cm of cement mortar lining can reduce seepage losses by 95 %.

5. *Brick lining.* The first class bricks are recommended for the work. The brick lining is preferred because of its low cost and work can be done very quickly.

6. *Shot crete lining.* Shot crete is a mixture of cement and sand in the ratio of 1 : 4. This lining is preferred for the repairing of an old but sound concrete lining. The thickness of shot crete lining varies from 2.5 cm to 5 cm.

7. *Sodium carbonate lining.* This lining consists of 10% clay and 6% sodium carbonate. This lining is not durable.

8. *Asphalt lining.* This lining is prepared by spraying asphalt (*i.e.* bitumen) at a very high temperature (about 150°C) on the subgrade to a thickness varying from 3 mm to 6 mm. This lining is very cheap and can control the seepage of water very effectively but it cannot control the growth of weeds.

7.19 Kennedy's Silt Theory

R.G. Kennedy who was an Executive Engineer in Irrigation Department of Punjab (in Pakistan) carried out long investigations on the channels of upper Bari Doab canal system from which silt was not cleared over a period of 30 years. He, therefore, considered these canals as stable and in regime state.

According to Kennedy, a regime channel is one which neither scours nor silts. He made the following observations during his study :

1. The silt sediment in a flowing canal is kept in suspension because of eddies generated from the roughness of the bed only.

2. Though the eddies are also generated from the sides of the channel, but they do not have any silt supporting power becasue they travel horizontally. He concluded that the silt supporting power of a channel is directly proportional to the bed width of the channel and not to its total wetted perimeter.

3. The velocity of water which neither scours nor silts the channels is known as *critical velocity* of flow. The relation given by Kennedy for critical velocity (V_o) in m/s is

$$V_o = 0.55\, m\, D^{0.64}$$

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where m = Critical velocity ratio, and

D = Depth of water over the bed portion of a channel in metre.

The following are some serious defects in Kennedy's theory :

(*a*) Kennedy did not suggest any equation for determining the bed slope.

(*b*) Kennedy did not take into account of silt concentration and bed load.

(*c*) Kennedy did not difine silt grade and silt charge.

(*d*) Kennedy did not give his own flow equation. He used Kutter's flow equation without any modification.

7.20 Lacey's Theory

Lacey, a civil engineer of U.P. Irrigation Department carried out extensive investigations on canals in alluviums. He found many draw backs in Kennedy's theory and put forward his new theory.

According to Kennedy, a channel is said to be in a state of regime if there is neither silting nor scouring in the channel. But Lacey came out with a statement that even though a channel showing no silting or scouring may actually not be in regime state. According to Lacey, a channel is said to be in regime state in the following three conditions :

(*a*) The channel flows in unlimited incoherent *alluvium of the same character as that of transported material.

(*b*) The silt grade and the silt charge are constant.

(*c*) The discharge is constant.

In actual practice, these conditions are seldom met with. Thus, Lacey gave the idea of initial and final regime for the channels.

The channel is said to be in *initial regime* when it only attains final section but does not attain its longitudinal slope. The channel is said to be in *final regime* when it attains its section as well as longitudinal slope.

According to Lacey,

(*a*) There is only one section and only one longitudinal slope at which the channel will carry a particular discharge with a particular silt grade. He found that in final regime, the channel cross section becomes semi-elliptical.

(*b*) The eddies are generated from the bed and also from sides, both normal to the surface for generation.

(*c*) The silt in flowing water is kept in suspension due to the force of vertical component of the eddies.

(*d*) The vertical component of the eddies generated from the sides will also support the silt.

(*e*) The grain size of the material forming the channel is an important factor and Lacey introduced a term called '*silt factor*' in his equation for the design of channels and connected it to the average particle size.

Lacey's silt factor (f) is given by

$$f = \frac{5V^2}{2R}$$

where V = Mean regime velocity, and

R = Hydraulic mean depth.

If m is the mean particle diameter of the silt in mm, then Lacey's silt factor (f) is given by

$$f = 1.76\, m^{1/2}$$

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* The incoherent alluvium is a soil composed of loose granular graded material which can be scoured with the same ease with which it is deposited.

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(*f*) The general regime flow equation is

$$V = 10.8\, R^{2/3} S^{1/3}$$

where S = Slope of water surface.

(*g*) If Q is the discharge in cumecs, then the velocity of flow (V) in the channel,

$$V = \left(\frac{Q f^2}{140}\right)^{1/6} \text{ m / s}$$

Wetted perimeter, $P = 4.75\sqrt{Q}$

Bed slope, $S = \dfrac{f^{5/3}}{3340\, Q^{1/6}}$

$$\text{scour depth} = 0.47\left(\frac{Q}{f}\right)^{1/3}$$

and

7.21 Water Logging

A land is said to be water logged when the air circulation is stopped in the root zone of the plant due to the rise in water table. The infertility of the soil and unproductivity in water logged areas is due to inhibiting activity of the soil bacteria, growth of weeds and increasing of harmful salts. The main causes of water logging are as follows :

(*a*) Inadequate drainage facilities;
(*b*) Over and intensive irrigation;
(*c*) Presence of impermeable strata;
(*d*) Seepage from canals;
(*e*) Nature of soil;
(*f*) Excessive rainfall;
(*g*) Topography of the land; and
(*h*) Occasional flood.

7.22 Canal Regulatory Works

The works or structures constructed in or across the canal in order to control and regulate discharges, depths, velocities etc. and distributing the same effectively are known as *canal regulation or regulatory works*. The following are the canal regulation works :

(*a*) Regulators; (*b*) Escapes; (*c*) Falls; and (*d*) Canal outlet and modules

These are discussed, in detail in the following pages.

7.23 Regulators

The irrigation works constructed for regulating the supply of irrigation water are called *regulators*. These may be head regulators and cross regulators.

The head regulators are provided at the head of the canal. When it is constructed at the head of the off-taking canal or distributory, then it is called distributory head regulator. The distributory head regulators are provided

(*a*) to control the supplies to the off-taking canal,
(*b*) to control the silt entry in the off-taking canal,
(*c*) to stop the supply, when not needed, in the off-taking canal, and
(*d*) for measuring the discharge entering into the off-taking canal.

A cross regulator is provided in the main canal downstream of an off-taking canal. It is provided

(*a*) to raise the water level to its upstream during the periods of low discharges in the parent canal.
(*b*) to help in closing the supply to downstream of the parent canal, and
(*c*) to absorb fluctuation in various sections of the canal system.

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7.24 Escapes

A structure constructed in an irrigation canal for the purpose of escaping excess water fro canals into some natural drainage are called *escapes* or *safety valves*.

The minimum capacity of the escape is generally kept as 50% of the canal capacity at the of the escape. The escapes may be scouring escape (or sluice escape or regular escape), surplus escape and tail escape or weir type escape.

7.25 Canal Falls

The masonry structures which are constructed to provide the designed bed slope of the ch at suitable intervals, are called *canal falls*. The canal falls are necessary in the following condi

1. When the slope of the ground suddenly changes to steeper slope.
2. When the slope of the ground is more or less uniform and the slope is greater tha permissible bed slope of canal.
3. In cross-drainage works, when the difference between bed level of canal and that of dra is small or when the F.S.L. of the canal is above the bed level of drainage.

Following are the different types of canal falls :

(*a*) *Ogee fall.* In this type of fall, an ogee curve (a combination of convex curve and cor curve) is provided for carrying the canal water from a higher level to a lower level.

(*b*) *Rapid fall.* The rapid fall is suitable when the slope of the natural ground surface is and long. It consists of a long sloping glacis with longitudinal slope which varies from 1 in 15 t 20. These falls are very satisfactory but expensive.

(*c*) *Trapezoidal notch fall.* It consists of a number of trapezoidal notches provided in a crested wall across the channel. Each notch possesses a smooth entrance and a flat circul projecting down stream to spread out the falling jet. This type of fall was very popular in olden

(*d*) *Sharda fall or Vertical drop fall.* It consists of vertical drop wall which is constructed masonry work. The water flows over the crest of the wall. This type of fall was provided o sharda canal in Uttar Pradesh.

The length of the crest is kept equal to bed width of the canal. Two types of crests are use different discharges. For a discharge less than 14 cumecs, a rectangular crest with faces vertic used. The top width is kept equal to $0.55\sqrt{d}$ and minimum base width is kept equal to $\frac{H}{}$ ($G = 2$ for masonry), where d is the height of the crest above the downstream bed level and H i head over the crest. The discharge (Q) over a rectangular crest of a sharda fall is given by

$$Q = 1.835\, L\, H^{3/2} \left(\frac{H}{B}\right)^{1/6}$$

For discharges greater than 14 cumecs, a trapezoidal crest with top width equal to $0.55\sqrt{H}$ is used. The discharge (Q) over a trapezoidal crest of a sharda fall is given by

$$Q = 1.99\, L\, H^{3/2} \left(\frac{H}{B}\right)^{1/6}$$

where L = Length of crest in metres,

H = Top width of crest in metres, and

B = Depth of water in metres.

(*e*) *Glacis fall.* It consists of a straight glacis provided after the raised crest. A water cus is provided on the down stream side to dissipate the energy of flowing water. A straight glacis when flumed is called a flumed type fall.

(*f*) *Montague fall.* In this type of fall, the straight sloping glacis is modified by giving parab shape which is known as Montague profile.

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(*g*) *Inglis fall or Baffle fall.* In this type of fall, the glacis is straight and sloping, but a baffle platform and a baffle wall are provided on the down stream floor to dissipate the energy of flowing water. The baffle wall is provided at a calculated height and distance from the toe of the glacis to ensure the formation of the jump on the baffle platform. Such falls are suitable for all discharges and for drops not exceeding 1.5 metres.

7.26 Canal Outlets or Modules

A work constructed at the head of a water course through which it gets supply from the canal or distributary is called an *outlet* or *module*.

A canal outlet should be so designed that the farmer cannot temper with its functioning. It should draw its fare share of silt carried by the distributing channel. It should be simple so that it can be constructed or fabricated by local masons. The outlets may be of the following three types :

1. Non-modular outlets; 2. Semi-modular or flexible outlets; and 3. Modular outlets or rigid modules.

An outlet in which the discharge depends upon the difference in level between the water levels in distributing channel and the water course is known as *non-modular outlet*. One of the most famous example of non-modular outlet is submerged pipe outlet.

An outlet in which the discharge depends only on the water level in the distributary, is known as *semi-modular* or *flexible outlet*. The discharge through such a outlet will increase with a rise in water surface level of distributary and *vice versa*. The common examples of semi-modular outlet are pipe outlet, venturi-flume, open flume and orifice semi-module.

An outlet in which discharge is independent of the water levels in the water course and the distributary, is called *modular outlet* or *rigid module*. A common example of such a module is Gibbs module.

7.27 Canal Head Works

In order to form a storage reservoir to raise the water level at the head of the canal, some structures are constructed which are known as *canal head works*. When a dam is constructed across a river valley to form a storage reservoir, it is known as *storage head work*. When a weir or barrage is constructed across a perennial river to raise the water level and to divert the water to the canal, then it is known as *diversion head work*. The following are the objects of diversion of head work :

1. to raise the water level at the head of the canal,
2. to regulate the intake of water into the canal,
3. to reduce the fluctuations of water level in the river during different seasons, and
4. to control the silt entry into the canal.

A canal head work in rocky stage of a river is not suitable because

(*a*) more cross-drainage works are required,

(*b*) more falls are necessary to dissipate the energy, and

(*c*) a costly regulator is required.

7.28 Weir or Barrage

A solid construction put across the river to raise its water level and to divert the water into the canal, is known as *weir*. When the water level on the upstream side of the weir is required to be raised to different levels at different times, then *barrage* is constructed. Practically, a barrage is an arrangement of adjustable gates or shutters at different tiers over the weir. A weir or barrage may fail due to the following :

1. Rupture of floor due to uplift,
2. Rupture of floor due to suction caused by standing wave, and
3. Scour on the upstream and downstream of the weir.

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The weirs, according to the materials of construction, are classified as follows :

(*a*) *Vertical drop weir.* It consists of a masonry weir wall over the horizontal floor. The cut-off walls are provided at both ends of the floor. The sheet piles are provided below the cut-off walls. The crest shutters are provided to raise the water level, if required. The shutters are dropped down during floods to reduce the afflux by increasing the water way capacity.

(*b*) *Dry stone slope weir.* It is also known as Rock fill weir. It consists of a masonry breast wall which is provided with adjustable crest shutters. The old Okhla weir on Yamuna river, in Delhi, is an example of such type of weir.

(*c*) *Concrete slope weir.* This type of weir is made of reinforced cement concrete. The cut-off walls are provided at the upstream and downstream end of the floor and at the toe of the weir. The sheet piles are provided below the cut-off walls. The crest shutters are also provided which are dropped down during the flood. This type of weir is used when the difference in weir crest and down stream river bed is limited to 3 metres.

7.29 Bligh's Creep Theory

According to Bligh's creep theory, the percolating water creeps along the base profile of the apron with the sub-soil. The path traced by the percolating water is known as *creep length*. The loss of head per unit creep length is known as *hydraulic gradient* or *percolation coefficient* which is constant throughout its passage. The reciprocal of hydraulic gradient is known as *Bligh's creep coefficient*.

The limitations of Bligh's creep theory are as follows :

1. There is no distinction between horizontal and vertical creep.
2. There is no significance of exit gradient.
3. The loss of head does not take place in the same proportion as the creep length.
4. The uplift pressure distribution is not linear, but follows a sine curve.

7.30 Khosla's Theory

According to Khosla's theory,

(*a*) The outer sheet piles are more effective than the intermediate piles.

(*b*) The outer face of the sheet pile is more effective than the inner face.

(*c*) If the intermediate piles are shorter than the outer piles, then these are not effective.

(*d*) The under mining of the floor starts from the tail end.

(*e*) The critical hydraulic gradient for alluvial soils is approximately equal to one.

7.31 River Training Works

The river training works are adopted on a river in order to

(*a*) pass high flood discharge safely and quickly through the breach,

(*b*) direct and guide the river flow,

(*c*) make the river course stable,

(*d*) reduce bank erosion to a minimum, and

(*e*) prevent water logging of submerged lands.

The Indian rivers pass through the following four stages :

1. Rocky stage; 2. Boulder stage; 3. Trough stage; and 4. Delta stage.

In *rocky stage*, the river flows on steep rocky bed. The water of the river in this stage is cle and flows with high speed. The water in the river is due to the melting of snow only.

After leaving the rocky stage, the river enters the *boulder stage*. The river flows at the foot the hills. The bed is made of disintegrated materials like sand, gravel, clay, shingle and boulders. T river water is very clear except in rainy season when the run-off is also contributed by the surroundi

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catchments.

When the river flows through the plain terrain, then it is known as *trough stage* or *alluvial stage*. In this stage, the cross-section of the river is formed by the alluvial soil. The water of the river contains huge amount of suspended clay and silt particles which is very useful in increasing the crop yield on the agricultural land.

As the river approaches the ocean, the formation of delta *i.e.* shoal starts due to very low velocity of flow. This region is known as delta stage. Here, the velocity of flow is unable to carry the sediment loads which are deposited at the junction point forming delta. The river course is divided into several channels by a number of deltas.

The rivers on alluvial plains may be further classified as *meandering type*, *degrading type* and *aggrading type*. In the trough stage, the river course takes the shape of a serpentile curve due to the formation of shoals in both the banks in a zig-zag manner which is known as meandering of river, as shown in Fig. 7.2. The primary cause of meandering is the excess of total charge during floods, when excess turbulence is developed. The factors which control the process of meandering are stream load, discharge, valley slope, nature of bed and side resistance. A river meandering through an alluvial plain flows in a sinuous curve *i.e.* the river flows in a series of consecutive curves of reversed order connected with short straight sketches, called *crossings*.

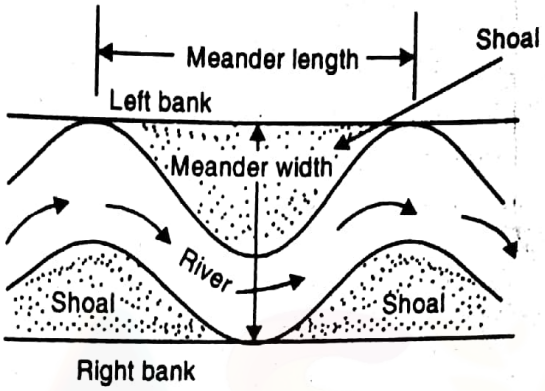

Fig. 7.2

The tangential distance between the successive points of a meander is known as *meander length*.

The transverse distance between the apex point of one curve and apex point on the reverse curve is called *meandering belt or width*.

The ratio of the curved length and the straight axial distance is called *degree of sinuosity*.

The ratio of curved length along the river to the direct axial length of the river is called *tortuosity*.

The alluvial river which tends to wear down its bed constantly, is called a *degrading type river*.

The alluvial river which tends to build up its bed by laying down of sedimentation, is called a *aggrading type river*.

7.32 Types of River Training Works

The following are different types of river training works, provided for training of rivers :

1. *Marginal embankment (Dyke or Levee).* The marginal embankment or dyke is an earthen embankment of trapezoidal section constructed approximately parallel to the bank of the river to confine the flood water to the minimum possible cross-section of the river in between the embankments. A margin of about 2 metres is provided between the toe of the embankment and top edge of the river bank. These are provided on those rivers in which the flood level is so high that the adjoining areas get flooded.

2. *Guide bank.* The guide bank is an earthen embankment with curved heads on both the ends. When a barrage is constructed across a river which flows through the alluvial soil, the guide banks must be constructed on both the approaches to protect the structure from erosion. The guide banks may be divergent, convergent or parallel guide banks.

3. *Groynes.* A groyne is a permanent structure constructed transverse to the river flow and extend from the bank into the river upto a certain limit. They are constructed in order to

(*a*) protect the river bank, by keeping away the river flow,

(*b*) train the flow along a certain course,

(*c*) contract a river channel to improve its depth, and

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(*d*) silt up the area in the vicinity by creating a slack flow.

The length of the groyne depends upon the width and nature of the river. The top width varies from 3 m to 4 m. The side slope may 1½ : 1 or 2 : 1. The spacing between the adjacent groynes is generally kept as twice the length of the groyne.

The groynes, depending upon the materials of construction, may be permeable and impermeable groynes. The groynes which permit the flow of water through them are called *permeable groynes*. These groynes obstruct the flow, reduces its velocity and reduce the erosive action of the stream. The groynes which do not permit any flow through them are known as *impermeable groynes* or *solid groynes*. These groynes may be constructed by a core of locally available material like sand, clay and gravel. The impermeable groynes may be classified as follows :

(*a*) Deflecting groynes; (*b*) Attracting groynes; (*c*) Repelling groynes; (*d*) Hockey groynes; and (*e*) T-shaped or Denehy's groynes.

The *deflecting groynes* are constructed perpendicular to the river bank to deflect the flow away from the bank.

The *attracting groynes* are constructed obliquely to the bank by making an angle of 60° to 75° towards the downstream. It has the property to attract the flow of water towards the river bank.

The *repelling groynes* are constructed in such a way that it is pointing towards upstream at an angle of 30°. It has the property to repel the flow of water away from it.

The *hockey groynes* are constructed in such a way that the head of the groyne is curved towards downstream in the shape of a hockey stick. It behaves like an attracting groyne.

The *T-shaped* or *Denehy's groynes* are the special types of groynes with the head in T-shape.

7.33 Cross-Drainage Works

The structures constructed at the crossing point for the easy flow of water of the canal and drainage in the respective directions, are known as *cross-drainage works*. The nature of cross drainage works may be different at different places, depending upon the bed levels of the canal and drainage. Thus the cross drainage works are classified as follows :

1. *Aqueduct and syphon aqueduct.* When the bed level of the canal is higher than the highest flood level (H.F.L) of the drainage, then the cross-drainage work (or structure) is said to be aqueduct. In this case, the drainage water passes clearly below the canal.

In case the bed level of the canal is below the highest flood level (H.F.L.) of the drainage so that the drainage water passes through the aqueduct barrels under syphonic action, then the structure provided is known as syphon aqueduct.

2. *Super-passage and canal syphon.* When full supply level (F.S.L) of the canal is much below the bed level of the drainage trough, so that he canal water flows freely under gravity, the structure provided is known as super-passage.

When the full supply level (F.S.L) of the canal is much above the bed level of the drainage trough, so that the canal water flows under syphonic action under the trough, the structure provided is known as canal syphon.

3. *Level crossing.* When the bed level of the canal and that of the drainage are at the same level, the structure provided is called level crossing. This is a type of cross-drainage works in which the canal water and drain water get intermixed.

OBJECTIVE TYPE QUESTIONS

1. The irrigation engineering may be defined as
   (*a*) the process of artificially supplying water to soil for raising crops
   (*b*) a science of planning and designing an efficient and economic irrigation system.
   (*c*) the engineering of controlling and harnessing the various natural sources of water, by the construction of dams, canals and finally distributing the water to the agricultural fields
   (*d*) all of the above

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2. The irrigation is necessary in an area
   (a) where there is a scanty rainfall
   (b) where the rainfall is non-uniform
   (c) where commercial crops require more water
   (d) all of the above
3. The irrigation water is said to be unsatisfactory, if it contains
   (a) chemicals toxic to plants or to persons using plants as food
   (b) chemicals which react with the soil to produce unsatisfactory moisture characteristics
   (c) bacteria injurious to persons or animals eating plants irrigated with water
   (d) all of the above
4. Sandy soils with good drainage become impermeable after prolonged use, if it is irrigated with a water containing ..... sodium.
   (a) 25% (b) 50% (c) 75% (d) 85%
5. For irrigation purposes, the p-H value of water should be
   (a) between 3 and 6
   (b) between 6 and 8.5
   (c) between 8.5 and 11
   (d) more than 11
6. Which of the salt present in water is harmful for cultivation purposes ?
   (a) Sodium carbonate
   (b) Potassium sulphate
   (c) Calcium sulphate
   (d) none of these
7. When an oven-dried sample of soil is kept open in the atmosphere, it absorbs some amount of water. This water is known as
   (a) capillary water
   (b) gravitational water
   (c) hygroscopic water
   (d) all of these
8. A part of water which exists in the porous space of the soil by molecular attraction, is known as
   (a) capillary water
   (b) gravitational water
   (c) hygroscopic water
   (d) all of these
9. A part of water which will move out of the soil, if proper drainage is provided, is known as gravitational water.
   (a) True (b) False
10. Super-fluous water is also called
   (a) capillary water
   (b) gravitational water
   (c) hygroscopic water
   (d) all of these
11. Irrigation is supplementary to rainfall.
   (a) Agree (b) Disagree
12. Irrigation ..... the chances of water logging.
   (a) increases (b) decreases
13. Irrigation is said to be a science of survival.
   (a) Correct (b) Incorrect
14. A useful soil moisture for plant growth is
   (a) capillary water
   (b) gravitational water
   (c) hygroscopic water
   (d) all of these
15. The amount of water required to fill up the pore spaces in soil particles by replacing all air held in pore spaces, is known as
   (a) field capacity
   (b) saturation capacity
   (c) available moisture
   (d) all of these

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16. The moisture content of the soil, after free drainage has removed most of the gravity water, known as
(a) field capacity (b) saturation capacity
(c) wilting co-efficient (d) available moisture

17. The water content at which plants can no-longer extract sufficient water from the soil for growth, is called
(a) field capacity (b) saturation capacity
(c) permanent wilting point (d) available moisture

18. Available moisture may be defined as the
(a) moisture content at permanent wilting point
(b) difference in water content of the soil between field capacity and permanent wilting
(c) maximum moisture holding capacity (d) all of these

19. The field capacity of a soil depends upon
(a) capillary tension in soil (b) porosity of soil
(c) either (a) or (b) (d) both (a) and (b)

20. Capillary water is a useful soil moisture for the growth of plants.
(a) Yes (b) No

21. Consumptive use of water by a crop is equal to
(a) the depth of water consumed by evaporation
(b) the depth of water consumed by transpiration
(c) the depth of water consumed by evaporation and transpiration during crop growth, including water consumed by accompanying weed growth
(d) none of the above

22. The consumptive use of water of a crop
(a) is measured as the volume of water per unit area
(b) is measured as depth of water on irrigated area
(c) may be supplied partly by precipitation and partly by irrigation
(d) all of the above

23. Which of the following statement is correct ?
(a) The gravity water is harmful to the crops.
(b) The hygroscopic water remains attached to the soil molecules by chemical bonds.
(c) The capillary water is utilised by the plants.
(d) all of the above

24. The ratio between the area of a crop irrigated and the quantity of water required during entire period of the growth, is known as
(a) delta (b) duty (c) base period (d) crop period

25. The total depth of water required by a crop during the entire period the crop is in the field known as
(a) delta (b) duty (c) base period (d) crop period

26. The duty is largest
(a) at the head of the main canal (b) at the head of the water course
(c) on the field (d) at all place

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27. The time (in days) that crop takes from the instant of its sowing to that of its harvest, is known as ..... period.
(a) base (b) crop (c) kor

28. The whole period of cultivation from the time when irrigation water is first supplied for preparation of the ground to its last watering before harvesting, is called
(a) base period (b) crop period (c) kor period (d) none of these

29. The duty of irrigation water goes on ..... as the water flows.
(a) increasing (b) decreasing

30. Crop ratio is the ratio of area irrigated
(a) in Rabi season to Kharif season (b) in Kharif season to Rabi season
(c) under perennial crop to total crop (d) under perennial crop to non-perennial crop

31. The duty of irrigation water will be less if
(a) area irrigated is more (b) water supply required is less
(c) water supply required is more (d) none of these

32. The relation between duty (D) in hectares/cumec, delta (Δ) in metres and base period (B) in days is
(a) $\Delta = \frac{8.64\ B}{D}$ (b) $\Delta = \frac{86.4\ B}{D}$ (c) $\Delta = \frac{864\ B}{D}$ (d) $\Delta = \frac{8640\ B}{D}$

33. The area in which crop is grown at a particular time or crop season, is called
(a) gross commanded area (b) culturable commanded area
(c) culturable uncultivated area (d) none of these

34. The first watering before sowing the crop, is known as
(a) kor watering (b) paleo (c) delta (d) none of these

35. The first watering, when the crop has grown a few centimetres, is called paleo.
(a) Agree (b) Disagree

36. The crops require maximum water during
(a) first watering before sowing the crops (b) last watering before harvesting
(c) first watering when the crop has grown a few centimetres
(d) all of the above

37. The maximum depth in soil strata, in which the crop spreads its root system, and derives water from the soil, is called
(a) kor depth (b) root zone depth (c) delta (d) overlap allowance

38. The depth of root zone is 90 cm for
(a) wheat (b) sugar cane (c) rice (d) cotton

39. The duty at outlet is called capacity factor.
(a) Correct (b) Incorrect

40. The duty of a crop is 432 hectares per cumec when the base period of the crop is ... days. The delta for the crop will be
(a) 100 (b) 200 (c) 432 (d) 864

41. The average delta of rice crop is nearly
(a) 30 cm (b) 60 cm (c) 120 cm (d) 150 cm

42. The average duty for sugar-cane in hectares/cumec is
(a) 200 (b) 400 (c) 600 (d) 800

43. The optimum depth of kor watering is 19 cm for
(a) wheat (b) sugar-cane (c) rice (d) cotton

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44. Outlet discharge for a particular crop is given by
(a) Area / Outlet factor (b) Outlet factor/Area
(c) Area × Outlet factor (d) none of these

45. The optimum depth of kor watering for wheat in the plains of north India is
(a) 13.5 cm (b) 16.5 cm (c) 19 cm (d) 21 cm

46. The kor depth for rice is 19 cm and kor period is 14 days. The outlet factor for the c
hectares per cumec will be
(a) 437 (b) 637 (c) 837 (d) 1037

47. Where steep land is available, the method of irrigation adopted is
(a) free flooding (b) border flooding (c) check flooding (d) basin floo

48. For closed growing crops (such as wheat), the method of irrigation used is
(a) free flooding (b) border flooding (c) check flooding (d) basin floo

49. Check flooding method of irrigation is used for
(a) closed growing crops (b) tracts with flat gradients
(c) crops which can stand inundation of water for sometime
(d) crops such as sugarcane, potatoes etc.

50. For potato, sugarcane and groundnut, the furrow method of irrigation is adopted.
(a) Yes (b) No

51. The flooding is also termed as wild flooding.
(a) Right (b) Wrong

52. Which of the following statement is correct ?
(a) In free flooding, the field is divided into a number of small sized plots which are pra level.
(b) In border strip method, the strips are separated by low levels.
(c) In furrow irrigation, the water is admitted between the rows of plants in the field
(d) all of the above

53. Sprinklar irrigation is adopted for ..... areas.
(a) level (b) uneven (c) hilly

54. The method of irrigation used for orchards is
(a) free flooding (b) border flooding (c) check flooding (d) basin floo

55. The hydrology is a science which deals with the
(a) occurrence of water on the earth (b) distribution of water on the earth
(c) movement of water on the earth (d) all of these

56. The knowledge of hydrology is necessary in civil engineering for
(a) designing and construction of irrigation structures
(b) designing and construction of bridges and culverts
(c) flood control works (d) all of these

57. The hydrology helps in
(a) predicting maximum discharge (b) deciding capacity of reservoir
(c) fore casting flood (d) all of these

58. The science which deals with the physical features and conditions of water on the earth s is called
(a) hydrome (b) hydrography (c) hydrosphere (d) hydraulic

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59. The science which deals with the measurement of water is called hydrometry.
(a) True (b) False

60. The earth's water circulatory system, is known as
(a) water cycle (b) hydrologic cycle
(c) precipitation cycle (d) all of these

61. The fall of moisture from the atmosphere to the earth surface in any form, is called
(a) evaporation (b) transpiration (c) precipitation (d) none of these

62. Liquid precipitation consists of
(a) snow (b) hail (c) sleet (d) rainfall

63. The hydrology cycle is expressed by the equation
(a) $P = E - R$ (b) $P = E + R$ (c) $P = E \times R$ (d) $P = E / R$
where P = Precipitation, E = Evaporation, and R = Run-off.

64. Cyclonic precipitation results from
(a) lifting of air masses converging into low pressure area
(b) natural rising of warmer, lighter air in colder and denser surroundings
(c) lifting of warm moisture-laden air masses due to topographic barriers
(d) all of the above

65. The precipitation caused by natural rising of warmer lighter air in colder and denser surroundings, is called
(a) convective precipitation (b) orographic precipitation
(c) cyclonic precipitation (d) none of these

66. The precipitation caused by lifting of warm moisture laden air masses due to topographic barriers, is called
(a) convective precipitation (b) orographic precipitation
(c) cyclonic precipitation (d) none of these

67. The process of loosing water from the leaves of plants, is termed as
(a) surface evaporation (b) water surface evaporation
(c) transpiration (d) precipitation

68. The movement of water through the soil surface into the soil, is called infilteration.
(a) Correct (b) Incorrect

69. The maximum rainfall during a short period measured in mm / hour is called mean annual rainfall.
(a) Agree (b) Disagree

70. The amount of precipitation is measured by
(a) rain gauge (b) osmoscope (c) turbidimeter (d) all of these

71. The commonly used rain gauge is
(a) weighing bucket type (b) tipping bucket type
(c) float type (d) none of these

72. The standard height of a standard rain gauge is
(a) 10 cm (b) 20 cm (c) 30 cm (d) 40 cm

73. According to Dicken's formula, the flood discharge (Q) in cumecs is given by
(a) $Q = CA^{2/3}$ (b) $Q = CA^{3/4}$ (c) $Q = CA^{5/6}$ (d) $Q = CA^{7/8}$
where C = Flood coefficient, and A = Area of basin in sq km.

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74. For Madras catchments, the flood discharge is estimated from $Q = CA^{2/3}$. This formula is known as
(a) Dicken's formula (b) Ryve's formula
(c) Nawab Jang Bahadur formula (d) Inglis formula

75. According to Fanning's formula, the flood discharge (Q) in cumecs is given by
(a) $Q = CA^{2/3}$ (b) $Q = CA^{3/4}$ (c) $Q = CA^{5/6}$ (d) $Q = CA^{7/8}$

76. Inglis formula is used for estimating flood discharge for
(a) the catchments of former Bombay Presidency
(b) the catchments of old Hyderabad State (c) the Madras catchments
(d) none of the above

77. Nawab Jang Bahadur formula is used to estimate the flood discharge of American catchments
(a) Right (b) Wrong

78. Dicken's formula for high flood discharge is useful for catchments in
(a) Southern India (b) Northern India (c) Eastern India (d) Western India

79. In order to estimate the high flood discharge in fan-shaped catchment, the formula used is
(a) Dicken's formula (b) Ryve's formula (c) Inglis formula (d) Fanning's formula

80. The estimation of flood can be made
(a) by physical indication of past floods (b) by flood discharge formulae
(c) by unit hydrograph (d) all of these

81. Which of the following method is useful for obtaining values of flood discharges for a high recurrence interval ?
(a) California method (b) Hazen's method (c) Gumbel's method (d) all of these

82. A graph showing variations of discharge with time, at a particular point of a stream is known as
(a) mass inflow curve (b) logistic curve (c) hydrograph (d) none of these

83. The graphical representation of average rainfall and rainfall excess (*i.e.* rainfall minus infiltration) rates over specified areas during successive unit time intervals during a storm is known as
(a) hydrograph (b) unit hydrograph (c) hyetograph (d) none of these

84. A hydrograph representing one cm of run off from a rainfall of some unit duration and specific area distribution is known as
(a) hyetograph (b) flood hydrograph (c) unit hydrograph (d) S-hydrograph

85. Run-off is measured in
(a) m^3/s (b) m^3/min (c) m^3/h (d) none of these

86. Flood frequency denotes the likelyhood of flood being equalled or exceeded.
(a) Yes (b) No

87. A canal aligned nearly parallel to the contours of a country, is known as
(a) side slope canal (b) contour canal (c) water shed canal (d) ridge canal

88. A canal aligned approximately parallel to the natural drainage of a country is called
(a) side slope canal (b) contour canal (c) water shed canal (d) ridge canal

89. A canal aligned roughly at right angles to the contours of the country is called ridge canal.
(a) True (b) False

90. The water shed canal is also called
(a) side slope canal (b) contour canal (c) ridge canal (d) all of these

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91. Irrigation canals are generally aligned along
(a) contour line (b) water shed (c) straight line (d) valley line

92. A canal aligned at right angles to the contour of a country, is known as
(a) side slope canal (b) contour canal (c) water shed canal (d) branch canal

93. The alignment of a canal
(a) should be such, so as to ensure minimum number of cross drainage works
(b) on a water shed is the most economical (c) should avoid valuable properties
(d) all of the above

94. Inundation canals draw their supplies from rivers whenever there is a ..... stage in the river.
(a) low (b) high (c) medium

95. In side slope canal, cross-drainage works are completely eliminated.
(a) Agree (b) Disagree

96. A contour canal
(a) is most suitable in hilly areas (b) irrigates only on one side
(c) is aligned parallel to the contour of the country
(d) all of the above

97. Which of the following is the correct sequence of the parts of a canal system ?
(a) Head works, distributary, branch canals and minor.
(b) Head works, main canal, branch canal, distributary and minor.
(c) Head works, main canal, branch canal, minor and distributary.
(d) none of the above

98. Match the correct answer form *Group B* for the statements given in *Group A*.

Group A	*Group B*
(a) In perennial canals	(A) water does not flow throughout the year
(b) In non-perennial canals	(B) revenue from water is not expected
(c) In protective canals	(C) revenue from water is expected
(d) In productive canals	(D) water flows throughout the year

99. In a canal section, which is in partial filling and partial cutting
(a) the full supply level of the canal is above the natural surface level
(b) the bed level of the canal is below the natural surface level
(c) the full supply level of the canal is below the natural surface level
(d) the bed level of the canal is above the natural surface level

100. The narrow strip of land left at the ground level between the inner toe of the bank and top edge the cutting, is known as
(a) free board (b) dowel (c) inspection roadway (d) berm

101. The gap or margin of height, between full supply level (F.S.L.) and top of the bank is called
(a) free board (b) dowel (c) inspection roadway (d) berm

102. The berms when fully formed
(a) reduce the absorption losses and prevents leaks
(b) protect the bank from erosion because of wave action
(c) provide a scope for future widening the channel
(d) all of the above

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103. Which of the following statements is wrong ?
(*a*) The top of dowel is kept above the free supply level by a margin of free board.
(*b*) The dowels are provided as a measure of safety for automobiles driven on the se roads.
(*c*) The dowels act as curbs on the side of roadway towards the canal.
(*d*) none of the above

104. The free board in a channel is governed by the
(*a*) size of the canal (*b*) location of the canal
(*c*) water surface fluctuations (*d*) all of these

105. The berms provide additional strength to banks and thus make it safe against breaches.
(*a*) True (*b*) False

106. The saturation gradient in an ordinary loam soil is
(*a*) 1 : 1 (*b*) 2 : 1 (*c*) 3 : 1 (*d*) 4 : 1

107. The height of dowel above the road level should not be more than
(*a*) 10 cm (*b*) 20 cm (*c*) 30 cm (*d*) 40 cm

108. The width of dowel is, usually, kept from
(*a*) 0.1 m to 0.3 m (*b*) 0.3 m to 0.6 m (*c*) 0.6 m to 0.9 m (*d*) 0.9 m to 1.

109. A spoil bank is formed when the
(*a*) canal has steep bed slope (*b*) canal section is too large
(*c*) volume of excavation is in excess of the embankment filling
(*d*) canal alignment is meandrous

110. The borrow pits should, preferably, be taken from
(*a*) the field on the right side of canal (*b*) the field on the left side of the canal
(*c*) the central half width of the section of the canal
(*d*) any one of the above

111. In case of small channels, the borrow pits should start from a distance not less than ..... from the toe of the embankment.
(*a*) 2 m (*b*) 3 m (*c*) 4 m (*d*) 5 m

112. When the quantity of the earth is much in excess of the quantity required for filling, it has t deposited in the form of spoil banks. The spoil banks are made on
(*a*) the right side (*b*) the left side (*c*) both the sides (*d*) all of these

113. The gaps created in the bank of a canal is called a breach.
(*a*) Correct (*b*) Incorrect

114. The term balancing depth has the same meaning as the depth of water in canal.
(*a*) Right (*b*) Wrong

115. A land is said to be water-logged when
(*a*) the air circulation is stopped in the root zone due to the rise in water table
(*b*) it is submerged in flood
(*c*) the soil pores within a depth of 40 cm are saturated
(*d*) all of the above

116. The infertility of the soil in water-logged areas is due to
(*a*) inhibiting activity of the soil bacteria (*b*) growth of weeds
(*c*) increasing of harmful salts (*d*) all of these

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117. Water logging is caused due to
(a) inadequate drainage facilities
(b) over irrigation
(c) presence of impermeable strata
(d) all of these

118. The soil becomes, practically, infertile if its *p-H* value is
(a) 0 (b) 7 (c) 11 (d) 14

119. Intensity of irrigation should be increased in order to prevent the area from water logging.
(a) Yes (b) No

120. The measure adopted to reclaim the water-logged area is
(a) installation of lift irrigation schemes
(b) lining of canals
(c) lowering the full supply level
(d) all of these

121. Water logging takes place due to ..... in ground water table.
(a) rise (b) fall

122. Which of the following statements is wrong ?
(a) Seepage drains reduce the chances of water logging.
(b) The water table generally follows the ground surface above it with a few exceptions.
(c) At the water table, the hydrostatic pressure is zero.
(d) Water logging makes the land more productive.

123. The most economical section of a lined canal is
(a) rectangular section with circular bottom for small discharges
(b) triangular section with circular bottom for small discharges
(c) trapezoidal section with rounded corners for higher discharges
(d) none of the above

124. Lining of a canal is necessary
(a) to minimise the seepage losses in canal
(b) to prevent erosion of bed and sides due to high velocities
(c) to increase the discharge in canal section by increasing the velocity
(d) all of the above

125. Lining of a canal ..... the maintenance of the canal.
(a) increases (b) decreases (c) does not effect

126. Lining of a canal
(a) assures economical water distribution
(b) reduces possibility of breaching
(c) increases available head for power generation
(d) all of the above

127. In a lined canal, the resistance to flow decreases and velocity of flow increases.
(a) Agree (b) Disagree

128. The sodium carbonate lining consists of at least
(a) 6% sodium carbonate and 10% clay
(b) 10% sodium carbonate and 6% clay
(c) 1% sodium carbonate and 6% clay
(d) 1% clay and 6% sodium carbonate

29. For the repairing of an old but sound concrete lining, the lining preferred is
(a) shotcrete lining
(b) precast concrete lining
(c) soil cement lining
(d) sodium carbonate lining

30. The weed growth in a canal leads to
(a) decrease in silting
(b) decrease in discharge
(c) increase in discharge
(d) increase in velocity of flow

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131. Garret's diagram gives the graphical method of designing a channel based on
(*a*) Lacey's theory (*b*) Gibb's theory (*c*) Kennedy's theory (*d*) Khosla's theory

132. Kennedy, in his silt theory, assumed that the silt is kept in suspension because of eddies generated from the
(*a*) bed only (*b*) sides only (*c*) whole perimeter (*d*) any one of the

133. According to Kennedy, the silt supporting power is ..... to the bed width of the stream
(*a*) directly proportional to (*b*) inversely proportional to

134. Non-silting, non-scouring velocity is called ..... velocity of flow.
(*a*) mean (*b*) critical

135. Kennedy gave a relation between
(*a*) velocity and hydraulic mean depth (*b*) area and velocity
(*c*) critical velocity and the depth of flowing water
(*d*) all of the above

136. The relation given by Kennedy for critical velocity in m/s is
(*a*) $V_o = 0.55\, m\, D^{0.64}$ (*b*) $V_o = 0.64\, m\, D^{0.55}$ (*c*) $V_o = 0.74\, m\, D^{0.84}$ (*d*) $V_o = 0.84\, m D^{0.}$
where m = Critical velocity ratio, and
D = Depth of water over the bed portion of a channel in metres.

137. A channel is said to be in scouring when the critical velocity ratio is ..... one.
(*a*) equal to (*b*) less than (*c*) greater than

138. When the critical velocity ratio is less than one, the channel is said to be in silting.
(*a*) True (*b*) False

139. Which of the following statement is wrong ?
(*a*) In Kennedy's silt theory, no account was taken of silt concentration and bed load.
(*b*) Kennedy did not gave any slope equation.
(*c*) In Kennedy's theory, silt grade and silt charge were not defined.
(*d*) none of the above

140. Kennedy gave his own formula for the determination of mean velocity.
(*a*) Correct (*b*) Incorrect

141. According to Kennedy, the silt transporting power of a channel is proportional to
(*a*) $V_o^{1/2}$ (*b*) $V_o^{3/2}$ (*c*) $V_o^{5/2}$ (*d*) $V_o^{7/2}$
where V_o = Critical velocity in a channel.

142. According to Lacey, a channel is said to be in regime, if
(*a*) it flows in incoherent unlimited alluvium of the same character as that transported materi
(*b*) its discharge is constant
(*c*) the silt grade and the silt charge are constant
(*d*) all of the above

143. The incoherent alluvium is a soil composed of loose granular graded material which can b scoured with the same ease with which it is deposited.
(*a*) Right (*b*) Wrong

144. The main cause of silting in channel is
(*a*) non-regime section (*b*) inadequate slope
(*c*) defective head regulator (*d*) all of these

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145. According to Lacey
(a) the silt is kept in suspension due to the force of vertical eddies
(b) the eddies are generated from bed and sides, both normal to the surface of generation
(c) the vertical component of eddies generated from sides will also support the silt
(d) all of the above

146. Lacey assumed that silt is kept in suspension because of the normal components of eddies generated from the
(a) bed only (b) side only (c) whole perimeter (d) none of these

147. Lacey gave a relation between
(a) velocity and hydraulic mean depth (b) area and velocity
(c) both (a) and (b) (d) none of these

148. The Lacey's silt factor (f) is equal to
(a) $\frac{3V^2}{2R}$ (b) $\frac{5V^2}{2R}$ (c) $\frac{7V^2}{2R}$ (d) $\frac{9V^2}{2R}$
where V = Mean regime velocity, and R = Hydraulic mean depth.

149. The channel after attaining its section and longitudinal slope, will be said to be in ..... egime.
(a) initial (b) final (c) permanent

150. Lacey assumed a trapezoidal cross-section of a regime channel.
(a) Yes (b) No

151. The general regime flow equation is
(a) $V = 10.8\, R^{2/3} S^{1/3}$ (b) $V = 10.8\, R^{1/3} S^{2/3}$ (c) $V = 10.8\, R^{3/2} S^{1/3}$ (d) $V = 10.8\, R^{3/2} S^{1/2}$
where V = Mean regime velocity, R = Hydraulic mean depth, and S = Slope of water surface.

152. If m is the mean particle diameter of the silt in mm, the Lacey's silt factor (f) is given by
(a) $f = 1.76\, m^{1/2}$ (b) $f = 1.76\, m^{3/2}$ (c) $f = 1.76\, m^{2}$ (d) $f = 1.76\, m^{5/2}$

153. Lacey's theory as applied to channel design, involves trial and error procedure.
(a) Agree (b) Disagree

154. The perimeter discharge (P-Q) relation is given by the equation
(a) $P = 2.25\, Q^{1/2}$ (b) $P = 2.25\, Q^{3/2}$ (c) $P = 4.75\, Q^{1/2}$ (d) $P = 4.75\, Q^{3/2}$

155. Which of the following satement is correct ?
(a) In Lacey's silt theory, the derivation of the various formulae depends upon a single factor 'f'.
(b) Lacey's equation includes a concentration of silt as variable.
(c) Lacey properly define the silt grade and silt charge.
(d) Lacey introduced semi-ellipse as ideal shape of a regime channel.

156. According to Lacey's equation, the scour depth is equal to
(a) $0.47\left(\frac{Q}{f}\right)^{1/2}$ (b) $0.47\left(\frac{Q}{f}\right)^{1/3}$ (c) $0.47\left(\frac{Q}{f}\right)^{1/4}$ (d) $0.47\left(\frac{Q}{f}\right)^{1/5}$

157. Distributary head regulators are provided
(a) to control the supplies to the off-taking channel
(b) to control the silt entry in the off-taking canal
(c) to stop the supply, when not needed, in the off-taking canal
(d) all of the above

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158. Cross regulators are provided
(*a*) to raise the water level to its upstream during the periods of low discharges in the parent channel
(*b*) to help in closing the supply to down stream of the parent channel
(*c*) to absorb fluctuation in various sections of the canal system
(*d*) all of the above

159. A structure constructed in an irrigation canal for the purpose of wasting some of its water known as a
(*a*) fall (*b*) escape (*c*) regulator (*d*) none of these

160. The escapes must lead the surplus water to natural drainage.
(*a*) True (*b*) False

161. Escapes are also known as ..... for the canals.
(*a*) outlet (*b*) safety valves (*c*) regulators

162. The capacity of escape channel should not be less than ..... of the capacity of the parent channel at that point.
(*a*) 20% (*b*) 30% (*c*) 40% (*d*) 50%

163. A fall, which maintains the depth is a
(*a*) trapezoidal notch fall (*b*) rectangular notch fall
(*c*) low weir fall (*d*) all of these

164. For a canal which irrigate the area directly, the fall should be provided at a location where the F.S.L. outstrips the gound level, but before the bed of the canal comes into filling.
(*a*) Right (*b*) Wrong

165. The Sarda canal has a
(*a*) glacis type fall (*b*) vertical drop fall (*c*) Ogee fall (*d*) rapid fall

166. In Sarda type fall, the length of the crest is kept ..... the bed width of the canal.
(*a*) more than (*b*) equal to (*c*) less than

167. In a Sarda type fall, the width of the trapezoidal crest (B) is given by
(*a*) $B = 0.44\sqrt{H + d}$ (*b*) $B = 0.44\sqrt{H - d}$
(*c*) $B = 0.55\sqrt{H + d}$ (*d*) $B = 0.55\sqrt{H - d}$
where H = Depth of water, and d = Drop at bed level.

168. The relation for discharge (Q) over a rectangular crest of a Sarda fall is
(*a*) $Q = 1.835\, LH^{3/2}\left(\frac{H}{B}\right)^{1/6}$ (*b*) $Q = 1.835\, LH^{3/2}\left(\frac{H}{B}\right)^{1/3}$
(*c*) $Q = 1.99\, LH^{3/2}\left(\frac{H}{B}\right)^{1/6}$ (*d*) $Q = 1.99\, LH^{3/2}\left(\frac{H}{B}\right)^{1/3}$
where L = Length of crest in metres,
B = Top width of the crest in metres, and
H = Depth of water in metres.

169. In a Sarda type fall, the trapezoidal crest is used for discharges over 14 m^3/s
(*a*) Correct (*b*) Incorrect

170. For a discharge of 4 m^3/s in Sarda type fall, ... crest is used.
(*a*) rectangular (*b*) trapezoidal

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171. A baffle wall is a sort of low weir constructed at the end of the cistern to
(a) head up water to its upstream to such a height that hydraulic jump is formed
(b) withstand the actual impact of the high velocity jet to dissipate the energy
(c) both (a) and (b)
(d) none of the above

172. In an Inglis type fall, the baffle holds the jump stable on a horizontal platform.
(a) Agree (b) Disagree

173. A parabolic glacis type fall is commonly known as
(a) Montague fall (b) Inglis fall (c) Sarda fall (d) vertical type fall

174. When the water is thrown into a well over a crest from where it escapes near its bottom, the type of fall is called
(a) rapid fall (b) cylinder fall (c) pipe fall (d) glacis fall

175. A sudden fall of level of ground along the alignment of a canal joined by an inclined bed is called a
(a) rapid fall (b) cylinder fall (c) sudden fall (d) hydraulic jump

176. The cylinder or well fall is quite suitable and economical for
(a) low discharges and low drops (b) low discharges and high drops
(c) high discharges and low drops (d) high discharges and high drops

177. According to Blench formula, the depth of cistern below the down stream bed (x) in metres is given by
(a) $x = D_c + 1/4\ (H_L - 3/8\ D_c) - D$ (b) $x = 2D_c + 1/4\ (H_L - 3/8D_c) - D$
(c) $x = 2D_c + 1/4\ (H_L - 1/3D_c) - D$ (d) $x = 2D_c + 1/4\ (H_L - 1/3D_c) - 2D$

178. Which of the following statement is wrong ?
(a) In a trapezoidal notch fall, the top width of the notch is kept between 3/4th to full water depth above the sill of the notch.
(b) The energy dissipation takes palce by the provision of roughening devices.
(c) The siphon fall is designed to maintain a fixed supply level in the channel.
(d) Energy dissipators are provided for small discharges.

179. The discharge (Q) over trapezoidal crest of Sarda fall is ..... as compared to rectangular crest of identical parameters.
(a) same (b) less (c) more

180. The Inglis type fall makes use of ..... impact for energy dissipation.
(a) straight (b) horizontal (c) vertical

181. The fall which can be used as a meter fall, is
(a) vertical drop fall (b) flumed glacis fall (c) unflumed glacis fall (d) none of these

182. A canal outlet should
(a) be so designed that the farmer cannot temper with its functioning
(b) be simple so that it can be constructed or fabricated by local masons
(c) draw its fare share of silt carried by the distributing channel
(d) all of the above

183. A device which ensures a constant discharge of water passing from one channel to another irrespective of water level in each within certain specified limits, is called
(a) flume (b) module (c) meter (d) none of these

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184. An outlet in which the discharge depends upon the difference in level between the water l in distributing channel and the water course, is known as

(*a*) non-modular outlet (*b*) semi-module outlet

(*c*) modular outlet (*d*) rigid module

185. In a flexible outlet, the discharge depends upon the

(*a*) water level in distributary (*b*) water level in water course

(*c*) difference of water levels between distributary and water course

(*d*) none of the above

186. When discharge of an outlet is independent of the water levels in the water course an distributary, the outlet is termed as a

(*a*) flexible outlet (*b*) non-modular outlet

(*c*) semi-module outlet (*d*) rigid module

187. Gibb's module is a type of

(*a*) non-modular outlet (*b*) semi-modular outlet

(*c*) rigid modular outlet (*d*) open flume outlet

188. The ratio of the rate of change of discharge of an outlet to the rate of change of the disch of the distributing channel, is termed as

(*a*) proportionality (*b*) flexibility (*c*) sensitivity (*d*) efficiency

189. In a proportional outlet, the rate of change of its discharge is ..... the rate of chang the discharge of the distributing channel.

(*a*) equal to (*b*) more than (*c*) less than

190. The ratio of the head recovered to the head put in an outlet, is called

(*a*) proportionality (*b*) flexibility (*c*) sensitivity (*d*) efficiency

191. The efficiency is a measure of conservation of head by an outlet.

(*a*) True (*b*) Flase

192. The sensitivity of an outlet is defined as the ratio of the

(*a*) rate of change of discharge of an outlet to the rate of change of discharge of the distributi channel

(*b*) rate of change of discharge of an outlet to the rate of change in level of the distributi surface, referred to normal depth of the channel

(*c*) depth of the sill or the crest level of the module below the full supply of the distributi channel to the full supply depth of the distributing channel

(*d*) head recovered to the head put in an outlet

193. An outlet is said to be proportional, if its flexibility is

(*a*) equal to zero (*b*) less than unity (*c*) equal to unity (*d*) more than uni

194. The sensitivity of a rigid module is

(*a*) equal to zero (*b*) less than unity (*c*) equal to unity (*d*) more than uni

195. The flexibility of a hyper-proportional outlet is ..... one.

(*a*) greater than (*b*) equal to (*c*) less than

196. The flexibility of a sub-proportional outlet is less than one

(*a*) Yes (*b*) No

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97. The setting of an outlet is defined as the ratio of the
(a) rate of change of discharge of an outlet to the rate of change of discharge of the distributing channel
(b) rate of change of discharge of an outlet to the rate of change in level of the distributing surface, referred to the normal depth of the channel
(c) depth of the sill or the crest level of the module below the full supply of the distributing channel to the full supply depth of the distributing channel
(d) head recovered to the head put in an outlet

98. For the pipe outlet to be proportional, the outlet is set at ..... the depth below the water face.
(a) 0.3 times (b) 0.5 times (c) 0.8 times

99. In the case of a proportional outlet, the setting is equal to the ratio of outlet index to the channel ex.
(a) Correct (b) Incorrect

100. The setting for a hyper-proportional outlet is ..... as compared to a proportional outlet.
(a) more (b) less (c) same

101. The setting for a sub-proportional outlet is ..... as compared to a proportional outlet.
(a) more (b) less (c) same

102. The ratio between the depths of water levels over crest on the downstream and upstream of the dule, is known as
(a) flexibility (b) sensitivity (c) drowning ratio (d) module ratio

103. Which of the following is a type of non-modular outlet ?
(a) Submerged pipe outlet (b) Open-flume outlet
(c) Kennedy's gauge outlet (d) all of these

104. Which of the following is a type of semi-module outlet ?
(a) Submerged pipe outlet (b) Open flume outlet
(c) Kennedy's gauge outlet (d) all of these

105. The slope of a canal, for a discharge of 300 cumecs, should be
(a) 1 in 4000 (b) 1 in 6000 (c) 1 in 8000 (d) 1 in 10000

106. A diversion head work is constructed to
(a) raise water level at the head of the canal
(b) regulate the intake of water into the canal
(c) reduce fluctuations in the supply level of the river
(d) all of the above

107. A weir is generally aligned at right angle to the direction of the main river flow because
(a) it is economical (b) less length of weir is required
(c) it gives better discharge capacity (d) all of these

108. A weir fails due to
(a) rupture of floor due to uplift
(b) rupture of floor due to suction caused by standing wave
(c) scour on the upstream and downstream of the weir
(d) all of the above

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209. A solid construction put across the river to raise its water level and divert the water into canal, is known as
(a) marginal bund (b) weir (c) barrage (d) dam

210. When the difference in weir crest and downstream river bed is limited into 3 metres, the generally used is
(a) vertical drop weir (b) drystone slope weir
(c) concrete slope weir (d) parabolic weir

211. Okhla weir on Yamuna river, in Delhi, is an example of
(a) vertical drop weir (b) drystone slope weir
(c) concrete slope weir (d) parabolic weir

212. In Bligh's creep theory, it is assumed that the percolation water creep
(a) along the contact of the base profile of the apron with the sub-soil
(b) in a straight path under the floor
(c) in a straight path under the foundation work
(d) none of the above

213. In Lane's weighted creep theory, he proposed a weight of
(a) three for vertical creep and one for horizontal creep
(b) three for horizontal creep and one for vertical creep
(c) two for vertical and two for horizontal creep
(d) any one of the above

214. In Bligh's creep theory
(a) there is no distinction between horizontal and vertical creep
(b) loss of head does not take place in the same proportion as creep length
(c) the uplift pressure distribution is not linear, but follows a sine curve
(d) all of the above

215. The function of a barrage is different to that a weir.
(a) Correct (b) Incorrect

216. In a barrage, crest level is kept
(a) low with large gates (b) high with large gates
(c) high with small gates (d) low with small gates

217. The coefficient of creep is the reciprocal of percolation coefficient.
(a) Right (b) Wrong

218. The loss of head per unit length of creep is called
(a) coefficient of creep (b) percolation coefficient
(c) Lane's coefficient (d) none of these

219. According to Khosla's theory, the undermining of the floor starts from the
(a) starting end (b) tail end (c) intermediate point (d) foundation

220. According to Khosla's theory, the critical hydraulic gradient for alluvial soils is approximately equal to
(a) 1 (b) 1.5 (c) 2 (d) 2.5

221. According to Khosla's theory, the exit gradient in the absence of a downstream cut-off
(a) zero (b) unity (c) infinity (d) none

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222. A hydraulic jump is formed when
(a) a sub-critical flow strikes against a super-critical flow
(b) a super-critical flow strikes against a sub-critical flow
(c) the two flows of super-critical velocity meet each other
(d) the two flows of sub-critical velocity meet each other

223. For low navigation dams, the type of gate used is
(a) rolling gate (b) bear trap gate (c) vertical lift gate (d) drum gate

224. The loss of head in the hydraulic jump is given by
(a) $\frac{(D_1 - D_2)}{4D_1D_2}$ (b) $\frac{(D_1 - D_2)^2}{4D_1D_2}$ (c) $\frac{(D_1 - D_2)^3}{4D_1D_2}$ (d) $\frac{(D_1 - D_2)^4}{4D_1D_2}$

where D_1 = Depth of water on the downstream, and
D_2 = Depth of water on the upstream.

225. Trough stage of river is most suitable location for diversion head works.
(a) Yes (b) No

226. A canal head work in rocky stage of a river is not suitable because
(a) more cross drainage works are required (b) a costly head regulator is required
(c) more falls are necessary to dissipate the energy
(d) all of the above

227. The crest level in a barrage is kept at a ..... level.
(a) low (b) high (c) moderate

228. The crest of the under-sluices should be lower than the crest of the head regulator (if silt excluder is provided) by at least
(a) 1 to 1.2 m (b) 1.8 to 2 m (c) 2 to 2.5 m (d) 4 to 5 m

229. The opening in the weir wall with a crest at low level on the canal side is known as under sluice or scouring sluice.
(a) Correct (b) Incorrect

230. The function of a scouring sluice is
(a) to control the silt entry into the canal
(b) to scour the silt deposited in the river bed above the approach channel
(c) to pass the low floods without dropping the shutters of the main weir
(d) all of the above

231. For smooth entry, the regulators are aligned at an angle of ..... to the water.
(a) 60° (b) 80° (c) 110° (d) 130°

232. The level of a canal diversion head work depends upon
(a) discharge perimeter (b) pond level
(c) full supply level of canal (d) all of these

233. Rivers on alluvial plains may be
(a) meandering type (b) aggrading type (c) degrading type (d) all of these

234. An aggrading river is a ..... river.
(a) scouring (b) silting

235. A degrading river is a scouring river.
(a) Yes (b) No

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236. A river meandering through an alluvial plain has a series of consecutive curves of reverse order connected with short straight sketches, is called
(*a*) crossing (*b*) meandering belt (*c*) meandering length (*d*) none of these

237. The width of meandering belt is the
(*a*) transverse distance between the apex point of one curve and apex point on reverse curve
(*b*) axial distance along the river between tangent point of one curve and tangent point of other curve of same order
(*c*) axial distance along the river between the apex point of one curve and apex point of reverse curve
(*d*) transverse distance along the river between tangent point of one curve and tangent point of other curve of same order

238. The degree of sinuosity is the ratio between the
(*a*) meander length and width of meander (*b*) meander length and the width of river
(*c*) curved length and the straight air distance (*d*) none of these

239. Tortuosity of a meandering river is the ratio of
(*a*) meander length to width of meander (*b*) meander length to width of river
(*c*) curved length along the river to the direct axial length of the river
(*d*) direct axial length of the river to the curved length along the river

240. The tortuosity of a meandering river is always ..... one.
(*a*) equal to (*b*) less than (*c*) greater than

241. The primary cause of meandering is the excess of total charge during floods, when excess turbulence is developed.
(*a*) Ture (*b*) False

242. The basic factor which controls the process of meandering is
(*a*) discharge (*b*) valley slope
(*c*) bed and side resistance (*d*) all of these

243. When river flows in a plain country, its stage is known as ..... stage.
(*a*) delta (*b*) boulder (*c*) trough (*d*) rocky

244. Which of the following statements is correct ?
(*a*) The aggrading type of river builds up its bed to a certain slope.
(*b*) The degrading type of river looses its bed gradually in the form of sediment load of the stream.
(*c*) The pattern of meander is altered by variation in discharge slope and bed forming material
(*d*) all of the above

245. The width and length of meander as well as width of river, vary approximately with
(*a*) discharge (*b*) square of discharge
(*c*) square root of discharge (*d*) cube root of discharge

246. The river training works are adopted on a river
(*a*) to pass high flood discharge safely and quickly through the breach
(*b*) to direct and guide the river flow (*c*) to reduce bank erosion to a minimum
(*d*) all of the above

247. The method used for training of rivers is
(*a*) guide bank (*b*) dyke or levee (*c*) groyne (*d*) all of these

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248. A river training work is generally required when the river is
(a) aggrading type (b) degrading type (c) meandering type (d) stable type

249. A groyne is a structure constructed transverse to the river flow and extend from the bank into the river upto a certain limit.
(a) Agree (b) Disagree

250. A groyne
(a) contracts a river channel to improve its depth
(b) silts up the area in the vicinity by creating a slack flow
(c) trains the flow along a certain course
(d) all of the above

251. The repelling groyne is constructed in such a way that it is pointing towards ..... at an angle of 30°.
(a) upstream (b) downstream

252. A deflecting groyne has a much ..... length than a repelling groyne.
(a) longer (b) shorter

253. A deflecting groyne in a river is
(a) inclined towards upstream (b) perpendicular to bank
(c) inclined towards downstream (d) none of these

254. The length of groyne depends upon the magnitude of river training required.
(a) Right (b) Wrong

255. Match the correct statement from *Group B* for the given statements in *Group A*.

Group A	*Group B*
(a) A head regulator is constructed	(A) to distribute water to folds
(b) A minor is constructed	(B) at the head of a minor
(c) A diversion head is constructed	(C) near the head regulator
(d) An outlet is constructed	(D) at the head of the canal

256. Which of the following statement is wrong ?
(a) The impermeable groynes do not permit any flow through them.
(b) The impermeable groynes may be constructed by a core of locally available material like sand, clay and gravel.
(c) The permeable groynes dampen the velocity and reduce the erosive action of the stream.
(d) none of the above

257. A levee on flood
(a) increases the water surface elevation of the river at flood
(b) decreases the surface slope of the stream above the leveed portion
(c) increases the velocity and scouring action through leveed section
(d) all of the above

258. A groyne with a curved head is known as
(a) hockey groyne (b) burma groyne (c) denehy groyne (d) none of these

259. When the bed level of the canal is higher than the highest flood level (H.F.L.) of the drainage, then the cross drainage work is said to be
(a) aqueduct (b) super-passage (c) canal syphon (d) syphon aqueduct

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260. When the drain is over the canal, the structure provided is known as
(*a*) aqueduct (*b*) super-passage (*c*) canal syphon (*d*) syphon aqueduct

261. When the full supply level (F.S.L.) of the canal is much below the bed level of the drainage trough, then the cross drainage provided is called syphon aqueduct.
(*a*) Yes (*b*) No

262. When a canal flowing under pressure is carried below a natural drainage such that its F.S.L. does not touch the under side of the supporting structure, the structure provided is super-passage.
(*a*) Correct (*b*) Incorrect

263. When the levels are such that the F.S.L. of the canal is much above the bed level of the drainage trough, so that the canal runs under syphonic action under the trough, the structure provided is known as
(*a*) syphon aqueduct (*b*) level crossing (*c*) canal syphon (*d*) super-aqueduct

264. When the irrigation canal and the drain are at the same level, then the cross drainage work is achieved by providing a
(*a*) aqueduct (*b*) super-passage (*c*) level crossing (*d*) canal syphon

265. In case of syphon aqueduct, the H.F.L. of the drain is
(*a*) much below the bottom of the canal trough
(*b*) much higher above the canal bed (*c*) in level with the canal bed
(*d*) none of the above

266. In a super-passage, the F.S.L. of the canal is
(*a*) lower than the underside of the trough carrying drainage water
(*b*) above the bed level of the drainage trough
(*c*) in level with the drainage trough
(*d*) none of the above

267. In a syphon, the underside of the trough carrying drainage water is ..... the F.S.L. of the canal.
(*a*) lower than (*b*) higher than (*c*) in level with

268. In level crossing, the water level of canal is much higher than that of the drainage.
(*a*) True (*b*) False

269. The bed of a canal is lowered in case of
(*a*) syphon aqueduct (*b*) canal syphon (*c*) level crossing (*d*) all of these

270. The floor of the aqueduct is subjected to uplift pressure due to
(*a*) seepage of water from the canal to the drainage
(*b*) sub-soil water table in the drainage bed (*c*) both (*a*) and (*b*)
(*d*) none of the above

ANSWERS

1. (*d*)	**2.** (*d*)	**3.** (*d*)	**4.** (*d*)	**5.** (*b*)	**6.** (*d*)
7. (*c*)	**8.** (*a*)	**9.** (*a*)	**10.** (*b*)	**11.** (*a*)	**12.** (*a*)
13. (*a*)	**14.** (*a*)	**15.** (*b*)	**16.** (*a*)	**17.** (*c*)	**18.** (*b*)
19. (*d*)	**20.** (*a*)	**21.** (*c*)	**22.** (*d*)	**23.** (*c*)	**24.** (*b*)
25. (*a*)	**26.** (*c*)	**27.** (*b*)	**28.** (*a*)	**29.** (*a*)	**30.** (*b*)
31. (*c*)	**32.** (*a*)	**33.** (*b*)	**34.** (*b*)	**35.** (*b*)	**36.** (*c*)
37. (*b*)	**38.** (*c*)	**39.** (*b*)	**40.** (*b*)	**41.** (*c*)	**42.** (*d*)
43. (*c*)	**44.** (*a*)	**45.** (*a*)	**46.** (*b*)	**47.** (*a*)	**48.** (*b*)

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49. (c) 50. (a) 51. (a) 52. (d) 53. (b) 54. (d)
55. (d) 56. (d) 57. (d) 58. (b) 59. (a) 60. (b)
61. (c) 62. (d) 63. (b) 64. (a) 65. (a) 66. (b)
67. (c) 68. (a) 69. (b) 70. (a) 71. (c) 72. (c)
73. (b) 74. (b) 75. (c) 76. (a) 77. (b) 78. (b)
79. (c) 80. (d) 81. (c) 82. (c) 83. (c) 84. (c)
85. (a) 86. (a) 87. (b) 88. (a) 89. (b) 90. (c)
91. (b) 92. (a) 93. (d) 94. (b) 95. (a) 96. (d)
97. (b) 98. (D), (A), (B), (C) 99. (a), (b) 100. (d) 101. (a)
102. (d) 103. (d) 104. (d) 105. (a) 106. (d) 107. (c)
108. (b) 109. (c) 110. (c) 111. (d) 112. (d) 113. (a)
114. (b) 115. (a) 116. (d) 117. (d) 118. (c) 119. (b)
120. (a) 121. (a) 122. (d) 123. (b), (c) 124. (d) 125. (b)
126. (d) 127. (a) 128. (a) 129. (a) 130. (b) 131. (c)
132. (a) 133. (a) 134. (b) 135. (c) 136. (a) 137. (c)
138. (a) 139. (d) 140. (b) 141. (c) 142. (d) 143. (a)
144. (d) 145. (d) 146. (c) 147. (c) 148. (b) 149. (b)
150. (b) 151. (a) 152. (a) 153. (b) 154. (c) 155. (a)
156. (b) 157. (d) 158. (d) 159. (b) 160. (a) 161. (b)
162. (d) 163. (d) 164. (a) 165. (b) 166. (b) 167. (c)
168. (a) 169. (a) 170. (a) 171. (c) 172. (a) 173. (a)
174. (b) 175. (a) 176. (b) 177. (b) 178. (d) 179. (c)
180. (b) 181. (a) 182. (d) 183. (b) 184. (a) 185. (a)
186. (d) 187. (c) 188. (b) 189. (a) 190. (d) 191. (a)
192. (b) 193. (c) 194. (a) 195. (a) 196. (a) 197. (c)
198. (a) 199. (a) 200. (a) 201. (b) 202. (c) 203. (a)
204. (c) 205. (c) 206. (d) 207. (d) 208. (d) 209. (b)
210. (c) 211. (b) 212. (a) 213. (a) 214. (d) 215. (b)
216. (a) 217. (a) 218. (b) 219. (b) 220. (a) 221. (c)
222. (b) 223. (b) 224. (c) 225. (a) 226. (d) 227. (a)
228. (b) 229. (a) 230. (d) 231. (c) 232. (d) 233. (d)
234. (b) 235. (a) 236. (a) 237. (a) 238. (c) 239. (c)
240. (c) 241. (a) 242. (d) 243. (c) 244. (d) 245. (c)
246. (d) 247. (d) 248. (c) 249. (a) 250. (d) 251. (a)
252. (b) 253. (b) 254. (a) 255. (D), (C), (B), (A) 256. (d)
257. (d) 258. (a) 259. (a) 260. (b) 261. (b) 262. (a)
263. (c) 264. (c) 265. (b) 266. (a) 267. (b) 268. (b)
269. (b) 270. (c)

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8.1 Introduction

The selection of source of water with minimum number of impurities is the most important essential of water supply system. The next thing in the water supply system is the complete layout from the source of supply to the distribution. The primary source of water is precipitation which falls on the earth's surface in the form of rain, snow, hails, dew etc. The rainfall, being the most important part of precipitation is carried off in the following four different ways :

(*a*) Run-off ; (*b*) Percolation or interflow ; (*c*) Transpiration ; and (*d*) Evaporation.

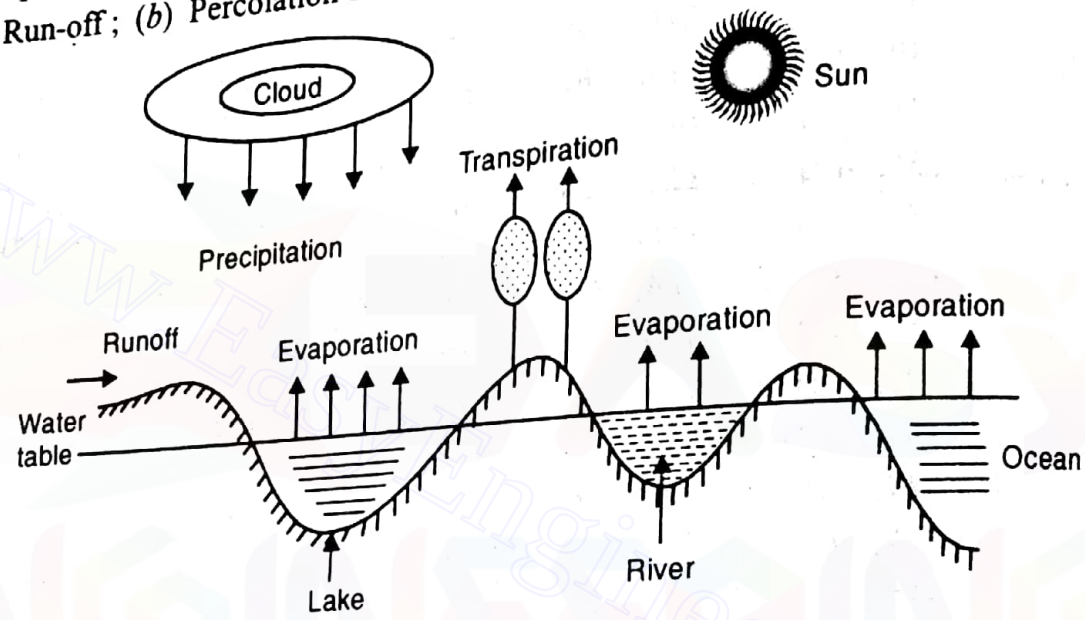

Fig. 8.1

In this way, the processes of precipitation and evaporation continue like an endless chain and thus a balance is maintained in the atmosphere. This phenomenon is known as *hydrological cycle* as shown in Fig. 8.1.

8.2 Sources of Water

The sources of water may be classified as surface sources and sub-surface sources. The *surface sources* of water are the sources in which the water flows over the earth's surface. These include rivers, lakes, streams, natural ponds, storage or impounded reservoirs. The water from these sources is known as surface water. The *sub-surface* or *ground water sources* are those which supply water from below the earth's surface. These include springs, infiltration galleries, wells and porous pipe galleries.

The quantity of surface water depends mainly upon rainfall. The topography of the catchment area is important in addition to the rainfall and run-off in case of impounded reservoirs. There are two types of impurities in water supply *i.e.* suspended and dissolved. The surface waters have suspended impurities. The suspended matter contains the pathogenic or disease producing bacteria. Therefore, surface waters are not considered safe for water supply without the necessary treatment.

The sub-surface sources are the important sources of water supply. The water of ground water sources does not require any treatment and its temperature remains uniform throughout the year. The

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rain that falls on earth's surface percolates partly through it and becomes the sub-surface water or ground water. The earth is formed of different layers of materials like sand, gravel and lime stone etc. The layers which allow the water to pass through them and contain quantities of water are known as pervious layer or *aquifers* or water bearing strata *i.e.* layers of sand, gravel etc. The layers such as limestone and sand stone which do not allow the water to pass through them are called impervious strata or *aquiclude*. The top surface of water in the soil is called underground water table or simply water table. The portion of the soil through which lateral movement of water takes place, is called *zone of saturation*.

The natural outflow of sub-surface or ground water at earth's surface is called a *spring*. This is also called out-cropping of the water table. Some springs discharge hot water due to the presence of sulphur and other materials. The spring may be *gravity springs* (surface spring and shallow spring) and *artesian* or *deep seated* spring.

When a acquifer is exposed in a valley against a vertical cut, a *surface spring* is formed.

In *shallow springs*, the ground water is collected in the form of reservoir and forces the water to overflow at the surface of the ground.

An *artesian* or *deep seated spring* is formed when pervious or water bearing stratum is closed between two impervious stratums and have too much hydraulic gradient and water flows out automatically.

The horizontal tunnels constructed at shallow depths along the banks of a river to intercept the ground water table are called *infiltration galleries*. The quantity of water available from infiltration gallery depends upon the yield of the source, nature of soil and size of gallery. The yield of the gallery may be about 15000 litres per metre length of the gallery. The infiltration galleries are most suitable for increasing the surface source supply in dry season.

The vertical wells provided along the banks of a river to draw ground water in dry season and percolated water in rainy season, are called infiltration wells. These are also called *rainy wells*.

A vertical hole dug out or drilled into the ground to get sub-surface or ground water is known as a *well*. The wells may be gravity wells, artesian wells, shallow wells, deep wells, open or dug wells, tube well and driven wells.

A tube or pipe fitted at the bottom with a filter sunk into the ground to tap the underground water is known as *tube well*. Now-a-days, tube wells are becoming more and more popular for supplying water. The quality of tube well water is good as compared to surface water.

8.3 Yield of a Well

The rate at which water percolates into well under safe maximum critical depression head is called *yield of a well*. The water level goes down when the water is drawn from the well. The difference between the depressed water level and the sub-soil water table level is called *depression head* or *infiltration head*.

The yield of the well is measured either in cum/hour or litres/hour. It depends upon the permeability of the soil, position of water table, depth of well in impervious layer and rate of withdrawl.

The yield of a surface stream may be obtained by stream gauging, cross-section velocity method and chemical method. The yield of a underground source may be obtained by constant level pumping test and recuperating test.

8.4 Quantity of Water

It is essential to determine the total quantity of water required for various purposes by the city or town while designing the water supply scheme. The quantity of water required depends upon the following two factors :

1. The probable population estimated at the end of the design period.
2. The rate of water consumed per capita per day.

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The period, for which the water supply projects are designed, is known as a *design period*. The design period for a water supply project is taken as 20 to 30 years which is fairly good and sufficient for design purposes.

According to Indian Standards (IS : 1172–1963), the water consumption for domestic purposes is 135 litres per capita per day under normal conditions. This amounts to about 50% of the total consumption per capita per day. The water requirements for commercial and industrial purposes may be upto 50 litres per capita per day which is about 20 to 25% of the total consumption of the city. The consumption of water for nursing homes, boarding schools and hostels is 135 litres per capita per day.

The quantity of water required for extinguishing fires (*i.e.* fire demand) is not more than 5 to 10% of the total demand of the city. The following empirical relations are used for determining the fire demand (Q) in litres per minute :

(*a*) *National board of fire under writers formula* : According to this formula,

$$Q = 4637\sqrt{P}\left[1 - 0.01\sqrt{P}\right]$$

where P = Population in thousands.

(*b*) *Freeman's formula* : According to this formula,

$$Q = 1135\left(\frac{P}{5} + 10\right)$$

(*c*) *Kuichling's formula* : According to this formula,

$$Q = 3182\sqrt{P}$$

(*d*) *Burton's formula* : According to this formula,

$$Q = 900\sqrt{P}$$

(*e*) *Buston's formula* : According to this formula,

$$Q = 5663\sqrt{P}$$

8.5 Forecasting Population

After deciding the design period and per capita consumption of the people per day, the next step is to determine the population for the prescribed design period. The quantity of water required is obtained by multiplying the future population and per capita consumption for a fixed design period. The following are the standard methods for forecasting population for a town for a fixed design period :

1. *Arithmetical increase method.* In this method, a constant increase in the growth of population is added periodically and the population at the required time is determined. This method is based upon the assumption that the population is increasing at a constant rate. This method is most suitable for old cities and towns which have stabilized.

2. *Geometrical increase method.* This method is based upon the assumption that the percentage increase in the population from decade to decade or a constant interval of time remains constant. This method is suitable for large cities.

3. *Incremental increase method.* In this method, the average of increase in population is found out by arithmetical increase method and to this is added the average of the net incremental increase once for energy future decade.

4. *Decreasing rate of growth method.* This method is similar to geometrical increase method except that a changing rate of decrease is assumed rather than a constant rate of increase. The changing rate of large and old cities is generally considered to be a decreasing rate.

5. *Simple graphical method.* This method consists in plotting of population of a city for the

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last few decades to a suitable scale on the graph paper with respect to decade and then extending the curve so obtained smoothly to forecast the future population of various decades.

6. *Comparative graph method.* The census population of towns which were in similar conditions of development over 40 to 50 years are noted and graphs of their population increase is plotted on the same graph paper. The curve of expected development of the town under consideration is drawn on the same graph. The future expected population of the town can be determined from this graph. This method gives quite accurate forecast of population.

8.6 Quality of Water

Pure water is not found in nature. It may contain impurities like sand, silt, clay and other inorganic matter. The impurities in water may be classified as follows :

1. *Suspended impurities.* The solid particles, which are dispersed in water and large enough to be removed by filtration or setting by sedimentation are known as *suspended impurities*. These impurities are microscopic and include algae, protozoa, fungi (which causes colour, odour and turbidity) silt, clay, mineral matter, organic and inorganic matter (which causes turbidity) and bacteria (which causes disease). The suspended impurities cause turbidity in water. The concentration of suspended matter in water is measured by its turbidity.

2. *Colloidal impurities.* The finely divided dispersion of solid particles which are not visible to the naked eye and cannot be removed by ordinary filters are known as *colloidal impurities*. These impurities if associated with organic matter having bacterias become the chief source of epidemic. The colour of water is mostly due to the presence of colloidal impurities. The amount of colloidal impurities is determined by colour tests.

3. *Dissolved impurities.* The impurities like organic compounds, inorganic salts and gases in the form of solids, liquids and gases which are dissolved in water, are known as *dissolved impurities*. The following are the various dissolved impurities and their effects :

(*a*) Salts	(*i*) Calcium and magnesium chlorides, carbonates and bicarbonates causes hardness and alkality in water. (*ii*) Sodium chloride, carbonate and bicarbonate causes softening of water.
(*b*) Metals	(*i*) Iron causes red colour in water, increases hardness and corrosion. (*ii*) Manganese causes brown colour. (*iii*) Lead and arsenic causes poisoning.
(*c*) Gases	(*i*) Oxygen corrodes the metal. (*ii*) Chlorine and ammonia causes bad taste and odour. (*iii*) Carbon dioxide and hydrogen sulphide causes acidity in water.

8.7 Physical Examination of Water

The physical examination of water includes the following tests :

1. *Temperature test.* The temperature of water is measured by an ordinary thermometer. It helps in determining the density, viscosity, vapour pressure and surface tension of water. The maximum permissible temperature for domestic supply is 10°C to 15°C.

2. *Colour test.* The water colour indicates the source of water and has little sanitary significance. The colour may stain in materials, complicate coagulation in treatment and may effect some industrial process.

The colour of water is expressed in numbers of a platinum cobalt scale. The maximum permissible colour for domestic supplies is 10 to 20 P.P.M. (parts per million) on platinum cobalt scale.

3. *Turbidity test.* The turbidity is the measure of resistance to the passage of light through the water. The water is said to be turbid when it contains visible material in suspension. It is caused due

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to the presence of suspended and colloidal matter in the water. It is expressed in P.P.M. on silica scale. The maximum permissible turbidity for domestic supplies is 5 to 10 P.P.M. on silica scale.

The turbidity of water may be determined by the following methods :

(*a*) Turbidity tube ; (*b*) Jacksons turbidimeter ; (*c*) Baylis turbidimeter ; and (*d*) Helli turbidimeter.

The low turbidity of water can be determined by Baylis turbidimeters and the high turbidity of water (above 50 P.P.M.) can be determined by Jacksons turbidimeter.

4. *Tastes and odour test.* The tastes and odours may result due to the presence of micro organisms either dead or alive, dissolved gases such as oxygen, carbon dioxide, methane etc. and mineral substances such as sodium chloride, iron compounds etc.

The odour in water changes with temperature. The water odour is tested at 20°C to 25°C. The apparatus used to measure odour in a water is known as *osmoscope*. A commercial osmoscope is graduated with *PO* values from 0 to 5. The different *PO* values represent the following meanings :

PO value	*Meaning*
0	No perceptable odour
1	Very faint odour
2	Faint odour
3	Distinct odour
4	Strong odour
5	Extremely strong odour

8.8 Chemical Examination of Water

The chemical examination of water is done to reveal the sanitary quality of water. The chemical tests involve the determination of the following :

1. *Total solids.* The total solids consist of chlorides, nitrates and compound which cause hardness in water. The maximum permissible total solids in water for domestic purposes should not exceed 500 P.P.M.

2. *Hardness.* It is caused due to the presence of bicarbonates, sulphates, chlorides and nitrates of calcium and magnesium. The hardness in water prevents the lathering of soap and forms boiler scales. The maximum permissible hardness in water for drinking purposes should not exceed 100 P.P.M.

3. *Chlorides.* The main substance in water is sodium chloride. The excess of chlorides is dangerous and unfit for use. The maximum permissible chloride content in water for domestic supplies should not exceed 250 P.P.M.

4. *Chlorine.* The chlorine remains as residual in treated water for the sake of safety against photogenic bacterias. The maximum permissible chlorine content for public supplies should be between 0.1 to 0.2 P.P.M.

5. *p–H value.* The p-H value indicates the hydrogen-ion concentration in water. The hydrogen ion concentration is an atom or group of atoms that carries an electric charge. Calorimetric or electrometric methods are used to determine the p-H value of water. The p-H value of water for public supplies is limited from 6.5 to 8. If the p-H value of water is equal to 7, then the water is said to be neutral. When the p-H value of water is less than 7, then the water is said to be acidic and when more than 7, it represents alkaline water.

6. *Iron and manganese.* These are found in water and not objectionable if present less than 0.3 P.P.M. These make the water brownish red in colour and leads to the growth of micro-organisms and corrodes the water pipes.

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7. *Arsenic.* It is rarely found in natural water. Its presence in water for domestic purposes should not be more than 0.05 P.P.M.

8. *Lead.* It is not usually found in natural water. The maximum permissible quantity of lead in water for domestic purposes is limited to 0.05 P.P.M.

9. *Copper.* The presence of copper indicates pollution. The copper contents in water for domestic purposes should not be more than 3 P.P.M. The small quantity of copper is desirable for health point of view.

10. *Fluorine.* It is found in natural water. The maximum permissible fluorine content in water for domestic supplies should be 1.5 P.P.M.

8.9 Living Organisms in Water

All organisms are classified as microscopic and macroscopic. The living organisms in water are bacteria, algae and protozoa.

The bacterias are single-celled organisms. Some bacterias are useful to human beings and some are harmful and cause diseases. The useful bacterias are called *non-pathogenic bacterias* whereas harmful or disease causing bacterias are known as *pathogenic bacterias*. Though the size, shape and structure of bacteria varies according to the environment in which they grow, yet the following are three main shapes of bacteria exist :

1. Sphere shaped bacterias called *cocci*.
2. Rod shaped bacterias called *bacilli*, and
3. Twisted rod shaped bacterias called *spirilla*.

The bacteria may be aerobic or anaerobic. The bacteria which require oxygen for their survival is known as *aerobic bacteria* and which can survive without oxygen is called *anaerobic bacteria*.

Algae and other living organisms related to planktons are responsible for taste and odour in water. Sometimes they render water unfit for public and cause sudden death of cattle and fish. Copper sulphate is most common chemical used for controlling algae. All the unicellular animals are called *protozoa*.

8.10 Biological Tests

The biological tests are as follows :

1. *Total count of bacteria test.* By this method, total number of bacteria present in a millilitre of water is counted. The total count of bacteria per cubic centimetre for domestic purposes varies from 0 to 100.

2. *Bacteria coli* (*B-coli*) *or Escherichia coli* (*E-coli*) *test.* There are two tests for B-coli or E-coli *i.e.* presumptive test and confirmative test. Now-a-days, a new technique known as membrane filter technique (M.F.T.) is used for finding out B-coli or E-coli.

8.11 Water Treatment

The treatment given to the water before supplying it to the public for use, according to the standards of quality required, is known as *water treatment*. The degree of treatment depends upon the impurities present in water and the standards of water required for public use. The following treatment processes are used for removing different types of impurities :

1. *Screening.* It is the process of removing large sized particles such as leaves, bushes, branches, debries etc. with the help of a screen provided in front of the intake works. The screens may be coarse or fine or both. In the process of screening, the screens are kept inclined at an angle of 45° to 60° to the horizontal. The main purpose of keeping the screens inclined is to increase the opening area and reduce the velocity of flow. The area of opening should be such so that the velocity of flow through them does not exceed 0.75 to 1 m/s.

2. *Plain sedimentation.* It is the process of retaining water in a basin so that the suspended

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particles settles down as a result of the action of gravity and forces. The rate of settling of a partic in water depends upon the viscosity of water, density of water, specific gravity of the particle, sh and size of the particle. It may be noted that the particles will settle down more rapidly in water higher temperatures than at lower temperatures. The process of plain sedimentation may remo 60% suspended matter and 75% bacteria.

The following are the important factors to be considered in designing a sedimentation tank.

(*a*) *Period of detention.* It is the time required to fill the tank at the given rate of flow. T detention time for an ordinary plain sedimentation tank is 6 to 8 hours.

(*b*) *Depth of tank.* It is also an important factor and should be 3 metres to 6 metres.

(*c*) *Velocity of flow.* The velocity of flow of water is obtained by dividing the volumetric flo by vertical cross-sectional area of the tank. The velocity should not exceed 5 mm/s (or 3 cm/min.)

(*d*) *Sludge capacity.* The sludge capacity depends upon the period of cleanings and the amou of matter removed from the water. Hence proper allowance should be given in designi the size of tanks. However, no allowance is provided if there is a mechanical provision f sludge removal.

3. *Sedimentation with coagulation.* The process of adding certain chemicals (known a coagulants) to water in order to form flocculent precipitate for absorbing and entraining colloida matter is called sedimentation with coagulation. The coagulation followed by sedimentation becom necessary when the turbidity of water exceeds about 45 P.P.M. The detention period may be kept 2 6 hours. The most common coagulants used for purification of water are alum or aluminium sulphat lime or ferrous sulphate, sodium aluminate, magnesium carbonate and ferric coagulants.

4. *Filteration.* The process of purifying water by passing it through a bed of sand or oth fine granular material, is called filteration. The filters are used for this purpose. The sand requir for filteration should have the following properties :

(*a*) It should be free from clay, loam, lime and organic matter.

(*b*) It should be of uniform size and nature.

(*c*) It should not be very fine nor too coarse.

(*d*) It should be resistant and hard.

(*e*) It should not loose weight more than 5% when placed in hydrochloric acid for 24 hours

It may be noted that the rate of filteration reduces when the water is filtered through a bed of very fine sand. The effective size of sand particles varies from 0.30 to 0.50 mm and *uniformity coefficient from 1.30 to 1.75.

The filters may be slow sand filters, rapid sand filters and pressure filters as discussed below

The effective size of sand particles for slow sand filters varies from 0.30 to 0.35 mm and the coefficient of uniformity is 1.75. The slow sand filters require larger area (from 100 to 2000 m^2) as compared to rapid sand filters. The under drainage system receives and collects the filtered water. These filters work under atmospheric pressure and no coagulation is required. The rate of filteration of a slow sand filter ranges from 100 to 200 litres/m^2/hour. The slow sand filter is more efficient for the removal of bacteria from the raw water to an extent of 99 per cent. It can remove turbidity of 5 P.P.M.

The cleaning of slow sand filter is required when the **loss of head or filteration head becomes more than 1.2 m. The cleaning period is taken as 1 month to 3 months. After cleaning the slow sand

* The coefficient of uniformity is defined as the ratio between the sieve size that will allow 60% to the effective depth.

** The difference between the water above the sand bed and in the outlet chamber is known as loss of head or filteration head.

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filter, the filtered water should not be used for a period of 24 hours to 48 hours. The slow sand filters are used for towns and villages.

The effective size of hand particles for rapid sand filters varies from 0.35 to 0.50 mm and the coefficient of uniformity is 1.6. The under drainage system receives and collects the filtered water and also allows back washing for cleaning the filter. The water is forced at a pressure higher than the atmospheric pressure in rapid gravity filters. These filters require coagulation. The rate of filteration of a rapid sand filter is about 30 times (*i.e.* about 3000 to 6000 litres/m^2/hour) to that of slow sand filter. The rapid sand filters can remove bacteria upto an extent of 80% to 90% and turbidity upto an extent of 35 to 40 P.P.M. The cleaning of rapid sand filter is required when the loss of head or filteration head exceeds 2.5 m and the cleaning period is taken as 2 to 3 days. The rapid sand filters are cheap and economical as compared to slow sand filters.

The pressure filters are just like small rapid sand filters and placed in closed and water tight steel vessels cylindrical in shape. The water is forced into the filters at a pressure greater than the atmospheric pressure. The rate of filteration varies from 6000 to 15000 litres/m^2/hour. The pressure filters are less efficient than the slow or rapid sand filters in removing bacteria and turbidity. These filters are not used for treating municipal water supplies because of their more cost. They are best suited for swimming pools, railway stations, individual industries, private estates etc.

5. *Disinfection.* The process of killing pathogenic bacterias from water and making it safe to the public use, is called disinfection. The most commonly used disinfectant for drinking water throughout the world is chlorine. The process of applying chlorine or chlorine compounds in small quantity to water to disinfect it, is known as *chlorination*. The time of contact for chlorination should be at least 20 minutes. The following are types of chlorination, depending upon the amount of chlorine added :

(*a*) *Plain chlorination.* When chlorine is added to the plain or raw water in the tanks or reservoirs, it is known as plain chlorination. The amount of chlorine required is 0.5 P.P.M. This method is used for treating water having turbidity less than 20 to 30 P.P.M.

(*b*) *Pre-chlorination.* When chlorine is added to raw water before any treatment (*i.e.* sedimentation, coagulation, filteration etc.), it is known as pre-chlorination. The amount of chlorine should be such that at least 0.2 to 0.5 P.P.M. of the residual chlorine comes to the filter plant. The pre-chlorination reduces the bacterial load on filters thereby increasing their efficiency.

(*c*) *Post-chlorination.* The addition of chlorine after all the treatment being applied to water, is known as post chlorination. The amount of chlorine added should be such that a residual chlorine of about 0.2 P.P.M. appears in water after a contact period of 20 minutes.

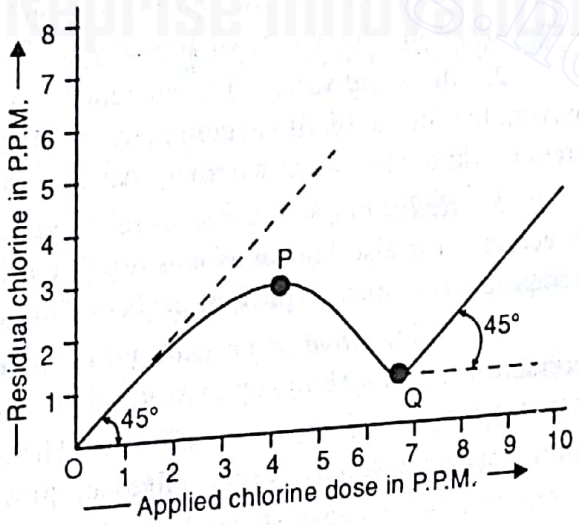

Fig. 8.2

(*d*) *Double chlorination.* When chlorine is added to water at more than one point, it is called double chlorination.

(*e*) *Super-chlorination.* When chlorine is added in excess of that required for adequate bacterial purification of water, it is called super chlorination. This is done under certain circumstances such as epidemics of water born diseases. A high dose of chlorine (*i.e.* 2 to 3 P.P.M) is added to water beyond break point for safety of public.

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(*f*) *Break point chlorination* : When the chlorine dose increases, the combined available chlorine also increases. On further increase of chlorine, the compound gets oxidised and the substances which are newly formed do not react to show any residual. This phenomenon is called *break point*. This is shown in Fig. 8.2. From the figure, we see that the residual chlorine in the beginning increases with the applied chlorine dose. But after point *P*, it suddenly drops upto point *Q* and then increases. The portion *OP* shows the formation of chloromines and the portion *PQ* shows their oxidation. The point *Q* at which the residue chlorine again starts increasing is known as *break point chlorination*.

The break point chlorination destroys completely all the disease bacteria (pathogenic). It oxidises the impurities of water such as ammonia. It also prevents the growth of weed and removes taste and odour from the water.

(*g*) *Dechlorination* : The removal of unwanted chlorine in water by chemical or physical treatment is known as dechlorination. The most commonly used chemicals for the dechlorination of water are sulphur dioxide, sodium bisulphate, sodium thiosulphate, activated carbon, potassium permanganate etc.

8.12 Softening of Water

The treatment for removing the hardness or dissolved impurities from water, is known as *softening of water*. The water containing chlorides, sulphates and bicarbonates of calcium and magnesium is referred as hard water. The hardness may be temporary and permanent.

The hardness due to the presence of calcium and magnesium carbonates or bicarbonates is known as *temporary hardness*. The hardness due to the presence of sulphates, chlorides and nitrates of calcium and magnesium is known as *permanent hardness*.

The temporary hardness may be removed by boiling the water or by adding lime water in the water which is called lime process.

The permanent hardness of water may be removed by lime soda process, zeolite (silicate of sodium) or base exchange process (also known as cation exchange method).

8.13 Distribution of Water

The process of supplying water to the consumer at the desired pressure is known as *water distribution*. The various devices used for this purpose are as follows :

1. *Sluice valve*. The sluice valves are used to regulate the flow of water through the pipe lines. These should be located at points of low pressure.

2. *Air relief valve*. The air relief valves are used to admit air to the pipe line in order to prevent the formation of vacuum in case of rapid flow negative pressure. This vacuum or negative pressure (known as water hammer) may hurt the pipe line at some lower point.

3. *Reflux or check valve*. A reflux valve is used to prevent water to flow back in the opposite direction. It is also known as *non-return valve*. This valve is installed on the delivery side of the pumping set in order to prevent the back flow when the pump is stopped.

4. *Safety valve or pressure relief valve*. The safety valve is used to release the excessive pressure which may build up in a closed pipe.

5. *Scour valve or blow off valve*. The scour valve is used to drain off the water from the pipe after closing the supply. These valves are provided at low points.

6. *Fire hydrant*. A fire hydrant is used for tapping water from mains for fire extinguishing, street, washing, flushing sewer lines and many other purposes. The two types of hydrants are flush hydrant and post hydrant.

7. *Pipe fittings*. In addition to the valve, various types of pipe fittings such as caps, flanges, nipples, elbows, bends, unions, tees, etc. are used during laying of water distribution pipes.

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8.14 Water Distribution System

The system of distributing water efficiently to the consumers is known as *water distribution system*. The distribution systems are as follows :

1. *Dead end system*. It is also known as *tree system*. There is only one main supply pipe. A number of sub-main pipes are taken out from it. Each sub-main is divided into many branch pipes called laterals. From laterals, the service connections are given to the consumers.
2. *Grid iron system*. This system is an improvement over the dead end system. In this system, the mains, sub-mains and branches are interconnected with each other.
3. *Ring system*. This system is adopted in well-planned cities only. In this system, each city is divided into square or circular blocks. The water mains are laid around all the four sides of the square or round the circle and the branches, sub-mains etc. are laid along the inner roads.
4. *Radial system*. This system is just opposite to the ring system and water flows towards outer periphery from one point.

8.15 Methods of Water Distribution System

The following methods are used for distributing water in a distribution system :

1. *Gravity flow method* : This method is used to distribute water from the higher level to the consumers at a lower level. In this method, no pumping is involved.
2. *Pumping method* : In this method, treated water is not stored but it is pumped directly into the water mains. Since the demand of water is not constant, therefore, high power pumps are required in this method.
3. *Combined gravity and pumping method* : In this method, the pump is connected to the mains and the elevated reservoirs. The water is pumped to the reservoir for storage and then it is supplied to the consumers by gravity flow.

8.16 Sanitary Engineering

It is that branch of Public Health Engineering which deals with the removal and disposal of sewage to maintain healthy living conditions. The main objects of the sewage disposal are as follows :

1. To dispose off properly the human excreta to a safe place before it creates unhealthy conditions in the locality.
2. To dispose off waste water from an area so that it may not become breeding place for mosquitoes.
3. To dispose off the sewage after giving it treatment so that the receiving land may not get polluted.
4. To supply sewage after treatment for irrigation purposes.

8.17 Terms used in Sanitary Engineering

The following are the important terms used in sanitary engineering :

1. *Sewage*. The used water mixed with organic and inorganic solids, fluid wastes from houses, factories and dry weather flow, is called sewage.
2. *Sanitary sewage*. The domestic sewage which originates from the sanitary conveniences of residential buildings, business buildings, factories and institutions etc., is called sanitary sewage.
3. *Crude or raw sewage*. The untreated sewage is called crude or raw sewage.
4. *Storm sewage*. The quantity of liquid waste which flows in sewers during rainy season, is called *storm sewage.
5. *Combined sewage*. A combination of sanitary sewage surface water and storm water with

* For further details, please refer Art. 8.18.

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or without industrial wastes, is known as combined sewage.

6. *Sewer.* An underground pipe or conduit of circular section used for carrying sewage, is called a sewer.

7. *Branch sewer.* A sewer which receives sewage from a small area and discharges into a main sewer, is called a branch sewer.

8. *Main or trunk sewer.* A sewer which receives sewage from the collection system serving as an outlet for large area, is known as main or trunk sewer.

9. *Outfall sewer.* A sewer which receives sewage from the collection system and conducts it to a point of final disposal, is called an outfall sewer.

10. *Combined sewer.* A sewer which receives storm water, surface run-off and sewage is called a combined sewer.

11. *Common sewer.* A sewer which can be used for flow of storm water or sewage with equal rights of use, is called a common sewer.

12. *Sanitary sewer.* A sewer which is intended to carry sanitary sewage, is called sanitary sewer.

13. *Sewerage.* A process of collecting sewage and delivering it to the disposal point, is called sewerage.

14. *Infiltration.* The water which leaks into sewers from the ground, is called infiltration.

15. *Ex-filtration.* The leakage of sewage from the sewer into the soil surrounding the water, is called ex-filtration.

16. *Waste.* The used water and other things which are thrown off in one form or the other, is called a waste. The waste may be dry waste, liquid waste and semi-liquid waste.

17. *Dry waste.* The waste which does not contain any moisture, is known as dry waste. The garbage, rubbish and ashes are the three form of dry waste.

18. *Liquid waste.* The used water from bathrooms, kitchens, washbasins, urinals, latrines, is called a liquid waste. The water from bathrooms, kitchens, washbasins and washing places is called *sullage*. It is free from organic matter.

19. *Semi-liquid waste.* The waste containing organic matter, is called a semi-liquid waste, *i.e.*, night soil and human excreta.

8.18 Storm Sewage

We have already discussed that the quantity of liquid waste which flows in sewers during rainy season is called storm sewage. The storm sewers are required due to the following reasons :

(*a*) For avoiding the creation of unfavourable healthy conditions.

(*b*) For improving the general appearance of the city.

(*c*) For disposing off the first washings of the early showers as quickly as possible.

(*d*) For keeping the structures safe by not allowing to enter the water in their foundations.

In order to determine the storm sewage (*i.e.* the quantity of storm water), the following empirical relations may be used :

1. According to Fanning's formula, the quantity of storm water (Q) in litres per second is given by

$$Q = C.A^{5/8}$$

where C = A constant, and

A = Area of catchment in sq. km.

2. According to Dicken's formula,

$$Q = C \,.\, A^{3/4}$$

3. According to Ryve's formula,

$$Q = C \,.\, A^{2/3}$$

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8.19 Design of Sewers

The internal diameter of the sewer should not be less than 15 cm. The small sewers require greater care as compared to larger sewers. The velocity which causes both floating and heavy solids to be transported easily with flow is called self cleaning velocity. The self cleaning velocity, recommended for Indian conditions, in order to prevent settling down of sewage at the bottom or on the sides of a large sewer is 0.75 m/s. The slope of the sewer line should be in the direction of the slope of the ground. It may be noted that larger the size of the sewer, the higher is the velocity of flow. Therefore, larger sewers should be laid at flatter slopes. The gradient should be such that the velocity of flow should not become too high or too low and should be within permissible limits.

8.20 Methods of Sanitation

The sanitation of a town is done by the following two methods :

1. Conservancy or dry method ; and 2. Water carriage method.

The waste products of a town are collected and carried by these methods to the treatment or disposal works. In the *conservancy or dry method*, different types of refuse are collected, carried and disposed off separately. In the *water carriage method*, water is used as a medium to convey the sewage to the point of treatment or disposal. This method is more hygienic, but the initial cost for the construction of the system and the maintenance cost is high. There is no smell or sight nuisance in the water carriage method and the sewers being all underground do not impair the beauty of the place.

8.21 Sewerage Systems

We have already discussed that the process of collecting and delivering the sewage to the disposal point is called *sewerage*. The following are three systems of sewerage :

1. Combined system ; 2. Separate system ; and 3. Partially separate system.

In a *combined system*, only one set of sewers are laid for carrying sanitary sewage and storm water. This system is most suitable for the locality which has narrow streets. The maintenance cost of this system is very small. It also provides automatic flushing of sewers.

In a *separate system*, two sets of sewers are required. One for carrying the sanitary sewage and the other for carrying the storm water. This system is most suitable for rocky areas because laying of two small sewers is easy than one large sewer. It is also suitable when the topography is flat necessitating deep excavation for combined sewers.

In a *partially separate system*, a small portion of storm water is allowed to enter in the sanitary sewage within permissible limits and the remaining storm water flows in separate set of sewers. This system is suitable by areas where storm water is small in quantity due to scarcity of rainfall.

8.22 Classification of Sewers

The sewers are classified as discussed below :

1. According to the construction material used, the sewers are classified as follows :

(*a*) Cast iron sewers ; (*b*) Stone ware sewers ; (*c*) Concrete or R.C.C. sewers ; (*d*) Masonry sewers ; (*e*) Asbestos concrete sewers ; and (*f*) Plastic sewer pipes.

2. According to the shape of the sewers, the sewers are classified as follows :

(*a*) Rectangular sewer ; (*b*) Horse-shoe type ; (*c*) semi-elliptical sewer ; (*d*) Basical handle type ; (*e*) circular sewer ; (*f*) Egg-shaped sewer.

8.23 Sewer Joints

The joints are essential for joining various pieces of sewer pipes in order to make one continuous length of sewer line. The sewer joints are of the following types :

(*a*) Spigot and socket joint ; (*b*) Collar joint ; (*c*) Mechanical joint ; (*d*) Bandage joint ; (*e*) Flush joint ; (*f*) Filled and poured type joints.

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For the sewers of diameters less than 600 mm, spigot and socket joint is preferred and for sewers of diameter more than 600 mm, a collar joint is used.

8.24 Sewerage Appurtenances

The different devices required for construction, operation and maintenance of the entire sewerage system is known as *sewerage appurtenances*. These are classified as follows :

1. *Man hole.* It is an opening in a sewer line to provide access for a man for the purpose of inspection and cleaning of sewer. The man holes are generally located at all changes of direction, all changes of gradients and at all junctions of main and branch sewers. The maximum distance between man holes, for large sewers, should be 300 metres. The essential parts of a man hole are : working chamber, an access shaft, cover and steps of iron. The lower portion of a man hole is called a working chamber. The minimum diameter of a man hole cover should be 50 cm.

2. *Catch basin.* It is a structure constructed in the form of a chamber and provided along the sewer line to admit clear rain water free from suspended silt and grit, floating rubbish etc. into the combined sewer. The catch basins are located when the sewers are laid at very small gradient and the velocity of flow of sewage is less than the self cleaning velocity.

3. *Flushing tanks.* These are used to hold and throw water into the sewer for the purpose of cleaning. These are usually provided at the beginning of the sewers and may be either hand operated or automatic.

4. *Ventilating shaft.* It is a shaft provided for the purpose of ventilation of sewers. The ventilating shafts are required to prevent the accumulation of dangerous explosive and corrosive gases.

8.25 House Drainage

The following terms are commonly used in the house drainage system :

1. *Soil pipe.* It is a pipe through which liquid waste carrying human excreta flows.
2. *Waste pipe.* It is a pipe through which liquid waste without human excreta flows.
3. *Vent pipe.* It is a pipe installed for ventilation purposes. This pipe should be one metre above the roof level.
4. *Rain water pipe.* It is a pipe which carries storm water.
5. *Anti-syphonage pipe.* It is a pipe installed in the house or building drainage to preserve the water seal of a trap. It maintains proper ventilation and does not allow syphonic action.

8.26 Plumbing Systems

The following are the plumbing systems for the building drainage.

1. *One pipe system.* The system in which only one pipe is provided to collect both the foul soil waste as well as unfoul waste from the building is known as one pipe system. In one pipe system of plumbing, waste water is carried away from kitchens, wash basins, bathrooms, water closets etc.

2. *Two pipe system.* The system in which two pipes are provided, one for collecting the unfoul water from kitchen, bathrooms, house washings, rain water etc. and the other for collecting soil waste, is called two pipe system. This system is mostly used in India.

8.27 Traps

A depression or bend provided in a drainage system which is always full of water to prevent the entry of foul gases in the atmosphere is known as a *trap*. A trap prevents the entry of foul gases in the atmosphere but it allows the sewage to flow through it. A good trap should provide an adequate water seal at all times.

It should be made of non-absorbent material and should have self-cleaning velocity.

8.28 Privy

The arrangement made for collection of human excreta is known as *privy*. There are many

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Types of privies such as privy pit, cess pool, chemical privy, septic tank etc.

The *privy pit* is the most suitable and economical disposal unit for human excreta. It should be located at least three metres away from the well or other ground water supply. A vent pipe is provided to take the foul gases.

A *cess pool* is an underground structure in the form of a circular or rectangular tank for the purpose of admitting sewage into it from the intercepting chamber. These are very cheap in construction. It is not recommended by the health authorities.

A *chemical privy* is a dry privy and most satisfactory method of disposal of human excreta without water carriage.

A *septic tank* is an underground sewage system with complete treatment of sewage. The septic tanks followed by sub-surface disposal of effluent are economical and most suitable. This method gives satisfactory results in areas having porous soil.

8.29 Sewage Disposal

The sewage should be disposed off without causing odour and nuisance. The sewage can be disposed off without treatment or after suitable treatment either on land or in natural water courses. The land disposal of sewage is suitable under the following circumstances :

1. When there is no natural courses such as streams, rivers etc. for the discharge of sewage into them.
2. When the quantity of sewage is more which will pollute the river or stream water.
3. When the rivers run dry or have a small flow during summer.
4. When the overall rainfall is very low so that the lands can be irrigated by sewage.

The land disposal of sewage requires large area of sandy land or alluvial soil. The sewage should be given either preliminary or primary treatment.

The disposal of sewage (raw or treated) into natural water courses such as streams, rivers, sea and lake, is known as sewage disposal by dilution. This method is only possible when large quantity of natural water is present near the town. It is suitable under the following circumstances :

1. When thorough mixing of sewage is possible.
2. When the sewage arriving at the point of disposal is fresh and non-septic.
3. When there are strong forward currents.
4. Where there are no backward currents.

When the sewage is discharged into streams, its organic matter get oxidised by the amount of dissolved oxygen present in water and this matter is converted into in offensive substances.

The natural water removes their deficiency of oxygen consumed by organic matter by the absorption of atmospheric oxygen. This action is known as self-purification of streams.

Thus the self-purification of streams may be defined as "*the natural process in which the oxygen of water of streams is consumed by the sewage and at the same time, it is replenished or filled again by the atmosphere.*"

8.30 Sewage Treatment

It is the artificial process of removing or changing the objectionable constituents present in the sewage in order to make it less offensive and dangerous for its disposal.

The sewage contains large quantity of bacterias (pathogens and non-pathogens). The sewage bacterias are also classified as aerobic bacterias and anaerobic bacterias. The bacterias which exist in the presence of light and take free oxygen in dissolved conditions, are known as *aerobic bacterias*. The bacterias which exist under dark and stagnate conditions in the absence of oxygen, are known as *anaerobic bacterias*.

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Notes : 1. The oxygen dissolved in the fresh sewage is known as dissolved oxygen. It depends upon temperature. As the temperature increases, the dissolved oxygen decreases.

2. The amount of oxygen required by sewage from an oxidising agent like potassium dichromate known as chemical oxygen demand (C.O.D.).

3. The amount of oxygen required for the biological decomposition of dissolved organic solids occur under aerobic conditions and at a specified time and temperature is called bio-chemical oxygen demand (B.O.D.).

8.31 Classification of Sewage Treatment

The sewage treatment may be classified as primary treatment and secondary treatment. The treatment which employs the mechanical and hydraulic separation principle for removing solids suspended organic matter is known as *primary treatment*. In primary treatment of sewage, light materials are removed. The primary treatment units are screening, *grit chamber, plain sedimentation and sedimentation followed by coagulation.

The treatment which works on the biological principles *i.e.* the degradation of organic matter by the agency of living organism is known as *secondary treatment*. In secondary treatment of sewage fine dissolved organic materials are removed. The secondary treatment or biological treatment of sewge is done by sewage filters and activated sludge process units. The filter mostly used is trickling filter. These filters may be low rate trickling filters or high rate trickling filters.

The activated sludge is a sludge floc produced in a raw settled sewage by the growth of bacteria and other organisms in the presence of dissolved oxygen and accumulated in sufficient concentration by returning floc previously formed. The activated sludge contains fertilising constituents, indicated the degree of aeration and high water content. The sludge treatment is mainly done in order to stabilize the organic matter, to destroy the pathogenic bacterias and to reduce the water content.

OBJECTIVE TYPE QUESTIONS

1. The water supply system means
- (*a*) the entire scheme of collection and disposal of liquid waste
- (*b*) the complete layout from the source of supply to the distribution
- (*c*) construction of reservoirs
- (*d*) construction of canals

2. The water obtained from the tube wells is known as
- (*a*) surface water
- (*b*) sub-surface water
- (*c*) run-off
- (*d*) potable water

3. The water obtained from a lake is known as surface water.
- (*a*) Agree
- (*b*) Disagree

4. The water obtained from ..... is generally known as underground water.
- (*a*) infiltration galleries
- (*b*) springs
- (*c*) rivers
- (*d*) wells

5. The water obtained from ..... is generally known as sub-surface water.
- (*a*) rains
- (*b*) rivers
- (*c*) reservoirs
- (*d*) artesian wells

6. The horizontal tunnels constructed at shallow depths along the banks of a river to intercept the ground water table are called
- (*a*) canals
- (*b*) infiltration galleries
- (*c*) springs
- (*d*) lakes

Grit chambers are used to remove grit from sewage. The grit removal is essential before sedimentation water, and before it settles in sedimentation tank.

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7. The vertical wells provided along the banks of a river to draw ground water in dry season are called
(a) open wells (b) tube wells
(c) artesian wells (d) infiltration wells

8. When a pervious strata is sandwitched between two impervious strata of cup shape, the well is called a tube well.
(a) True (b) False

9. A pipe sunk into the ground to tap the underground water is called
(a) open well (b) tube well (c) artesian well (d) infiltration well

10. When in the pervious strata, the surface of water surrounding the well is at atmospheric pressure, the well is known as
(a) gravity well (b) artesian well (c) open well (d) deep well

11. Absolute pure water is good for health.
(a) Right (b) Wrong

12. The earth's water circulatory system is known as
(a) water cycle (b) hydrological cycle
(c) precipitation cycle (d) all of these

13. An artesian spring is formed
(a) when an aquifer gets exposed in a valley against a vertical cut
(b) due to continuous fault in a rock through which water under pressure comes out
(c) when a porous strata gets enclosed between two impervious strata
(d) none of the above

14. The quantity of water available from an infiltration gallery depends upon the
(a) size of gallery (b) nature of soil (c) yield of source (d) all of these

15. The quality of tube well water is ..... as compared to surface water.
(a) good (b) poor

16. The continuous flow of water may be expected from
(a) surface springs (b) artesian springs (c) gravity springs (d) all of these

17. The layers such as sand and gravel which allow the water to pass through them are known as
(a) previous layers (b) aquifers (c) water bearing strata (d) all of these

18. Which of the following statement is correct ?
(a) The sub-surface sources are not affected by draught.
(b) Infiltration galleries are most suitable for increasing the surface source supply, in dry season.
(c) The rate at which water percolates into well under safe maximum critical depression head is called yield of well.
(d) all of the above

19. The artesian spring has too much hydraulic gradient and water flows out automatically.
(a) Right (b) Wrong

20. The water bearing strata *i.e.* layers of sand, gravel etc. is called
(a) an acquifer (b) an aquiclude (c) an aquifuge (d) zone of saturation

21. The layers such as lime stone and sand stone which do not allow the water to pass through them are known as
(a) aquifers (b) aquiclude (c) aquifuge (d) none of these

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22. The portion of soil through which lateral movement of water takes place is
(a) water table (b) an aquiclude
(c) zone of saturation (d) none of these

23. The open wells or dug wells are also known as
(a) shallow wells (b) draw wells (c) percolation wells (d)

24. The most important source of water for public water supply is
(a) lake (b) pond (c) river (d)

25. The natural outflow of sub-surface water at the surface is termed as spring.
(a) Correct (b) Incorrect

26. The open wells or dug wells
(a) act as a small storage reservoir (b) are suitable for a small discharge
(c) are cheap in construction (d) all of these

27. The water of a river has an important property called
(a) turbidity (b) self purification
(c) permeability (d) infiltration capacity

28. Which of the following statement is wrong ?
(a) The quality of tube well water is better than that of surface sources.
(b) The discharge of tube well is more than that of an open well.
(c) The tube well should not derive water from the first pervious strata.
(d) none of the above

29. Run-off is the water which flows
(a) in infiltration galleries (b) in sewer pipes
(c) due to leakage of pipes (d) in rivers

30. According to Vermule's formula, the annual run-off (F) in cm is given by
(a) $F = R + (0.279 + 0.116\,R)(0.063\,T - 0.47)$
(b) $F = R - (0.279 + 0.116\,R)(0.063\,T + 0.47)$
(c) $F = R - K(1.8\,T + 32)$
(d) $F = R + K(1.8\,T - 32)$

where R = Annual rainfall in cm,
T = Mean annual temperature in °C, and
K = A constant.

31. The formula, $F = R - K(1.8\,T + 32)$, for obtaining the annual run-off is known as
(a) Justin's formula (b) Vermule's formula
(c) Inglis formula (d) Khosla's formula

32. The growth of population may be conveniently represented by
(a) semi-logarthmic curve (b) logistic curve
(c) straight line curve (d) all of these

33. The yield of a surface stream may be obtained by
(a) cross-section velocity method (b) stream gauging
(c) chemical method (d) all of these

34. The yield of a underground source may be obtained by
(a) pumping test (b) recupating test (c) both (a) and (b) (d)

35. The yield of the well depends upon the
(a) permeability of the soil (b) position of water table
(c) depth of well in impervious layer (d) all of these

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36. The yield of the well is measured in
(a) cum / h (b) litres / h (c) either (a) or (b) (d) none of these

37. The amount of water collected in a reservoir is divided into three portions and the order of their existance from bottom to the top is
(a) useful storage, surcharge storage, dead storage
(b) useful storage, dead storage, surcharge storage
(c) dead storage, useful storage, surcharge storage
(d) none of the above

38. Which of the following statement is correct ?
(a) The rate of silting in a reservoir is more in the beginning and less in the end.
(b) At the economical height of a dam, its cost per million cubic metre of storage is minimum.
(c) The percentage of water required for public use amounts to about 10% of the total water requirements.
(d) all of the above

39. In India, as per Indian standards, water consumption per capita per day for domestic purpose is
(a) 85 litres (b) 100 litres (c) 115 litres (d) 135 litres

40. The domestic use of water amounts to ..... of the total water requirements per capita per
(a) 20% (b) 30% (c) 40% (d) 50%

41. The average consumption of water for commercial use varies from 20 to 25% of total sumption.
(a) Yes (b) No

42. According to Indian standards, the consumption of water per capita per day for nursing homes, rding schools and hostels is
(a) 85 litres (b) 100 litres (c) 115 litres (d) 135 litres

43. The water supply system should be designed for the present population only.
(a) Agree (b) Disagree

44. According to Indian standards, 45 litres of water per person per day is provided in case of
(a) hotels (b) hostels (c) offices (d) all of these

45. Which of the following formula is used for computing the quantity of water for fire demand ?
(a) Freeman's formula (b) Kuichling formula
(c) Buston's formula (d) all of these

46. Freeman formula for estimating, the fire demand (Q) in litres per minute is given by
(a) $Q = 1135\left(\frac{P}{5}+10\right)$ (b) $Q = 2500\left(\frac{P}{5}+10\right)$
(c) $Q = 3182\sqrt{P}$ (d) $Q = 5663\sqrt{P}$
where P = Population in thousands.

47. According to Kuichling formula, the fire demand (Q) in litres per minute is given by
(a) $Q = 1135\left(\frac{P}{5}+10\right)$ (b) $Q = 2500\left(\frac{P}{5}+10\right)$
(c) $Q = 3182\sqrt{P}$ (d) $Q = 5663\sqrt{P}$

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48. The fire demand (Q) in litres per minute, according to Buston's formula, is given

(a) $Q = 1135\left(\frac{P}{5} + 10\right)$ (b) $Q = 2500\left(\frac{P}{5} + 10\right)$

(c) $Q = 3182\sqrt{P}$ (d) $Q = 5663\sqrt{P}$

49. In designing a water works for a city to meet the water demand for public use, a provision about ..... of the total consumption is made.

(a) 5% (b) 10% (c) 20% (d) 25%

50. The design period for a water supply project is taken as

(a) 5 to 10 years (b) 10 to 15 years (c) 15 to 20 years (d) 20 to 30 years

51. The water mains should be designed for ..... of the average daily water requirement

(a) 100% (b) 150% (c) 225% (d) 250%

52. For large cities, the suitable method for forecasting population is

(a) arithmetical increase method (b) graphical method

(c) geometrical increase method (d) comparative method

53. The increase in population of a young and rapidly developing city is estimated by comparative method.

(a) True (b) False

54. The arithmetical increase method of forecasting population gives ..... as compared to geometrical increase method.

(a) same value (b) lesser value (c) higher value

55. Match the correct answer from *Group B* for the statements given in *Group A*.

Group A	*Group B*
(a) Arithmetical increase method of predicting population is suitable	(A) for old cities
(b) Geometrical increase method of predicting population is suitable	(B) 50 litres
(c) Water consumption for domestic use per capita per day is	(C) 135 litres
(d) Water consumption for industrial use per capita per day is	(D) for large cities

56. If P is the present population, P_N is the population estimated after N years and I is average percentage growth, then according to geometrical increase method

(a) $P_N = P\left(1 + \frac{I}{100}\right)^N$ (b) $P_N = P\left(1 - \frac{I}{100}\right)^{1/N}$

(c) $P_N = P + \frac{I}{100} \times N$ (d) $P_N = P - \frac{I}{100} \times N$

57. Suspended impurities consist of

(a) iron (b) chlorine (c) bacteria (d) all of these

58. Dissolved impurities consist of

(a) bacteria (b) iron (c) slit (d) fungi

59. The presence of bacteria in water causes

(a) hardness (b) alkalinity (c) diseases (d) bad taste

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60. Colloidal impurities if associated with organic matter having bacterias becomes the chief source of
(a) hardness (b) epidemic (c) alkalinity (d) bad taste

61. The presence of calcium and magnesium chloride in water causes
(a) softening (b) bad taste (c) hardness (d) turbidity

62. The ground water is generally free from ..... impurities.
(a) suspended (b) dissolved

63. The finely divided dispersion of solid particles which are not visible to the naked eye and cannot be removed by ordinary filters are known as
(a) suspended impurities (b) dissolved impurities
(c) colloidal impurities (d) none of these

64. The turbidity in water is caused due to
(a) silt (b) clay
(c) finely divided organic matter (d) all of these

65. Suspended impurities cause turbidity in water.
(a) Yes (b) No

66. Suspended impurities include
(a) algae (b) protozoa (c) fungi (d) all of these

67. The presence of sodium chloride in water
(a) causes bad taste (b) softens the water
(c) increases hardness of water (d) stops epidemic

68. The presence of calcium and magnesium bi-carbonates in water causes hardness in the water.
(a) Correct (b) Incorrect

69. The sodium carbonate in water
(a) causes bad taste (b) softens the water
(c) increases hardness of water (d) stops epidemic

70. The presence of ..... causes red colour in water.
(a) iron (b) manganese
(c) sodium fluoride (d) calcium carbonate

71. When manganese is present in water, it reduces the degree of hardness.
(a) Yes (b) No

72. When lead is present in water, it
(a) changes its colour (b) causes turbidity
(c) causes alkalinity (d) none of these

73. The presence of hydrogen sulphide in water causes
(a) softening (b) alkalinity (c) acidity (d) bad taste

74. The presence of carbon dioxide in water causes acidity.
(a) True (b) False

75. Turbidity is the measure of resistance to the passage of ..... through the water.
(a) light (b) air

76. Turbidity of water is expressed in terms of
(a) silica scale (b) platinum cobalt scale
(c) pO value (d) none of these

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77. The colour of water is expressed in numbers of a
(a) silica scale (b) platinum cobalt scale
(c) *pO* value (d) none of these

78. The odour of water can be determined by
(a) thermometer (b) Osmoscope
(c) Jackson's turbidimeter (d) none of these

79. The odour of water does not change with the temperature.
(a) Agree (b) Disagree

80. The commercial osmoscope is graduated with *pO* values from
(a) 0 to 5 (b) 5 to 10 (c) 10 to 15 (d) 15 to 20

81. When the *pO* value of water is 5, then it has
(a) no perceptible odour (b) distinct odour
(c) faint odour (d) extremely strong odour

82. The maximum permissible temperature for domestic supply is
(a) 5 to 10°C (b) 10 to 15°C (c) 15 to 20°C (d) 20 to 25°C

83. The maximum permissible colour for domestic supplies, on platinum cobalt scale is
(a) 5 to 10 ppm (b) 10 to 20 ppm (c) 20 to 30 ppm (d) 30 to 40 ppm

84. Odours and tastes may result due to the presence of
(a) micro-organisms either dead or alive
(b) dissolved gases such as oxygen, carbon dioxide, methane etc.
(c) mineral substances such as sodium chloride, iron compounds etc.
(d) all of the above

85. The maximum permissible turbidity for domestic supplies, on silica scale is
(a) 5 to 10 ppm (b) 10 to 20 ppm (c) 20 to 30 ppm (d) 30 to 40 ppm

86. High turbidity of water can be determined by
(a) turbidity tube (b) Jacksons turbidimeter
(c) Baylis turbidimeter (d) Hellipe turbidimeter

87. Low turbidity of water can be determined by
(a) turbidity tube (b) Jacksons turbidimeter
(c) Baylis turbidimeter (d) Hellipe turbidimeter

88. The maximum permissible total solid content in water for domestic purposes should not exce
(a) 300 ppm (b) 400 ppm (c) 500 ppm (d) 1000 ppm

89. The maximum permissible hardness in water for drinking purposes should not exceed 1(
ppm.
(a) Correct (b) Incorrect

90. The maximum permissible chloride content in water for domestic supplies should not exce
(a) 250 ppm (b) 350 ppm (c) 450 ppm (d) 550 ppm

91. *pH* value is a symbol for ..... concentration.
(a) magnesium (b) hydrogen (c) calcium (d) sodium

92. Alkalinity is caused by positively charged hydrogen ions.
(a) Right (b) Wrong

93. Residual chlorine in water is determined by ..... method.
(a) versenate (b) starch-iodide

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94. Lead should be present in large quantity in water.
(a) Yes (b) No

95. Match the correct answer from *Group B* for the statements given in *Group A*.

Group A (Substance)	*Group B (Permissible quantity for domestic purposes)*
(a) Iron and manganese	(A) 3.0 ppm
(b) Arsenic	(B) 1.5 ppm
(c) Copper	(C) 0.05 ppm
(d) Fluorine	(D) 0.3 ppm

96. Calcium sulphate present in water causes corrosion.
(a) True (b) False

97. Which of the following statement is correct ?
(a) If the *pH* value of water is equal to 7, the water is said to be neutral.
(b) The *pH* value determines the strength of the acid or alkali in water.
(c) The *pH* value of water can be obtained by a potentiometer.
(d) all of the above

98. The product of H^+ ions and OH^- ions in a water solution is equal to
(a) 0 (b) 10^{-1} (c) 10^{-7} (d) 10^{-14}

99. The maximum acidity in water will occur at a *pH* value of
(a) 0 (b) 2 (c) 7 (d) 14

100. The most common cause of acidity in water is
(a) hydrogen (b) oxygen (c) carbon dioxide (d) all of these

101. When the *pH* value of water is ..... the water is said to be acidic.
(a) equal to 7 (b) less than 7 (c) more than 7

102. When the *pH* value of water is more than 7, it represents ..... water.
(a) neutral (b) acidic (c) alkaline

103. The alkalinity in water is caused by
(a) sodium carbonate (b) potassium carbonate
(c) calcium hydroxide (d) all of these

104. The maximum permissible chlorine content for public supplies should be between
(a) 0.1 to 0.2 ppm (b) 0.3 to 0.4 ppm (c) 1.2 to 4 ppm (d) 6.5 to 8 ppm

105. The maximum permissible quantity of iron and manganese in water for domestic purposes should be
(a) 0.1 ppm (b) 0.3 ppm (c) 0.6 ppm (d) 0.8 ppm

106. The *pH* value of water for public supplies is limited from
(a) 2.5 to 6.5 (b) 6.5 to 8 (c) 8 to 10.5 (d) 10.5 to 15

107. The quantity of arsenic in water for domestic purposes should not be more than 0.05 ppm.
(a) True (b) False

108. The maximum permissible quantity of lead in water for domestic supplies is
(a) 0.01 ppm (b) 0.05 ppm (c) 0.50 ppm (d) 1 ppm

109. The copper contents in water for domestic purposes should not be ..... 3 ppm.
(a) less than (b) more than

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110. Sodium carbonate causes ..... of water.
(a) hardness (b) softness

111. Hard water may cause bursting of boilers.
(a) Agree (b) Disagree

112. The maximum permissible fluorine content in water for domestic supplies should be
(a) 0.15 ppm (b) 1.5 ppm (c) 15 ppm (d) 150 ppm

113. Sphere shaped bacterias are called
(a) spirilla (b) bacilli (c) cocci (d) trichobacteria

114. B-coli or E-coli are harmless organisms but their presence in water indicates the
(a) presence of pathogenic bacteria (b) absence of pathogenic bacteria
(c) presence of non-pathogenic bacteria (d) absence of non-pathogenic bacteria

115. Membrane filter technique is used for testing
(a) E-coli (b) copper
(c) pathogenic bacterias (d) none of these

116. Water is ..... when pathogenic bacterias are present.
(a) safe (b) harmful

117. The bacteria which require oxygen for their survival is known as
(a) anaerobic bacteria (b) pathogenic bacteria
(c) aerobic bacteria (d) non-pathogenic bacteria

118. The bacteria which can survive without oxygen is called
(a) anaerobic bacteria (b) pathogenic bacteria
(c) aerobic bacteria (d) non-pathogenic bacteria

119. Bacteria which can survive with or without free oxygen is known as facultative bacteria.
(a) Correct (b) Incorrect

120. The bacterias which do not cause any disease are called pathogenic bacterias.
(a) Right (b) Wrong

121. Bacterias which cause disease are called
(a) anaerobic bacterias (b) facultative bacterias
(c) aerobic bacterias (d) none of these

122. The total count of bacteria per cubic centimetre for domestic purposes varies from
(a) 0 to 100 (b) 100 to 150 (c) 150 to 200 (d) 200 to 250

123. Copper sulphate is the most common chemical used for controlling
(a) bacteria (b) algae (c) silt (d) mineral matter

124. Bio-chemical oxygen demand (B.O.D.) of safe drinking water must be
(a) 0 (b) 10 (c) 50 (d) 100

125. The pocess of excluding large sized particles from water with the help of screens is called filteration.
(a) Yes (b) No

126. The method adopted for removing, bushes branches, debries etc. from water is known as
(a) sedimentation (b) coagulation (c) screening (d) filtration

127. In the process of screening, the screens should be inclined at an angle of
(a) 10° to 20° (b) 30° to 40° (c) 45° to 60° (d) 70° to 90°

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128. The area of the openings in screens should be such that the velocity of flow through them does not exceed
(a) 0.75 to 1 m/s (b) 1.5 to 3 m/s (c) 3 to 5 m/s (d) 5 to 6 m/s

129. Plain sedimentation is a process of retaining water in a basin so that the suspended particles settles down as a result of the
(a) action of sun-rays (b) action of gravity and forces
(c) action of velocity of the particles (d) none of these

130. The rate of settling of a particle in water depends upon the
(a) viscosity of water (b) density of water
(c) specific gravity of particle (d) all of these

131. The particle will settle down more rapidly in water at high temperatures than at lower temperatures.
(a) True (b) False

132. The detention time for an ordinary plain sedimentation tank is
(a) 1 to 2 hours (b) 2 to 4 hours (c) 6 to 8 hours (d) 20 to 24 hours

133. In a plain sedimentation tank, under normal conditions, impurities are removed upto
(a) 50% (b) 60% (c) 70% (d) 80%

134. In the design of a sedimentation tank, the essential factor to be considered is
(a) period of detention (b) sludge capacity (c) velocity of flow (d) all of these

135. The velocity of flow in any sedimentation tank should not exceed
(a) 0.05 mm/s (b) 0.5 mm/s (c) 5 mm/s (d) 50 mm/s

136. The process of adding certain chemicals to water in order to form flocculent precipitate for absorbing and entraining colloidal matter is called sedimentation with coagulation.
(a) Agree (b) Disagree

137. The length of rectangular sedimentation tank should not be more than ..... the width of the tank.
(a) twice (b) three times (c) four times (d) six times

138. The efficiency of sedimentation tank for a given discharge, can be increased by
(a) increasing the depth of tank (b) decreasing the depth of tank
(c) increasing the surface area of tank (d) decreasing the surface area of tank

139. Which of the following statement is correct ?
(a) Screens are inclined to increase the opening area.
(b) Plain sedimentation is useful as a process preliminary to further treatments.
(c) Ratio of the volume of the basin of sedimentation tank to the rate of flow is called detention period.
(d) all of the above

140. The most common coagulant is
(a) magnesium sulphate (b) alum
(c) chlorine (d) bleaching powder

141. When turbidity of water exceeds about 45 ppm, coagulation ..... adopted.
(a) should be (b) should not be

142. In dry feeding type of coagulants, the dose of coagulant is controlled by
(a) scrapers (b) worm wheel (c) paddles (d) none of these

143. Which of the following is not a coagulating agent ?
(a) Ferric sulphate (b) Ferric chloride (c) Aluminium sulphate (d) Copper sulphate

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144. The alum when mixed with water as a coagulant,
(a) does not effect *pH* value of water (b) decreases *pH* value
(c) increases *pH* value of water (d) none of these

145. Coagulation is required when the particles are of ..... size.
(a) fine (b) coarse

146. Aluminium sulphate may be used for coagulation.
(a) Correct (b) Incorrect

147. The volume of a settling basin is large due to
(a) large volumes of floc added for coagulation
(b) large amount of water entrapped into it
(c) greater amount of suspended solids to be removed
(d) none of the above

148. The process of purifying water by passing it through a bed of fine granular material, is called
(a) screening (b) filteration (c) coagulation (d) sedimentation

149. The void spaces in the filtering material act like a
(a) drain (b) inlet (c) tiny settling basins (d) outlet

150. The organic impurities in water form a layer on the top of a filtering media. Such a layer is called
(a) permeable layer (b) filtering layer (c) dirty skin (d) [illegible]

151. The sand, used for filteration, should not loose weight more than ..... when treated with hydrochloric acid for 24 hours.
(a) 2.5% (b) 5% (c) 7.5% (d) 10%

152. The rate of filteration ..... when the water is filtered through a bed of very fine sand.
(a) increases (b) decreases

153. Water is forced at a pressure higher than the atmospheric pressure in rapid gravity filters.
(a) Right (b) Wrong

154. The effective size of sand particles for slow sand filters varies from
(a) 0.30 to 0.35 mm (b) 0.35 to 0.50 mm (c) 0.50 to 0.65 mm (d) 0.65 to 0.75 mm

155. The effective size of sand particles for rapid sand filters varies from
(a) 0.30 to 0.35 mm (b) 0.35 to 0.50 mm (c) 0.50 to 0.65 mm (d) 0.65 to 0.75 mm

156. The coefficient of uniformity for slow sand filters is
(a) 1.35 (b) 1.55 (c) 1.75 (d) 2.05

157. The coefficient of uniformity for rapid sand filters is ..... as compared to slow sand filters.
(a) more (b) less

158. The under drainage system in slow sand filters
(a) receives and collects the filtered water (b) allows back washing for cleaning the filter
(c) both (a) and (b) (d) none of these

159. The under drainage system in a rapid sand filters
(a) receives and collects the filtered water (b) allows back washing for cleaning the filter
(c) both (a) and (b) (d) none of these

60. Slow sand filter requires ..... area as compared to rapid sand filter.
(a) more (b) less

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161. Which of the following statement is correct ?
(a) Slow sand filters work under atmospheric pressure.
(b) Rapid sand filters require coagulation.
(c) Rapid sand filters should be cleaned after 2 to 3 days.
(d) all of the above

162. The coagulation is not required in ..... filters.
(a) slow sand (b) rapid sand

163. The slow sand filter should be cleaned if the loss of head becomes more than
(a) 0.75 m (b) 1.2 m (c) 2.2 m (d) 3.5 m

164. After cleaning the slow sand filter, the filtered water should not be used for a period of
(a) upto 6 hours (b) 6 hours to 12 hours
(c) 12 hours to 24 hours (d) 24 hours to 48 hours

165. Cleaning period for a slow sand filter is taken as
(a) 1 hour to 3 hours (b) 1 day to 3 days
(c) 1 week to 3 weeks (d) 1 month to 3 months

166. Rate of filteration of a slow sand filter ranges from
(a) 10 to 100 litres/h/m^2 (b) 100 to 200 litres/h/m^2
(c) 200 to 400 litres/h/m^2 (d) 400 to 1000 litres/h/m^2

167. Slow sand filter is efficient to remove the bacterias from the raw water to an extent of
(a) 50% (b) 70% (c) 85% (d) 99%

168. Slow sand filter is more efficient for the removal of
(a) bacteria (b) odour (c) turbidity (d) all of these

169. In a rapid sand filter
(a) raw water from the source is supplied (b) disinfected raw water is supplied
(c) raw water passed through coagulation tank is supplied
(d) any one of the above

170. The yield of a rapid sand filter is ..... to that of slow sand filter.
(a) 10 times (b) 15 times (c) 20 times (d) 30 times

171. An arrangement for back washing is provided in
(a) slow sand filter (b) sedimentation tank
(c) rapid sand filter (d) all of these

172. In a rapid sand filter, the filter head varies from
(a) 1 to 1.5 m (b) 1.5 to 2 m (c) 2 to 4 m (d) 4 to 5 m

173. Cleaning of rapid sand filters is done by
(a) scraping the top layer of filter media (b) back washing
(c) providing new sand layers (d) all of these

174. Cleaning period for a rapid sand filter is taken as
(a) 2 to 3 hours (b) 2 to 3 days (c) 2 to 3 weeks (d) 2 to 3 months

175. Air binding means accumulation of ..... in the filter media.
(a) air (b) impurities

176. Rpid sand filters are suitable for small towns and villages.
(a) Yes (b) No

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177. Rapid sand filter can remove bacterias upto an extent of
(a) 60% to 70% (b) 70% to 80% (c) 80% to 90% (d)

178. Rapid sand filter can remove turbidity from water upto an extent of
(a) 15 to 25 ppm (b) 25 to 35 ppm (c) 35 to 40 ppm (d)

179. Rapid sand filters are cheap and economical as compared to slow sand filters
(a) True (b) False

180. Pressure filters are not used for treating municipal water supplies, becasue
(a) the rate of filteration is high (b) the overall plant capacity is small
(c) they are inefficient in the removal of turbidity and bacterias
(d) they are more costly

181. In pressure filters, water is forced at a pressure ..... the atmospheric pressure.
(a) equal to (b) less than (c) greater than

182. Pressure filters are best suited for
(a) swimming pools (b) railway stations
(c) individual industries (d) all of these

183. The process of killing pathogenic bacterias from water is called
(a) sedimentation (b) filteration (c) coagulation (d) disinfection

184. The most commonly used disinfectant for drinking water throughout the world is
(a) alum (b) nitrogen (c) lime (d) chlorine

185. The ideal method of disinfection of swimming pool water is by
(a) chlorination (b) lime treatment (c) ozonisation (d) ultra-violet ray

186. The amount of residual chlorine in treated water is determined by the
(a) Orthotolodine test (b) Iodometric test (c) Amperometric test (d) all of these

187. The time of contact for chlorination should be at least
(a) 5 minutes (b) 20 minutes (c) 1 hour (d) 2 hours

188. The treatment of water with only chlorine is known as
(a) plain chlorination (b) post chlorination (c) pre-chlorination (d) de-chlorination

189. Pre-chlorination
(a) improves coagulation (b) reduces odours
(c) reduces tastes (d) all of these

190. To prevent the formation of crystalline hydrates of 'Ice' of chlorine, the chlorine supply cylinders are kept at a temperature from
(a) 10°C to 20°C (b) 20°C to 27°C (c) 27°C to 37°C (d) 38°C to 42°C

191. Crystalline hydrates of 'Ice' of chlorine are formed at a temperature of
(a) below 10°C (b) 15°C (c) 20°C (d) above 20°C

192. Th apparatus used for feeding chlorine into water is called
(a) chlorine tank (b) aeration fountain (c) chlorinator (d) none of these

193. In pre-chlorination, the raw water is treated with chlorine only.
(a) Agree (b) Disagree

194. Plain chlorination is adopted for treating the water having turbidities less than 20 to 30 ppm
(a) Correct (b) Incorrect

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195. Which of the following statement is correct ?
(a) Pre-chlorination reduces the bacterial load on filters.
(b) The substance used for disinfection of water is known as coagulant.
(c) Chlorine cannot be applied in the form of chloramines.
(d) all of the above

196. The residual chlorine ..... at the break point of chlorination.
(a) is zero (b) is maximum (c) reappears

197. When the chlorine is added beyond the break point, the process of treating the water is known as
(a) plain chlorination (b) post-chlorination (c) dechlorination (d) super-chlorination

198. The process of removing excess chlorine from water is called
(a) plain chlorination (b) post-chlorination
(c) dechlorination (d) super-chlorination

199. The process of dechlorination is followed by
(a) pre-chlorination (b) post chlorination
(c) super chlorination (d) double chlorination

200. The amount of chlorine used for plain chlorination of water is about
(a) 0.2 ppm (b) 0.3 ppm (c) 0.4 ppm (d) 0.5 ppm

201. When chlorine is added to raw water at more than one point, the process is termed as break point chlorination.
(a) Right (b) Wrong

202. The most commonly used chemical for dechlorination of water is
(a) sodium thiosulphate (b) sodium sulphite
(c) potassium permanganate (d) all of these

203. In orthotolodine test, safe residual for drinking water is indicated by
(a) yellow colour (b) green colour
(c) lemon yellow colour (d) none of these

204. Bleaching powder is
(a) slaked lime (b) chloride of lime
(c) hypo-chloride of lime (d) hypo-chlorite of lime

205. The percentage of chlorine in fresh bleaching powder is
(a) 20 to 25% (b) 25 to 30% (c) 30 to 35% (d) 35 to 40%

206. The temporary hardness in water is caused due to the salts like
(a) chlorides (b) nitrates (c) carbonates (d) sulphates

207. The permanent hardness in water is caused due to the salts like
(a) chlorides (b) nitrates (c) sulphates (d) all of these

208. The temporary hardness due to calcium bicarbonates can be removed by
(a) boiling (b) lime process (c) lime-soda process (d) zeolite process

209. The permanent hardness of water can be removed by
(a) adding alum (b) adding chlorine (c) boiling (d) zeolite process

210. By lime soda process, hardness can be reduced to less than
(a) 50 ppm (b) 75 ppm (c) 100 ppm (d) 150 ppm

211. By base exchange method, water of zero degree hardness can be obtained.
(a) Yes (b) No

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212. The lime soda process of water softening
(a) requires less quantity of coagulant (b) helps in killing pathogens
(c) is suitable for turbid and acidic water (d) all of these

213. Zeolite is
(a) hydrated silica (b) sodium silicate
(c) dehydrated calcium silicate (d) none of these

214. In Zeolite process
(a) no sludge is formed (b) water of varying quality can be treated
(c) ferrous and manganese from water are removed
(d) all of the above

215. Zeolite process is also known as
(a) base exchange process (b) Cation exchange process
(c) both (a) and (b) (d) none of these

216. In lime soda process, the *pH* value of treated water is increased.
(a) True (b) Flase

217. The aeration of water is done to remove
(a) colour (b) odour (c) taste (d) all of these

218. A sluice valve, in water distribution system, is used to
(a) protect the pipe against negative pressure (b) regulate the flow of water through the pip
(c) prevent water to flow back in the opposite direction
(d) all of the above

219. A reflux valve, in water distribution system, is used to
(a) protect the pipe against negative pressure (b) regulate the flow of water through the pip
(c) prevent water to flow back in the opposite direction
(d) all of the abvoe

220. A reflux valve is also known as
(a) safety valve (b) scour valve (c) air valve (d) check valve

221. A scour valve, in a water distribution system, is provided at
(a) low points (b) high points (c) junction points (d) all of these

222. If the level of source of water is higher than that of the place of consumption, the syste adopted for supplying water is
(a) pumping system (b) gravitational system
(c) combined pumping and gravity system (d) any one of these

223. When high level spots are not available for the construction of ground level reservoirs, elevate reservoirs can be used.
(a) Agree (b) Disagree

224. Flush type fire hydrants remain standing above the road.
(a) Correct (b) Incorrect

225. The hydrants are used for tapping water from mains for
(a) fire extinguishing (b) street washing (c) flushing sewer lines (d) all

226. The minimum size of a fire hydrant is
(a) 5 cm (b) 10 cm (c) 15 cm (d) 20

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227. Which of the following statement is correct ?
(a) The pumping system is the best system of water distribution.
(b) A sluice valve prevents water to flow back in the opposite direction.
(c) In a ring system, there is one main supply pipe.
(d) all of the above

228. Wrought iron pipes are more costly and are ..... durable.
(a) less (b) more

229. The valve provided on the suction pipe in a tube well is
(a) sluice valve (b) air relief valve (c) pressure relief valve (d) reflux valve

230. A pressure relief valve is provided to prevent
(a) the water flowing out of the suction pipe (b) the back flow, when the pump is stopped
(c) the increase of pressure after certain safe limit
(d) all of the above

231. A valve which allows the water to flow in one direction but prevents its flow in the reverse direction, is known as
(a) sluice valve (b) reflux valve (c) air relief valve (d) pressure relief valve

232. The corrosion in pipe is due to
(a) dissolved oxygen in water (b) *pH* value of water
(c) impurities in the material particularly those having a lower potential
(d) all of the above

233. The type of joint to be used in pipes depends upon the
(a) material of pipe (b) internal pressure
(c) conditions of support (d) all of these

234. The plain ends of cast iron pipes are joined by
(a) spigot and socket joint (b) flanged joint
(c) victuallic joint (d) dresser coupling joint

235. The pipe joint commonly used in pumping stations is
(a) flexible joint (b) flanged joint
(c) expansion joint (d) spigot and socket joint

236. In order to control the flow of water through pipes, a ..... is provided.
(a) scour valve (b) air valve (c) gate valve (d) safety valve

237. In order to prevent water to flow back in opposite direction, we shall use a
(a) scour valve (b) air valve (c) gate valve (d) reflux valve

238. Under steady low heads ..... pumps are used.
(a) reciprocating (b) centrifugal

239. For high and fluctuating heads ..... pumps are used.
(a) reciprocating (b) centrifugal

240. The capacity of the pumps is normally expressed as
(a) litres per minute (b) cubic metres per day
(c) thousands of litres per hour (d) all of these

241. For an area developed in haphazard way, the type of layout used for the distribution of pipes is known as
(a) dead end system (b) ring system (c) radial system (d) grid iron system

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242. Which of the following statement is wrong ?
(a) A check valve is provided on the delivery side in between the pump and
(b) A pressure relief and air valve are provided on the delivery side.
(c) Scour valves are provided at high points.
(d) all of the above

243. The suitable layout of a distribution system for well planned cities is
(a) dead end system (b) ring system (c) radial system (d)

244. For a city or town with roads of rectangular pattern, the type of layout used for the
of pipes is
(a) dead end system (b) ring system (c) radial system (d)

245. For a well planned city, we shall use the grid iron system for the distribution of
(a) Right (b) Wrong

246. Garbage is a
(a) dry waste (b) semi-liquid waste (c) liquid waste (d)

247. The water from kitchens, bathrooms, wash basins is called
(a) sewage (b) sullage (c) raw sewage (d)

248. The quantity of liquid waste which flows in sewers during rainy season is called
(a) storm sewage (b) dry weather flow (c) sanitary sewage (d)

249. The water which leaks into sewers from the ground is termed as infiltration.
(a) Yes (b) No

250. A sewer which receives storm water, surface run-off and sewage is called a
(a) common sewer (b) combined sewer (c) branch sewer (d)

251. A sewer which receives sewage from the collection system and conducts it to a
disposal is called a
(a) common sewer (b) trunk sewer (c) branch sewer (d)

252. The human excreta is a ..... waste.
(a) dry (b) semi-liquid (c) liquid

253. The main object of sewage disposal is
(a) to dispose off properly human excreta to a safe place before it creates unhealthy
in the locality
(b) to dispose off waste water from an area so that it may not become breeding
mosquitoes
(c) to dispose off the sewage after giving it treatment so that the receiving land may
polluted
(d) all of the above

254. A pipe conveying sewage from the plumbing system of a singe building to a common
the point of immediate disposal is called
(a) common sewer (b) house sewer (c) lateral sewer (d)

255. A sewer which receives discharge of a number of house sewers is called a
(a) common sewer (b) trunk sewer (c) lateral sewer (d)

256. A sewer which gets discharge from two or more main sewers is called
(a) main sewer (b) trunk sewer (c) combined sewer (d)

257. The discharge from washing places is called sullage.
(a) True (b) False

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8. The leakage of sewage from the sewer into the soil surrounding the water is called ex-filtration.
(a) Agree (b) Disagree

9. The self cleaning velocity, recommended for Indian conditions, in order to prevent settling m of sewage at the bottom or on the sides of a large sewer is
(a) 0.25 m/s (b) 0.50 m/s (c) 0.75 m/s (d) 1.5 m/s

0. The method in which different types of refuse are collected, carried and disposed off separately lled
(a) conservancy method (b) dry method
(c) water carriage method (d) either (a) or (b)

1. Which of the following statement is wrong ?
(a) The water carriage system is more hygienic.
(b) There is no smell or sight nuisance in the case of water carriage system.
(c) The sewers in the water carriage system being all underground do not impair the beauty of the place.
(d) The initial cost of construction of water carriage system is very low.

2. The water carriage sewage system removes
(a) domestic sewage (b) industrial sewage (c) storm sewage (d) all of these

3. A combined system will be favourable when
(a) the sewers are to be laid in rocks (b) the finances are limited
(c) the topography is flat necessitating deep excavation for combined sewers
(d) the locality to be served has narrow streets

4. In combined system, automatic flushing is not possible.
(a) Correct (b) Incorrect

5. House plumbing is difficult in ..... system.
(a) separate (b) combined

6. A separate system will be favourable when
(a) the sewers are to be laid in rocks (b) the finances are limited
(c) the topography is flat necessitating deep excavation for combined sewers
(d) all of the above

7. The sanitation system in which a small portion of storm water is allowed to enter in the sanitary e sewers and the remaining storm water flows in separate set of sewers, is known as
(a) separate system (b) combined system
(c) partially separate system (d) partially combined system

8. The storm sewers are essentially required to
(a) avoid creation of unfavourable healthy conditions
(b) improve the general appearance of the city
(c) dispose off the first washings of early showers as quickly as possible
(d) all of the above

9. According to Fanning's formula, the quantity of storm water (Q) in litres per second is given

(a) $Q = CA^{2/3}$ (b) $Q = CA^{5/8}$ (c) $Q = CA^{3/4}$ (d) $Q = CA^{3/2}$

where A = Area in square kilometres, and
C = A constant.

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270. The quantity of storm water (Q) in litres per second is given by $Q = CA^{1/4}$, called
(a) Fanning's formula (b) Ryve's formula (c) Dicken's formula (d) Inglis formula

271. The internal diameter of the sewer should not be less than
(a) 15 cm (b) 25 cm (c) 50 cm (d) 75 cm

272. If the size of the sewer is small, then the velocity of flow will be high.
(a) Yes (b) No

273. No deposition will take place in ..... sewers.
(a) larger (b) smaller

274. For house drainage and lateral connections, we shall use
(a) stone ware sewers (b) cast iron sewers (c) concrete sewers (d) masonry sewers

275. Egg-shaped sewers are generally used for
(a) separate system (b) combined system
(c) partially separate system (d) all of these

276. The cross-section recommended for separate system of sewerage is
(a) circular (b) egg-shaped (c) rectangular (d) none of these

277. An egg-shaped cross-section of a sewer
(a) is economical than circular cross-section (b) is more stable than circular cross-section
(c) provides self cleaning velocity in dry weather
(d) none of the above

278. For the sewers of diameter less than 600 mm, the type of joint preferred is
(a) spigot and socket joint (b) collar joint
(c) bandage joint (d) mechanical joint

279. For the sewers of diameter more than 600 mm, the type of joint preferred is
(a) spigot and socket joint (b) collar joint
(c) bandage joint (d) mechanical joint

280. Manholes are, generally, located
(a) at all changes of direction (b) at all changes of gradients
(c) at all junctions of main and branch sewers (d) all of these

281. For large sewers, the maximum distance between manholes should be
(a) 75 m (b) 150 m (c) 200 m (d) 300 m

282. The lower portion of a manhole is known as
(a) access shaft (b) base (c) working chamber (d) cover

283. The minimum diameter of a manhole cover should be
(a) 25 cm (b) 50 cm (c) 75 cm (d) 100 cm

284. Manholes on sewer lines are provided for
(a) periodic cleaning (b) providing air for oxidation
(c) removal of part of sewerage (d) all of these

285. A drop manhole is provided if
(a) a sewer drops from a height
(b) a branch sewer discharges into the main sewer at a higher level
(c) both (a) and (b) (d) none of these

286. The equipment used for checking the levels of the sewer inverts is
(a) dumpy level (b) theodolite (c) boning rod (d) all of these

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287. For building drainage pipes, a smoke test is applied.
(a) Correct (b) Incorrect

288. Water test is conducted for house plumbings.
(a) Yes (b) No

289. A good trap should
(a) not have self cleaning property (b) restrict the flow of water
(c) provide an adequate water seal at all times (d) all of these

290. Ventilation of house drainage is required to
(a) relieve the pressure of foul gases (b) dilute the foul air in the drain
(c) reduce the obnoxious effect of foul air (d) all of these

291. In one pipe system of plumbing,
(a) only one pipe is provided
(b) the main pipe is connected directly to the drainage system
(c) all the traps are fully ventilated and connected to the ventilation pipe
(d) all of the above

292. In one pipe system of plumbing, waste water is carried away from
(a) bath rooms (b) kitchens (c) wash basins (d) all of these

293. The pipe through which liquid waste carrying human excreta flows, is called
(a) waste pipe (b) soil pipe (c) vent pipe (d) all of these

294. A pipe used to carry discharge from sanitary fittings like bathrooms, kitchens etc. is called
(a) waste pipe (b) soil pipe
(c) vent pipe (d) anti-siphonage pipe

295. A pipe installed for ventilation purpose is called
(a) waste pipe (b) soil pipe
(c) vent pipe (d) anti-siphonage pipe

296. The pipe installed in the house or building drainage to preserve the water seal of a trap is called anti-siphonage pipe.
(a) Right (b) Wrong

297. Which of the following statement is wrong ?
(a) The water closets should be such that excreta do not stick to it.
(b) The trap prevents the entry of foul gases.
(c) The trap should have self cleaning velocity.
(d) The water closet is provided for receiving garbage.

298. The anti-siphonage pipe is not required in
(a) one pipe system (b) two pipe system (c) single stack system (d) none of these

299. The most suitable excreta disposal unit for human excreta is
(a) privy pit (b) cess pool (c) soak pit (d) none of these

300. Cess pool is not recommended by the health authorities.
(a) Agree (b) Disagree

301. Air vent pipe is not essentially required in a septic tank.
(a) True (b) False

302. The underground structure in the form of a circular or rectangular tank for the purposes of admitting sewage into it from the intercepting chamber is called a
(a) septic tank (b) cess pool (c) privy pit (d) soak pit

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303. The privy pit should be located at least ..... from the well or oth
(a) 3 m (b) 10 m (c) 30 m

304. A septic tank is a
(a) sedimentation tank (b) digestion tank
(c) combination of sedimentation and digestion tank
(d) aeration tank

305. The effluents from the septic tank are discharged into
(a) soak pit (b) drainage (c) oxidation pond (d)

306. The equipment used for removing paper and rags from sewers is called
(a) gouge (b) scoop (c) claw (d)

307. The equipment used for cleaning the sewers easily is called
(a) gouge (b) scoop (c) claw (d)

308. Land disposal of sewage will be favourable where
(a) the rivers run dry or have a small flow during summer
(b) rainfall is very high
(c) climate is wet and rates of evaporation is low
(d) all of the above

309. Disposal by dilution will be suitable where
(a) there are strong forward currents (b) there is no back currents
(a) the sewage arriving at the out fall point is fresh and non-septic
(d) all of the above

310. When the sewage is to be distributed over a level area surrounded by dykes (*i.e.* trenches), method of sewage used is called
(a) flooding (b) surface irrigation (c) ride and furrow (d) spray irriga

311. Which of the following statement is wrong ?
(a) For land disposal, large areas with preferably sandy types of soil are required.
(b) The land disposal requires either preliminary or primary treatment of sewage.
(c) The land disposal saves the inland stream from getting polluted by sewage.
(d) none of the above

312. The natural process in which the oxygen of water of streams is consumed by sewage and at same time, it is replenished (filled again) by the atmosphere, is known as
(a) oxidation (b) deoxidation (c) self purification (d) sedimentation

313. The minimum dissolved oxygen required in water to save the aquatic life is
(a) 1 ppm (b) 2 ppm (c) 4 ppm (d) 8 ppm

314. The amount of oxygen required for the biological decomposition of dissovled organic sol to occur under aerobic conditions is called bio-chemical oxygen demand (B.O.D.).
(a) Correct (b) Incorrect

315. The bio-chemical treatment of sewage effluent is a process of
(a) oxidation (b) deoxidation (c) self purification (d) sedimentation

316. Th amount of oxygen consumed by sewage from an oxidising agent like potassium dichromat is termd as
(a) bio-chemical oxygen demand (B.O.D.) (b) chemical oxygen dem
(c) relative stability (d) none of these

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317. The percentage ratio of the oxygen available in sewage to the oxygen required to satisfy one stage of bio-chemical oxygen demand (B.O.D.) is termed as
(a) chemical oxygen demand (b) oxygen consumed
(c) relative stability (d) bio-oxygen demand

318. The sewage should be disposed off without causing odour and nuisance.
(a) Right (b) Wrong

319. Aerobic bacterias takes place in the ..... of light.
(a) presence (b) absence

320. The treatment which employs mechanical and hydraulic separation principles is referred as secondary treatment.
(a) Yes (b) No

321. In preliminary treatment of sewage, the operation which takes place, is
(a) removal of fine suspended particles
(b) removal of fine dissolved organic material
(c) removal of lighter floating material
(d) removal of harmful bacterias and other organisms

322. In secondary treatment of sewage, the operation which takes place is
(a) removal of heavier suspended inorganic material
(b) removal of fine dissolved organic material
(c) removal of harmful bacterias
(d) all of the above

323. The secondary treatment of sewage is carried out by the use of
(a) screens (b) grit chambers (c) trickling filters (d) chlorinators

324. In primary settling tank, suspended solids are reduced from
(a) 10 to 20 % (b) 20 to 40 % (c) 40 to 70 % (d) 70 to 90 %

325. In high rate activated sludge treatment, bacterias are removed from
(a) 20 to 40 % (b) 40 to 60 % (c) 60 to 80 % (d) 80 to 95 %

326. Grit chambers of a sewage plant are usually changed after
(a) 1 day (b) 1 week (c) 2 weeks (d) 4 weeks

327. Grit chambers are used to remove sand and other organic matter from sewage.
(a) Agree (b) Disagree

328. Grit should be removed from sewage before
(a) their disposal in dilution water
(b) their lifting by means of pump etc.
(c) settling of sewage in sedimentation tank
(d) all of the above

329. Biological action is used in
(a) screens (b) sedimentation tanks
(c) trickling filters (d) all of these

330. In the freshly produced sewage, aerobic activity is maximum.
(a) True (b) False

331. The sewage is treated by aerobic bacteria action in
(a) settling tank (b) trickling filter
(c) oxidation pond (d) all of these

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332. Which of the following statement is correct ?
(a) Sewage, if not treated, will create healthy conditions.
(b) Secondary treatment of sewage works on hydraulic separation principle.
(c) Primary clarifiers are to the sedimentation tanks located just after the grit chamber.
(d) Trickling filter is different from percolating filter.

333. The activated sludge
(a) contains fertilising constituents
(b) indicates the degree of aeration
(c) indicates high water content
(d) all of these

334. Sludge treatment is mainly done in order to
(a) stablize the organic matter
(b) destroy the pathogenic bacterias
(c) reduce the water content
(d) all of these

335. The activated sludge process of sewage treatment
(a) requires smaller area for construction of whole unit
(b) requires smaller water head for operation than trickling filters
(c) has high efficiency
(d) all of the above

ANSWERS

1. (b)	2. (b)	3. (a)	4. (b)	5. (d)
6. (b)	7. (d)	8. (b)	9. (b)	10. (a)
11. (b)	12. (b)	13. (c)	14. (d)	15. (a)
16. (b)	17. (d)	18. (a)	19. (a)	20. (a)
21. (b)	22. (c)	23. (d)	24. (a)	25. (a)
26. (d)	27. (b)	28. (d)	29. (d)	30. (b)
31. (d)	32. (b)	33. (d)	34. (c)	35. (d)
36. (c)	37. (c)	38. (d)	39. (d)	40. (d)
41. (a)	42. (d)	43. (b)	44. (c)	45. (d)
46. (a)	47. (c)	48. (d)	49. (b)	50. (d)
51. (c)	52. (a)	53. (b)	54. (b)	55. (D) (A), (C), (B)
56. (a)	57. (c)	58. (b)	59. (c)	60. (b)
61. (c)	62. (a)	63. (c)	64. (d)	65. (a)
66. (d)	67. (b)	68. (a)	69. (b)	70. (a)
71. (b)	72. (d)	73. (c)	74. (a)	75. (a)
76. (a)	77. (b)	78. (b)	79. (b)	80. (a)
81. (d)	82. (b)	83. (b)	84. (d)	85. (a)
86. (b)	87. (c)	88. (c)	89. (a)	90. (a)
91. (b)	92. (b)	93. (b)	94. (b)	95. (D), (C), (A), (B)
96. (a)	97. (d)	98. (d)	99. (a)	100. (c)
101. (b)	102. (c)	103. (d)	104. (a)	105. (b)
106. (b)	107. (a)	108. (b)	109. (b)	110. (b)
111. (a)	112. (b)	113. (c)	114. (a)	115. (a)
116. (b)	117. (c)	118. (a)	119. (a)	120. (b)
121. (d)	122. (a)	123. (b)	124. (a)	125. (b)
126. (c)	127. (c)	128. (a)		

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130. (d) 131. (a) 132. (c) 133. (c) 134. (d) 135. (c)
136. (a) 137. (c) 138. (c) 139. (d) 140. (b) 141. (a)
142. (b) 143. (d) 144. (b) 145. (a) 146. (a) 147. (d)
148. (b) 149. (c) 150. (c) 151. (b) 152. (b) 153. (b)
154. (a) 155. (b) 156. (c) 157. (b) 158. (a) 159. (c)
160. (a) 161. (d) 162. (a) 163. (b) 164. (d) 165. (d)
166. (b) 167. (d) 168. (a) 169. (c) 170. (d) 171. (c)
172. (c) 173. (b) 174. (b) 175. (a) 176. (b) 177. (c)
178. (c) 179. (a) 180. (d) 181. (c) 182. (d) 183. (d)
184. (d) 185. (c) 186. (d) 187. (b) 188. (a) 189. (d)
190. (d) 191. (a) 192. (c) 193. (b) 194. (a) 195. (a)
196. (c) 197. (d) 198. (c) 199. (c) 200. (d) 201. (b)
202. (d) 203. (a) 204. (d) 205. (c) 206. (c) 207. (d)
208. (a) 209. (d) 210. (a) 211. (a) 212. (d) 213. (b)
214. (d) 215. (c) 216. (a) 217. (d) 218. (b) 219. (c)
220. (d) 221. (a) 222. (b) 223. (a) 224. (b) 225. (d)
226. (c) 227. (c) 228. (a) 229. (d) 230. (c) 231. (b)
232. (d) 233. (d) 234. (d) 235. (b) 236. (c) 237. (d)
238. (b) 239. (a) 240. (d) 241. (a) 242. (c) 243. (b)
244. (d) 245. (a) 246. (a) 247. (b) 248. (a) 249. (a)
250. (b) 251. (d) 252. (b) 253. (d) 254. (b) 255. (c)
256. (b) 257. (a) 258. (a) 259. (c) 260. (d) 261. (d)
262. (d) 263. (d) 264. (b) 265. (a) 266. (d) 267. (c)
268. (d) 269. (b) 270. (c) 271. (a) 272. (b) 273. (b)
274. (a) 275. (d) 276. (a) 277. (c) 278. (a) 279. (b)
280. (d) 281. (d) 282. (c) 283. (b) 284. (a) 285. (b)
286. (c) 287. (a) 288. (b) 289. (c) 290. (d) 291. (d)
292. (d) 293. (b) 294. (a) 295. (c) 296. (a) 297. (d)
298. (c) 299. (a) 300. (a) 301. (b) 302. (b) 303. (a)
304. (c) 305. (a) 306. (c) 307. (d) 308. (a) 309. (d)
310. (a) 311. (d) 312. (c) 313. (c) 314. (a) 315. (a)
316. (b) 317. (c) 318. (a) 319. (a) 320. (b) 321. (c)
322. (b) 323. (c) 324. (c) 325. (d) 326. (c) 327. (a)
328. (d) 329. (c) 330. (a) 331. (c) 332. (c) 333. (d)
334. (d) 335. (d)

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Highway Engineering

9.1 Introduction

The transportation system in India comprises of distinct services such as railways, road shipping, air lines etc. Kautilya, the first Prime Minister of the Emperor Chandra Gupta Maurya, constructed a National Highway connecting North-West Frontiers Province and Patna in about B.C. The first major road (longest road) was constructed during the time of Shershah Suri (1545 A.D) from Calcutta (now Kolkata) to Lahore. The present Grand Trunk (G.T.) Road (National Highway No. 1) has been constructed along this road. In 1927, the Indian Roads and Transport Development Association (I.R.T.D.A.) was set up with headoffice at Bombay (now Mumbai) and branch offices at Delhi, Guwahati and Madras (now Chennai), to study the transport problems of the country. In 1928, on the recommendations of I.R.T.D.A, Jayakar Committee (under the chairmanship of Mr. M.R. Jayakar) was formed to look into the Road Transport and Road Development problems in India. In 1930, the Central Road Organisation (C.R.O) was set up. In 1934, a Semi-Government body named Indian Roads Congress (I.R.C.) was set up with headquarters at New Delhi. In 1939, Motor Vehicle Act was enacted for the administration of transport. In 1943, the conference of Chief Engineers of all provinces was held at Nagpur to look into the problems of road transport.

There were two major recommendations of this conference. Firstly, the Indian roads be classified into four categories, *i.e.* National highways, Provincial (or state) highways, District roads (major district roads and other district roads) and village roads. Secondly, the central government should take up complete financial responsibility of construction, development and maintenance of National highways. In 1956, an act known as National Highway Act was passed by both the houses of Parliament under which the central government took up the complete financial responsibility of the National Highway. This act came into force from 15th April, 1957.

In 1951, the Central Road Research Institute (C.R.R.I) was started on Dehi-Mathura National Highway at New Delhi under the control of shipping and transport ministry, for research in various aspect of highway engineering.

In 1960, the Border Roads Development Board (B.R.D.B) was established, under the chairmanship of the Prime Minister.

A department of public works (now known as Central Public Works Department) was formed to look after the road construction during the period of Lord Dalhousie in 1865 when he was Governor General. The construction of G.T. Road was under taken by this new department.

The road making, as a building science, was first conceived by French Engineer Sully in 1599 using broken stones for construction work.

The road foundation for modren highway construction was developed by *John Macadam (1756 - 1836) and Telford (1757 - 1834).

According to Macadam "The size of stone used on a road must be in due proportion to the space occupied by a wheel of ordinary dimensions on a smooth level surface. This point of contact will be found to be longitudinally about 25 mm and every piece of stone put into a road which exceeds

* Macadam was the Surveyor General of Roads in England and his new concept of road construction became known by the year 1827.

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25 mm in any of its dimensions is mischievous."

According to Telford "The size of stone at the centre varied from 160 mm to 200 mm and gradually decreased to 75 mm to 125 mm towards the haunches. The central 5.4 metres width of the road was covered with layers of stones about 100 mm and 50 mm thick respectively. The size of stone used was 63 mm diameter. The side portion were made up of only one layer of broken stones and levelled off to give a camber not greater than 1 in 60".

9.2 Classification of Roads

The roads in India are classified as urban roads and non-urban or rural roads. A road within a city or town is called an *urban road* whereas a road outside the city or town in called *non-urban* or *rural road*. The urban roads are further classified as follows :

1. *Express ways.* The central protion of a road for high speed vehicles is known as express way or motor way. The express ways are to be provided with divided carriage ways, controlled access, grade separations at cross roads and fencing. The parking, loading and unloading of the goods are not permitted on the express ways. The pedestrians are also not allowed to cross the expressways.

2. *Arterial streets.* The city roads which are meant for thorough traffic, usually on a continuous route, are called arterial streets. There are also divided highways, to connect areas within the town and cities with the express highways.

3. *Sub-arterial streets.* The city roads which provide lower level of travel mobility than the arterial streets, are called sub-arterial streets.

4. *Collector streets.* The city roads which are constructed for collecting and distributing the traffic to and from local streets are called collector streets. These are located in residential, industrial and commercial areas. These are connected to sub-arterial streets. There are no parking or loading restrictions.

5. *Local streets.* The city roads which provide an access to residence, business and other buildings are called local streets. A local street may be residential, industrial or commercial.

The non-urban or rural roads are classified as ofllows :

(*a*) *National highways.* The term highway is used for major or important roads of a country. The highways of national importance, connecting commercial or industrial centres with airports or sea-ports, state capitals and tourist centres. These are constructed and maintained by Central Public Works Department (C.P.W.D.) under Central Government.

(*b*) *State highways.* The highways connecting district headquarters with state headquarters or highways of neighbouring states, are called state highways. These are constructed and maintained by Public Works Department (P.W.D.) under the state government.

(*c*) *Major district roads.* The roads traversing each district serving areas of production and markets and connecting those with eachother or with the National or State highways, are called major district roads. The construction and maintenance of these roads is the responsibility of the State Government or the Local District Boards.

(*d*) *Village roads.* The roads which connect village to adjoining village or group of villages with each other and to the nearest district road, are called village roads. These are constructed and maintained by Local District Boards or Blocks.

9.3 Components of a City Road

The following technical terms, as shown in Fig. 9.1, should be clearly understood before making detailed study of road construction :

1. *Right of way.* The area of land acquired for construction and future development of a road symmetrically about the central alignment is called right of way. The width of these acquired land is known as land width and it depends upon the importance of the road and possible future development.

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2. *Formation width.* The top width of the highway embankment or the bottom width of highway cutting excluding the side drains, is called formation width or road way. The formation width is the sum of widths of pavements or carriage way including the separators and width of the shoulders on either side of the carriage way.

3. *Carriage way.* The portion of the road surface which is used for vehicular traffic is known as carriage way or pavement. The width of carriage way depends upon the width and number of lanes. For single lane roads, the width of pavement is generally kept 3.75 m.

4. *Crown.* The highest point on the road surface is called crown.

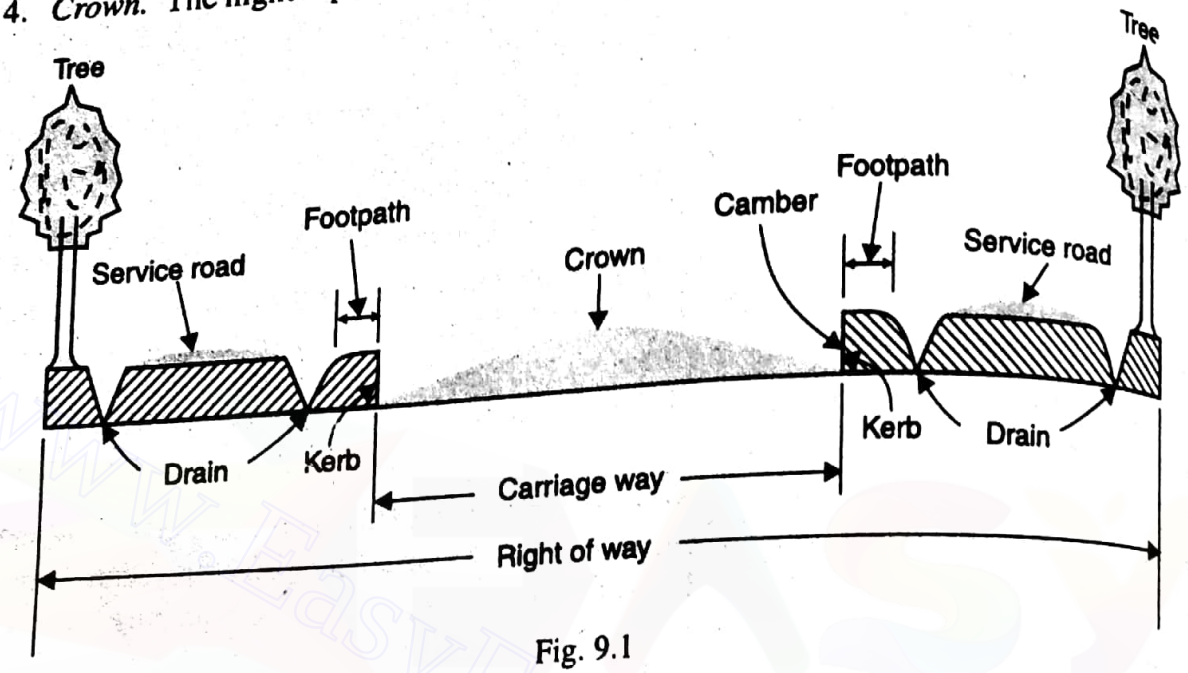

Fig. 9.1

5. *Camber or cross-slope.* The rise of the centre of the carrige way about its edges along the straight portion of a road, is called *camber or cross slope. The transverse slope of the pavement provided for the drainage of rainwater. The amount of camber for the roads is decided according to the road surface and the amount of rainfall.

6. *Separater or divider.* The narrow continuous structure provided for dividing the two directions of the traffic flow, is known as separator or divider.

7. *Shoulders.* The portions of the roadway between the outer edges of the carriage way and edges of the top surface of the embankment or inner edges of the side drains in cuttings of the road are called shoulders. The shoulders are generally in level with road surface, having a slope towards drain side. The shoulders and foot paths prevent the edges of the road from wear and tear. The minimum shoulder width recommended by IRC is 2.5 m.

8. *Kerbs.* The boundaries between the pavement and shoulder of footpath are known as kerbs. These are also provided between the pavement and the traffic separator or divider. It is desirable to provide kerbs on urban roads.

9. *Side slopes.* The slopes of the sides of earth work of embankments and cuttings to ensure their stability, are called side slopes. The embankments are generally given a side slope of 1 : 1.5.

10. *Berms.* The width of the land left in between the toes of the embankment and the inner edges of the borrow pits, is called berm.

9.4 Water Bound Mecadam Roads

The road whose wearing course consists of clean crushed aggregates, mechanically interlocked by rolling and bound together with filler material and water and laid on a well compacted base course is called *water bound macadam (W.B.M) road*. The strength of a water bound mecadam course is due

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to the mechanical interlocking of the aggregate particles and the cohesion between the aggregate particles due to cementious film of soil moisture binder. The W.B.M. roads are in use in our country both as a finished pavement surface for minor roads and as a good base course for superior pavements carrying heavy traffic.

In water bound mecadam roads, the stone pieces used are keyed together by means of sand and clay and no other cementing material is used. The binding effect of sand and clay depends upon the presence of water. When a fast moving vehicle passes over a W.B.M. road, the slurry of sand and clay is sucked out by the pneumatic wheel tyres. The stone pieces get disturbed and finally the road surface is disintegrated. Thus, the W.B.M. roads are not suitable for fast moving vehicles with wheel tyres. These roads are only suitable for slow moving iron wheeled traffic such as tongas, bullock cart etc.

The water bound mecadam roads produce dust while in service. In order to minimise the dust nuisance, water should be sprinkled periodoically on the road surface and a coat of road oil may be applied so that the dust settles down. The calcium chloride in powdered from may also be spread over the road surface.

9.5 Elements of Transportation Cost of Highway

The transportation cost of any highway consists of the following two elements :

1. The annual cost of highway, and
2. The vehicle operation cost.

The annual cost of highway consists of the first annual cost plus the annual maintenance charges.

The total cost of highway transportation (A) may be expressed as

$$A = B + C.N$$

where

B = Annual cost of highway,

C = Annual cost of vehicle operation (single vehicle), and

N = Total number of vehicles on the road per year.

The unit cost of transportation (A_U) on a section of the highway may roughly be calculated by

$$A_U = \frac{A}{N.L}$$

where

L = Length of the highway in kilometres.

9.6 Various Components of a Road Surface

In order to give satisfactory service throughout the year, the road surface should remain dry and a good wearing surface. It should have a good carriage-way and smooth gradient.

The following are the *various components of a road surface :

1. *Sub-grade.* The top of the ground on which the foundation of a road rests, is called sub-grade. It is provided by digging up the sub-soil. The level of the sub-grade is decided by subtracting the total thickness of the pavement from the finished level of the road pavement. The strength and durability of a road depends upon its sub-grade.

2. *Sub-base.* When the bearing capacity of the soil is poor and the intensity of traffic is high, an additional layer is provided between the soling and sub-grade. This additional layer is called sub-base.

3. *Base.* The foundation of a road is also called soling or base. The thickness of base, in no case, should be more than 30 cm. The base course receives the impact of the traffic through the wearing course. The load of the traffic is transferred to the sub-base and sub-grade through the base course.

* See also Art. 9.20

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4. *Wearing course.* The super structure of a road is called wearing course or road surfacing or wearing layer. It should be stable, durable and impervious. The wearing course may be laid in one or two layers according to the total designed thickness and the thickness of each layer should not exceed 10 cm. The thickness of the road surfacing depends upon the type of traffic, intensity of traffic and the type of material.

9.7 Camber

The main object of providing a camber is to make the road surface durable, impervious and to drain off rain water from the road surface, as quickly as possible. The slope of the line joining the crown and edge of the road surface is known as *camber* or *cross slope* or *cross fall*. The camber on straight roads is usually provided by raising the centre of the carriage way with respect to edges forming a highest point on the centre line called crown.

A camber consisting of a continuous curve either parabolic or elliptical is known as *barrel camber*. This type of camber is preferred by fast moving vehicles as they have to frequently cross the crown line during overtaking operation on a two lane highway.

A camber consisting of two straight slopes joining at the centre, is called *sloped camber*. Sometimes, a composite or combined camber consisting of two straight slopes with a parabolic crown in the centre, is preferred.

The required camber of a road surface depends upon the type of road surface and the amount of rainfall. A flat camber of 1.7 to 2% is sufficient on relatively impervious road surface like cement concrete or bituminous concrete. In pervious surface like water bound mecadam or earth road which may allow surface water to get into the sub grade soil, steeper camber is required. The steeper cambers are also provided in areas of heavy rainfall. Too steep camber is not desirable.

The values of camber recommended by I.R.C. for different types of road surfaces are given in the following table.

Type of road surface	*Range of camber*	
	Heavy rainfall	*Light rainfall*
Cement concrete and high type bituminous surface	1 in 50 (2%)	1 in 60 (1.7%)
Thin bituminous surface	1 in 40 (2.5%)	1 in 50 (2%)
Water bound macadam and gravel pavement	1 in 33 (3%)	1 in 40 (2.5%)
Earth surface	1 in 25 (4%)	1 in 33 (3%)

9.8 Superelevation

When a vehicle negotiates a curved path, it is subjected to an outward force known as centrifugal force. In order to resist this force, the outer edge of the road is generally raised above the inner edge. This is known as *superelevation* or *cant* or *banking*. It is also defined as the inward tilt given to the cross-section of the road surface, throughout the length of the horizontal curve. The superelevation is expressed as the difference of heights of two edges of the carriage-way to the width of the carriage-way. The main advantages of providing super-elevation is

(*a*) to achieve higher speed of vehicles,

(*b*) to increse the stability of the fast moving vehicles, when they negotiate a horizontal curve, and

(*c*) to decrease the intensity of stresses on the foundation.

It may be noted that greater the superelevation, more will be convenience to the slow moving traffic. The superelevation should not be less than the camber. In the absence of superelevation on road along curves, pot holes are likely to occur at the outer edge of the road. In order to prevent the overturning of a bullock cart on the curves, the Indian Road Congress (I.R.C.) has prescribed the maximum value of superelevation as 1 in 15.

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e = Rate of super-elevation,
f = Lateral friction coefficient = 0.15,
V = Speed of the vehicle in kmph, and
R = Radius of curvature in metres.

If

$$e + f = \frac{V^2}{127\,R}$$

Then

When coefficient of friction is neglected (*i.e.* if $f = 0$), then the superelevation (known as equilibrium superelevation),

$$e = \frac{V^2}{127\,R}$$

From practical considerations, it is suggested that superelevation should be provided to fully counter act the centrifugal force due to 75% of the design speed (V) by neglecting lateral friction developed. Thus, the maximum rate of superelevation is given by

$$e = \frac{(0.75\,V)^2}{127\,R} = \frac{V^2}{225\,R}$$

Gradient

The slope of the road pavement in the longitudinal direction is called *grade* or *gradient*. It may be expressed either as a ratio of rise or fall in a specified horizontal distance. When a road ascends 1 metre in every 16 metres horizontal distance, it is called 1 in 16 upgrade or 6.25% upgrade. Similarly, if a road descends 1 m in every 20 metres horizontal distance, it is called 1 in 20 downgrade or 5% downgrade. The gradient of a road depends upon the nature of traffic, nature of ground and rainfall of the locality. The various types of gradients, depending upon the steepness of the road pavements, are as follows :

1. *Minimum gradient.* An essential gradient which has to be provided in the longitudinal direction of the road pavement for the purpose of easy drainage of rain water, is called minimum gradient. A minimum gradient of 1 in 250 (0.4%) for flexible pavements and 1 in 300 (0.33%) for concrete roads is desirable to provide longitudinal drainage.
2. *Maximum or limiting gradient.* The steepest gradient which is to be permitted on the road is called maximum or limiting gradient.
3. *Average gradient.* The total rise or fall between any two points chosen on the alignment divided by the horizontal distance between the two points is called average gradient.
4. *Ruling gradient.* The suitable gradient which may be normally provided in the aligenment of a road and in such a way that the vehicle may negotiate long stretches of the gradient without much fatigue, is known as ruling gradient.
5. *Exceptional gradient.* The gradient less than the minimum gradient and more than the maximum gradient, is called exceptional gradient. The maximum length of an exceptional gradient should not exceed 60 metres in one kilometre road length. The exceptional gradient becomes necessary to avoid deep cuttings. The stretches of exceptional gradient should be separated by a minimum length of 100 m with limiting or flatter gradient.

The various gradients recommended by Indian Roads Congress (I.R.C.) are as follows :

Nature of terrain	*Ruling gradient*	*Limiting gradient*	*Exceptional gradient*
1. Plains	1 in 30 (3.3%)	1 in 20 (5%)	1 in 15 (6.7%)
2. Hills	1 in 20 (5%)	1 in 17 (6%)	1 in 14 (7%)
3. Steep terrain	1 in 17 (6%)	in 14 (7%)	1 in 12.5 (8%)

Notes : (*a*) When the rainfall is more, flatter gradients should be provided in the side drains and the road.
(*b*) The road meant for slow moving traffic only must not have very steep gradient.

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(c) Sometimes, steeper gradients are provided to avoid deep excavations and long detours.

(d) Generally, ruling gradient is adopted for design purposes.

9.10 Sight Distance

The length of a road visible to a driver, clear of objects, while driving a vehicle is known as *sight distance*. It depends upon the height of the *line of sight* of the driver above the road surface when the vehicle is moving on a level stretch, on a horizontal curve or on the incline of a vertical curve. The standard height of the line of sight of the driver above the road surface is taken as 1.2 metres. The sight distances are of the following types :

1. *Stopping (Non-passing or Non-overtaking) sight distance.* The minimum sight distance required by the driver of a vehicle travelling at a given speed to bring his vehicle to a stop after an object on the carriage way becomes visible, is called stopping sight distance. It is also called *absolute minimum sight distance* or *non-passing* or *non-overtaking sight distance*. The minimum stopping sight distance is equal to the sum of reaction distance and the braking distance. For the purpose of measuring the stopping sight distance or visibility ahead, Indian Roads Congress suggested the height of the line of sight of the driver above the road surface as 1.2 metres and the height of the object as 15 cm above the road surface.

The stopping sight distance (S) of a vehicle for Indian highways is given by

$$S = 0.28\, V.t + \frac{0.01\, V^2}{\eta}$$

where V = Speed of the vehicle in kmph,

t = Brake reaction time in seconds, and

η = Efficiency of brakes in percent.

2. *Overtaking (or Passing) sight distance.* The minimum distance required for overtaking another vehicle safely and without interfering the speed of an opposing vehicle travelling at the design speed is called minimum overtaking or safe passing sight distance.

According to Indian Roads Congress, it is assumed that depending upon the speed of the overtaking vehicle, the overtaking manoeuvre takes about 9 to 14 seconds. A two-third duration of this time is taken by the opposing vehicle with designed speed. The distance travelled during the total duration by the design speed of the overtaking vehicle is the requried overtaking sight distance. The following are the recommended values of overtaking sight distance, by the Indian Roads Congress.

Speed in kmph	*Time in seconds*			*Safe overtaking sight distance (metres)*
	Overtaking manoeuvre	*Opposing vehicle*	*Total*	
40	9	6	15	165
50	10	7	17	235
60	10.8	7.2	18	300
65	11.5	7.5	19	340
80	12.5	8.5	21	470
100	14	9	23	640

3. *Intermediate sight distance.* It is defined as twice the safe stopping sight distance and affords opportunity to the drivers to overtake with caution. The design values of intermediate sight distance for different speeds are given below :

Speed in kmph	20	25	30	35	40	50	60	65	80	100
Intermediate sight distance in metres	40	50	60	80	90	120	160	180	240	360

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9.11 Curves

The curves are provided on highways to change the direction either in horizontal or vertical plane, in a gradual way. The necessity of providing curves arises due to the following reasons :

(a) Topography of the country.
(b) To provide access to a particular locality.
(c) Restrictions imposed by some unavoidable reasons of land.
(d) Preservations of existing amenites.
(e) Avoidance of existing religious, monumental and other costly structures.
(f) Making use of existing right of way

The various factors which affect the design of curves are as follows :

(a) Design speed of the vehicle,
(b) Allowable friction,
(c) Maximum permissible superelevation, and
(d) Permissible centrifugal ratio.

The curves are divided into two classes *i.e.* a horizontal curve and a vertical curve. A horizontal curve provides change in direction of the centre line of a road while a vertical curve on a road provides change in gradient. The circular and transition curves are used as horizontal curves and the parabolic curves as vertical curves.

The circular curves may be simple, compound and reverse curves. The transition curves are true spiral or clothoid, cubic spiral, cubic parabola and lemniscate.

A curve which consists of a single arc connecting two straights is called a *simple circular curve*. In India, a curve is expressed in terms of angle in degrees subtended at the centre by an arc of 30 m radius.

A curve which consists of a series of two or more simple curves that turn in the same direction and join at the common tangent points, is known as a *compound curve*.

A curve which consists of two simple curves of opposite direction that join at the common tangent point, is known as a *reverse curve*.

9.12 Transition Curve

A curve whose radius gradually changes from an infinite value to a finite value or vice versa for the purpose of giving easy change of direction of a road, is called a *transition or spiral or easement curve*.

This tends to counter act the swaying outwards of a vehicle when subject to sudden application of a centrifugal force at the instant of its entering or leaving the cure. This may be provided either between a tangent and a circular curve or between two branchs of a compound or reverse curve.

The necessity of introducing a transition curve is to have a smooth change of direction of a vehicle from a straigh path to a curved path or vice versa.

The main advantages of providing transition curves on highways are as follows :

(a) To obtain gradually the transition from the tangent to the circular curve and from the circular curve to the tangent.
(b) To obtain a gradual increase of curvature from a value of zero at the tangent point to a maximum of the circular curve.
(c) To have a gradual increase of superelevation from zero at the tangent to a specific value on the main circular curve.

A transition curve should satisfy the following conditions :

(a) It should meet the straight path tangentially.

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(*b*) It should meet the circular curve tangentially.

(*c*) It should have the same radius as that of the circular curve at its junction with the circular curve.

(*d*) The rate of increase of curvature and superelevation should be the same.

The length of a transition curve may be determined by the following methods and the larger value is adopted for the design :

(*i*) By the rate of change of radial acceleration.

(*ii*) By an ordinary rate of change of superelevation.

(*iii*) By the time rate.

The length of a transition curve (L) in metres according to Indian Roads Congress, is given by

$$L = \frac{V^3}{48\,CR}$$

where V = Speed of the vehicle in kmph,

C = Rate of change of radial acceleration in m/s^3,

$= \frac{80}{75 + V}$, subject to a maximum of 0.8 and minimum of 0.5.

R = Radius of circular curve in metres.

The transition curves are of the following four types :

1. *True spiral or clothoid.* It is an ideal shape of a transition curve, as shown in Fig. 9.2, in which the radius of curvature at any point is inversely proportional to the distance of the point from the beginning of the curve. The equation of an ideal transition curve representing a true spiral or clothoid is given by

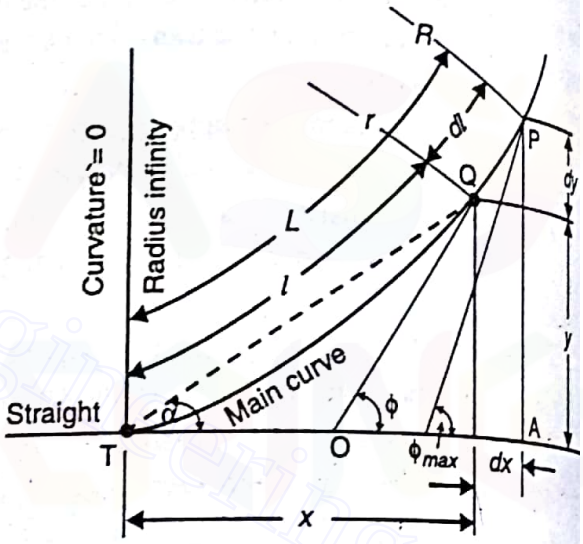

Fig. 9.2

$$\phi = \frac{l^2}{2RL}$$

where ϕ = Inclination of the tangent at a point Q on the transition curve with the initial tangent TA. It is also known as deviation angle,

R = Radius of the circular curve,

l = Length of the transition curve from the start to the point Q on the transition curve, and

L = Total length of the transition curve = TP.

The shift (S) of a transition curve is given by

$$S = \frac{L^2}{24R}$$

2. *Cubic spiral.* For simplifying the calculations of the quantities required in setting out the acute transition curve, certain modifications are made, resulting in the cubic spiral and cubic parabola types of transition curves. A cubic spiral is superior to cubic parabola as for as the degree of accuracy of a transition curve is concerned. In case of cubic spiral curve,

$$y = \frac{l^3}{6\,R.L}$$

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The polar deflection angle (α) in case of cubic spiral may be assumed as one-third of the deviation angle of the curve, *i.e.*

$$\alpha = \frac{\phi}{3} = \frac{l^2}{6\,R.L}$$

Note : The type of transition curve recommended by I.R.C. is cubic spiral.

3. *Cubic parabola.* This is also known as Froude's transition or easement curve. Though the cubic parabola is inferior to cubic spiral, yet it has been extensively used owing to the ease with which it can be set out by rectangular coordinates. In case of cubic parabola,

$$y = \frac{x^3}{6\,R.L}, \text{ and } x = l$$

4. *Bernoulli's lemniscate curve.* This type of curve is mostly used in modren road construction as it is symmetrical and can be well adopted when the deflection angle between the tangents is large. It has the following advantages over the spiral curve :

(*a*) The radius of curvature decreases more gradually with length.

(*b*) It follows a path which is actually traced by a vehicle when turning freely.

(*c*) Towards the end of the curve, for deflection angles greater than 30°, the rate of increase of curvature decrease and this is not uniform.

(*d*) This curve can be easily set by polar coordinates.

The polar equaion of the lemniscate is

$$r = \sqrt{2\,R.L \sin 2\alpha}$$

The main difference between the true spiral and the cubic spiral or the cubic spiral and the lemniscate is that in the former case, $\alpha = \phi/3$ approximately, while in case of lemniscate $\alpha = \phi/3$ exactly.

9.13 Vertical Curves

When two different or contrary gradients meet, they are connected by a curve in the vertical plane, known as *vertical curve*. These are needed to secure a gradual change in grade so that abrupt change in grade at the apex is avoided. The vertical curves are provided to get safety and adequate visibility. It also provides comfort to the passengers. The following are the two types of vertical curves :

1. *Summit curves.* A vertical curve with convexity upward is called a summit curve. The major factor in the design of a summt curve is the sight distance to be allowed on the highway since it is essential that an obstruction on the other side of the summit whether stationary or in motion (*e.g.* another vehicle) must be visible to the driver on this side of the summit and vice versa.

The summit curves are required to be introduced at the situations where

(*a*) a positive grade meets a negative grade,

(*b*) a positive grade meets another milder positive grade,

(*c*) a positive grade meets a level stretch, and

(*d*) a negative grade meets a steeper negative grade.

In determining the length (L) of the summit curve (assumed to be a square parabola), the following two cases have to be considered :

(*i*) For safe overtaking or passing sight distance (S),

$$L = \frac{GS^2}{9.6} \quad \text{...(when } S \text{ is less than } L\text{)}$$

$$= 2S - \frac{9.6}{G} \quad \text{...(when } S \text{ is greater than } L\text{)}$$

(*ii*) For stopping or non-passing sight distance (S),

$$L = \frac{GS^2}{4} \quad \text{...(when } S \text{ is less than } L\text{)}$$

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$$= 2S - \frac{4}{G}$$

where G = Algebraic difference of the grades on the two sides of the ... of intersection.

It may be noted that according to I.R.C., the minimum length of the curve adopted should ... be less than one-half the design speed in kmph.

Note. In deriving the above equations, it is assumed that the height of line of sight of the driver is 1.2 m ... height of the object (needed for computing the safe stopping sight distance) is 10 cm above the road surface.

2. *Valley curves.* A vertical curve with convexity downward is called a valley curve. ... valley curves are required to be introduced at the situations where

(*a*) a negative grade meets a positive grade,

(*b*) a negative grade meets another milder negative grade,

(*c*) a negative grade meets a level stretch, and

(*d*) a negative grade meets a steeper positive grade.

The design criterion for the valley curves is the centrigugal force developed. In order to ... a shock-free travel along a valley curve, two cubic parabolic curves of equal length are provided ... According to I.R.C., a square parabolic curve is also accepted. The length of the valley curve ... designed on the basis of passenger's comfort conditions and on the head light sight distance. ... addition, the length of the curve should be such that it ensures satisfactory drainage at the lowest point.

The length of valley curve (L) based on the comfort conditions is given by

$$L = 2 \times \text{Length of transition curve} = 2 L_s$$

$$= 2\left[\frac{GV^3}{C}\right]^{1/2} = 0.4\,(GV^3)^{1/2} \quad \text{...(Taking } C = 0.5 \text{ m/s}^3\text{)}$$

When the valley curves are designed as a square parabola, the stopping sight distance(S) should be equal to head light beam distance. According to Indian Road Congress (I.R.C), length of the valley curve,

$$L = \frac{GS^2}{1.5 + 0.035\,S} \quad \text{...(When } L \text{ is greater than } S\text{)}$$

$$= 2S - \frac{1.5 + 0.035\,S}{G} \quad \text{...(When } L \text{ is less than } S\text{)}$$

While deriving the above formulae for the length of valley curve, it is assumed that the head light is 0.75 m above the road surface.

9.14 Procedure for Fixing Alignment of a Hill Road

The Indian Roads Congress publication on Hill Roads (IRC : 52 - 1973) lays down the following three stages for fixing up alignment of a hill road :

1. *Reconnaissance.* The first stage for fixing the alignment of a road is reconnaissance. It requires the study of survey sheets, geological, meterological and aerial photographs (if available). This may be followed by aerial reconnaissance where it is necessary and feasible. Subsequently, the ground reconnaissance and detailed study of difficult stretches are carried out. At the end of reconnaissance phase, the selected alignment is pegged by using about 2 metres high poles on which are marked the number, direction, distance and relative elevation of the peg. The tops of any two adjacent pegs viewed together from a distance would then give an idea about the grade.

2. *Trace-cut.* It is a track of width 1 m to 1.2 m constructed along the selected alignment to facilitate access to the area for inspection and detailed survey. The gradients along the trace-cut ...

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hill roads are kept 10 to 20% easier than the ruling gradient and may even be level for short distance where land-slide areas are encountered and in which case the same may be compensated by steep rise and fall. In rocky areas and dense jungles, the trace-cuts may be avoided and some suitable arrangement may be made so as to gain access for ascertaining details.

3. *Detailed survey.* During the detailed survey, the first operation is to fix the bench marks, and finalising the longitudinal and cross-sections. The necessary adjustments are made in the alignment combined with the design of horizontal curves and hair pin bends. The hydrological and soil surveys are carried out for the route. The detailed survey should be conducted for a strip covering on either side of the chosen centre line a width of about 15 m in case of straigth stretches and 30 m in case of sharp curves and hair pin bends.

The longitudinal levels should be taken at 10 m intervals and cross-sections at 20 m intervals. The interval for plotting of contours at sharp curves and other difficult locations may be 2 m.

9.15 Important Terms Used in Hill Roads

The following are some important technical terms used in connection with hill roads :

1. *Level terrain.* The terrain with cross-slope less than 10 percent is called level terrain.
2. *Rolling terrain.* The terrain with cross-slope varying between 10 and 25 percent, is called rolling terrain.
3. *Mountainous terrain.* The terrain with cross-slope from 25 to 60 percent, is called mountainous terrain.
4. *Steep terrain.* The terrain with cross slope greater than 60 percent is called steep terrain.
5. *Salient curve.* A curve at the ridge of a hill having a convex shape is called a salient curve.
6. *Re-entrant curve.* A curve at the valley between two hills having a concave shape is called a re-entrant curve.
7. *Floating gradient.* The gradient at which no tractive effort is required to maintain a constant speed by the vehicle, is called floating gradient. The gradients less than the floating gradient requires some tractive effort to maintain a constant speed by the vehicle and the gradients more than the floating gradient result in increase of speed.

9.16 Classification of Hill Roads

The hill roads, according to I.R.C., are classified in the similar way as roads in plains, *i.e.* National highways, State highways, District major roads, Other district roads and Village roads. These have already been discussed in Art. 9.2.

The Border Roads Organisation, keeping in view its special requirements, has also classified the hill roads as follows :

1. *National highways.* These are the roads of national importance as discussed earlier. These are to be designed and constructed as per I.R.C. specifications.
2. *Class - 9 roads.* These roads are 6 metres wide and are designed to carry 3-tonne vehicles.
3. *Class - 5 roads.* These roads have a width of 4.9 metres and designed to carry 1-tonne vehicles.
4. *Class - 3 roads.* These roads have width ranging between 2.45 m and 3.65 m. These roads are designed to carry jeeps.

9.17 Geometrics of Hill Road

The roads in hills need special attention in fixing up geometric standard for gradient, superelevation, radius of curvature etc. which are different from those in plains. The main reasons for the difference are the topography and other problems in alignment of hill road. The following modifications are necessary from hill roads point of view :

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1. *Width of pavement or Carriage way.* A minimum width of 3.75 m may be adopted for a pavement or motorable metalled roads or carriageways in case the road is unmetalled but carries motor traffic. A width of 3 m will suit the jeepable roads.

2. *Formation width.* The formation width in hill roads depends more upon the type of vehicles plying on it. The following standards may be considered.

(*a*) The formation width for motorable road carrying a total load less than 100 tonnes per day is 4.5 to 5 m on straights and 7.25 m on curves.

(*b*) The formation width for motorable road carrying a total load between 100 and 400 tonnes and above per day is 7.25 m on straights and 11 m on curves.

3. *Camber or Cross slope.* The hill roads are provided steeper camber or cross slope. Where the road has longitudinal gradients greater than 1 in 20, flatter camber may be provided.

4. *Sight distance.* The minimum sight distance required will be the stopping sight distance conforming to the design speed of the road.

5. *Curve radius.* In the initial stages of construction, no curve shall have a radius less than 30 m. Each curve must have transitions on the two sides, as far as possible.

6. *Superelevation.* The maximum superelevation on hill roads should not exceed 10 percent (1 in 10) and 7 percent (1 in 15) in snow-bound sections.

7. *Gradients.* At horizontal curves, the percentage compensation in gradient may be provided by using the formula $\frac{30 + R}{R}$ with a maximum of $75/R$. The compensated gradients may not however be flatter than 4 percent.

9.18 Construction of Hill Roads (Retaining Walls, Breast Walls and Parapets)

The *retaining walls* are the most important structure in hill road contruction to provide adequate stablity to the road way and to the slope. The retaining walls are usually constructed on the valley side of the road way and also on the cut hill side to prevent land slide towards the roadway. The thickness of the wall at the top is usually kept as 60 cm and at the bottom it may be kept according to the following thumb rule :

For walls less than 6 m in height, thickness of the retaining wall at the bottom is equal to 0.4 times the height.

For walls more than 6 m in height, the thickness of the retaining wall at the bottom is equal to 0.4 times the height *plus* 30 cm.

A batter of 1 in 12 may be given to the wall on the outside.

The *breast walls* are constructed on the hill side of the roadway to retain the earth from slipping. The wall may be kept 60 cm thick throughout and sloped along the natural slope of the earth, it has to protect.

The *parapet walls* are usually required on the valley side of the roadway in order to guide the vehicles properly to the roadway. The thickness of the wall is uniform throughout and may be kept as 60 cm. The height is usually kept as 75 cm above the berm level.

9.19 Flexible Pavement

A pavement which consists of a mixture of asphaltic or bituminous material and aggregate placed on a good quality and compacted granular material is termed as *flexible pavement* as shown in Fig. 9.3 (*a*). The water bound macadam roads is an example of flexible pavement. The pavement consisting of a portland cement concrete slab is referred to as *rigid pavement* as shown in Fig. 9.3(*b*). The cemented grouted roads may be termed as *semi-rigid pavement*.

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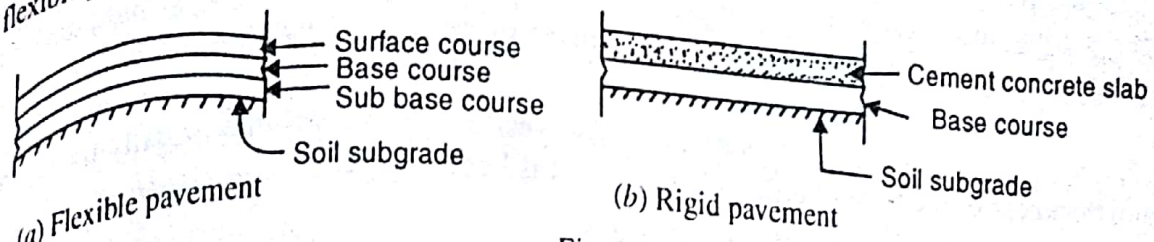
The essential points of difference between flexible and rigid pavements are as follows :

1. The flexible pavements have low or negligible flexural strength and are rather flexible in their structural action under the loads. The rigid pavements possess noteworthy flexural strength or flexural rigidity. The stresses are not transferred from grain to grain to the lower layers as in the case of flexible pavement layers.



(*a*) Flexible pavement (*b*) Rigid pavement

Fig. 9.3

2. The flexible pavements have self healing properties but the rigid pavements do not have any. In other words, whatever deformation occurs in a flexible pavement due to heavier wheel loads, it is recoverable to some extent after some time but it is not so in case of rigid pavement.

3. The temperature variations due to changes in atmospheric conditions do not produce stresses in flexible pavements but induce heavy stresses in the rigid pavements.

4. The structural capacity of the flexible pavement is influenced by the strength of the sub-grade while the strength of the sub-grade has only little influence upon the structural capacity of the rigid pavements.

5. The cost of construction of flexible pavements is less as compared to rigid pavements.

9.20 Structure of a Road

The structure of a road, as shown in Fig. 9.3, is composed of the following :

1. *Sub-grade.* It is the natural soil on which the pavement rests and to which the entire load of the structre as well as that of traffic plying on the surface above is ultimately transferred. It is thus the final load carrying part of the structure.

2. *Sub-base.* It is placed immediately above the sub-grade soil and is composed of hard well-burnt clinker, natural gravel or any other suitable material excavated at or near the site.

3. *Base.* It forms the structure which may be either rigid as in case of concrete road or flexible composed of broken stone cemented together by materials which allow some degree of flexibility in the pavement. The function of the base is to withstand the high shearing stresses imposed by concentrated loads at the surface and to distribute these loads to underlying layers of pavement or to the sub-grade soil as the case may be.

4. *Wearing course or surface course.* In case of a flexible pavement, it consists of a mixture of bituminous material and aggregate and forms the natural wearing coat. In concrete roads, no separate surface course may usually be provided. The principal functions of the surface course are to water proof the base against the penetration of surface water and to resist the effects of abrasion and impacts caused by wheel roads.

9.21 Flexible Pavement Design

The following are the four universally recognised factors which must be considered in arriving at the rational design of flexible pavement :

1. The characteristics of the natural soil which underlines the pavement.
2. The volume and character of traffic that will use the highway.
3. The moisture which will exist under the completed pavement and the general drainage conditions of the area.
4. The climatic conditions.

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These factors have been recognised both in the group ratio (C.B.R.) methods of flexible pavement design as discussed below :

9.22 Group Index Method

The group index (G.I.) of a soil is a number which reflects the characteristics of the soil. The value of the group index varies from 0 to 20. The sub-base thickness is directly proportional to the group index of the soil. Thus, the higher the group index of the soil, the larger is the thickness of the base.

The thickness of the base and surface course varies with the volume of daily traffic. The minimum thickness of the base of a flexible pavement is kept as 10 cm.

9.23 California Bearing Ratio (C.B.R) Method

The California bearing ratio (C.B.R.) of a soil which varies from 0 to 100 percent, gives an idea about the quality of a material compared to that of an excellent base material for which the C.B.R. is assumed to be 100 percent. There are many versions of the C.B.R. method of flexible pavement design. Almost every agency that makes use of it has modified the testing procedure, the design curves or both. Due importance has been given by certain agencies to account for differences in annual rainfall, position of ground water table, frost action, sub-surface drainage conditions and traffic. The wyoming method recognises all these factors and so has been presented first. It is then followed by the procedure laid down by the Indian Roads Congress.

9.24 Concrete Pavements

A portland cement concrete pavemet consists of concrete slab which may or may not be reinforced. Under favourable conditions, special preparation of the sub-base is not required and the slabs are laid directly on the properly finished subgrade. According to I.R.C. recommendations, the sub-grade or the sub-base layer whatever underlies the concrete wearing slab must conform to the following requirements :

1. No soft spots are present in the sub-grade or sub-base.
2. The base or sub-base extends to at least 30 cm wider on either side of the width to be concreted.
3. The sub-grade is properly drained.

A portland cement concrete pavement has the following advantages and disadvantages :

Advantages

(*a*) It is very easy to clean and practically dust-free.

(*b*) The resistance to traffic is low.

(*c*) When clean, it is not slippery.

(*d*) When properly designed and constructed, it has long life and comparatively low maintenance cost.

(*e*) It can withstand any amount of traffic.

Disadvantages

(*a*) It has high initial cost.

(*b*) It requres skilled personnel and cautious handling of the materials.

The concrete pavement are usually provided reinforcement about 50 mm below the surface of the pavement which consists of woven wire, wire mats, expanded metal etc. Its major function is to strengthen the slab but to hold together the cracks that form, to control their developement and thus add to the aesthetics of the road surface.

9.25 Stresses in Concrete Pavements

The most significant forces stressing a concrete pavement are those imposed by the wheel loads. The concrete is also affected volumetrically by temperature and moisture changes and the

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pavement is subjected to external forces such as the vertical forces of reaction with the sub-grade and restraining horizontal forces of friction which make the slab slide.

The concrete expands and contracts with temperature variations, as a result of which stresses are set up if this expansion or contraction is prevented. A large difference of temperature between the top and bottom of the slab causes *warping* of the slab inducing *warping stresses*. The plastic cracks due to shrinkage are developed immediately after the concrete starts hardening. When the exposed surface dries and shrinks more than the underlying concrete as a result of which surface shrinkage cracks may develop. This is known as *crazing* of the surface.

The stresses set up due to changes in moisture content are very low and generally opposed to those set up by temperature variations.

9.26 Thickness of the Slab

The thickness of the slab can be calculated either on the theory of maximum tensile stress due to Wastergaard, Southerland, Picket and other recent authorities or on the baiss of a formula developed by Older. Another empirical formula is due to Sheets for the design of the thickness of the concrete slab.

According to Older's theory, the thickness of concrete slab (t) is given by

$$t = \sqrt{\frac{3W}{\sigma}}$$

where W = Wheel load, and

σ = Unit stress in tension.

According to Sheet's formula, the thickness of concrete slab,

$$t = \sqrt{\frac{2.4\,WC}{\sigma}}$$

where C = Coefficient of subgrade support.

9.27 Joints in Concrete Pavement

The joints in concrete pavement may either be longitudinal (being parallel to the centre line of the road) or transverse (being at right angles to the length of the road). The longitudinal joints are provided so as to divide the pavement in parallel strips when the width of the road is more than 4 metres. The joints in transverse direction may be provided to accommodate the longitudinal expansion of the slab when the temperature increases or to take care of its contraction when the temperature falls. In order to allow angular movement or twisting of the slab, also due to temperature variations, warping joints may be provided in the transverse direction. Lastly, construction joints may also be necessary at the end of the day's work.

The joints, for forming satisfactory constituents of a concrete pavement must satisfy the following requirements :

1. They must continue to remain waterproof for all times.
2. They must permit free movement of the slab.
3. They must not result into deterioration in the riding quality of the pavement.
4. They should not induce structural weakness in the pavement.
5. They should not interfere with the concreting operation of the pavement as far as possible.

The joints should be limited to a minimum, consistent with the requirements and should be properly sealed with appropriate sealing materials so as to stop the possibility of the ingress of moisture to the subgrade through the joints. The various types of joints are as follows :

(*a*) *Longitudinal joint* : The longitudinal joints in concrete pavement divide the pavement into lanes and serve to reduce transverse warping due to difference in temperature at the centre and the

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edge of the road. The joints also take care of the unequal settlement of the sub-grade and also of the expansion in transverse direction. They furter help in laying of concrete in convenient widths.

The longitudinal joints may be tongue and groove type, weakened plane type or butt type. The tongue and groove type joint is considered to be superior to other types, since it also helps to correct the differential up lift between the two adjacent edges. The weakened plane type of joint consists in introducing a plane of weakness so as to induce the occurrence of the crack at this section and thus have a controlled cracking of the pavement. The butt type of joint has been recommended for general use by I.R.C.

In order to avoid opening up of the gap between the adjacent slabs and to arrest the vertical movement of one side relative to the other, the two slab sections are tied together with the help of tie bars. According to I.R.C. specifications, the length of any tie bar should atleast be equal to twice the length required to develop a bond strength equal to the working stress of steel. Assuming the maximum permissible bond stress in deformed tie-bars to be 2.46 N/mm^2, the length of the tie bar (L_t) in mm is given by

$$L_t = \frac{2\,a\,.\,\sigma_s}{2.46\,P}$$

where a = Cross-sectional area of one tie-bar in sq. mm,

σ_s = Allowable working stress in steel in N/mm^2, and

P = Perimeter of the tie-bar in mm.

The major function of the tie bars is to ensure firm contact between slab faces and to prevent abutting slabs from separating along the longitudinal joint. The tie-bars, however, act as a load transfer devices.

(*b*) *Transverse joint* : The transverse joint may be expansion joint, construction joint, warping joint and contraction joint. The expansion joint in the transverse direction prevents the development of excessive compressive stresses in the concrete pavements as a result of expansion caused by increase in temperature and moisture. The width of the expansion joint may be 20 to 25 mm extending to the full depth of slab.

According to I.R.C. recommendations, the maximum spacing of transverse expansion joint in unreinforced concrete pavements for a slab thickness of 20 cm should be 37 cm.

In order to prevent slabs from rising or sinking to elevations different from their neighbours, recourse has been made to load-transfer devices such as mild steel dowels which are so inserted that they extend from one slab into the next. The dowels are designed to transfer half the design wheel load across the joint. The dowels may be generally 20 to 25 mm in diameter, 300 to 500 mm in length and spaced 350 to 450 mm centre to centre, depending upon the thickness of the slab.

The transverse contraction joints are provided to permit the contraction of the slab. These joints in unreinforced concrete pavements, are provided at much closer intervals than the expansion joints. According to I.R.C. recommendations, the maximum spacing of contraction joints in unreinforced concrete slabs is 4.5 metres for a slab thickness of 20 cm.

The transverse warping joints are provided to relieve tensile stresses included due to warping. These are known as hinged joints. The longitudinal joints with tie bars fall in this class of joint. These joints are rarely needed if the suitably designed expansion and contraction joints are provided to prevent cracking.

9.28 Criteria for Highway Design

The design elements of a highway are influenced to a considerable degree by the following factors :

1. *Topography, physical and man-made features of the area.* The topography, in general, influences the physical location of a highway. The design elements *e.g.*, the gradients, sight distances

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cross-sections and speeds etc. are also affected to a considerable degree by the physical features like hills, valleys, steep slopes, rivers, ponds and lakes etc. as they impose lot of limitations on locations. The topography of the area, sometimes decides the type of a highway to be constructed. The cultural features or the man-made features of the area have a pronounced affect on highway geometrics.

2. *Traffic volume, its directional distribution and its composition.* The traffic volume is the number of vehicles moving in a specified direction on a roadway that passes a given point during a specified unit of time. The design of a highway should be based on the factual data about traffic volume, its directional distribution and its composition. The most important items in the study of traffic volume are average daily traffic, peak hour traffic and the traffic projection factor.

The *average daily traffic* (A.D.T.) is defined as the average number of vehicles per day passing over a section of the road during a particular year. For design purposes, a reasonable hourly volume called design hourly volume, D.H.V.) which represents a volume higher than the volume during most of the hours in a year, should be taken.

In order to take into consideration the future needs of traffic over a period of 20–25 years, which is taken as the normal life of a highway, it is essential to know the development of traffic and its ultimate volume at the end of the design period. Though it is not possible to project the traffic to some future year exactly, yet a reasonably exact value can be arrived by considering the following elements :

(*a*) Current traffic, made up of existing traffic and diverted traffic.

(*b*) Increase in traffic due to normal traffic growth, generated traffic and development traffic.

The *current traffic* may be defined as the volume of traffic that would immediately use a new road or an improved one, when opened to traffic. In case of an improved facility, the current traffic constitutes the existing traffic now plying on the road and the volume of the traffic that would be diverted to the improved highway due to the improvements.

The *increase in traffic* consititutes the normal traffic growth, the generated traffic and the development traffic. The *normal traffic growth* is the increase in traffic volume due to the general increase in the number of transport vehicles from year to year. The *generated traffic* is the traffic created due to the construction of new facility which would not have been present otherwise. The *development traffic* is that traffic which is due to the improvements in the adjacent area over and above the development which would have taken place had the new highway not been there or had the improvements not taken place on the existing highway.

3. *Traffic capacity.* The traffic capacity or highway capacity may be defined as the total number of vehicles that can pass a given point on the highway in a unit period of time. The highway or traffic density is defined as the total number of vehicles that can be accommodated on a unit length of the road.

In a mixed traffic flow, the traffic capacity is generally expressed as Passenger Car Unit (PCU) per hour and the traffic density as PCU per kilometre length of lane.

The highway capacity, depending upon a number of prevailing roadway and traffic conditions, are as follows :

(*a*) *Basic capacity.* The basic capacity is the maximum number of passenger cars that can pass a given point on a lane or a roadway during one hour under the most ideal roadway and traffic conditions that can possibly be attained.

(*b*) *Possible capacity.* The possible capacity is the maximum number of vehicles that can pass a given point on a lane or a roadway during one hour under the prevailing roadway and traffic conditions. The possible capacity of a road is generally much lower than the basic capacity as the prevailing roadway and traffic conditions are seldom ideal. The prevailing conditions referred to under the possible capacity are ideal if

(*i*) There are atleast two lanes for the exclusive use to traffic moving in one direction.

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(*ii*) All the vehicles move at the same

(*iii*) The width of lanes, shoulders and clearances to vertical obstructions beyond edge of the traffic lane are adequate.

(*iv*) There are no restrictive sight distance, grades, improperly super-elevated intersections or interferences by pedestrians.

(*c*) *Practical capacity.* The practical capacity is the maximum number of vehicles that pass a given point on a lane or a roadway during one hour with creating unreasonable delay under the prevailing roadway and traffic conditions. The value of the practical capacity is less than the possible capacity.

(*d*) *Design capacity.* It is the practical capacity or a smaller value determined for designing the highway to accommodate the design hourly volume (D.H.V.). It is normally, applied to existing highways.

(*e*) *Theoretical capacity.* The theoretical capacity is the number of vehicles passing any point in one hour per lane. It depends upon the average length of the vehicle and the average spacing of the moving vehicles. Mathematically, theoretical capacity,

$$C = \frac{1000\,V}{S}$$

where V = Design speed of the vehicle in kmph, and

S = Centre to centre spacing of moving vehicles

= Reaction distance + Average length of a vehicle

4. *Speed of vehicles* : The speed that a driver adopts on a highway depends upon the following four factors :

(*a*) The physical characteristics of the highway and its surroundings,

(*b*) The weather conditions in the area,

(*c*) The presence of other vehicles and the nature of such vehicles, and

(*d*) The speed limitations placed upon the vehicles.

The speed fixed for design and correlation of the physical features of a highway that influence vehicle operation, is called *design speed.* It is essential that the assumed design speed should be logical. In relation to the design speed standards, it is necessary to study the running speed and the spot speed attained by most of the drivers. The *running speed* is the speed over a specified section of the highway, being the distance covered by the actual running time (excluding any stopping time). The *spot speed* is the instantaneous speed of a vehicle as it passes a point in a highway. The simplest method of determining the spot speed is by using *enoscope* which is just like a mirror box supported on a tripod stand.

5. *Vehicle characteristics and vehicle design.* It is essential to examine all the vehicle types and the proportions of various sizes and their weights in order to arrive at design standards for use in the various geometric design elements. The dimensions like overall length, width and height of the vehicles or combination thereof have tremendous bearing on the design of elements. The major effects of these are as follows :

(*a*) *Effect of overall length of the vehicle.* The length of the vehicle affects the highway design in the following manner :

(*i*) The turning radii of the curves specially in the city areas shall have to be based on the length of the vehicles on the roads.

(*ii*) The time required by a fast moving vehicle to over take another slow moving vehicle moving ahead of it, shall depend upon the length of the slow moving vehicle, since the distance needed to overtake for different lengths of vehicles is different.

(*iii*) The off-tracking of vehicles of different lengths on different radii of curves is different.

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(b) *Effect of overall width of the vehicle.* The overall width of a vehicle determines the width of the pavement needed for the highway and the width of the bridges and other drainage structures on the highway.

(c) *Effect of overall height of the vehicle.* The overall height of the vehicle determines the length of the valley curves at the underpass in the city areas. It also determines the height of the tunnels along the highways.

(d) *Effect of weight of the vehicle.* The weight of the vehicle affects the thickness of the pavement.

9.29 Traffic Engineering

The traffic engineering is that branch of engineering which deals with the improvement of traffic operation, design and application of control devices such as pavement markings, traffic markers, signs and traffic signal etc. and analysis of traffic characteristics. It also deals with the improvement of the existing road and street systems either by replanning and improving them or by controlling the use of the existing systems, by different types of users.

9.30 Traffic Signs

The most common device for regulating, warning and guide drivers is the *traffic sign*. The signs should be placed such that the road user can see them easily and in time. These are generally installed at a height of 2.75 m to 2.8 m above the ground level. The traffic sings, according to Indian Motor Vehicles Act, are divided into the following three categories :

1. *Regulatory or Mandatory signs.* These signs impose the legal restrictions applicable at particular locations being usually unenforceable in the absence of such signs. The violation of these signs is a legal offence. These signs include Stop and Give-way signs ; Prohibitory signs ; No parking and No stopping signs ; Speed limit and Vehicle control signs ; Restriction ends sign ; Compulsory direction control and other signs.

2. *Warning or Cautionary signs.* These signs are used to warn the road users of certain hazardous conditions that exist on or adjacent to the roadway. The warning signs include bends, dips, road junctions, schools, level crossings, narrow bridges, U-turns, and cross-roads etc. The signs such as 'Road under repair' and 'Speed breaker ahead' are also warning sings. These signs are painted on rectangular plates 40 cm ′ 45 cm. An equilateral triangular plate of 45 cm sides is provided 15 cm above each of these signs. The bottom of the triangle is kept 2.75 m above the ground level.

3. *Informatory or Guide signs.* These signs are used to guide the road users along routes, inform them of destination and distance and provide with information such as 'End of speed limit', 'Parking zone' etc.

9.31 Traffic Signals

All electrically operated devices employed for controlling, directing or warning motorists or pedestrians are known as *traffic signals*. They serve one or more of the following purposes :

1. To provide an orderly movement of traffic.
2. To reduce the frequency of accidents of some special nature.
3. To control speed on the main and secondary highways.
4. To direct traffic on different routes.
5. To control traffic at rail-road crossings, draw-bridges and other hazardous situations.

The factors which governs the installation of signals are as follows :

1. Minimum vehicular volume from different streets at an intersection.
2. Minimum pedestrian volume at an intersection.
3. Need for interruption of high-volume continuous traffic on main street to allow the low volume traffic on the secondary street to pass.

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4. Need for accident reduction at hazardous situations by signal installation, when other measures have failed.

9.32 Types of Signals

The signals are classified as follows :

1. Traffic control signals. These signals may be fixed time signals and traffic actuated signals (Full traffic actuated, semi-traffic actuated and speed control).
2. Pedestrian signals.
3. Special traffic signals. These signals are flashing beacons, lane-direction traffic signals and traffic signals at draw-bridges.

A complete signal-time cycle constitutes of red, yellow (or amber) and green timing. The red colour indicates that the vehicle on the street towards which it is facing must stop and the green colour indicates that the vehicles on the street towards which it is facing can proceed. The yellow or amber colour indicates the clearance time for the vehicles which have entered the intersection area by the end of green light.

The *fixed time signals* are set to repeat regularly a cycle of red, yellow (amber) and green lights. The timing of each phase of the cycle is predetermined depending upon the traffic intensity. The fixed time signals are the simplest type of automatic traffic signals which are electrically operated.

In the *traffic actuated signals*, the timings of the phase and cycle are changed according to the traffic demand. In the *full traffic actuated signals*, the detectors are located on all the approaches to an intersection and assign the right of way for the traffic movement on the basis of each traffic demand. In the *semi-traffic actuated signals*, the detectors are used on some of the approaches to the intersection.

When the vehicles remain stopped by the red or stop signal on road intersection, the pedestrians can cross the road during this time. Such type of signals are known as *pedestrian signals*.

The *flashing beacon singals* are used to warn the traffic. When there is a red flashing signal the drivers of vehicles must stop before entering the nearest cross walk at the intersection or at a stop line where marked. The flashing yellow signals are used to direct the drivers of the vehicle to proceed with cautions.

9.33 Signal Systems

In the case of fixed time signals installed in an area, the following four systems are employed :

1. *Simultaneous system*. In this system, all the signals on a street give the same indication at any particular time.

2. *Alternate system*. In this system, alternate signals or alternate group of signals give opposite indications at a time.

3. *Simple progressive system*. In this system, the various signals controlling a street give green (or Go) indications according to a predetermined schedule to permit continuous movement of groups of vehicles along the street at a planned rate of speed, which way vary in different parts of the system. This is mostly suited where intersections are at equal spacings and the traffic volumes are uniform.

4. *Flexible progressive system*. In this system, it is possible at each signalised location to automatically vary the following :

(*a*) the cycle division,

(*b*) the timing offset, envabling two or more completely different time schedules, and

(*c*) the flashing during off hours of shut down.

In the flexible progressive system, the difference in traffic volumes at different locations and an unequal spacing of intersections can be brought into the best possible adjustment.

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OBJECTIVE TYPE QUESTIONS

1. For transportation purposes in India, the first preference is given to
(a) air lines (b) roads (c) shipping (d) railways

2. The term used for major or important roads of a country is
(a) country road (b) urban road (c) highway (d) none of these

3. A road connecting two towns is called a
(a) country road (b) urban road (c) highway (d) none of these

4. A road within a city or town is called an urban road.
(a) True (b) Flase

5. The portion of a road surface, which is used by vehicular traffic, is known as
(a) carriage-way (b) shoulder (c) express way (d) all of these

6. The city roads which are meant for through traffic usually on a continuous route are known as
(a) carriage way (b) express way (c) arterial streets (d) sub-arterial streets

7. The central portion of a road for high speed vehicles is known as
(a) motor way (b) express way (c) shoulder (d) carriage way

8. Carriage-way is protected by ..... wide shoulders.
(a) 0.5 to 1.25 m (b) 1.25 to 2 m (c) 2 to 4 m (d) 4 to 6 m

9. The importance of roads in a country is comparable to the veins in the human body.
(a) Agree (b) Disagree

10. Which of the following statement is correct ?
(a) Footpaths are particularly provided in the case of urban roads.
(b) Footpaths are 15 cm to 20 cm higher than the road surface.
(c) Shoulders are generally in level with road surface, having a slope towards the drain side.
(d) all of the above

11. The longest road constructed during the time of Shershah Suri was from
(a) Delhi to Kolkata (Calcutta) (b) Lahore to Delhi
(c) Lahore to Kolkata (Calcutta) (d) Lahore to Agra

12. The grand trunk (G.T.) road was constructed during
(a) 1440 to 1445 A.D. (b) 1540 to 1545 A.D.
(c) 2000 to 2500 B.C. (d) 2500 to 3000 B.C.

13. Kautilya got constructed a National Highway connecting North West Fronter Province and Patna in about
(a) 295 B.C. (b) 300 B.C. (c) 310 B.C. (d) 337 B.C.

14. The roads connecting capital cities of states is called
(a) national highway (b) express way (c) state highway (d) capital highway

15. A department of public works (now known as Central Public Works Department) was formed to look after the work of road construction during the period of
(a) Lord William Bentincic (b) Lord Dalhousie
(c) Lord Mayo (d) Lord Ripon

16. The Central Road Organisation (C.R.O.) was set up in
(a) 1930 (b) 1934 (c) 1948 (d) 1956

17. The Indian Roads Congress (I.R.C.) was set up in
(a) 1930 (b) 1934 (c) 1948 (d) 1956

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18. The Motor Vehicle Act was enacted in
(a) 1930 (b) 1934 (c) 1939 (d) 1948

19. The Central Road Research Institute (C.R.R.I.) was started in Delhi, in
(a) 1951 (b) 1955 (c) 1964 (d) 1965

20. The Central Road Research Institute is controlled by ..... Ministry.
(a) Shipping and Transport (b) Science and Technology
(c) Planning (d) Finance

21. The conference of chief engineers of all provinces was held at Nagpur in ..... to l into the problem of road development.
(a) 1943 (b) 1947 (c) 1958 (d) 1960

22. The headquarter of the Indian Roads Congress is at
(a) Mumbai (Bombay) (b) Kolkata (Calcutta)
(c) Chennai (Madras) (d) New Delhi

23. The Indian Roads and Transport Development Association (I.R.T.D.A.) was set up in
(a) 1927 (b) 1934 (c) 1947 (d) 1951

24. The headquarter of the Indian Roads and Transport Development Association is at
(a) Mumbai (Bombay) (b) Kolkata (Calcutta)
(c) Chennai (Madras) (d) New Delhi

25. The Border Roads Development Board was estabilised in
(a) 1934 (b) 1948 (c) 1951 (d) 1960

26. In Nagpur conference, the minimum width of village roads was recommended as
(a) 2 m (b) 2.25 m (c) 2.45 m (d) 3.2 m

27. The size of a stone used on a road must be in due proportion to the space occupied by a wh of ordinary dimensions on a smooth level surface. This point of contact will be found to longitudinally about 25 mm and every piece of stone put into a road which exceeds 25 mm in any its dimensions is mischievous. This statement is according to Macadam.
(a) Correct (b) Incorrect

28. For the water-bound macadam road, the recommended camber is
(a) 1 in 24 to 1 in 30 (b) 1 in 30 to 1 in 48 (c) 1 in 60 to 1 in 80 (d) 1 in 80 to 1 in 1

29. According to Telford
(a) the size of stone at the centre varied from 160 mm to 200 mm and gradually decreased 75 mm to 125 mm towards the haunches
(b) the central 6 metre width of the road was covered with two layers of stones about 100 m and 50 mm respectively
(c) the size of stone used was of 63 mm diameter
(d) all of the above

30. In Telford construction, the side portions were made up of only one layer of broken stones a evelled off to give a camber not greater than
(a) 1 in 40 (b) 1 in 60 (c) 1 in 80 (d) 1 in 120

31. The camber, for the drainage of surface water, was first introduced by
(a) Telford (b) Tresaguet (c) Sully (d) Macadam

32. National Highways Act, 1956 came into force from
(a) 15th April, 1957 (b) 15th April, 1958 (c) 15th April, 1960 (d) 15th April 196

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33. In water-bound Macadam roads
(a) small broken stones are laid in two layers
(b) voids between the stones are filled by stone dust
(c) camber for drainage is given at the formation level itself
(d) all of the above

34. The total annual cost of highway transportation (A) may be expressed as
(a) $A = B - CN$ (b) $A = B + CN$ (c) $A = B/CN$ (d) $A = CN/B$
where B = Annual cost of highway,
C = Annual cost of vehicle operation (single vehicle), and
N = Total number of vehicles on the road per year.

35. The unit cost of transportation (A_U) on a section of the highway may roughly be calculated by
(a) $A_U = \frac{AL}{N}$ (b) $A_U = \frac{AN}{L}$ (c) $A_U = \frac{A}{NL}$ (d) $A_U = A.N.L$
where L = Length of the highway in kilometres.

36. According to Indian Roads Congress, the maximum width of a road vehicle is
(a) 1.85 m (b) 2.25 m (c) 2.45 m (d) 3.2 m

37. On the recommendations of the Indian Roads Congress, the National Highways should have two-lane traffic at least ..... wide with minimum 2 m wide shoulder on each side.
(a) 4 m (b) 6 m (c) 8 m (d) 10 m

38. The State Highways should have 8 m wide carriage-way with 2 m wide shoulder on each side
(a) Right (b) Wrong

39. In order to give satisfactory service throughout the year, the road surface should
(a) have a good carriage-way (b) have smooth gradient
(c) have a good wearing surface (d) all of these

40. The top of the ground on which the foundation of road rests, is called
(a) sub-grade (b) soling (c) base (d) wearing layer

41. The foundation of a road is also called
(a) soling (b) base (c) either (a) or (b) (d) none of these

42. The super structure of a road is called
(a) wearing layer (b) wearing course (c) road surfacing (d) any one of these

43. When the bearing capacity of soil is poor and the intensity of traffic is high, an additional layer provided between the soling and sub-grade. This additional layer is called
(a) wearing layer (b) sub-base (c) road surfacing (d) all of these

44. The strength and durability of a road depends upon its sub-grade.
(a) True (b) False

45. The thickness of base, in no case, should be more than
(a) 10 cm (b) 15 cm (c) 20 cm (d) 30 cm

46. The highest point on road surface is called
(a) crown (b) camber (c) gradient (d) berm

47. The function of a road base is to transmit load of the traffic from the ..... to the subgrade.
(a) soling (b) surfacing

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48. The road surfacing should be
(a) impervious (b) durable (c) stable (d) all of these

49. The slope of the line joining the crown and edge of the road surface is known as
(a) cross-fall (b) corss-slope (c) camber (d) any one of

50. A camber of 1 in 30 means that for a 30 m wide road, the crown of the road will be ..... above the edge of the road.
(a) 0.5 m (b) 1 m

51. The thickness of road surfacing depends upon the
(a) type of traffic (b) intensity of traffic
(c) type of material (d) all of these

52. The main object of providing a camber is
(a) to make the road surface impervious (b) to make the road surface durable
(c) to drain off rain water from road surface, as quickly as possible
(d) all of the above

53. In scanty rainfall areas, the camber provided will be
(a) flatter (b) steeper (c) zero (d) none of these

54. On kankar road, the camber generally provided is
(a) 1 in 24 to 1 in 30 (b) 1 in 30 to 1 in 48 (c) 1 in 48 to 1 in 60 (d) 1 in 60 to 1 in

55. The shape of the camber provided for cement concrete pavement is
(a) straight line (b) parabolic (c) elliptical (d) none of these

56. On cement concrete roads, the camber generally provided is 1 in 70 to 1 in 80.
(a) Agree (b) Disagree

57. A barrel camber consists of
(a) two straight slopes joining at the centre
(b) two straight slopes with a parabolic crown in the centre
(c) a continuous curve either parabolic or ellptical
(d) none of the above

58. A camber consisting of two straight slopes joining at the centre is called
(a) barrel camber (b) sloped camber (c) composite camber (d) none of these

59. Steeper camber may cause deterioration of the central portion of the road surface.
(a) Correct (b) Incorrect

60. The camber recommended for water bound macadam roads in
(a) 1 in 24 to 1 in 30 (b) 1 in 30 to 1 in 48 (c) 1 in 48 to 1 in 60 (d) 1 in 60 to 1 in

61. The camber of road should be approximately equal to ..... the longitudinal gradient
(a) one-half (b) two times (c) three times (d) four times

62. Which of the following statement is correct ?
(a) The amount of camber depends upon the rainfall of that area in which the road is to be constructed.
(b) The steeper the camber of road, the more inconvenient it is for the traffic.
(c) On a pavement with parabolic camber, the angle of inclination of the vehicles will be more at the edges.
(d) all of the above

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63. A vehicle while passing from a straight to a curved path, is under the influence of the weight of the vehicle and the centrifugal force.
(a) True (b) False

64. The inward tilt given to the cross-section of the road surface, throughout the length of the horizontal curve, is known as
(a) super-elevation (b) cant (c) banking (d) all of these

65. The raising of outer edge of the road above the inner edge is known as
(a) super-elevation (b) cant (c) banking (d) all of these

66. Super-elevation is expressed as
(a) the difference of heights of two edges of the carriage-way to the width of the carriage-way
(b) the difference of radii of curves (c) the difference of the road gradients
(d) none of the above

67. Super-elevation should not be ..... than the camber.
(a) more (b) less

68. Greater the super-elevation, more will be convenience to the slow moving traffic.
(a) Right (b) Wrong

69. The main advantage of providing super-elevation is
(a) to decrease the intensity of stresses on the foundation
(b) to increase the stability of the fast moving vehicles, when they negotiate a horizontal curve
(c) to achieve higher speed of vehicles
(d) all of the above

70. In the absence of super-elevation on road along curves, pot holes are likely to occur at the ..... of the road.
(a) centre (b) outer edge (c) inner edge

71. To prevent the overturning of a bullock cart on curves, the maximum value of super-elevation s prescribed by the Indian Roads Congress is
(a) 1 in 5 (b) 1 in 10 (c) 1 in 15 (d) 1 in 20

72. The super -elevation is
(a) directly proportional to the velocity of vehicles
(b) inversely proportional to the velocity of vehicles
(c) directly proportional to the width of pavement
(d) inversely proportional to the width of pavement

73. If the width of cariage way is 10 m and the outer edge is 40 cm higher than the inner edge, then he super-elevation required is
(a) 1 in 25 (b) 1 in 100 (c) 1 in 400 (d) none of these

74. The rate of rise or fall of the road surface along its length, is called
(a) cant (b) super-elevation (c) gradient (d) banking

75. If the difference of levels between two points A and B is 1 metre and their distance apart is 50 metres, the gradient is said to be
(a) 1 in 50 or 2% (b) 1 in 5 or 20% (c) 1 in 20 or 5% (d) none of these

76. The equilibrium super-elevation is given by
(a) $\frac{V^2}{R}$ (b) $\frac{V^2}{g.R}$ (c) $\frac{V^2}{127R}$ (d) none of these

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77. The maximum rate of super-elevation (e) is given by
(a) $e = \frac{V^2}{225R}$ (b) $e = \frac{V^2}{424R}$ (c) $e = \frac{V^2}{540R}$ (d) $e = \frac{V^2}{1000R}$
where V = Speed of vehicle in kmph, and R = Radius of curvature in metres.

78. According to Indian Roads Congress, superelevation balances the centrifugal force corresponding to
(a) full design speed (b) half of the design speed
(c) three-fourth of the design speed (d) none of these

79. The gradient of a road depends upon the
(a) nature of traffic (b) nature of ground
(c) rainfall of the locality (d) all of these

80. When the rainfall is more, flatter gradients should be provided in the side drains and the road
(a) Yes (b) No

81. Roads only meant for slow moving traffic ..... have very steep gradient.
(a) must (b) must not

82. The steepest gradient which is to be permitted on the road is called
(a) maximum gradient (b) limiting gradient (c) both (a) and (b) (d) none of these

83. The value of maximum gradient for hill roads is
(a) 1 in 5 (b) 1 in 10 (c) 1 in 15 (d) 1 in 20

84. The suitable gradient within which the engineer must endeavour to design the road is called
(a) limiting gradient (b) ruling gradient
(c) average gradient (d) exceptional gradient

85. The value of ruling gradient in plain, as recommended by Indian Roads Congress, is
(a) 1 in 10 (b) 1 in 20 (c) 1 in 30 (d) 1 in 40

86. The value of ruling gradient in hills, as recommended by Indian Roads Congress, is
(a) 1 in 10 (b) 1 in 20 (c) 1 in 30 (d) 1 in 40

87. An essential gradient, which has to be provided for the purpose of road drainage, is called
(a) maximum gradient (b) minimum gradient
(c) exceptional gradient (d) floating gradient

88. The total rise or fall between any two points chosen on the alignment divided by the horizontal distance between the two points, is called
(a) average gradient (b) exceptional gradient
(c) ruling gradient (d) floating gradient

89. For cement concrete roads, a minimum gradient of 1 in 330 can be provided.
(a) True (b) False

90. Which of the following statement is correct ?
(a) Steeper gradients are, sometimes, provided to avoid deep excavations.
(b) Steeper gradients are, sometimes, provided to avoid long detours.
(c) Exceptional gradient becomes necessary to avoid deep cuttings.
(d) all of the above

91. An gradient on a road is said to be an exceptional gradient if it is
(a) less than the minimum gradient (b) more than the maximum gradient
(c) more than the minimum gradient (d) less than the maximum gradient

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92. Exceptional gradient should not be provided in a length more than
(a) 10 m (b) 20 m (c) 50 m (d) 100 m

93. Floating gradients are provided at ..... curves.
(a) summit (b) valley

94. The distance, measured along the centre line of a road, over which a driver can see the opposite object on the road surface, is called
(a) sight distance (b) visibility (c) clear distance (d) none of these

95. The stopping sight distance is the ..... of reaction distance and the braking distance.
(a) sum (b) difference (c) product

96. The stopping sight distance (S) of a vehicle for Indian highways is given by
(a) $S = 0.28\ V.t + \frac{0.01\,V^2}{\eta}$ (b) $S = 0.28\ V.t + \frac{0.01\,\eta}{V^2}$
(c) $S = 0.01\ V.t + \frac{0.28\,V^2}{\eta}$ (d) $S = 0.01\ V.t + \frac{0.28\,\eta}{V^2}$

where V = Speed of the vehicle in kmph,
t = Brake reaction time in seconds,
η = Efficiency of brakes in percent.

97. The stopping sight distance depends upon the
(a) reaction time (b) braking time (c) speed of vehicle (d) all of these

98. The longest distance at which a driver, whose line of sight is 1.2 m above the road surface, can see the top of an object 10 cm high on the surface of road, is called
(a) crossing sight distance (b) stopping or non-passing sight distance
(c) over taking or passing sight distance (d) lateral sight distance

99. On horizontal and vertical curves, crossing sight distance must be provided to avoid any collision of two vehicles coming from opposite directions.
(a) Agree (b) Disagree

100. The reaction time of a driver ..... with the increase in speed.
(a) remains constant (b) increases (c) decreases

101. The stopping sight distance is always ..... overtaking sight distance.
(a) equal to (b) less than (c) greater than

102. The opportunities to cross slow moving traffic at intervals is not provided in case of
(a) two-lane highways (b) three-lane highways
(c) four lane highways (d) all of these

103. The reason for providing curves on a highway is
(a) to provide access to a particular locality
(b) restriction imposed by some unavoidable reasons of land
(c) preservation of existing amenities
(d) all of the above

104. The factor which influences the design of curves, is
(a) speed of vehicle (b) maximum permissible super-elevation
(c) permissible centrifugal ratio (d) all of these

105. According to I.R.C. recommendations, the absolute minimum radius of curve for safe operation for a design speed of 100 kmph is
(a) 100 m (b) 200 m (c) 300 m (d) 400 m

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106. A horizontal curve on a road provides
(a) change in the direction (b) change in the gradient of road
(c) both (a) and (b) (d) none of these

107. A vertical curve on a road provides change in gradient.
(a) Correct (b) Incorrect

108. A curve whose radius gradually changes from an infinite value to a finite value or vice-ve for the purpose of giving easy change of direction of a road, is called a
(a) circular curve (b) transition curve (c) simple curve (d) compound cu

109. A curve which consists of a single arc connecting two straights is known as
(a) simple circular curve (b) reverse circular curve
(c) cubic spiral curve (d) lamniscate

110. In India, a curve is expressed in terms of angle in degrees subtended to the centre by an ar ..... radius.
(a) 25 m (b) 30 m (c) 45 m (d) 60 m

111. Transition curves are not provided on highways.
(a) Right (b) Wrong

112. A circular curve may be a vertical curve.
(a) Yes (b) No

113. A transition curve can not be a
(a) true spiral (b) cubic spiral (c) compound curve (d) cubic parab

114. The main advantage of providing transition curves on highways, is
(a) to obtain transition from the tangent to the circular curve and from the circular to tangent
(b) to obtain a gradual increase of curvature from a value of zero at the tangent to a maxim at the circular curve
(c) to have a gradual increase of super-elevation from zero at the tangent to a specific maxim at the circular curve
(d) all of the above

115. The shape of a vertical curve is
(a) parabolic (b) spiral (c) elliptical (d) any one of th

116. Clothoid is the ideal shape of a transition curve.
(a) Agree (b) Disagree

117. An ideal vertical curve is a cubic spiral.
(a) True (b) False

118. The rate of change of radial acceleration governs the
(a) length of a transition curve
(b) extra width of pavement on the curve
(c) length of the tangent of a simple circular curve
(d) all of the above

119. A cubic spiral is ..... to cubic parabola as for as the degree of accuracy of a transit urve is concerned.
(a) superior (b) inferior

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In case of a cubic spiral, the polar deflection angle may be assumed equal to
(a) $\phi/2$ (b) $\phi/3$ (c) $\phi/4$ (d) $\phi/5$
where ϕ = Deviation angle of the curve.

The type of transition curve recommended by the IRC is
(a) cubic parabola (b) cubic spiral (c) lamniscate (d) none of these

If L is the length of wheel base of vehicle and R is the mean radius of a curve, then the amount of extra width (b) to be provided on roads is given by
(a) $b = \frac{nL}{R}$ (b) $b = \frac{nL^2}{R}$ (c) $b = \frac{nL}{2R}$ (d) $b = \frac{nL^2}{2R}$
where n = Number of lanes.

Which of the following is not a transition curve ?
(a) Compound curve (b) Cubic spiral (c) Cubic parabola (d) True spiral

The expression for the length of a transition curve (L) in metres is
(a) $L = \frac{V^3}{CR}$ (b) $L = \frac{V^3}{16CR}$ (c) $L = \frac{V^3}{24CR}$ (d) $L = \frac{V^3}{48CR}$
where C = Rate of change of radial acceleration in m/s^3,
R = Radius of circular curve in metres, and
V = Speed of the vehicle in kmph.

As per Indian Roads Congress recommendations, the rate of change of radial acceleration (C) in m/s^3 for highways varies according to the relation
(a) $C = \frac{65+V}{75}$ (b) $C = \frac{75}{65+V}$ (c) $C = \frac{85+V}{95}$ (d) $C = \frac{95}{85+V}$

The fundamental condition for a perfect transition curve is that radius of curvature at any point should be ..... proportional to the distance from the start of the curve.
(a) directly (b) inversely

A lamniscate fulfils the requirements of a true transition curve.
(a) Right (b) Wrong

The intrinsic equation of an ideal transition curve representing a clothoid is given by
(a) $\phi = \frac{l^2}{2RL}$ (b) $\phi = \frac{l^2}{4RL}$ (c) $\phi = \frac{l^2}{8RL}$ (d) $\phi = \frac{l^2}{16RL}$

The standard equation of a cubic parabolic transition curve provided on roads is
(a) $\frac{x}{6R.L}$ (b) $\frac{x^2}{6R.L}$ (c) $\frac{x^3}{6R.L}$ (d) none of these

The length of the tangent of a simple curve having angle of deflection θ and radius of curvature R is equal to
(a) $R \sin \theta/2$ (b) $R \cos \theta/2$ (c) $R \tan \theta/2$ (d) $R \cot \theta/2$

The shift (S) of a transition curve is given by
(a) $S = \frac{L^2}{6R}$ (b) $S = \frac{L^2}{12R}$ (c) $S = \frac{L^2}{24R}$ (d) $S = \frac{L^2}{48R}$
where L = Length of the transition curve, and
R = Radius of the curve.

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132. Which of the following statement is wrong ?
(a) A summit curve is provided where a positive grade meets a negative grade.
(b) A circular curve may be a reverse curve.
(c) A transition curve tends to counteract the swaying outwards of a vehicle.
(d) none of the above

133. The design criterion for the summit curves is the sight distance to be allowed on the
(a) Correct (b) Incorrect

134. Valley curves are required to be introduced at the situations where
(a) a negative grade meets a positive grade
(b) a negative grade meets another milder negative grade
(c) a negative grade meets a steeper positive grade
(d) all of the above

135. Design of both summit and valley curves is based on the assumption that the
(a) curve is so flat that the length of curve is equal to the length of chord
(b) two portions of the curve along the two tangents on either side of the point of inter are equal
(c) angles made by the tangent with the horizontal are very small and tangents of those are equal to the angles themselves (in radians)
(d) all of the above

136. Summit curves are required to be introduced at the situations where
(a) a positive grade meets a negative grade
(b) a positive grade meets another milder positive grade
(c) a negative grade meets a steeper negative grade
(d) all of the above

137. The design criterion for the valley curves is the centrifugal force developed.
(a) Yes (b) No

138. A ..... is considered to be best for the valley curves.
(a) cubic spiral (b) cubic parabola (c) lamniscate

139. The minimum length of a valley curve should be such that the head light beam sight dista equal to the
(a) stopping sight distance (b) passing sight distance
(c) braking distance (d) none of these

140. According to IRC, the minimum length of the summit or valley curve should not be les ..... the design speed in km / h.
(a) one-half (b) one-fourth (c) two-third

141. When the valley curves are designed as square parabola, the stopping sight distance shou equal to head-light beam distance.
(a) Agree (b) Disagree

142. If S is the passing sight distance, then the length of the summit curve (L), when S is less th s given by

(a) $L = \frac{GS^2}{4}$ (b) $L = \frac{GS^2}{9.6}$ (c) $L = 2S - \frac{9.6}{G}$ (d) $L = 2S -$

where G = Algebraic difference of the grades on the two sides of the point of intersec

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144. If S is the non-passing sight distance, then the length of the summit curve (L), when S is greater than L, is given by
(a) $L = \frac{GS^2}{4}$ (b) $L = \frac{GS^2}{9.6}$ (c) $L = 2S - \frac{9.6}{G}$ (d) $L = 2S - \frac{4}{G}$

145. According to IRC, the length of the valley curve (L), when the length of curve exceeds the sight distance (S), is given by
(a) $L = \frac{GS^2}{1.5 + 0.035S}$ (b) $L = \frac{1.5 + 0.035S}{G^2}$
(c) $L = 2S - \frac{1.5 + 0.035S}{G}$ (d) $L = 2S - \frac{G}{1.5 + 0.035S}$

146. While deriving the formulae for the length of valley curve, it is assumed that the head light is ..... above the road surface.
(a) 0.25 m (b) 0.5 m (c) 0.75 m (d) 1m

147. According to IRC : 52-1973, the first stage for fixing up alignment of a hill road is
(a) trace cut (b) detailed survey (c) preliminary survey (d) reconnaissance

148. Alignment of a road is finally decided on the basis of
(a) selection of route (b) field survey (c) trace cut (d) none of these

149. A track of width 1 to 1.2 m constructed along the selected alignment to facilitate access to the area for inspection and detailed survey is known as
(a) inspection trace (b) terrain (c) trace out (d) all of these

150. The gradients of trace cuts for hill roads are kept
(a) 10 to 20% easier than the ruling gradient
(b) 20 to 25% easier than the ruling gradient
(c) 10 to 20% steeper than the ruling gradient
(d) 20 to 25% steeper than the ruling gradient

151. At the end of the reconnaissance phase, the selected alignment is pegged by using about 2m high poles on which the
(a) number of peg is marked (b) direction of proposed alignment is marked
(c) distance between the two pegs is marked (d) all of these

152. Which of the following statement is correct ?
(a) In rocky areas and dense jungles, the trace cut may be avoided and some suitable arrangement may be made so as to gain access for ascertaining details.
(b) Reconnaissance is best done by topographical surveys.
(c) The detailed survey should be conducted for a strip covering on either side of the chosen centre line a width of about 15 m in case of straight stretches and 30 m in case of sharp curves.
(d) all of the above

153. During the detailed survey of a hill road, the first operation is to fix the bench marks.
(a) True (b) False

154. In detailed survey of a hill road, the interval for plotting the contours at sharp curves is generally
(a) 1 m (b) 2 m (c) 4 m (d) 6 m

155. The longitudinal levels, in detailed survey of a hill road, should be taken at ..... intervals.
(a) 4 m (b) 6 m (c) 8 m (d) 10 m

156. A terrain with cross-slope less than 10 percent, is called
(a) steep terrain (b) mountainous terrain
(c) level terrain (d) rolling terrain

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156. Rolling terrain is a terrain with cross-slope
(a) upto 10%
(b) 10 to 25%
(c) 25% to 60%
(d) greater than 60%

157. A curve at the ridge of a hill having a convex shape is called a
(a) valley curve
(b) summit curve
(c) re-entrant curve
(d) salient

158. A curve at the valley between two hills having a concave shape is called a valley curve
(a) Right
(b) Wrong

159. A gradient at which no tractive force is required to maintain constant speed by a vehicle
(a) average gradient
(b) limiting gradient
(c) exceptional gradient
(d) floating gradient

160. Steep terrain is a terrain with cross-slope greater than 60 percent.
(a) Correct
(b) Incorrect

161. Gradients more than the floating gradient result in the ..... of speed.
(a) decrease
(b) increase

162. The width of the class 9 roads is
(a) 2.45 m
(b) 3.65 m
(c) 4.9 m
(d) 6 m

163. Class-9 roads are designed to carry
(a) jeeps
(b) 1-tonne vehicles
(c) 3-tonne vehicles
(d) 10-tonne vehicles

164. Class-5 roads have a width of
(a) 2.45 m
(b) 3.65 m
(c) 4.9 m
(d) 6 m

165. Class-5 roads are designed to carry 3-tonne vehicles.
(a) Yes
(b) No

166. For jeepable roads, the width of pavement adopted is
(a) 3 m
(b) 3.75 m
(c) 5 m
(d) 5.5 m

167. Class-3 roads are designed to carry jeeps.
(a) True
(b) False

168. Formation width on straights for motorable road carrying a total load less than 100 tonne
day, is
(a) 3 to 4.5 m
(b) 4.5 to 5 m
(c) 5 to 7.25 m
(d) none of th

169. Formation width on curves of motorable road carrying a total load above 400 tonnes per
cept as
(a) 4 m
(b) 5 m
(c) 7.25 m
(d) 11 m

170. In hill roads, minimum sight distance required is
(a) stopping sight distance
(b) passing sight distance
(c) braking distance
(d) none of these

171. In the initial stage of construction of hill roads, no curve should have a radius less than
(a) 20 m
(b) 30 m
(c) 40 m
(d) 50 m

172. According to IRC : 52-1973, for a single lane National highway in a hilly area
(a) the total width of the road-way must be 6.25 m
(b) the width of the carriage way must be 3.75 m
(c) the shoulder on either side must be 1.25 m
(d) all of the above

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174. The maximum super-elevation on hill roads should not exceed
(a) 7% (b) 8% (c) 9% (d) 10%

175. In snow-bound sections, the super-elevation on roads should not be more than
(a) 7% (b) 8% (c) 9% (d) 10%

176. If R is the radius of curvature of a hill road, the maximum grade compensation (in percentage) is equal to
(a) $65/R$ (b) $75/R$ (c) $85/R$ (d) $95/R$

177. Retaining wall is constructed usually on the ..... of the roadway.
(a) hill side (b) valley side

178. For walls less than 6 m in height, the thickness of the retaining wall at the bottom is equal to
(a) 0.2 times the height (b) 0.3 times the height
(c) 0.4 times the height (d) 0.5 times the height

179. For walls more than 6 m in height, thickness of retaining wall at the bottom is equal to 0.4 times the height plus
(a) 10 cm (b) 20 cm (c) 30 cm (d) 40 cm

180. A wall constructed to retain the earth from slippage on the hill side of the roadway is called
(a) breast wall (b) retaining wall (c) parapet wall (d) none of these

181. A parapet well is usually constructed on the ..... of the roadway.
(a) hill side (b) valley side

182. A breast wall is usually constructed on the hill side of the roadway.
(a) Agree (b) Disagree

183. The thickness of the parapet wall, on the valley side of the roadway, is usually kept as
(a) 20 cm (b) 40 cm (c) 60 cm (d) 80 cm

184. The height of the parapet wall is usually kept as ..... above the berm level.
(a) 25 cm (b) 50 cm (c) 75 cm (d) 100 cm

185. A batter of 1 in 12 may be given to the retaining wall on the outside.
(a) Correct (b) Incorrect

186. The parapet walls are usually required on the valley side of the roadway, in order to
(a) retain the earth from slippage
(b) properly guide the vehicles to the roadway
(c) provide a good drainage system
(d) keep the road dry

187. The side drains are provided on both sides of the roadway, when the road is
(a) in cutting (b) along salient curve
(c) along re-entrant curve (d) all of these

188. A water bound macadam road is an example of
(a) rigid pavement (b) semi-rigid pavement
(c) flexible pavement (d) none of these

189. A cement concrete road is an example of semi-rigid pavement.
(a) Yes (b) No

190. A cement grouted road is an example of ..... pavement.
(a) semi-rigid (b) rigid (c) flexible

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190. Which of the following statement is correct
(a) The sub-grade strength has only little influence upon the structural capacity of the pavement.
(b) The major factor in the design of rigid pavements is the flexural strength of concrete
(c) The temperature variations due to changes in atmospheric conditions do not produce stress in flexible pavements.
(d) all of the above

191. The flexible pavement distribute the wheel load
(a) directly to sub-grade
(b) through a set of layers to sub-grade
(c) through structural action
(d) none of these

192. The flexible pavements have self-healing properties.
(a) Right
(b) Wrong

193. The cost of construction of rigid pavements is ..... as compared to flexible pavem
(a) same
(b) less
(c) more

194. The structure of a road is composed of
(a) sub-grade
(b) sub-base
(c) base
(d) all of these

195. The natural soil on which the pavement rests and to which the entire load of structure is ultima ransferred, is known as the
(a) base of road
(b) sub-base of road
(c) sub-grade of road
(d) all of these

196. The sub-base course is placed immediately above the
(a) sub-grade
(b) base
(c) wearing course
(d) none of the

197. The wearing course in the case of flexible pavements consist of
(a) hard well burnt clinker
(b) broken stone and granular material mixed with tar
(c) a mixture of bituminous material and aggregate
(d) all of the above

98. The sub-grade is the final load carrying part of the structure.
(a) True
(b) False

99. The selection of design curve in Wyoming method of flexible pavement design, is based u
(a) annual precipitation
(b) water-table
(c) frost action
(d) all of these

00. Match the correct answer from *Group B* for the statements given in *Group A*.

Group A	*Group B*
(a) The natural soil beneath the road construction is called	(A) sub-base
(b) The course placed immediately above the sub-grade is called	(B) base
(c) A mixture of bituminous material and aggregate is used for	(C) sub-grade
(d) The course which withstands the high shearing stresses is called	(D) wearing course

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201. Which of the following statement is correct ?
(a) The sub-base course is composed of hard well burnt clinker natural gravel or any other suitable material excavated at or near the site.
(b) The base is composed of broken stone and granular material with tar.
(c) The wearing surface in the case of flexible pavement consists of a mixture of bituminous material and aggregate.
(d) all of the above

202. The universally recognized factor which affects the flexible pavement design, is the
(a) characteristics of the natural soil which underlies the pavement
(b) volume and character of traffic that will use the highway
(c) drainage condition of the area
(d) all of the above

203. The California bearing ratio (CBR) method of flexible pavement design gives an idea about
(a) the quality of road making material (b) the traffic intensities
(c) the characteristics of soil (d) all of these

204. In CBR test, the value of CBR is calculated at
(a) 2.5 mm penetration only (b) 5 mm penetration only
(c) both 2.5 and 5 mm penetration (d) none of these

205. Which of the following method is recommended by I.R.C. for design of flexible pavement ?
(a) Group index method (b) CBR method
(c) Westergaard method (d) none of these

206. The group index method of designing flexible pavement is
(a) an empirical method based on the physical properties of the sub-grade soil
(b) an empirical method based on the strength characteristics of the sub-grade soil
(c) a semi-empirical method
(d) none of these

207. The value of group index of a soil varies from
(a) 0 to 10 (b) 0 to 20 (c) 20 to 30 (d) 30 to 40

208. Which of the following statement is correct ?
(a) The sub-base thickness is directly proportional to the group index of the soil.
(b) The higher the group index of the soil, the larger is the thickness of the sub-base.
(c) If the group index value of the sub-base is between 5 and 9, then the sub-base is poor.
(d) all of the above

209. The minimum thickness of the base of a flexible pavement is kept as
(a) 5 cm (b) 10 cm (c) 15 cm (d) 20 cm

210. As per IRC recommendations, the sub-grade or sub-base layer whatever underlies the concrete wearing slab, in concrete pavements, must confirm to the requirement that
(a) no soft spots are present in the sub-grade or sub-base
(b) the base or sub-base extends to atleast 30 cm wider on either side of the width to be concreted
(c) the sub-grade is properly drained
(d) all of the above

211. Cement concrete pavements are classified as flexible pavements.
(a) Agree (b) Disagree

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212. The main advantage of concrete pavements is that
(a) it offers less resistance to traffic
(b) it is not slippery when clean
(c) it has low maintenance cost
(d) all of these

213. The main disadvantage of concrete roads is that
(a) the initial cost is high
(b) it requires skilled personnel for construction
(c) it requires cautious handling of the material
(d) all of the above

214. The depth of reinforcement, below the surface of pavement, is kept as
(a) 25 mm (b) 50 mm (c) 75 mm (d) 100 mm

215. The major function of reinforcement, in concrete pavements, is
(a) to strengthen the slab
(b) to hold together the cracks
(c) to control the development of cracks
(d) all of these

216. Of all the forces stressing a concrete pavement, the most significant are those imposed by
(a) change in temperature
(b) change in moisture
(c) wheel loads
(d) force of friction

217. A large difference of temperature between the top and the bottom of the slab causes ..... of the slab.
(a) hardening (b) warping (c) crazing

218. Plastic cracks due to shrinkage are developed immediately after the concrete starts harden
(a) Correct
(b) Incorrect

219. When the exposed surface of a pavement dries and shrinks more than the underlying conc a phenomenon known as ..... of the surface may occur.
(a) hardening (b) warping (c) crazing

220. The stresses set up in concrete pavements due to change in moisture content are very ..... and are generally opposed to those set up by temperature variations.
(a) high
(b) low

221. If 'W' is the wheel load and 'σ' is the unit stress in tension, then the thickness of conc pavement (t) is given by

(a) $t = \sqrt{\frac{W}{\sigma}}$ (b) $t = \sqrt{\frac{2W}{\sigma}}$ (c) $t = \sqrt{\frac{3W}{\sigma}}$ (d) $t = \sqrt{\frac{4W}{\sigma}}$

222. According to Sheets' formula, the thickness of slab (t) is given by

(a) $t = \sqrt{\frac{WC}{\sigma}}$ (b) $t = \sqrt{\frac{1.2WC}{\sigma}}$ (c) $t = \sqrt{\frac{2.4WC}{\sigma}}$ (d) $t = \sqrt{\frac{3.6WC}{\sigma}}$

where C = Coefficient of sub-grade support.

223. The joints, parallel to the centre-line of the road, are called
(a) longitudinal joints (b) transverse joints (c) expansion joints (d) all of these

224. The longitudinal joints are provided when the width of road is more than
(a) 3 m (b) 4 m (c) 5.5 m (d) 6.75 m

225. The longitudinal joints may be
(a) tongue and groove type
(b) butt type
(c) weakened plane type
(d) all of these

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226. The tongue and groove type of longitudinal joint do not help to control the differential uplift between the two adjacent edges.
(a) Right (b) Wrong

227. Longitudinal joints in concrete pavements
(a) divide the pavement into lanes
(b) take care of the unequal settlement of the sub-grade
(c) help in laying out concrete in convenient widths
(d) all of the above

228. The longitudinal joint in concrete pavements, as recommended by IRC, is of
(a) tongue and groove type (b) butt type
(c) weakened plane type (d) hinged type

229. According to IRC specifications, the length of any tie bar in concrete pavements should atleast be equal to ..... the length required to develop a bond strength equal to the working strength of steel.
(a) one-half (b) twice (c) thrice

230. If the maximum permissible bond stress in deformed tie bars is assumed to be 2.46 N/mm^2, the length of the tie bar (L_t) in mm, is given by

(a) $L_t = \dfrac{a.\sigma_s}{2.46\,P}$ (b) $L_t = \dfrac{2a.\sigma_s}{2.46\,P}$ (c) $L_t = \dfrac{3a.\sigma_s}{2.46\,P}$ (d) $L_t = \dfrac{4a.\sigma_s}{2.46\,P}$

where a = Cross-sectional area of one tie-bar in mm^2,
σ_s = Allowable working stress in steel in N/mm^2, and
P = Perimeter of the tie bar in mm.

231. Tie bars in longitudinal joints in concrete pavements
(a) ensure firm contact between slab faces
(b) prevent abutting slabs from separating along the longitudinal joint
(c) act as load transfer devices
(d) all of the above

232. The transverse joint may be a
(a) expansion joint (b) contraction joint (c) warping joint (d) all of these

233. To prevent the development of excessive compressive stresses in the concrete pavements as a result of expansion caused by increase in temperature, the type of transverse joint provided is
(a) construction joint (b) contraction joint (c) expansion joint (d) all of these

234. The maximum spacing of contraction joints in unreinforced concrete slabs for a slab thickness of 20 cm is
(a) 4.5 m (b) 10 m (c) 15 m (d) 20 m

235. The dowel bars are used in rigid pavements for
(a) resisting tensile stresses (b) resisting bending stress
(c) resisting shear stresses (d) transferring load from one portion to another

236. Transverse joints are provided at right-angles to the length of road.
(a) Yes (b) No

237. Transverse contraction joints relieve ..... stresses in concrete.
(a) compressive (b) tensile (c) shear

238. According to IRC recommendations, the width of transverse expansion joint should be ..... extending to full length of slab.
(a) 10 mm (b) 20 mm (c) 30 mm (d) 40 mm

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239. According to IRC recommendations, the maximum spacing of a transverse expansion joint in unreinforced concrete pavements for a slab thickness of 20 cm should be
(*a*) 4.5 m (*b*) 15 m (*c*) 27 m (*d*) 37 m

240. The transverse contraction joints in unreinforced concrete pavements are provided at more closer intervals than the expansion joints.
(*a*) Agree (*b*) Disagree

241. The joints, for forming satisfactory constituents of a concrete pavement, must
(*a*) continue to remain water-proof for all times
(*b*) not induce structural weakness in the pavement
(*c*) not result into deterioration in the riding quality of the pavement
(*d*) all of the above

242. The traffic volume is equal to
(*a*) $\frac{\text{traffic density}}{\text{traffic speed}}$ (*b*) $\frac{\text{traffic speed}}{\text{traffic density}}$
(*c*) traffic density × traffic speed (*d*) none of these

243. The average number of vehicles per day passing on a section of the road during a particular year, is called
(*a*) peak hour traffic (*b*) average daily traffic
(*c*) design hourly volume (*d*) any one of these

244. The volume of traffic, that would immediately use a new or an improved road when opened to traffic, is known as
(*a*) generated traffic (*b*) development traffic
(*c*) current traffic (*d*) all of these

245. The increase in traffic constitutes the
(*a*) normal traffic growth (*b*) generated traffic
(*c*) development traffic (*d*) all of these

246. The increase in traffic volume, due to the general increase in the number of transport vehicles from year to year, is known as
(*a*) normal traffic growth (*b*) generated traffic
(*c*) development traffic (*d*) existing traffic

247. For design purposes, average daily traffic should be considered.
(*a*) True (*b*) False

248. As per IRC recommendations, traffic volume study is carried out for rural roads for ..... days continuously during harvesting and lean season.
(*a*) 7 (*b*) 14 (*c*) 21 (*d*) 28

249. Which of the following statement is correct ?
(*a*) Seasonal cycle of traffic volume during April and November is usually near the annual average.
(*b*) Mid-summer seasonal cycle of traffic is the least of traffic volume.
(*c*) Mid-winter seasonal cycle of traffic is the highest of traffic volume.
(*d*) all of the above

250. Highway capacity is defined as the total number of vehicles
(*a*) that can be accomodated on a unit length of the road
(*b*) that can pass a given point in a unit period of time
(*c*) that can pass a given point in a specified period of time

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251. The highway capacity is expressed in passenger car unit (PCU). According to IRC, for a passenger car, the PCU is
(a) 1 (b) 2 (c) 3 (d) 4

252. Highway density is defined as the total number of vehicles
(a) that can be accomodated on a unit length of the road
(b) that can pass a given point in a unit period of time
(c) that can pass a given point in a specified period of time
(d) none of the above

253. The practical capacity of a highway is ..... that of possible capacity.
(a) same as (b) less than (c) more than

254. The traffic capacity of a highway is always ..... as compared to traffic volume.
(a) equal (b) more (c) less

255. The design capacity is also known as
(a) basic capacity (b) theoretical capacity
(c) practical capacity (d) possible capacity

256. The speed that a driver adopts on a highway depends on the
(a) physical characteristics of the highway and its surroundings
(b) weather conditions in the area
(c) speed limitations placed upon the vehicles
(d) all of the above

257. The instantaneous speed of a vehicle as it passes a point in a highway is known as
(a) design speed (b) running speed (c) spot speed (d) overall speed

258. The average speed maintained by a vehicle over a particular stretch of road, while the vehicle in motion, is known as
(a) design speed (b) running speed (c) spot speed (d) overall speed

259. The overall length of the vehicle effects the
(a) turning radii of the curve (b) time needed to overtake
(c) off-tracking of vehicle (d) all of these

260. The overall width of a vehicle determines the
(a) width of the pavement needed for the highway
(b) width of the bridges on the highway
(c) lengths of the valley curves at the underpasses in the city area
(d) height of the tunnels along the highway

261. The theoretical capacity of a highway depends upon the
(a) average length of the vehicles (b) average spacing of the moving vehicles
(c) either (a) or (b) (d) both (a) and (b)

262. The enoscope is used to determine
(a) running speed (b) spot speed (c) travel time (d) average speed

263. The theoretical capacity (C) of a highway (*i.e.* the number of vehicles passing any point in one hour per lane) is given by

(a) $C = \frac{100V}{S}$ (b) $C = \frac{500V}{S}$ (c) $C = \frac{1000V}{S}$ (d) $C = \frac{2000V}{S}$

where V = Design speed of vehicle in kmph, and
S = Centre to centre spacing of moving vehicles
= Reaction distance + Average length of a vehicle.

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264. The overall height of the vehicle determines the
(*a*) width of the pavement needed for the highway
(*b*) width of the bridges on the highway
(*c*) lengths of the valley curves at the underpasses in the city areas
(*d*) height of the tunnels along the highways

265. The length of the vehicles does not effect the widths of shoulders.
(*a*) Correct (*b*) Incorrect

266. The width of parking spaces is effected by the ..... of the vehicle.
(*a*) width (*b*) length

267. Weight of a vehicle affects
(*a*) passing sight distance (*b*) extra widening
(*c*) pavement thickness (*d*) width of lanes

268. The number of vehicles passing at a point on the highway in unit time is known as
(*a*) traffic capacity (*b*) traffic volume (*c*) traffic density (*d*) all of these

269. The maximum number of vehicles that can pass a given point on a lane or a roadway du one hour under the prevailing roadway and traffic conditions, is known as
(*a*) basic capacity of a traffic lane (*b*) possible capacity of a traffic lane
(*c*) practical capacity of a traffic lane (*d*) all of these

270. The prevailing conditions referred to under the possible capacity of a traffic lane are ide
(*a*) there are at least two lanes for the exclusive use to traffic moving in one direction
(*b*) all the vehicles move at the same uniform speed
(*c*) the widths of lanes, shoulders and clearances to vertical obstructions beyond the edg the traffic lane are adequate
(*d*) all of the above

271. The design capacity of the road may be defined as the
(*a*) practical capacity or a smaller value determined for use in designing the highway accommodate the design hourly volume (D.H.V.)
(*b*) basic capacity or a higher value determined for use in designing the highway accommodate the D.H.V.
(*c*) practical capacity or smaller value determined for use in designing the highway accommodate the average daily traffic (A.D.T.)
(*d*) basic capacity or a higher value determined for use in designing the highway accommodate the A.D.T.

272. The maximum number of vehicles that can pass a given point on a lane during one hour with reating unreasonable delay, is known as practical capacity.
(*a*) Yes (*b*) No

273. Which of the following statement is wrong ?
(*a*) Where the traffic flow is uninterrupted, the design capacity of a road is numerically eq to practical capacity.
(*b*) The design capacity, normally, is a term applied to existing highways.
(*c*) The practical capacity, normally, is a term applied to new highways.
(*d*) all of the above

274. Traffic engineering deals with the
(*a*) traffic operation (*b*) design and application of control devi
(*c*) analysis of traffic characteristics (*d*) all of these

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275. The traffic manoeuvre means
(a) diverging (b) merging (c) crossing (d) all of these

276. The purpose of traffic surveys is to
(a) know the type of traffic
(b) determine the facilities to traffic regulations
(c) design proper drainage system
(d) all of the above

277. The traffic census is carried out to study
(a) speed and delay (b) traffic volume
(c) road parking (d) origin and destination

278. The purpose of traffic signals is to
(a) provide an orderly movement of traffic
(b) reduce the frequency of accidents of some special nature
(c) control speed on the main highways
(d) all of the above

279. Traffic-actuated signals may be
(a) full traffic-actuated signals (b) semi-traffic actuated signals
(c) speed control signals (d) all of these

280. If the traffic detectors are used on all the approaches to an intersection, the control signal is known as
(a) full traffic-actuated signal (b) semi-traffic actuated signal
(c) speed control signal (d) all of these

281. A complete signal-time cycle constitutes
(a) red timing (b) yellow timing (c) green timing (d) all of these

282. Flashing yellow beam are sometimes employed as
(a) stopping signal (b) proceeding signal (c) warning signal (d) none of these

283. In large cities, especially in congested areas, one way streets are provided in order to
(a) reduce to a minimum the possible conflicting points
(b) increase the carrying capacity of the street
(c) eliminate, at night, the glare from head lamps of opposite vehicles
(d) all of the above

284. The parking of vehicles is usually preferred at 75° to the aisles.
(a) True (b) False

285. In case of multi-lane road, overtaking is generally permitted from
(a) left side (b) right side (c) both sides (d) any one of these

286. At a road junction, ... cross conflict points are severe if both are two-way roads.
(a) 5 (b) 7 (c) 9 (d) 16

287. The factor which governs the installation of signals, is
(a) minimum vehicular volume from different streets at an intersection
(b) minimum pedestrian volume of an intersection
(c) need for interruption of high volume continuous traffic on main street
(d) all of the above

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288. 'Dead slow' is a
(a) regulatory sign (b) warning sign (c) informatory sign (d) none of the

289. 'Level crossing' is a
(a) regulatory sign (b) warning sign (c) informatory sign (d) none of the

290. 'End of speed limit' is a
(a) regulatory sign (b) warning sign (c) informatory sign (d) none of the

291. A road sign is generally installed above the ground at a height of
(a) 2.75 m to 2.80 m (b) 2.95 m to 3.00 m (c) 3.15 m to 3.5 m (d) more than 3

292. The maximum number of vehicles can be parked with
(a) parallel parking (b) right angle parking
(c) 45° angle parking (d) 75° angle parking

293. The colour of light used for visibility during fog is
(a) red (b) yellow (c) green (d) white

294. The length of the side of warning sign boards of roads is
(a) 30 cm (b) 45 cm (c) 60 cm (d) 75 cm

295. The most efficient traffic signal system is
(a) simultaneous system (b) alternate system
(c) flexible progressive system (d) simple progressive system

ANSWERS

1. (b)	2. (c)	3. (a)	4. (a)	5. (a)	6. (c)
7. (a), (b)	8. (b)	9. (a)	10. (d)	11. (c)	12. (b)
13. (b)	14. (c)	15. (b)	16. (a)	17. (b)	18. (c)
19. (a)	20. (a)	21. (a)	22. (d)	23. (a)	24. (a)
25. (d)	26. (c)	27. (a)	28. (b)	29. (d)	30. (b)
31. (b)	32. (a)	33. (d)	34. (c)	35. (c)	36. (b)
37. (c)	38. (a)	39. (d)	40. (a)	41. (c)	42. (d)
43. (b)	44. (a)	45. (d)	46. (a)	47. (b)	48. (d)
49. (d)	50. (a)	51. (d)	52. (c)	53. (a)	54. (a)
55. (a)	56. (a)	57. (c)	58. (b)	59. (a)	60. (b)
61. (a)	62. (d)	63. (a)	64. (d)	65. (d)	66. (a)
67. (b)	68. (b)	69. (d)	70. (b)	71. (c)	72. (a)
73. (a)	74. (c)	75. (a)	76. (c)	77. (a)	78. (c)
79. (d)	80. (b)	81. (b)	82. (c)	83. (c)	84. (b)
85. (c)	86. (b)	87. (b)	88. (a)	89. (a)	90. (d)
91. (a), (b)	92. (d)	93. (a)	94. (a)	95. (a)	96. (a)
97. (d)	98. (b)	99. (a)	100. (c)	101. (b)	102. (c)
103. (d)	104. (d)	105. (d)	106. (a)	107. (a)	108. (b)
109. (a)	110. (b)	111. (b)	112. (b)	113. (c)	114. (d)
115. (a)	116. (a)	117. (b)	118. (a)	119. (a)	120. (b)

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121. (b) 122. (d) 123. (a) 124. (d) 125. (b) 126. (b)
127. (b) 128. (a) 129. (c) 130. (c) 131. (c) 132. (d)
133. (a) 134. (d) 135. (d) 136. (d) 137. (a) 138. (c)
139. (a) 140. (a) 141. (a) 142. (b) 143. (d) 144. (a)
145. (c) 146. (d) 147. (b) 148. (c) 149. (a) 150. (d)
151. (d) 152. (a) 153. (b) 154. (d) 155. (c) 156. (b)
157. (d) 158. (b) 159. (d) 160. (a) 161. (b) 162. (d)
163. (c) 164. (c) 165. (b) 166. (a) 167. (a) 168. (b)
169. (d) 170. (a) 171. (b) 172. (d) 173. (d) 174. (a)
175. (b) 176. (b) 177. (c) 178. (c) 179. (a) 180. (b)
181. (a) 182. (c) 183. (c) 184. (a) 185. (b) 186. (a)
187. (c) 188. (b) 189. (a) 190. (d) 191. (b) 192. (a)
193. (c) 194. (d) 195. (c) 196. (a) 197. (c) 198. (a)
199. (d) 200. (C), (A), (D), (B) 201. (d) 202. (d) 203. (a)
204. (c) 205. (b) 206. (a) 207. (b) 208. (d) 209. (b)
210. (d) 211. (b) 212. (d) 213. (d) 214. (b) 215. (b), (c)
216. (c) 217. (b) 218. (a) 219. (c) 220. (b) 221. (c)
222. (c) 223. (a) 224. (b) 225. (d) 226. (b) 227. (d)
228. (b) 229. (b) 230. (b) 231. (d) 232. (d) 233. (c)
234. (a) 235. (d) 236. (a) 237. (b) 238. (b) 239. (d)
240. (a) 241. (d) 242. (c) 243. (b) 244. (c) 245. (d)
246. (a) 247. (b) 248. (a) 249. (a) 250. (b) 251. (a)
252. (a) 253. (b) 254. (b) 255. (c) 256. (d) 257. (c)
258. (b) 259. (d) 260. (a), (b) 261. (d) 262. (b) 263. (c)
264. (c), (d) 265. (b) 266. (a) 267. (c) 268. (a) 269. (b)
270. (d) 271. (a) 272. (a) 273. (a) 274. (d) 275. (d)
276. (d) 277. (c) 278. (d) 279. (d) 280. (a) 281. (d)
282. (c) 283. (d) 284. (a) 285. (c) 286. (d) 287. (d)
288. (a) 289. (b) 290. (c) 291. (a) 292. (a) 293. (b)
294. (b) 295. (c)

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Railway Engineering

10.1 Introduction

The modern steam engine was invented by George Stephenson of England in 1814. He succeeded in running the first train of the world on 27th September, 1825 between Stockton and Darlington in the country of Durham. The first train in India was run on 16th April, 1853 between Mumbai (Bombay) and Thane, with four coaches and one steam locomotive. This train took four hours to cover a distance of approximately 34 kilometres. The Indian Railways (Under the Central Government) have been divided into *sixteen zonal divisions, for the purpose of effective administration. Each zonal railway is headed by its General Manager, assisted by the various departmental heads. There is a Research, Design and Standard Organisation (RDSO) with its headquarters at Lucknow. There are three production units which not only meets the demand of the Indian Railways but have started exporting wagons and locomotives. These units are

(*a*) Chitranjan Locomotive Works which started production in 1950.

(*b*) Integral coach factory at Permabur (Chennai) which started production in1955.

(*c*) Diesel Locomotive Works at Varanasi which started production in 1964.

Note : The railway system in India is the biggest in Asia and the second longest in the world under a single management.

10.2 Railway Gauges

The clear distance between inner faces of two rails near their tops is called a *gauge*. The choice of a gauge depends upon the intensity of traffic, nature of the country and speed of the train.

The various gauges in Indian Railways are as follows :

(*a*) *Broad gauge* (*B.G.*). The broad gauge is 1.676 metres wide. This type of gauge is adopted for main cities and routes of maximum intensities. In India, the speed of locomotive on broad gauge is restricted between 96 and 120 kmph.

(*b*) *Metre gauge*. The metre gauge, as the name implies, is one metre wide. This gauge is adopted for undeveloped areas. The speed of locomotive on the metre gauge track is restricted upto 80 kmph.

(*c*) *Narrow gauge*. The narrow gauge is 0.762 metre wide. This gauge is adopted for hilly areas and thinly populated areas.

(*d*) *Loading gauge*. The gauge representing the maximum width and height upto which a railway vehicle may be built, is known as loading gauge. In India, the maximum height of a loaded goods

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*The sixteen zonal divisions with their headquarters are as follows :
1. Central Railway (Mumbai V.T); 2. Western Railway (Mumbai, Central); 3. Eastern Railway (Kolkata); 4. Northern Railway (New Delhi); 5. Southern Railway (Chennai); 6. North Eastern Railway (Gorkhpur); 7. North Eastern Frontier Railway (Guwahati); 8. South Central Railway (Secundrabad); 9. South Eastern Railway (Kolkata); 10. North Central Railway (Allahabad); 11. North Western Railway (Jaipur); 12. East Coast Railway (Bhubaneshwar); 13. East Central Railway (Hazipur); 14. South Western Railway (Bangalore); 15. West Central Railway (Jabalpur); 16. South East Central Railway (Bilaspur).*

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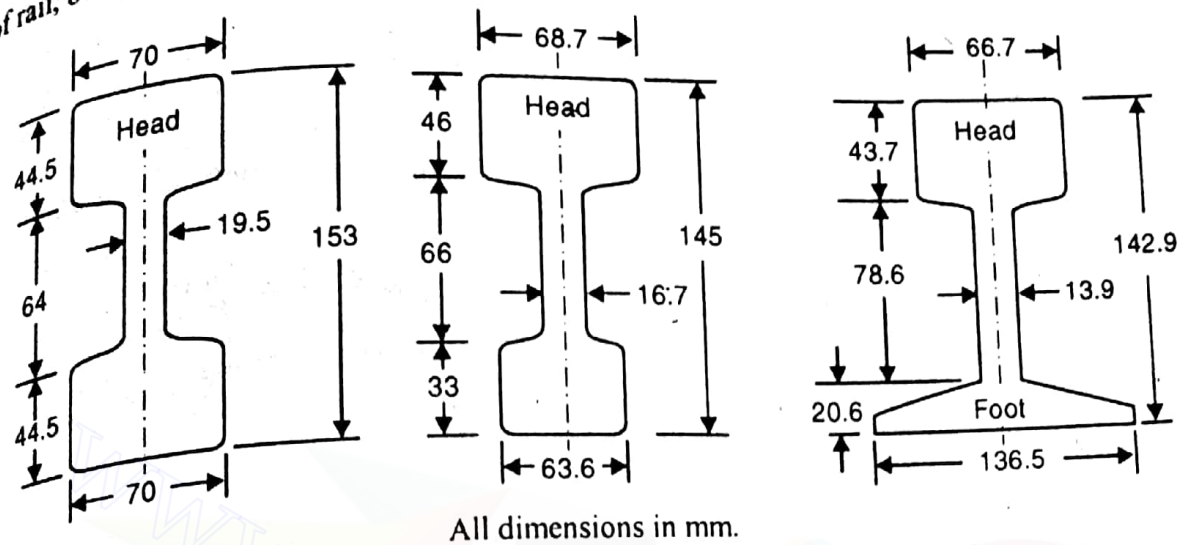
Railway Engg.

wagon, for a broad gauge track, is fixed as 4.72 metres and for a metre gauge track as 3.43 metres.

10.3 Rail Sections

The rails are continuous steel sections laid along two parallel lines over sleepers. They form a suitable track for the train and should be strong enough to bear the stresses developed in the track due to wheel loads, lateral and other forces as well as variation due to temperature changes. The rail section is designated by the mass per metre length. The rail sections generally used in Indian Railways are as follows :

1. *Double headed rail.* The double headed rail was first designed in Indian railways. In this type of rail, both heads of the rail section are kept equal, as shown in Fig. 10.1 (*a*).



(*a*) Double headed rail. (*b*) Bull headed rail. (*c*) Flat footed rail.

All dimensions in mm.

Fig. 10.1

2. *Bull headed rail.* In this type of rail, as shown in Fig.10.1 (*b*), the top head is made heavier and the lower head is provided with only the required quantity of steel to bear the stresses caused by the moving wheels. The length of the bull head rail varies from 9.2 metres to 18.3 metres and its mass varies from 29.8 kg to 48.6 kg per metre length. These rails maintain better alignment and can be removed and replaced easily.

3. *Flat footed rail.* In this type of rail, as shown in Fig. 10.1 (*c*), the top head is made slightly less than that of bull headed rail and the bottom is made flat footed. This rail was invented by Charles Vignole. These rails are cheaper and are stronger in every direction than bull headed rails for the same cross -sectional area. It is mostly used in Indian railways because of its better rigidity and stiffiness to resist lateral and vertical forces. It is simple in fixing to the sleepers as neither chairs nor keys are required.

Note : In order to assess the suitability of the rail section, the mass of the rail in tonnes is linked to that of locomotive in tonnes to an empirical value of 1 / 510. For example, if the mass of the locomotive is 23 tonnes, then the corresponding section will be 23 × 1000 / 510 = 45kg/m.

The following table shows the standard rail sections on Indian Railways.

S.No.	*Particulars of gauge*	*Type of rail section*	*Mass (kg/m)*
1.	Broad gauge	55 R	55
		45 R	45
2.	Metre gauge	35 R	35
		30 R	30
		25 R	25
3.	Narrow gauge		

10.4 Length of Rail

Indian Railway have adopted the following lengths of rails :

(*a*) For broad gauge, the standard length of the rail is 12.8 metres, and

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(*b*) For metre gauge, the standards length of the rail is 11.89 metres.

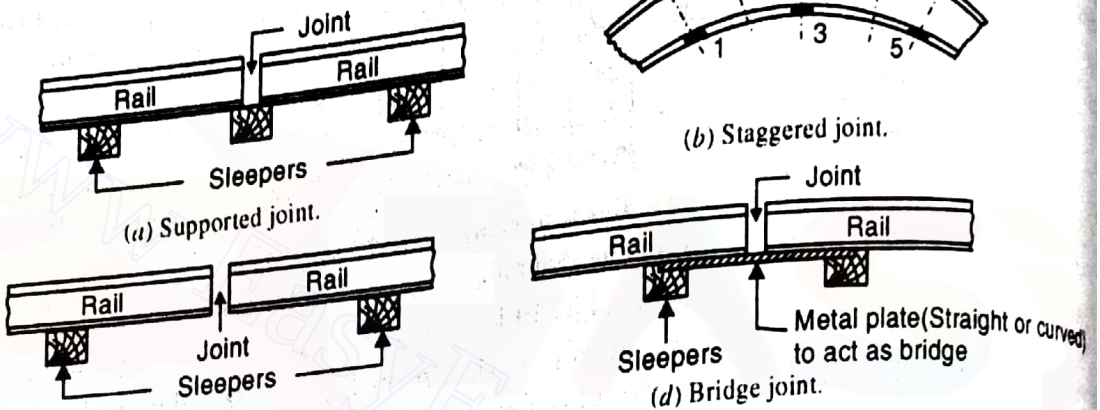
The standard rail lengths adopted in America, England, France and Germany are 11.89 m, 12 m, 24 m and 30 m respectively.

10.5 Rail Joints

A standard rail joint should satisfy the following requirements :

1. It should be as strong as other portion of the track.
2. It should have just enough rail gap between the two rails.
3. It should have the same elasticity as the other portion of the track.
4. It should provide facility for removal and replacement.
5. The ends of the joint should not get battered.
6. It should provide for expansion.

The various types of joints used on Indian railways are supported joint, staggered joint, suspended joint and bridge joint. These joints are shown in Fig. 10.2.



(*a*) Supported joint.

(*b*) Staggered joint.

(*c*) Suspended joint.

(*d*) Bridge joint.

Fig. 10.2

The length of the rails can be considerably increased by welding the rail joints. The main purpose of welding rails are as follows :

(*a*) To reduce the number of joints thereby saving construction and maintenance cost.

(*b*) To increase the length of rail.

(*c*) To build up the worn - out parts of points and crossings for increasing their life.

(*d*) To build up the battered or worn heads of rail ends.

(*e*) To build those portions of rail ends which are burnt due to slipping of wheels at the time applying brakes.

10.6 Coning of Wheels

The art of providing an outward slope of 1 in 20 to the treads of wheel is known as *coning of wheels*. It is made to prevent the lateral movement of the axle and wheels. It also prevents the damage of the inside edge of the rails. Due to coning of wheels, the pressure of wheels is always on the inner edge of the rail. It is provided for smooth running of the train.

10.7 Tilting of Rails

The placing of rails of the track at an inward slope of 1 in 20 is known as *tilting of rails*. The main purpose of this treatment is to reduce wear on the inside edges of the rails in a track.

10.8 Hogging of Rails

The loose packing under the rails and loose fish plates cause the rail ends to bent down and deflect. This is known as *hogging of rails*. This is rectified either by changing the rails, worn ends improved by welding or by dehogging machines.

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10.9 Buckling of Rails

When the rails get out of their original position due to insufficient expansion joint gap, the phenomenon is known as *buckling of rails*. This is prevented by providing expansion joints, avoiding excessive tightening of the joint and properly lubricating contact surface between the fish plates and the rails.

10.10 Creep of Rails

The longitudinal movement of the rails in a permanent track due to speedy rolling stock is known as *creep of rails*. The principal causes of creep are as follows :

1. When the wheel passes over a rail joint, the impact of wheels results in the depression of the rail which causes creep in the forward direction (*i.e.* positive creep).
2. The train wheels causes slight depression on the table of the rails due to their own weight, forming lifts and crests immediately at the rear or in front. This action pushes the rail forward resulting creep in the direction of motion.
3. The braking action tends to push the rail forward resulting creep in the forward direction.
4. The insufficient and defective packing of ballast causes creep.
5. The steep gradients cause creep in the downward direction.

The common effects of creep are as follows :

(*a*) The refixing of rails is difficult.
(*b*) The gauge and alignment of the track gets disturbed.
(*c*) The rail joints get opened and ballast is forced out of place.
(*d*) The points and crossings get pulled or pushed and it is very difficult to keep them to correct alignment.
(*e*) The operation of switches become difficult.

10.11 Wear of Rails

The flow of rail metal due to abnormally heavy loads is called *wear of rails*. In India, the permissible limit of rail wear is 5 percent by weight. Though coning of wheel and tilting of wheels reduce the rail wear to a great extent, yet the following precautions must the employed for reducing wear and prolonging the life of rails :

1. The rail should be replaced when it loses its weight more than 5% of its oriented weight.
2. The expansion gaps and rail joints should be minimum.
3. The battered ends should be welded at proper time.
4. The track should be properly maintained with special attention to the joints.
5. The ballast under joints should be packed properly and fish bolt be tightened, to reduce wear at the ends.
6. The inner faces of the outer rail should be lubricated.
7. The heavy mineral oil should be applied on the top of rails to minimise the corrosion of rail metal.

10.12 Fish Plates

The *fish plates are a pair of plates of designed section, which are used in rail joints to maintain the continuity of rails and to provide expansion and contraction of the rails due to temperature variation. These plates bear vertical and lateral stresses without distortion and resist wear.

10.13 Sleepers

The members which are laid transverse to the rails, to support the rails and to transfer the loads from the rails to the ballast, are called *sleepers*. The main functions of sleepers in a railway track are as follows :

1. To support the rails firmly and evenly.

* See also Art. 10.17

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2. To keep the two rails at correct gauge and level.
3. To distribute the load coming on the rails to the ballast.
4. To act as an elastic medium.
5. To provide stability to the permanent way.

The requirements for a good sleeper are as follows :

(*a*) It should provide sufficient bearing area for the rail and the ballast.
(*b*) The rails should be easily fixed and taken out from the sleeper without moving them.
(*c*) It should be strong enough to withstand bending stresses.
(*d*) It should be economical in respect of initial cost and subsequent maintenance.
(*e*) It should be capable of maintaining alignment of track and level of ballast.

10.14 Types of Sleepers

The sleepers may be classified as

(*a*) Wooden sleepers; (*b*) Steel sleepers; (*c*) Cast iron sleepers ; and (*d*) R.C.C. sleepers.

The *wooden sleepers* made of teak wood are largely used. The life of wooden sleepers (which may be taken as 12 years) depends upon the quality of timber used, ability to wear decay, resistance to white ants and resistance to atmospheric action. The wooden sleepers require adzing to give slope of 1 in 20. The standard sizes of wooden sleepers are given in the following table

Gauge	Length (*m*)	Width (*mm*)	Thickness (*mm*)
Broad gauge	2.74	250	130
Metre gauge	1.83	200	110
Narrow gauge	1.52	150	100

The suitability of a particular sleeper in respect of its strength is checked from the Composite Sleeper Index (CSI) given by the following formula,

$$CSI = \frac{S + 10H}{20}$$

where S represents the strength of timber at 12% moisture content, and H represents the hardness number at 12% moisture content. The minimum composite sleeper index for wooden sleepers used on over bridge and cross overs are 1455 and 1352 respectively.

The *steel sleepers* cover 30% of the track on Indian railways. These sleepers consist of steel troughs made out of about 6 mm thick steel sheets with its both ends bent down in order to prevent running of ballast. A cant of 1 in 20 is provided towards the centre. In order to fix the rails on steel sleepers, lugs or jaws are pressed out of metal and keys are used. The holes are made in sleepers and clips, bolts and four keys are used for fixing the rails to prevent the change in gauge and creep. The main disadvantage of steel sleepers is that they get rusted very quickly and lugs get sometimes cracked and broken.

The *cast iron sleepers* are most popular on Indian railways. They cover about 50% of the rack. The main disadvantage of cast iron sleeper is that they are liable to crack and break. These sleepers may be classified as pot or bowl sleepers, plate sleepers, box sleepers, CST-9 sleepers and duplex sleepers. The *pot sleepers* consist of two oval shaped bowls (or pots inverted) under each rail and connected together by a tie - bar (2.62 m × 50 mm × 20 mm) with the help of gibs and cotter. The gib and cotter for connecting pot sleepers are so casted that by interchanging them, gauge is slackened by 3.18 mm. The rail is kept on the top of the rail seat with a cant of 1in 20 and is held in position by key. The total effective area of the pot sleepers is 0.46m^2 which is equal to the effective bearing area of a wooden sleeper. The mass of a cast iron pot sleeper is 113.4 kg. Two holes are provided in each

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for inspection and packing of ballast.

The plate sleepers consist of two rectangular plates of size 851 × 254mm laid parallel to the rails. The plate is provided with projecting ribs in the bottom in order to provide a grip in the ballast and to check the lateral movement of the sleeper. In order to increase the strength of plate sleepers, the stiffeners are provided at the top of the plate.

The box sleepers are similar to plate sleepers with a difference that the box is provided on the top of each plate for holding the rails. It is however obsolete.

A CST-9 sleeper is a combination of pot, plate and box sleeper.

The reinforced cement concrete (*R.C.C.*) *sleepers* are used in railways due to their heavy mass which improves the track modulus. It has the capacity to maintain the gauge properly and suitability for track circuiting. It has long life and free from fire hazard.

10.15 Sleeper Density

The number of sleepers used per rail length on the track is known as *sleeper density*. The number of sleepers used for rail varies from $(n + 2)$ to $(n + 6)$, where n is the length of rail in metres. In India, the sleeper density provided is 18 sleepers per rail length. The sleeper density on main lines is increased due to fast moving trains such as Rajdhani Express.

10.16 Ballast

A layer of broken stones, gravel, moorum or any other gritty material, packed below and around the sleepers, so that the load from the sleepers may be transmitted to the formation, is known as *ballast*. The chief functions of providing ballast in the railway track are as follows :

1. It uniformly distributes the load from sleepers over a large area of formation.
2. It holds the sleepers in position during the passage of moving trains.
3. It provides elasticity and resilience to the track.
4. It provides a proper drainage to the track and keeps the sleepers in dry conditions.
5. It prevents lateral, longitudinal and vertical movement of the track.
6. It provides proper super-elevation to the outer rail on curves.

Notes : (*a*) The size of ballast used on Indian railways for wooden sleepers is 50 mm and for steel sleepers, it is 38 mm.

(*b*) The size of ballast used on Indian railways under points and crossings is 25 mm.

(*c*) The standard width of ballast for broad gauge track on Indian railways is 3.35 metres and for metre gauge track, it is 2.3 metres.

(*d*) The minimum depth of ballast for broad gauge track on Indian railways is 250 mm for metre gauge track, it is 200 mm.

(*e*) The quality of stone ballast required per metre tangent length for broad gauge is $1.11 m^3$ and for metre gauge, it is $0.767 m^3$.

10.17 Railway Fastenings and Fixtures

The common rail fastenings and fixtures are as follows :

1. *Fish plates*. These rail fastenings are used to hold the adjoining ends of rails in correct horizontal and vertical planes. The fish plates should be designed for bearing the vertical and lateral stresses, allowing free contraction and expansion of rails and for easy renewal and

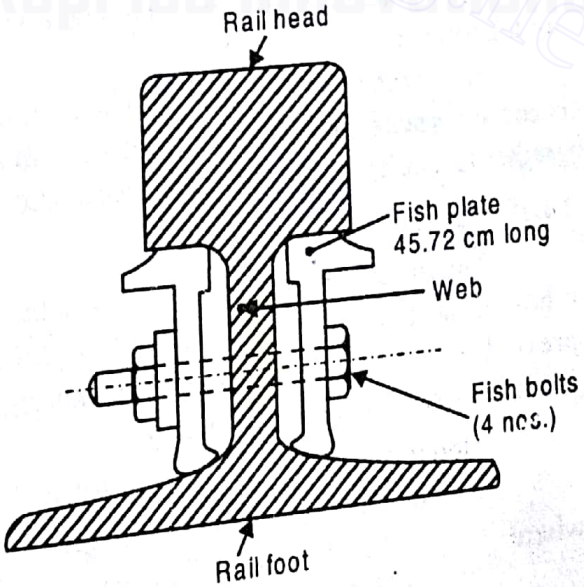

Fig. 10.3

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replacement of rails. The fish plates are made of steel and fit the web of the rail section (under... rail head and top of rail foot) of the flat footed rails as shown in Fig. 10.3.

The length of each fish plate is 45.72 cm. On Indian railways, each pair of fish plates... connected to the rails by means of four fish bolts made of high carbon steel. The fish bolts... 31.75 mm diameter.

Note : In order to fix bull headed rails and double headed rails, rail chairs are used. These are generally... of cast iron and has a mass of about 22 kg.

2. *Bearing plates.* These are used to fix the flat footed rails on wooden sleepers. The... purpose of using bearing plates is to distribute the pressure over wider area and to eliminate... adzing of wooden sleepers. It also prevents the widening of gauge of curves.

Note : The bull - headed and double headed rails do not require bearing plates for fixing.

3. *Spikes.* The spikes commonly used to fix the rails on wooden sleepers are dog spikes... round spikes and screw spikes. The overall depth of a dog spike is 12.06 cm. The round spikes are... not used for fixing flat footed rails on wooden sleepers. The screw spikes have more lateral rigidity... than dog spikes. These are just like coach screws. The holding power of screw spikes is less than... spikes and takes more time in driving and extraction from the sleeper as compared to dog spikes. The... screw spikes do not spoil the sleeper. These spikes are not popular on Indian railways.

10.18 Gradient

The rate of rise and fall provided to the formation of a rail track is known as *gradient*. The... various types of gradients provided on railway tracks are as follows :

1. *Ruling gradient.* The maximum gradient, to which a railway track may be laid in a particular... section, is known as ruling gradient. In India, ruling gradient provided are 1 in 150 to 1 in 200... plains and 1 in 100 to 1 in 150 in hilly terrain. Since additional power is required to pull the train... along curves, therefore, along curves some compensation has to be provided in the ruling gradient... failing which the speed of the train have to be reduced. In order to avoid lowering of speed of a train... a reduction is carried out in the gradient of the track. Such a reduction of gradient is termed as *grade... compensation*. On Indian railway, the grade compensation of 0.04% per degree is provided on broad... gauge curves, 0.03% per degree on metre gauge curves and 0.02% per degree on narrow gauge curves.

2. *Pusher gradient.* The gradient where extra engine is required to push the train, is known... as pusher gradient. It is steeper than ruling gradient. The example of such a gradient is found on... broad gauge track in Ghat section between Mumbai and Pune where a gradient of 1 in 37 is provided.

3. *Momentum gradient.* The rising gradient which is followed by a falling gradient and... along which the train climbs easily due to momentum gained by them over the falling gradient, is... known as momentum gradient. The track section along which the gradient is provided is kept as one... signal zone.

4. *Station yard gradient.* The minimum gradient provided on station yards for easy drainage... is known as station yard gradient or minimum gradient. On Indian railways, the maximum and minimum... gradient recommended for station yards are 1 in 400 and 1 in 1000 respectively.

10.19 Superelevation

The difference in the elevations of the top of the outer raised rail and the top of the inner rail... a horizontal curve of a railway track, is called *superelevation* or *cant*. It is provided on curves... prevent wear and tear of rails and for smooth riding. The equilibrium superelevation or cant (S) to be... provided on rails is determined by

$$S = \frac{V^2 G}{gR}$$

where

V = Speed of train in m/s,

G = Gauge in metres,

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R = Radius of curve in metres, and

g = Acceleration due to gravity in m/s^2.

The maximum limit of superelevation by Indian railways is as follows :

(*a*) On broad gauge - 16.61 cm; (*b*) On metre gauge - 10.16 cm; and (*c*) On narrow gauge - 7.62 cm.

10.20 Cant Deficiency

The difference between the equilibrium cant necessary for the maximum permissible speed on the curved track and the actual cant provided, is known as *cant deficiency*. It causes discomfort to passengers and stresses on fastenings. The maximum cant deficiency prescribed on Indian railways for speeds upto 100 kmph is as follows :

(*a*) On broad gauge - 7.6 cm

(*b*) On metre gauge - 5.1 cm

(*c*) On narrow gauge - 3.8 cm

10.21 Negative Superelevation or Cant

When the branch line on a curve joins the main line and the curvatures of the lines are contrary, it is not possible to provide the superelevation on the main line required for design speed. In order to overcome this difficulty, the outer rail of the turnout or branch line is purposely kept at lower level than the inner rail. The difference of the level of the inner rail (higher) and outer rail (lower) of the turnout is called *negative superelevation* or *cant*.

In Fig. 10.4, the main line *ABCD* is such that the portion *AB*, which forms the outer rail, is higher than the portion *CD*, which represents the inner rail. Since *CF* is the outer rail, it should be higher than the inner rail *AE*.

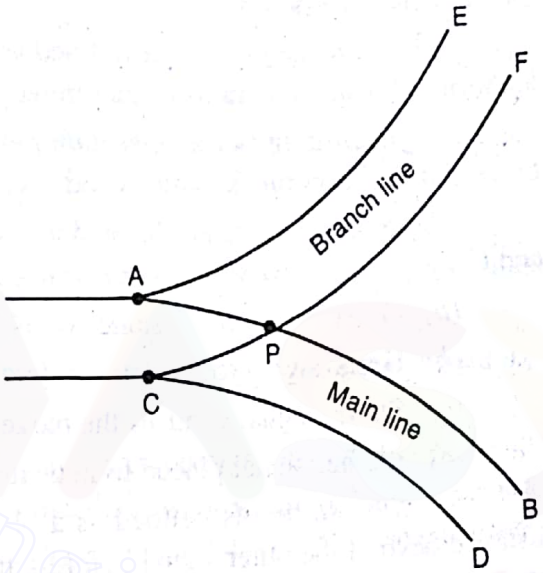

Fig. 10.4

10.22 Curves

The purpose of providing curves on railway track is to connect important points as well as to avoid obstructions. The curves on railways may be horizontal and vertical curves. A curve is represented by the degree of the curvature subtended by a chord of 30.48 metres. If R is the radius of curve, then the degree of curvature (D) is given by

$$D = \frac{30.48 \times 360}{2\pi \times R} = \frac{1746.5}{R}$$

The horizontal curves may be classified as simple curve, compound curve, reverse curve and transition curve (also called easement curve). According to railway code formula, the length of transition curve (L) is given by

$$L = 4.4\sqrt{R}$$

where R = Radius of simple curve in metres.

The minimum length of the transition curve (L) is given by

$$L = \frac{S\,V}{198}$$

where S = Superelevation in mm, and

V = Maximum permissible speed in kmph.

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The maximum permissible speed (V) of trains for good order track on transition curves is given by

$$V = 4.4\sqrt{R-70}, \text{ for broad gauge and metre gauge}$$

$$= 3.65\sqrt{R-6}, \text{ for narrow gauge}$$

The maximum permissible speed, calculated from the above relation, for non - transition curves is reduced by 20%.

10.23 Plate Laying

The operation of laying out sleepers on the compacted formation is known as *plate laying*. The methods used for plate laying are as follows :

1. Tramline method or Side method, 2. Telescopic method, and 3. American method.

The telescopic method of plate laying is extensively used in Indian railways.

10.24 Railway Station

A railway station may be defined as the defacto headquarters of the running train without the authority of which the trains cannot move. The Indian railway stations are classified as follows :

1. *According to the operation performed.* According to this, the stations are classified as block stations, non-block stations and special class stations.

The block stations are located at the end of the block. These stations are divided into *A*, *B* and *C* classes. *A-class stations* are equipped with the following signals :

(*a*) Outer signal at a distance of 540 m for broad gauge and 400 m for metre gauge.

(*b*) Home signal located at the door of the station.

(*c*) Starter signal controls the movement of the train which is to start.

(*d*) Warner signal placed to indicate vicinity of home signal.

B - class station is defined as a block station where track has to be clear upto a specified distance beyond the outer signal before a train is permitted to approach the station. These stations have an outer signal and home signal.

C - class station is only a block station for controlling movement of the train. It has only home signal and a warner signal. Normally trains do not stop at these stations.

The *non - block stations* do not have any signals and are known as *D- class stations* or *flag stations*. They may have crossing facilities.

The *special class stations* do not come under *A*, *B*, *C* and *D* class.

2. *According to the function.* According to this, the stations are classified as terminal station, junction station and way - side station.

The *terminal station* is a station where a railway line or a branch line terminates. The additional facilities provided at this station are engine reversing function, sidings and examination pit.

The *junction stations* provide crossings for trains, overtaking by fast trains, facility for booking of passengers and goods.

The *way - side station* may be on a single line or double line, depending upon the importance of the station. These stations are provided with proper arrangements for crossing of an up and a down train or for overtaking a slower train by a faster train.

10.25 Platform

The platforms are classified as passenger platforms and goods platforms. The height of the passenger platform above the rail surface should be 76.2 cm to 83.8 cm for broad gauge, 30.5 cm to 40 cm for metre gauge and 22.9 cm to 40.6 cm for narrow gauge. The distance between the centre line of the track and the platform should not be less than 1.676 metres for broad gauge, 1.346 metres

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for metre gauge and 1.219 metres for narrow gauge. The width of platform, under no circumstances, should be less than 4 metres. The length of the platform should be more than the longest train which is moving on that section. It should not be less than 300 metres for broad gauge. It may be noted that Kharagpur on broad gauge line of South - Eastern railway has a length of 861 metres (which is the longest platform in the whole world) while Sonpur in North - Eastern railway has the longest platform of length 736 metres on metre gauge track.

The goods platforms are used for loading and unloading of goods from the wagons. The height of the goods platform above the rail surface should be 107 cm for broad gauge, 69 cm for metre gauge and 61 cm for narrow gauge. The minimum horizontal distance between the centre line of the track and any structure or building (in metres) for passenger and goods platform are given below :

Platform	*Broad gauge*	*Metre gauge*	*Narrow gauge*
Passenger	5.33	5.00	4.88
Goods	4.72	3.18	3.05

10.26 Railway Yards

The system of tracks laid usually on a fairly level ground for receiving, storing, sorting, making uptrains, and despatch of vehicles, is called a *railway yard*. These are classified as follows :

1. Passenger yards, 2. Goods yards, 3. Marshalling yards, and 4. Locomotive yards.

The passenger platform is used as a *passenger yard*. The main purpose of this is to provide facilities for the safe movement of passengers and passenger bogies.

The goods platform is treated as a *goods yard*. It is provided for receiving, loading and unloading the goods and for the movement of goods vehicle.

The *marshalling yard* is required to separate goods wagons received from various centres in the order of stations to which they are to be sent. An ideal marshalling yard should have reception siding, sorting siding and departure siding. The number of sidings required for reception and departure sidings depends upon the following factors :

(*a*) The maximum number of wagons to be marshalled at a time.

(*b*) The time required to marshal each wagon.

(*c*) The intensity of traffic on main line.

(*d*) The time required for inspection of wagons of incoming trains for locating defects.

The marshaling yard may be flat yard, hump yard and gravity yard.

The *locomotive yards* are provided for cleaning, repairing, servicing, watering, oiling etc. of locomotives. These are generally constructed on the same side as the marshalling yard.

10.27 Important Terms Used in Rails

The following are some important terms used in rails :

1. *Triangle*. It is a device used for changing the direction of engine.

2. *Turn table*. It is also used for changing the direction of engine. The level of rails on the turn table is kept the same as that of the track radiating from the edge of the pit.

3. *Traverser*. Its function is to shift the position of wagons, coaches and locomotives side ways. They provide an arrangement for transfer of engine and vehicle from one track to a parallel track.

4. *Buffer stop*. It is provided to prevent the vehicles from moving beyond the end of rails at terminals or siding.

5. *Scotch block and sand hump*. These are used for preventing the movement of vehicles beyond the dead end sidings.

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10.28 Points and Crossings

The arrangement which are made for directing the trains from the main lines to branch lines to cross over from one track to another track without any obstruction are called *points* and crossings. The points are operated for diverting trains from one track to another while crossings provide required gap between the rails to be crossed to enable wheel flanges pass through gaps.

The combination of points and crossings which enables the trains to be diverted from one track to another track or to siding, is known as a *turn out*. The track from which train diverts, is known as a main line. A turnout may be a right handed or left handed, depending upon whether the train from the main track is diverted to the right or left in the facing direction. The simplest arrangement of points and crossings is usually known as a *split - switch*. It makes one turnout rail and one main rail movable. It gives more lateral rigidity to the turnout and can be used by the trains moving at high speeds. The type of turn out in which both the turn out rails are movable, is known as *Wartow switch*.

The technical terms used in points and crossings are as follows :

1. *Stock rails*. These are the fixed rails of the track against which tongue rails fit.
2. *Tongue rails*. These are the tapered rails which moves and fit snugly against their respective stock rails. The tongue rails are also commonly known as *switch rails* or *point rails*.
3. *Switch angle*. It is the angle subtended between the gauge faces of the stock rail and the tongue rail.
4. *Throw of switch*. It is the distance between the running face of the stock rail and the toe of the tongue rail. On Indian railways, it is specified as 95 mm for broad gauge and 89 mm for metre gauge tracks.
5. *Heel block*. It is a cast iron block to which tongue rail and lead rails are both bolted to their respective stock rail.
6. *Heel clearance or heel divergence*. It is the distance between the running edge of the stock rail and the switch rail at the switch heel. It is always measured perpendicular to the stock rail. The heel clearance (which is equal to the sum of the width of rail top and flange way clearance) recommended by Indian railways is 133 mm for broad gauge tracks.
7. *Flange way clearance*. It is the distance between the adjacent faces of the stock rail and the check rail. Its minimum value is 60 mm.
8. *Check rail*. These are the rails which are provided to guide the wheel flanges, while the opposite wheel is jumping over the gap in front of the nose and thus prevents side ways movement.
9. *Lead rails*. These are the rails which lead the train from the heels of the tongue rail to the toe of the crossing.
10. *Point rail*. It is the rail of the main track which forms the one side of nose of crossing.
11. *Nose of crossing*. It is the point of intersection of the running faces of the splice rail and the point rail.
12. *Splice rail*. It is the rail of the branch line which meets the point rail at the nose of crossing.
13. *Angle of crossing*. It is the angle between the point rail and the splice rail of a crossing.
14. *Wing rails*. It is the bent up length of lead rails in front of the nose of crossing, which are provided for channelising the wheel flanges to their proper routes.
15. *Facing points*. These are such points in the track where the train first pass over switches and then over crossings.
16. *Trailing points*. These are such points in the track where the train first pass over the crossings and then over the switches. The trailing points are on the opposite side of the facing points.
17. *Flare*. It is the gradual widening of the flange way formed by bending or splaying the ends of a check rail or wing rail away from the running faces of the adjacent rails.

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10.29 Crossings

The arrangement made at the intersection of two rails to permit the wheels of vehicles moving along the track to pass over one or both of the rails of the other track with maximum safety and minimum disturbance to the wheel, is called *crossing* or *frog*.

The crossing is designated by the number which is the ratio of the spread at the leg of the crossing to the length of the crossing from its theoretical nose. On Indian railways, their number is taken as the cotangent of the angle formed by the crossing. In India, crossing number 8½ is used for goods and 12 for passenger turnouts.

The crossings, on the basis of the angle of crossing, are classified as follows :

1. *Acute angle crossing or V-crossing.* The crossing in which the right hand rail of one track crosses the left hand rail of another track at an acute angle, is called acute angle crossing or V - crossing. It consists of point and splice rails or two point rails, a pair of wing rails and a pair of check rails.

2. *Obtuse angle crossing or diamond crossing.* The crossing in which a track crosses another track of the same or different gauge at an obtuse angle, is called obtuse angle crossing or diamond crossing. It consists of a bent running rail partly used for both tracks, a pair of point rails and a bent wing rail fixed opposite the throat.

3. *Square crossing.* The crossing in which one track crosses another track of the same or different gauge at right angles, is called square crossing. This type of crossing on the main line should be avoided as it causes heavy wear due to impact of moving load.

10.30 Track Junctions

The track junction is formed by the combination of points and crossings for diverting trains from one track to another. The track junctions are classified as follows :

1. *Turnouts.* We have already discussed that a turnout enables the train to be diverted from one track to another. It consist of points or switch, two straight lead rails, two curved lead rails, two check rails and a crossing angle.

2. *Double turnout or Tandem.* The arrangement of two turnouts taking off from the main track for different directions, is known as double turnout or tandem. It requires two pairs of switches located at two different tracks with four check rails and three acute angle crossings.

3. *Diamond crossing.* When two tracks of the same gauge or of different gauge cross each other at any angle, is known as diamond crossing.

4. *Symmetrical split.* When a straight track is split up in two different directions at equal radii, it is known as symmetrical split.

5. *Three throw switch.* When two turnouts take off from the same point of the main straight track, it is known as three throw switch. It requires two sets of switches and three crossings.

6. *Double junction.* The arrangement made for two parallel tracks to diverge from two parallel tracks, is called double junction.

7. *Single slip and double slip.* A slip in which the track can be changed from one direction only, is known as single slip and a slip in which the track can be changed in two directions, is called double slip.

8. *Cross - over.* The arrangement made to divert a train from one track to another parallel track, is called cross - over. It requires two sets of switches and two crossings.

9. *Scissors cross - over.* When two cross - overs are laid between two tracks, it is known as scissors cross - over. It is also known as double cross-over. It enables the trains from opposite directions to change the track.

10. *Gaunlet track.* When one track (say metre gauge) is superimposed on the other track (say broad gauge) such as on river, bridges, is called Gaunlet track.

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10.31 Signalling

The object of signalling is to control and regulate the movement of trains safely and effi
The signals are provided to achieve the following :

1. To regulate the arrival and departure of trains.
2. To ensure safety between trains which cross or approach each other.
3. To ensure safe and efficient shunting.
4. To ensure safety of cross - traffic at road - rail crossing.
5. To ensure safety ot trains where branch or siding meets main line.
6. To guide trains during maintenance and repair of the track.

The signals are classified according to the following categories :

(*a*) *According to the function.* These signals are stop or semaphore signal, warner signa
or shunting signal and coloured light signal.

(*b*) *According to the location.* These signals are outer signal, home signal, starter sign
advance starter signal.

The *stop or semaphore signal* mechanism in such that in its normal or horizontal posi
indicates stop or danger position. When the signal is lowered by pulling the wire, it is said to be
position.

The *warner signal* is similar to semaphore signal except that a V - notch is provided at th
end. Its function is to warn the driver of the corresponding position of the semaphore signal.

The *disc* or *shunting signal* is used for shunting operation for low speeds. These signa
in the form of circular discs with red band on white background.

The *coloured light signals* are automatically operated and give indications by electric lig

The *outer signal* is the first stop signal which regulates the entry of trains from a block s
station yard. In India, an outer signal is kept from the station limit at a distance of about 540 m
for broad gauge and 400 metres for metre gauge. In danger position, the driver should bring the
to stop as a distance of 90 metres before the outer signal.

The *home signal* is located at the entry of the station. It is generally used to indicate the li
be used by the train. This signal is generally located not more than 180 metres from the start of swit

The *starter signal* is located at a place where trains, stopping at the station, should come
stop. For each line, a separate starting signal is provided. The starter signal actually control
movement of the train when it starts from the station.

The *advance starter signal* is provided about 180 metres beyond the trailing switches. T
signal is the last stop signal at the station, if provided.

Note : The outer and home signals are called *reception signals* while starter and advance starter signa
called *departure signals.*

10.32 Signalling System

The main signalling systems are as follows :

1. *Absolute block system.* In this system, the railway line is developed into block sect
Only one train can move at a time in one block station. All the block stations are linked in series
telegraphically and telephonically for verbal exchange of information relating to the control o
movement of the train.

2. *Space interval system.* This system of signalling is used on single line working.

3. *Time interval system.* This system of signalling is used in emergency when the block sy
fails.

4. *Pilot guard system.* This system is used when the message can not be conveyed to
next station by telephone or telegraph.

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10.33 Interlocking

The term interlocking stands for relationship between various levers operating the signals and points. The process of interlocking is considerably facilitated by grouping levers at one point. In order to have easy identification, levers are generally painted as follows :

For stop - Red; For locks - Blue; For warner - Green; For crossing gate - Yellow; For points - Black; For spare use - White.

The standard methods of interlocking are as follows :

1. *Key system.* It is also known as indirect locking. It is used in a number of small stations in India. It works on two systems namely single lock and key system and secondly double lock and key system.
2. *Route relay system.* In this system, the points and signals for the movement of trains are electrically operated. It is the most modern and sophisticated system of interlocking.
3. *Tappet and locks system.* This method is very useful when levers are required to be interlocked to prevent conflicting movements. The tappets are attached to levers.

OBJECTIVE TYPE QUESTIONS

1. George Stephenson succeeded in running the first train of the world in
   (*a*) 1825 (*b*) 1835 (*c*) 1841 (*d*) 1853
2. The first train in India was run in
   (*a*) 1825 (*b*) 1835 (*c*) 1841 (*d*) 1853
3. The first train in India was run between
   (*a*) Delhi and Kolkata (Calcutta) (*b*) Mumbai (Bombay) and Thane
   (*c*) Delhi and Mumbai (Bombay) (*d*) Mumbai (Bombay) and Kolkata (Calcutta)
4. The Indian railway has been divided into
   (*a*) six zones (*b*) eight zones (*c*) twelve zones (*d*) sixteen zones
5. The clear distance between inner faces of rails near their tops is known as ..... of the track.
   (*a*) clear width (*b*) gauge
6. The railway system of India is the biggest in Asia.
   (*a*) Agree (*b*) Disagree
7. The railway system of India is the ..... longest in the world under a single management.
   (*a*) first (*b*) second (*c*) third (*d*) fourth
8. At the time of construction of railway in India, after long controversy, the gauge adopted as a standard gauge was
   (*a*) 1.435 m (*b*) 1.524 m (*c*) 1.676 m (*d*) 1.843 m
9. The broad gauge is ..... wide.
   (*a*) 0.6096 m (*b*) 0.762 m (*c*) 1.00 m (*d*) 1.676 m
10. For main cities and routes of maximum intensities, the type of gauge adopted is
    (*a*) broad gauge (*b*) metre gauge (*c*) narrow gauge (*d*) all of these
11. For undeveloped areas, the type of gauge adopted is
    (*a*) broad gauge (*b*) metre gauge (*c*) narrow gauge (*d*) all of these
12. For hilly areas and thinly populated areas, narrow gauge is adopted.
    (*a*) True (*b*) False

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13. Which of the following statement is correct ?
(a) At every change of gauge, the passengers have to change their train.
(b) The timings of trains at gauge - change points should not coincide.
(c) During war times, change in gauge is convenient to the army for quick movement.
(d) If the intensity of traffic becomes more, it requires smaller gauge.

14. The width of narrow gauge is same as that of metre gauge.
(a) Right (b) Wrong

15. The gauge representing the maximum width and height up to which a railway vehicle may be built, is known as
(a) broad gauge (b) narrow gauge (c) loading gauge (d) all of these

16. In India, for broad gauge track, the maximum height of a loaded goods wagon is fixed as
(a) 3.40 m (b) 4.72 m (c) 5.32 m (d) 5.87 m

17. In India, for metre gauge track, the maximum height of a loaded goods wagon is fixed as
(a) 3.43 m (b) 4.72 m (c) 5.32 m (d) 5.87 m

18. The speed of a locomotive, in India, on broad gauge is restricted between
(a) 60 and 75 km/h (b) 75 and 96 km/h
(c) 96 and 120 km/h (d) 120 and 140 km/h

19. The speed of a locomotive, in India, on metre gauge is restricted up to
(a) 60 km/h (b) 80 km/h (c) 100 km/h (d) 120 km/h

20. The resistance of the train is due to
(a) speed (b) gradient (c) curves (d) all of these

21. The rail section, now-a-days, used in Indian railways is
(a) double headed type (b) dumb-bell type (c) bull headed type (d) flat footed type

22. The rail section first designed in Indian railways was
(a) double headed type (b) bull headed type (c) flat footed type (d) none of these

23. The speed of the locomotives will be more if the gauge is wider.
(a) Correct (b) Incorrect

24. Tractive force, due to which engine pulls the train, is ..... the resistance of train.
(a) more than (b) equal to (c) less than

25. The width of top portion of a flat - footed rail, is
(a) 66.67 mm (b) 69.80 mm (c) 73.25 mm (d) 75.87 mm

26. The bull headed rails are provided on points and crossings.
(a) Yes (b) No

27. For broad gauge main lines with maximum traffic loads, the rail section provided should be
(a) 29.77 to 37.25 kg/m (b) 44.7 to 56.8 kg/m
(c) 49.8 to 52.3 kg/m (d) 49.8 to 56.8 kg/m

28. For metre gauge, 49.8 to 52.3 kg/m rail section is used.
(a) True (b) False

29. The rail section is designated by its
(a) total length (b) total weight
(c) cross - sectional area (d) weight per metre length

30. The largest dimension of a rail section is
(a) head width (b) foot width (c) height (d) all of these

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31. The rail section is divided on the basis of
(a) type of rails (b) spacing of sleepers
(c) gauge of the track (d) speed of trains

32. Generally, the rail section is designed by assuming that it can bear a load equal to ..... its own weight per metre length.
(a) 100 times (b) 350 times (c) 460 times (d) 560 times

33. The flat - footed rail is mostly used in Indian railways because of its lateral rigidity.
(a) Agree (b) Disagree

34. Charles Vignole invented ..... type of rail section.
(a) double headed (b) bull headed (c) flat footed

35. Which of the following statement is correct ?
(a) Bull headed rails keep better alignment than flat footed rails due to chairs.
(b) Flat footed rails are cheaper than bull headed rails.
(c) Flat footed rails are stronger in every direction than the bull headed rails for the same cross-sectional area.
(d) all of the above

36. The fillet in a rail section is provided to
(a) increase the vertical stiffness (b) increase the lateral strength
(c) reduce wear (d) avoid stress concentration

37. For metre gauge track, in Indian railways, the standard length of the rail is
(a) 10.06 m (b) 10.97 m (c) 11.89 m (d) 12.8 m

38. For broad gauge track, in Indian railways, the standard length of the rail is
(a) 10.06 m (b) 10.97 m (c) 11.89 m (d) 12.8 m

39. The rail gauge is the distance between
(a) outer faces of rails (b) running faces of rails
(c) centre to centre of rails (d) none of these

40. The choice of gauge depends upon
(a) volume and nature of traffic (b) speed of train
(c) physical features of the country (d) all of these

41. A standard rail point should
(a) be as strong as the other portion of the track
(b) have just enough rail gap between two rails
(c) have the same elasticity as the other portion of the track
(d) all of the above

42. In U.S.A., rails used are ..... long.
(a) 20 m (b) 30 m (c) 40 m (d) 50 m

43. The joint generally not used on Indian railway is
(a) supported joint (b) suspended joint (c) base joint (d) bridge joint

44. Staggered rail joints are generally provided on curves.
(a) Correct (b) Incorrect

45. In supported rail joint, both the ends of adjoining rails are supported on a
(a) single sleeper (b) single fish plate (c) double sleeper (d) none of these

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46. Between two rails, a gap of ..... is provided for free expansion of the rails due to temperature.
(a) 1.5 mm to 3 mm (b) 3 mm to 6 mm (c) 6 mm to 9 mm (d) 9 mm to 12 mm

47. Two fish plates are fixed at each rail joint with eight fish bolts.
(a) Right (b) Wrong

48. No sleeper is placed just below the rail joint, as it will cause
(a) more impact (b) discomfort to passengers
(c) either (a) or (b) (d) both (a) and (b)

49. The main purpose of welding rails is to
(a) build up the worn - out parts of points and crossings
(b) build up the battered or worn heads of rail ends
(c) to rebuild those portions of rail ends, which are burnt due to slipping of wheels at the time of applying brakes
(d) all of the above

50. A welded rail joint is generally
(a) supported on a sleeper (b) suspended
(c) supported on a metal plate (d) none of these

51. To reduce the wearing of rails, the rails are placed at an
(a) inward slope of 1 in 20 (b) outward slope of 1 in 20
(c) inward slope of 1 in 30 (d) outward slope of 1 in 30

52. The coning of wheels is made to prevent the
(a) lateral movement of the axle (b) lateral movement of the wheels
(c) damage of the inside edges of rails (d) all of these

53. To prevent the flanges of wheels from rubbing the inside face of the rail, the distance between the inside edges of flanges is kept ..... the gauge.
(a) equal to (b) less than (c) more than

54. In coning of wheels, the wheels are given a slope of
(a) 1 in 20 (b) 1 in 25 (c) 1 in 30 (d) 1 in 40

55. Due to the coning of wheels, the pressure of wheels is always near the ..... edge of the rail.
(a) inner (b) outer

56. Which of the following statement is wrong?
(a) The coning of wheels is provided for smooth running of trains.
(b) The coning of wheel prevents the wear of the inner faces of rails.
(c) If the axle moves laterally towards one rail, the diameter of wheel rim increases on that rail.
(d) On curves, the outer wheel has to travel lesser distance than the inner wheel.

57. The rails are laid without bending, at flat curves, where the degree of curve is
(a) less than 3° (b) equal to 3° (c) more than 3°

58. The distance between two adjoining axles fixed in a rigid frame is known as
(a) gauge (b) wheel base distance
(c) creep (d) none of these

59. Creep is the ..... movement of rail.
(a) longitudinal (b) lateral (c) vertical

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Creep is greater
(a) on curves (b) in new rails than in old rails
(c) both (a) and (b) (d) none of these

When the degree of curve is more than 3°, the rails are bent to the correct curvature before them on to the sleepers.
(a) Yes (b) No

The versine (h) for the curves is given by
(a) $h = l^2/r$ (b) $h = l^2/2r$ (c) $h = l^2/4r$ (d) $h = l^2/8r$
where l = Length of rail on curve portion, and r = Radius of curve.

Creep causes
(a) opening of rail joints (b) distortion of points and crossings
(c) buckling of track (d) all of these

In Indian railways, the maximum wheel base distance on broad gauge is 4.058 m.
(a) True (b) False

The gauge is widened on curves of ..... 4½° curvature.
(a) equal to (b) less than (c) more than

The gauge should be ..... slack for curves of more than 438 m.
(a) 6 mm (b) 12 mm (c) 20 mm (d) 30 mm

Match the correct answer from *Group B* for the statements given in *Group A*.

Group A	*Group B*
(a) Distance between two adjoining axles is called	(A) gauge
(b) Clear horizontal distance between inner faces of rails near tops is called	(B) rail wear
(c) Longitudinal movement of rails in a track is called	(C) wheel base distance
(d) Flow of rail metal due to abnormally heavy loads is called	(D) rail creep

The longitudinal movement of the rails in a track is technically known as
(a) buckling (b) hogging (c) creeping (d) none of these

The impact of the rail wheel ahead of the joint gives rise to the creep of the rail. This statement according to
(a) wave theory (b) percussion theory (c) drag theory (d) none of these

In hogging
(a) the rail ends get bent down and deflected due to loose packing under the joints
(b) the rails get out of their original positions due to insufficient expansion joint gap
(c) the longitudinal movement of the rails in track takes place
(d) all of the above

When the rails get out of their original position due to insufficient expansion joint gap, the phenomenon is known as buckling.
(a) Agree (b) disagree

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72. Which of the following statement is correct ?
(a) When wheel passes over a rail joint, it causes positive creep.
(b) Insufficient and defective packing of ballast causes creep.
(c) Train wheels cause slight depression on the table of the rails due to their own weight
(d) all of the above

73. The adjustment of rails is usually needed when creep exceeds
(a) 50 mm (b) 100 mm (c) 150 mm (d) none of these

74. The flow of rail metal due to abnormally heavy loads is called
(a) hogging (b) buckling (c) wear of rails (d) creeping

75. In India, permissible limit of rail wear is ..... by weight.
(a) 5% (b) 10% (c) 25% (d) 30%

76. When a train passes on curves which have no superelevation, it will give thrust on the
(a) inner rail (b) outer rail
(c) inner side of inner rail (d) inner side of outer rail

77. When the train moves on the rail, it causes constant reversal of stresses.
(a) Right (b) Wrong

78. A good sleeper should be such that
(a) the rails can be easily fixed and taken out from the sleeper without moving them
(b) it can provide sufficient bearing area for the rail
(c) it can provide sufficient effective bearing area on the balast
(d) all of the above

79. The chief function of sleepers is to
(a) support the rails
(b) keep the two rails at correct gauge
(c) distribute the load coming on rails to the ballast
(d) all of the above

80. The wooden sleepers are the ideal sleepers.
(a) Yes (b) No

81. Sleepers which satisfy all of the requirements and are only suitable for track circuiting are
(a) wooden sleepers (b) steel sleepers
(c) cast iron sleepers (d) R. C.C. sleepers

82. The life of wooden sleepers depends upon
(a) quality of the timber used (b) ability to wear decay
(c) resistance to white ants (d) all of these

83. Which of the following sleeper provide best elasticity of track ?
(a) Wooden sleeper (b) Cast iron sleeper
(c) Steel sleeper (d) R.C.C.sleeper

84. The number of sleepers used for rail varies from
(a) $(n + 1)$ to $(n + 4)$ (b) $(n + 3)$ to $(n + 6)$
(c) $(n + 2)$ to $(n + 7)$ (d) $(n + 4)$ to $(n + 8)$
where n = Length of rail in metres.

85. The railway sleepers should act as elastic medium between the rails and the ballast.
(a) Correct (b) Incorrect

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89. Minimum packing space provided between two sleepers is
(a) 250 to 300 mm (b) 300 to 350 mm (c) 350 to 400 mm (d) 400 to 450 mm

90. The spacing of sleepers is kept
(a) closer near the joints (b) closer at the middle of rails
(c) same throughout the length of rail (d) none of these

91. The type of sleeper used, depends upon
(a) initial and maintenance cost
(b) easy fixing and removal of rails
(c) provision for sufficient bearing area for rail
(d) all of the above

92. The standard size of wooden sleepers on metre gauge railway track is
(a) 1.52 m × 15 cm × 10 cm (b) 1.83 m × 20 cm × 11 cm
(c) 2.74 m × 25 cm × 13 cm (d) any one of these

93. The standard size of wooden sleepers on broad gauge railway track is
(a) 1.52 m × 15 cm × 10 cm (b) 1.83 m × 20 cm × 11 cm
(c) 2.74 m × 25 cm × 13 cm (d) any one of these

94. The standard size of timber sleepers in railway tracks of metre gauge and narrow gauge is same.
(a) Yes (b) No

95. The best wood for sleepers is
(a) sal (b) deodar (c) teak (d) chir

96. Adzing is done in the sleepers to give a slope of
(a) 1 in 10 (b) 1 in 20 (c) 1 in 30 (d) 1 in 40

97. The composite sleeper index is the index of
(a) strength and hardness (b) strength and toughness
(c) hardness and wear resistance (d) toughness and wear resistance

98. The composite sleeper index determines the
(a) suitability of the wooden sleepers (b) number of sleepers per rail length
(c) permissible stresses in the steel sleepers (d) all of these

99. The minimum composite sleeper index for wooden sleepers used over bridge girders, is
(a) 1352 (b) 1455 (c) 1555 (d) 1652

100. The minimum composite sleeper index for wooden sleepers used over cross-overs, is
(a) 1352 (b) 1455 (c) 1555 (d) 1652

101. To prevent the change in gauge and creep, the steel sleepers are fixed by clips, bolts and
(a) one key (b) two keys (c) three keys (d) four keys

102. Steel sleepers consist of steel troughs made out of about 6 mm thick steel sheets, with
(a) its both ends bent down (b) its both ends bent up
(c) its one end bent up and another bent down (d) any one of these

103. At the time of pressing the steel sleepers, a cant of 1 in 20 is provided towards the centre.
(a) True (b) False

104. For fixing the rails on steel sleepers
(a) lugs or jaws are pressed out of metals and keys are used
(b) holes are made in sleepers and clips and bolts are used
(c) gib and cotters are used
(d) none of the above

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102. Which of the following statement is correct?
(a) Bearing plates are used in the case of hard sleepers.
(b) Chairs are used for flat - footed rails instead of bearing plates.
(c) Spacing of sleepers near the rail joint is closer.
(d) Spacing of sleepers in the middle of the rail is closer.

103. The main disadvantage of steel sleepers is
(a) that they get rusted very quickly
(b) that their lugs sometimes get cr
(c) that their lugs sometimes get broken
(d) all of these

104. The sleepers in the form of two bowls placed under each rail and connected together bar, are known as
(a) pot sleepers (b) box sleepers (c) plate sleepers (d) duplex slee

105. Which of the following is a cast iron sleeper?
(a) Pot sleeper (b) Box sleeper (c) Plate sleeper (d) all of these

106. The total effective area of the pot sleepers is
(a) 0.26 m^2 (b) 0.36 m^2 (c) 0.46 m^2 (d) 0.56 m^2

107. The total effective area of the pot sleepers is equal to the effective bearing area of a
(a) steel sleeper (b) wooden sleeper (c) R.C.C. sleeper (d) all of these

108. Two holes are provided in each pot sleeper for inspection and packing of ballast.
(a) Agree (b) Disagree

109. The rail seat is given a slope of
(a) 1 in 10 (b) 1 in 20 (c) 1 in 30 (d) 1 in 40

110. Gib and cotters for connecting pot sleepers are so casted that by interchanging them slackened by
(a) 3.18 mm (b) 6.18 mm (c) 8.81 mm (d) 13.8 mm

111. Plate sleepers consist of a plate of dimensions
(a) 454 mm × 254 mm (b) 551 mm × 254 mm
(c) 851 mm × 254 mm (d) 951 mm × 254 mm

112. The 254 mm side of a plate sleeper is
(a) intersecting the rail (b) parallel to the rail
(c) connected with the rail (d) none of these

113. To increase the strength of plate sleepers, the ..... at the top of the plate are pro
(a) bearing plates (b) stiffeners (c) anchors

114. In plate sleepers, the plate is provided with projecting ribs in the bottom in order to
(a) provide a grip in the ballast (b) check the lateral movement of the
(c) either (a) or (b) (d) both (a) and (b)

115. A CST - 9 sleeper is
(a) same as pot sleeper (b) same as plate sleeper
(c) a combination of plate, pot and box sleeper (d) none of these

116. The mass of a cast iron sleeper is
(a) 56 kg (b) 78.4 kg (c) 113.4 kg (d) 121.8 kg

117. A CST - 9 sleeper consists of
(a) two inverted pots on either side of the rail seat
(b) a single two way key on the gauge side
(c) both (a) and (b)
(d) none of the above

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118. The main disadvantage of cast iron sleeper is
(a) that they are liable to crack (b) that they are liable to break
(c) that they are liable to get rusted (d) both (a) and (b)

119. R.C.C. sleepers are used in railways due to their
(a) suitability for track circuiting
(b) capacity to maintain the gauge properly
(c) heavy weight which improves the track modulus
(d) all of the above

120. A mono-block sleeper has a square cross - section.
(a) Right (b) Wrong

121. Which of the following statement is wrong?
(a) The pot sleepers can be used if degree of the curve is more than 4°.
(b) Track circuiting is not possible in R.C.C. sleepers.
(c) The effective bearing area of all types of sleepers is not the same.
(d) all of the above

122. The number of sleepers used per rail length on the track is known as
(a) sleeper strength (b) sleeper density (c) sleeper ratio (d) all of these

123. In India, the sleeper density provided is
(a) 18 sleepers per rail length (b) 25 sleepers per rail length
(c) 28 sleepers per rail length (d) 40 sleepers per rail length

124. The sleeper density on main lines is ..... due to fast moving trains such as Rajdhani Express.
(a) decreased (b) increased

125. The chief function of providing ballast in the railway track is
(a) to uniformly distribute the load from sleepers over a large area of formation
(b) to hold the sleepers in position
(c) to provide elasticity and resilience to the track
(d) all of the above

126. The ballast material generally used on Indian railways consist of
(a) broken stone (b) gravel (c) moorum (d) all of these

127. Under the sleepers, ... of ballast is done to transmit the load of the train from the sleepers.
(a) boxing (b) packing

128. The ballast thrown around the sleepers and loosely filled on slopes is called boxing of ballast.
(a) Correct (b) Incorrect

129. The boxing of ballast is done to prevent
(a) lateral movement of sleepers (b) longitudinal movement of sleepers
(c) both lateral and longitudinal movement of sleepers
(d) none of the above

130. To keep the railway yard dry, the ballast used is
(a) sand (b) coal ash (c) broken stone (d) both (a) and (b)

131. For new embankments in black cotton soil, the material used as blanket is
(a) sand (b) moorum (c) coal ash (d) broken stone

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132. A good ballast, when laid on formation, should have sufficient voids.
(a) Yes (b) No

133. Packing of ballast is done near the ends of sleeper.
(a) True (b) False

134. The size of ballast used on Indian railways for wooden sleepers is
(a) 25 mm (b) 38 mm (c) 43 mm (d) 50 mm

135. The size of ballast used on Indian railways for steel sleepers is
(a) 25 mm (b) 38 mm (c) 43 mm (d) 50 mm

136. To provide maximum stability to the track, graded stones from ..... are used.
(a) 20 to 50 mm (b) 50 to 75 mm (c) 75 to 100 mm (d) 100 to 125 mm

137. The size of ballast used on Indian railways under points and crossings is 25 mm.
(a) Agree (b) Disagree

138. The quantity of stone ballast required per metre tangent length for broad gauge is
(a) 0.767 m^3 (b) 1.11 m^3 (c) 1.51 m^3 (d) 2.11 m^3

139. The quantity of stone ballast required per metre tangent length for metre gauge is
(a) 0.767 m^3 (b) 1.11 m^3 (c) 1.51 m^3 (d) 2.11 m^3

140. In order to counteract the increased lateral thrust on curves, an extra shoulder provided on outside of curves is
(a) 50 mm (b) 100 mm (c) 150 mm (d) 200 mm

141. Which of the following statement is correct ?
(a) The coal ash is used in the initial stages of new construction if steel sleepers are used
(b) The broken stone has very poor interlocking action.
(c) The gravel ballast has very poor drainage property.
(d) The sand ballast causes wear of rail - seats and keys.

142. The minimum depth of ballast for broad gauge tracks on Indian railways is
(a) 200 mm (b) 250 mm (c) 300 mm (d) 350 mm

143. An extra width of ballast is not provided on the outer side of curve, if its degree is 3°.
(a) Correct (b) Incorrect

144. The standard width of ballast for broad gauge track on Indian railways, is
(a) 2.3 m (b) 2.9 m (c) 3.35 m (d) 5.53 m

145. The standard width of ballast for metre gauge track on Indian railways, is
(a) 2.3 m (b) 2.9 m (c) 3.35 m (d) 5.53 m

146. To hold the adjoining ends of rails in correct horizontal and vertical planes, the rail fastening used are
(a) fish plates (b) spikes (c) anchors (d) bearing plates

147. The fish plates should be designed for
(a) bearing the vertical and lateral stresses
(b) allowing free contraction and expansion of rails
(c) easy renewal and replacement of rails
(d) all of the above

148. The fish plates fit the web of the rail section.
(a) Right (b) Wrong

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149. The length of each fish plate is
(a) 317.5 mm (b) 457.2 mm (c) 514.3 mm (d) 623.4 mm

150. On Indian railways, the number of fish bolts used to connect one pair of fish plates to the rails are
(a) two (b) four (c) six (d) eight

151. Fish bolts are made of
(a) cast iron (b) low carbon steel
(c) high carbon steel (d) stainless steel

152. Rail chairs are used to fix
(a) flat footed rails (b) bull headed rails
(c) double headed rails (d) none of these

153. The rail chairs are generally made of
(a) cast iron (b) low carbon steel
(c) high carbon steel (d) stainless steel

154. Which of the following bolt is not used in rail tracks?
(a) Fish bolt (b) Dog bolt (c) Eye bolt (d) Rag bolt

155. The mass of a rail chair is about
(a) 10 kg (b) 15.6 kg (c) 22 kg (d) 30 kg

156. Which of the following statement is wrong?
(a) The fish plates are so designed that they fit the underside of the rail head and top of the rail foot in case of front footed rails.
(b) Now-a-days, fish plates are manufactured of steel.
(c) Due to entering of sand between contact surface of rail and the fish plates, the wearing of fish plates start.
(d) In case of steel sleepers, the chairs are not welded.

157. The bearing plates are used to fix ..... rails on wooden sleepers.
(a) flat footed (b) bull headed (c) double headed

158. The main purpose of using bearing plates is to
(a) distribute the pressure over wider area (b) eliminate the adzing of wooden sleepers
(c) prevent the widening of gauge of curves (d) all of these

159. The spike commonly used to fix the rails on wooden sleepers is
(a) dog spike (b) round spike (c) screw spike (d) all of these

160. The overall depth of a dog spike is
(a) 120.6 mm (b) 159.5 mm (c) 175.9 mm (d) 180.6 mm

161. Round spikes are not used for fixing ..... rails on wooden sleepers.
(a) flat footed (b) bull headed (c) flat footed

162. The spike used for fixing chairs of bull headed rail to wooden sleepers is
(a) dog spike (b) round spike (c) elastic spike (d) all of these

163. The holding power of screw spikes is less than dog spikes.
(a) Yes (b) No

164. The screw spikes take ..... in driving and extraction from the sleeper as compared to dog spike.
(b) less time

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165. The bull - headed and double headed rails do not require bearing plates for fixing.
(a) Agree (b) Disagree

166. The dog spikes are used for fixing rail to the
(a) wooden sleepers (b) concrete sleepers (c) steel sleepers (d) CST - 9 sleeper

167. The number of dog spikes normally used per rail seat on curved track is
(a) one on either side (b) one inside and two outside
(c) one outside and two inside (d) two on either side

168. The screw spikes used for fixing the rails to wooden sleepers
(a) are not popular on Indian railways
(b) do not spoil the sleeper
(c) have more lateral rigidity than dog spikes
(d) all of the above

169. Creeping of rails can be checked by using
(a) chairs (b) bearing plates (c) anchors (d) spikes

170. A track is laid over
(a) sleepers (b) formation (c) rails (d) ballast

171. According to Indian Railways Board, the minimum distance between the centre to centre two tracks for broad gauge is
(a) 4.725 m (b) 6.1 m (c) 7.49 m (d) 10.82 m

172. On Indian railways, minimum formation width in embankment for a single line of broad gauge
(a) 4.725 m (b) 6.1 m (c) 7.49 m (d) 10.82 m

173. In the cross - sections of railway tracks, side slope in embankments is kept as
(a) 1 : 1 (b) 1 : 5 (c) 2 : 1 (d) 3 : 1

174. In the cross - sections of railway tracks, the side slope in cutting is same as that in embankment
(a) True (b) False

175. The maximum gradient, in which a railway track may be laid in a particular section is known as
(a) pusher gradient (b) ruling gradient
(c) momentum gradient (d) all of these

176. Anchors are also known as anti - creepers.
(a) Correct (b) Incorrect

177. Which of the following statement is correct?
(a) The ruling gradient is maximum gradient to which the track may be laid.
(b) In order to avoid the resistance after a certain limit, gradients on curves are reduced.
(c) Grade compensation is denoted by percentage per degree of curve.
(d) all of the above

178. On Indian railways, the grade compensation provided on broad gauge curves is
(a) 0.02 percent per degree (b) 0.03 percent per degree
(c) 0.04 percent per degree (d) 0.05 percent per degree

179. On Indian railways, the grade compensation provided on metre gauge curves is
(a) 0.02 percent per degree (b) 0.03 percent per degree
(c) 0.04 percent per degree (d) 0.05 percent per degree

180. On Indian railways, the grade compensation provided on narrow gauge curves is same as in metre gauge.
(a) Right (b) Wrong

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181. In India, the ruling gradient provided in plains for one locomotive train, is
(a) 1 in 150 to 1 in 200 (b) 1 in 200 to 1 in 250
(c) 1 in 250 to 1 in 300 (d) 1 in 300 to 1 in 350

182. In India, the ruling gradient provided in hilly tracks for one locomotive train is 1 in 100 to 1 in 150.
(a) Yes (b) No

183. No signals are provided in case of
(a) ruling gradient (b) momentum gradient
(c) pusher gradient (d) station yards gradient

184. The gradient where extra engine is required to push the train is known as
(a) ruling gradient (b) momentum gradient
(c) pusher gradient (d) station yards gradient

185. Match the correct answer from *Group B* for the statements given in *Group A*.

Group A	*Group B*
(a) The grade compensation provided on broad gauge curves is	(A) 1 in 100 to 1 in 150
(b) The ruling gradient provided in hilly tracks is	(B) 1 in 1000
(c) The gradient recommended for station yards is	(C) 0.02 percent / degree
(d) The grade compensation on narrow gauge curves is	(D) 0.04 percent / degree

186. For station yards, Indian railways have recommended a gradient of
(a) 1 in 100 (b) 1 in 200 (c) 1 in 500 (d) 1 in 1000

187. A curve is represented by the degree of the curvature subtended by a chord of
(a) 15 m (b) 20.8 m (c) 30.48 m (d) 40.8 m

188. The relation between the radius of curve (R) and its degree of curvature (D) is given by
(a) $R = \frac{1245}{D}$ (b) $R = \frac{1546.8}{D}$ (c) $R = \frac{1746.5}{D}$ (d) $R = \frac{1835.6}{D}$

189. The super-elevation (S) to be provided on rails is determined by
(a) $S = \frac{VG}{gR}$ (b) $S = \frac{V^2G}{gR}$ (c) $S = \frac{V^3G}{gR}$ (d) $S = \frac{V^4G}{gR}$

where V = Speed of train,
G = Gauge,
R = Radius of curve, and
g = Acceleration due to gravity.

190. When the main line is on a curve and has a turn out of contrary flexure leading to a branch line, then the branch line curve has a
(a) cant deficiency (b) negative cant (c) cant excess (d) none of these

191. On Indian railways, cant deficiency allowed on broad gauge track is
(a) 56 mm (b) 66 mm (c) 76 mm (d) 87 mm

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192. On Indian railways, cant deficiency allowed on metre gauge is ..... broad gauge.
(*a*) equal to (*b*) less than (*c*) more than

193. The maximum limit of superelevation prescribed by Indian railways on broad gauge is
(*a*) 76.2 mm (*b*) 83.2 mm (*c*) 101.6 mm (*d*) 165.1mm

194. The maximum limit of superelevation prescribed by Indian railways on narrow gauge is
(*a*) 76.2 mm (*b*) 83.2 mm (*c*) 101.6 mm (*d*) 165.1mm

195. The maximum limit of superelevation prescribed by Indian railways on metre gauge is ..... broad gauge.
(*a*) equal to (*b*) less than (*c*) more than

196. The maximum limit of superelevation prescribed by Indian railways on narrow gauge is as that on metre gauge.
(*a*) Agree (*b*) Disagree

197. Which of the following statement is wrong?
(*a*) Superelevation is provided on curves to prevent the wear and tear of rails.
(*b*) Superelevation is provided on curves for smooth riding.
(*c*) Spiral transition curve should not be provided.
(*d*) none of the above

198. According to railway code formula, the length of transition curve is equal to
(*a*) $1.4\sqrt{R}$ (*b*) $2.4\sqrt{R}$ (*c*) $3.4\sqrt{R}$ (*d*) $4.4\sqrt{R}$
where R = Radius of simple curve in metres.

199. The minimum length of the transition curve is equal to
(*a*) $\frac{SV}{121}$ (*b*) $\frac{SV}{153}$ (*c*) $\frac{SV}{175}$ (*d*) $\frac{SV}{198}$
where S = Superelevation in mm, and
V = Maximum permissible speed in km / h.

200. The maximum permissible speed (V) of trains for good order track on transition curve is given by
(*a*) $V = 1.4\sqrt{R-70}$ (*b*) $V = 2.4\sqrt{R-70}$
(*c*) $V = 3.4\sqrt{R-70}$ (*d*) $V = 4.4\sqrt{R-70}$
where R = Radius of curve in metres.

201. Superelevation on curves is provided by means of
(*a*) cant-board (*b*) straight edge (*c*) spirit level (*d*) all of these

202. In India, the method used for plate laying is
(*a*) side method (*b*) American method
(*c*) telescopic method (*d*) all of these

203. The level of both the rails on straight lengths should be different.
(*a*) True (*b*) False

204. The technical term used to denote the pulling back of the tracks is known as
(*a*) heaved track (*b*) slewing
(*c*) turn out (*d*) all of these

205. The station where lines from three or more directions meet is called a
(*a*) crossing station (*b*) flag station
(*c*) junction station (*d*) terminal station

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206. The station having two lines is called a
(a) crossing station (b) flag station
(c) junction station (d) terminal station

207. The height of the platform above the rail surface for broad gauge tracks should be
(a) 229 to 406 mm (b) 305 to 406 mm
(c) 762 to 838 mm (d) 838 to 982 mm

208. The height of the platform above the rail surface for narrow gauge tracks should be
(a) 229 to 406 mm (b) 305 to 406 mm
(c) 762 to 838 mm (d) 838 to 982 mm

209. The length of platform for broad gauge should not be less than
(a) 100 m (b) 200 m (c) 300 m (d) 400 m

210. The length of platform should be ..... the longest train which is moving on that section.
(a) equal to (b) less than (c) more than

211. The width of platform, under no circumstances, should be less than
(a) 2 m (b) 4 m (c) 6 m (d) 8 m

212. The platform should be provided ..... away from the centre line of the track for broad gauge.
(a) 1.219 m (b) 1.346 m (c) 1.676 m (d) 1.854 m

213. The distance between the centre line of the track, for narrow gauge, and the platform should not be less than 1.219 m.
(a) Correct (b) Incorrect

214. The device used for changing the direction of engines is called
(a) turn-tables (b) triangles (c) buffer stops (d) scotch blocks

215. The device provided to prevent the vehicles from moving beyond the end of rail at terminals is called
(a) turn-tables (b) buffer stops (c) triangles (d) scotch blocks

216. Scotch blocks are used for preventing the movement of vehicles beyond the dead end sidings.
(a) Right (b) Wrong

217. A track assembly used for diverting train from one track to another is known as
(a) turn-out (b) crossings (c) junction (d) none of these

218. A triangle is used for
(a) diverting trains from the main line to branch line
(b) crossing over between parallel tracks
(c) changing the direction of the engine
(d) all of the above

219. The track from which train diverts is known as
(a) turn-out (b) main line (c) crossing track (d) point

220. The type of turn-out in which both the turn -out rails are movable is known as
(a) Wharton safety switches (b) split switches
(c) stub switches (d) none of these

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221. The split switch type of turn -out
(a) makes one turn - out rail and one main rail line movable
(b) gives more lateral rigidity to the turn - out
(c) can be used by the trains moving at high speeds
(d) all of the above

222. The trailing points in a track are those points at which the train
(a) first pass over switches and then over crossings
(b) first pass over crossings and then over switches
(c) first pass either over switches or crossings
(d) none of the above

223. The distance between the running edge of the stock and switch rails at the switch heel, is c
(a) heel clearance (b) heel divergence (c) heel spacing (d) either (a) or (b)

224. The heel clearance is always measured ..... to the stock rail.
(a) parallel (b) perpendicular

225. The distance between the adjacent faces of the stock rail and the check rail, is called
(a) heel divergence (b) heel clearance
(c) flangeway clearance (d) throw of switch

226. The minimum value of flangeway clearance is
(a) 60 mm (b) 80 mm (c) 100 mm (d) 120 mm

227. Wing rails are provided in crossings.
(a) Yes (b) No

228. Stock rails are fitted
(a) near tongue rails (b) near check rails
(c) against tongue rails (d) against check rails

229. The heel divergency recommended for broad gauge tracks by the Indian railways is
(a) 116 mm (b) 128 mm (c) 133 mm (d) 156 mm

230. The switch angle is the angle subtended between the gauge faces of the
(a) tongue rail and check rail (b) stock rail and check rail
(c) stock rail and tongue rail (d) none of these

231. If α is the switch angle and R is the radius of the turn out, the length of tongue rail will b
(a) $R \tan \alpha$ (b) $R \tan \alpha / 2$ (c) $R \cot \alpha$ (d) $R \cot \alpha/2$

232. The distance between the running face of the stock rail and the toe of the tongue rail, is kn
s
(a) heel divergence (b) heel clearance
(c) flangway clearance (d) throw of switch

233. The heel divergence is always ..... flangway clearance.
(a) equal to (b) less than (c) greater than

234. The switch angle depends upon
(a) length of tongue rail (b) heel divergance
(c) both (a) and (b) (d) none of these

235. The maximum value of throw of switch for a broad gauge track is
(a) 89 mm (b) 95 mm (c) 108 mm (d) 121 mm

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236. Which of the following statement is correct?
(a) The tongue rail should be longer than the stock rail.
(b) The tongue rail should be smaller than rigid wheel base of the vehicle.
(c) Track spacing is the distance between the running edge of stock and switch rails at the switch heel.
(d) Facing points are such places in the track where trains first pass over switches and then over crossings.

237. Trailing points are on the ..... side of facing points.
(a) same (b) opposite

238. The number of a crossing is defined as the cotangent of the crossing angle.
(a) True (b) False

239. In India, the crossing number for passenger turnouts is taken as
(a) 6 (b) 8.5 (c) 10 (d) 12

240. A cross-over requires
(a) two sets of switches and two crossings (b) two sets of switches and four crossings
(c) four sets of switches and four crossings (d) none of these

241. Two cross-overs are laid between two tracks in the case of
(a) diamond crossing (b) scissors crossing
(c) level crossing (d) all of these

242. The crossing in which the right hand rail of one track crosses the left hand rail of another track or vice versa is called
(a) acute angle crossing (b) obtuse angle crossing
(c) square crossing (d) none of these

243. When one track is superimposed on the other track, it is known as
(a) ladder track (b) double slip track
(c) Gaunlet track (d) none of these

244. A three-throw requires
(a) two sets of switches and two crossings (b) three sets of switches and two crossings
(c) two sets of switches and three crossings (d) three sets of switches and three crossings

245. When two tracks of same or different gauges cross each other at any angle, the crossing provided is
(a) diamond crossing (b) scissors crossing
(c) level crossing (d) all of these

246. The system of signalling used on single-line working, is
(a) absolute block system (b) space interval system
(c) time interval system (d) pilot guard system

247. In case the block system fails, then the system used is
(a) space interval system (b) time interval system
(c) pilot guard system (d) any one of these

248. The levers for ..... are painted in black colour.
(a) points (b) stop signal (c) crossing gate (d) all of these

249. The main device used for interlocking is
(a) point lock (b) handle bar (c) detector

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250. In case of level crossing, the railway track and road cross each other at the ..... level.
(a) same (b) different

251. A warner signal, which is first seen by the driver is known as
(a) disc signal (b) home signal (c) outer signal (d) routing signal

252. The reception signal is
(a) outer signal (b) home signal (c) both (a) and (b) (d) none of these

253. Which of the following statement is wrong?
(a) The length of gap at crossing between two noses of a diamond crossing increases as crossing angle decreases.
(b) The sand hump is a device to check the movement of a vehicle.
(c) The next signal after outer signal towards station is a routing signal.
(d) A stop signal placed at the end of a platform is called a starter signal.

254. An advance starter signal is used for
(a) shunting (b) goods train (c) loco-sheds (d) all of these

255. In a shunting signal, if the red band is horizontal, it indicates
(a) stop (b) proceed cautiously
(c) proceed (d) none of these

ANSWERS

1.	(a)	2.	(d)	3.	(b)	4.	(d)	5.	(b)	6.	(a)
7.	(b)	8.	(c)	9.	(d)	10.	(a)	11.	(b)	12.	(a)
13.	(a)	14.	(b)	15.	(c)	16.	(b)	17.	(a)	18.	(c)
19.	(b)	20.	(d)	21.	(c)	22.	(a)	23.	(a)	24.	(b)
25.	(a)	26.	(a)	27.	(b)	28.	(b)	29.	(d)	30.	(c)
31.	(c)	32.	(d)	33.	(a)	34.	(c)	35.	(d)	36.	(d)
37.	(d)	38.	(c)	39.	(b)	40.	(d)	41.	(d)	42.	(b)
43.	(d)	44.	(a)	45.	(a)	46.	(a)	47.	(b)	48.	(d)
49.	(d)	50.	(b)	51.	(a)	52.	(d)	53.	(b)	54.	(a)
55.	(a)	56.	(d)	57.	(a)	58.	(b)	59.	(a)	60.	(c)
61.	(a)	62.	(d)	63.	(d)	64.	(b)	65.	(c)	66.	(a)
67.	(C) (A) (D) (B)			68.	(c)	69.	(b)	70.	(a)	71.	(a)
72.	(d)	73.	(c)	74.	(c)	75.	(a)	76.	(d)	77.	(a)
78.	(d)	79.	(d)	80.	(a)	81.	(a)	82.	(d)	83.	(a)
84.	(b)	85.	(a)	86.	(b)	87.	(b)	88.	(d)	89.	(b)
90.	(c)	91.	(b)	92.	(c)	93.	(b)	94.	(a)	95.	(a)
96.	(b)	97.	(a)	98.	(d)	99.	(a)	100.	(a)	101.	(a) (b)
102.	(d)	103.	(d)	104.	(a)	105.	(d)	106.	(c)	107.	(b)
108.	(a)	109.	(b)	110.	(a)	111.	(c)	112.	(b)	113.	(b)
114.	(d)	115.	(c)	116.	(c)	117.	(c)	118.	(d)	119.	(d)
120.	(b)	121.	(d)	122.	(b)	123.	(a)	124.	(b)	125.	(d)
126.	(d)	127.	(b)	128.	(a)	129.	(c)	130.	(d)	131.	(b)

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132. (a) 133. (b) 134. (d) 135. (b) 136. (a) 137. (a)
138. (b) 139. (a) 140. (c) 141. (d) 142. (b) 143. (a)
144. (c) 145. (a) 146. (a) 147. (d) 148. (a) 149. (b)
150. (b) 151. (c) 152. (c) 153. (a) 154. (c) 155. (c)
156. (d) 157. (a) 158. (d) 159. (d) 160. (a) 161. (a)
162. (b) 163. (b) 164. (a) 165. (a) 166. (a) 167. (b)
168. (d) 169. (c) 170. (b) 171. (a) 172. (b) 173. (c)
174. (b) 175. (b) 176. (a) 177. (d) 178. (c) 179. (b)
180. (b) 181. (a) 182. (a) 183. (b) 184. (c)
185. (D),(A),(B),(C) 186. (d) 187. (c) 188. (c) 189. (b)
190. (b) 191. (c) 192. (b) 193. (d) 194. (a) 195. (b)
196. (b) 197. (d) 198. (d) 199. (d) 200. (d) 201. (d)
202. (c) 203. (b) 204. (b) 205. (c) 206. (a) 207. (c)
208. (a) 209. (c) 210. (c) 211. (b) 212. (c) 213. (a)
214. (a) 215. (b) 216. (a) 217. (a) 218. (c) 219. (b)
220. (a) 221. (d) 222. (b) 223. (d) 224. (b) 225. (c)
226. (a) 227. (a) 228. (c) 229. (c) 230. (a) 231. (b)
232. (d) 233. (c) 234. (c) 235. (b) 236. (d) 237. (b)
238. (a) 239. (d) 240. (a) 241. (b) 242. (a) 243. (c)
244. (c) 245. (a) 246. (b) 247. (b) 248. (a) 249. (d)
250. (a) 251. (c) 252. (c) 253. (c) 254. (a) 255. (a)

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11 Soil Mechanics and Foundations

11.1 Introduction

According to Dr. Karl Terzaghi, Soil Mechanics is the application of laws of Mechanics and Hydraulics to engineering problems dealing with sediments and other unconsolidated accumulations of soil particles produced by the mechanical and chemical disintegration of rocks, regardless of whether or not they contain an admixture of organic constituents. The term soil has various meanings, depending upon the general professional field in which it is being considered. For engineering purposes, soil is defined as a natural aggregate of mineral grains, loose or moderately cohesive, inorganic or organic in nature. According to a geologist, soil is defined as a disintegrated rock and according to an agriculturist, soil is the loose mantle at the surface of the earth which favours the growth of plant.

The soil is produced by the mechanical or chemical weathering of the solid rocks which may be igneous rock, sedimentary rock or metamorphic rock. The mechanical weathering is caused by the physical agencies such as periodical temperature changes, impact and splitting action of flowing water, ice and wind, and spliting action of ice, plants and animals. Cohesionless soils (sands) are formed due to physical disintegration of rocks. The chemical weathering may be caused due to oxidation, hydration, carbonation and leaching by organic acids and water.

The soil obtained due to weathering may be residual or transported soil. The *residual soils* are formed by weathering of rocks, but located at the place of origin. These soils are formed from rocks like granite, basalt, sandstone, limestone and salts. The sand, silt* and clays are residual soils. The *transported soils* are those soils which are carried away by the force of wind, ice, water and gravity. The soil transported by wind is *aeolian soil* such as loess while the soil transported by running water is called *alluvial soil*. The soil which is deposited at the bottom of the lakes is known as *lacustrine soil* and the soil transported by gravitational force is termed as *colluvial soil* such as *talus*. The soil transported by glaciers either by ice or by water issuing from melting of glaciers is termed as *glacier soil* or *glacier drift* or *simple drift*.

Note : The accumulation of decaying and chemically deposited vegetable matter under conditions of excessive moisture results in the formation of *cumulose soils* such as peat and muck.

11.2 Properties of Fine Grained Soil

The important properties of the fine grained soil are as follows :

1. *Plasticity.* It is defined as that property of a soil which allows it to be deformed rapidly without rupture, without elastic rebound and without volume change. A soil is said to be plastic, if within some range of water content it can be rolled into thin threads. The two tests which fix the water content are the plastic limit and the liquid limit tests.

The *plastic limit* is defined as the minimum water content at which a soil will just begin to crumble when rolled into a thread approximately 3 mm in diameter.

The *liquid limit* is defined as the minimum water content at which the soil is sufficiently fluid to flow a specified amount when jarred 25 times in a standard apparatus.

* Silt is a fine grained soil with little or no plasticity. The minimum size of grains of silts is about 0.0002 mm and the maximum size is 0.06 mm.

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as cohesion. This strength is basically due to shearing strength of the absorbed layer that separates the grains at these points.

2. *Cohesion and Thixotrophy.* The capacity of the soil to resist shearing stresses is known

When sensitive clays are used in construction, they loose strength due to remoulding during construction operations. However, with the passage of time, the strength again increases, though not to the same original level. This phenomenon of 'strength lose and strength gain' with no change in volume or water content is called thixotrophy.

3. *Consolidation and Swelling.* When a compressive load is applied to soil mass, a decrease in its volume takes place. The decrease in the volume of soil mass under stress is known as compression and the property of soil mass pertaining to its susceptibility to decrease in volume under pressure is known as *compressibility.*

According to Terzaghi, 'every process involving a decrease in the water content of saturated soil without replacement of the water by air is called a *process of consolidation*'. The opposite process is called a *process of swelling* which involves an increase in the water content due to an increase in the volume of voids.

11.3 Three Phase System of Soil

A soil mass is a three phase system consisting of solid particles (called soil grains), water and air, as shown in Fig. 11.1. The total volume (V) of the soil mass consists of volume of air (V_a), volume of water (V_w) and the volume of solids (V_s). The volume of voids (V_v) is, therefore, equal to the volume of air plus the volume of water. Since weight of air (W_a) is considered to be negligible, therefore, the weight of voids (W_v) is equal to the weight of water (W_w).

The weight of solids is represented by W_s which is evidently equal to the dry weight of soil sample. The total weight (W) of the soil mass is, therefore, equal to ($W_s + W_w$).

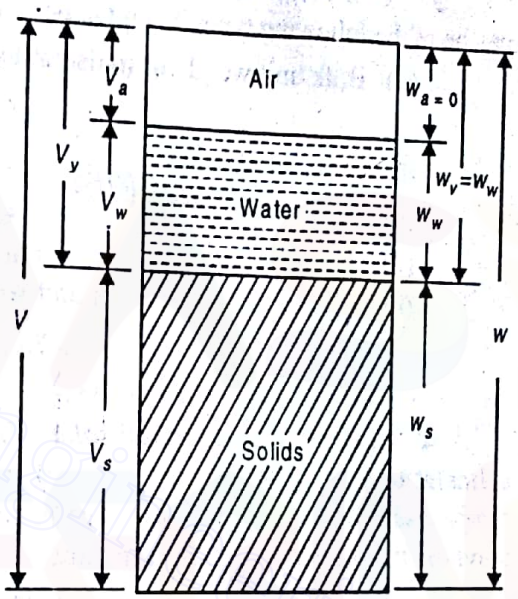

Fig. 11.1

11.4 Technical Terms used in Soil Mechanics

The following technical terms are widely used in Soil Mechanics :

1. *Water content* (w). It is the ratio of the weight of water (W_w) to the weight of solids (W_s) in a given soil mass. It is usually expressed as a percentage. Mathematically,

$$w = \frac{W_w}{W_s} \times 100 = \frac{W - W_s}{W_s} \times 100 = \left[\frac{W}{W_s} - 1\right] 100$$

If instead of weights, corresponding masses are known, then water content,

$$w = \frac{M_w}{M_s} \times 100 = \frac{M - M_s}{M_s} \times 100 = \left[\frac{M}{M_s} - 1\right] 100$$

2. *Density of soil.* The density of the soil may be of the following types :

(a) *Bulk density or moist density* (ρ). It is the ratio of the total mass (M) of the soil to the total volume (V) of the soil. It is expressed in kg / m^3. Mathematically,

$$\rho = M/V$$

(b) *Dry density* (ρ_d). It is the ratio of the mass of solids (M_s) to the total volume (V) of the soil (in moist condition). Mathematically,

$$\rho_d = M_s / V$$

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(c) *Density of solids* (ρ_s). It is the ratio of the mass of solids (M_s) to the volume of soli (V_s). Mathematically,

$$\rho_s = M_s / V_s$$

(d) *Saturated density* (ρ_{sat}). When the soil mass is saturated, its bulk density is call saturated density. It is the ratio of total mass of a fully saturated soil (M_{sat}) to the to volume (V) of the soil. Mathematically,

$$\rho_{sat} = M_{sat} / V$$

(e) *Submerged or buoyant density* (ρ_{sub}). It is the ratio of the submerged mass of s solids $(M_s)_{sub}$ to the total volume (V) of the soil. Mathematically,

$$\rho_{sub} = (M_s)_{sub} / V$$

The submerged density or buoyant density is also expressed as

$$\rho_{sub} = \rho_{sat} - \rho_w$$

where ρ_w = Density of water = 1000 kg / m^3

3. *Unit weight of soil mass*. In the similar way as discussed above, the unit weight of soil m may be of the following types by replacing M to W. The unit weight is expressed in N/m^3 or kN/m^3.

(a) Bulk unit weight or moist unit weight, $\gamma = W / V$

(b) Dry unit weight, $\gamma_d = W_s / V$

(c) Unit weight of solids, $\gamma_s = W_s / V_s$

(d) Saturated unit weight, $\gamma_{sat} = W_{sat} / V$

(e) Submerged or buoyant unit weight,

$$\gamma_{sub} = (W_s)_{sub} / V = \gamma_{sat} - \gamma_w$$

The unit weight of water (γ_w) is 9.81 kN/m^3.

4. *Specific gravity of soil solids* (G). It is the ratio of the weight of a given volume of s solids at a given temperature (27°C) to the weight of an equal volume of distilled water at th temperature, both weights being taken in air. In other words, it is the ratio of the unit weight of s solids to that of water. Mathematically,

$$G = \gamma_s / \gamma_w$$

The ratio of the unit weight of the given soil mass to that of water, is called *apparent* or *ma* or *bulk specific gravity* (G_m). Mathematically,

$$G_m = \gamma / \gamma_w$$

Note: Unless otherwise stated, we shall denote the specific gravity (G) as the specific gravity of soil solids.

5. *Void ratio* (e). It is the ratio of the total volume of voids (V_v) to the volume of soil soli (V_s) in a given soil mass. Mathematically,

$$e = V_v / V_s$$

6. *Porosity of soil mass* (n). It is the ratio of total volume of voids (V_v) to the total volume the given soil mass (V). Mathematically,

$$n = V_v / V$$

7. *Degree of saturation of soil mass* (s). It is the ratio of the volume of wate: (V_w) present i a given soil mass to the total volume of the voids (V_v) in it. Mathematically,

$$s = V_w / V_v$$

For a fully saturated soil mass $V_w = V_v$ and hence $s = 1$. The submerged soils are fully saturate soils.

For a perfectly dry soil mass, $V_w = 0$ and hence $s = 0$.

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8. *Percentage air voids* (n_a). It is the ratio of the volume of air voids (V_a) to the total volume of the soil mass (V) and is expressed as percentage. Mathematically,

$$n_a = \frac{V_a}{V} \times 100$$

9. *Air content* (a_c). It is the ratio of the volume of air voids (V_a) to the volume of voids (V_v). Mathematically,

$$a_c = V_a / V_v$$

Since $V_a = V_v - V_w$, therefore,

$$a_c = 1 - \frac{V_w}{V_v} = 1 - s$$

10. *Density index or relative density or degree of density of soil mass* (I_D). It is the ratio of the difference between the voids ratio of the soil in its loosest state (e_{max}) and its natural voids ratio (e) to the difference between the voids ratio in the loosest (e_{max}) and the densest state (e_{min}). Mathematically,

$$I_D = \frac{e_{max} - e}{e_{max} - e_{min}}$$

The value of I_D varies from zero to unity.

11.5 Important Relationships Between Soil Parameters

The important relationship between soil parameters are given below :

1. *Relation between void ratio* (e) *and porosity* (n)

We know that $e = \frac{V_v}{V_s} = \frac{V_v}{V - V_v}$

$$= \frac{V_v / V}{V/V - V_v/V} \quad \text{...(Dividing the numerator and denominator by } V)$$

$$= \frac{n}{1-n} \quad \text{...}(\because V_v / V = n)$$

2. *Relation between porosity* (n) *and void ratio* (e)

We know that

$$n = \frac{V_v}{V} = \frac{V_v}{V_s + V_v}$$

$$= \frac{V_v / V_s}{V_s / V_s + V_v / V_s} \quad \text{...(Dividing the numerator and denominator by } V_s)$$

$$= \frac{e}{1+e} \quad \text{...}(\because V_v / V_s = e)$$

3. *Relation, between void ratio* (e), *degree of saturation* (s), *water content* (w) *and specific gravity of solids* (G)

We know that

$$w = \frac{W_w}{W_s} = \frac{\gamma_w . V_w}{\gamma_s . V_s} = \frac{1}{G} \times \frac{V_w}{V_s} \quad \text{...}(\because G = \gamma_s / \gamma_w)$$

$$= \frac{1}{G} \times \frac{V_w}{V_s} \times \frac{V_v}{V_v} \quad \text{...(Multiplying the numerator and denominator by } V_v)$$

$$= \frac{1}{G} \times s \times e \quad \text{...}\left(\because \frac{V_w}{V_v} = s \text{ and } \frac{V_v}{V_s} = e\right)$$

$$\therefore \quad w \times G = s \times e$$

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4. *Relation between dry unit weight (γ_d), bulk unit weight (γ) and water content (w)*

We know that $$w = \frac{W_w}{W_s}$$

or $$w + 1 = \frac{W_w}{W_s} + 1 = \frac{W_w + W_s}{W_s} \quad \text{...(Adding 1 on both sides)}$$

$$= \frac{W}{W_s}$$

$$\therefore \quad W_s = \frac{W}{1 + w}$$

Dividing both sides by V, we get

$$\frac{W_s}{V} = \frac{W}{(1 + w)\,V}$$

$$\therefore \quad \gamma_d = \frac{\gamma}{1 + w} \quad \text{...}\left(\because \frac{W_s}{V} = \gamma_d \text{ ; and } \frac{W}{V} = \gamma\right)$$

5. *Relation between dry unit weight (γ_d), specific gravity (G), void ratio, (e) or porosity (n)*

We know that $$\gamma_d = \frac{W_s}{V} = \frac{\gamma_s \times V_s}{V} \quad \text{...}(\because W_s = \gamma_s \times V_s)$$

Since $\gamma_s = G \times \gamma_w$, therefore,

$$\gamma_d = \frac{G \times \gamma_w \times V_s}{V} = \frac{G \times \gamma_w \times V_s}{V_s + V_v} \quad \text{...}(\because V = V_s + V_v) \ldots(i)$$

$$= G \times \gamma_w \left(\frac{1}{1 + V_v / V_s}\right) = \frac{G \times \gamma_w}{1 + e} \quad \text{...}\left(\because \frac{V_v}{V_s} = e\right)$$

From equation (i), $$\gamma_d = \frac{G \times \gamma_w \times V_s}{V} = G \times \gamma_w \left(\frac{V - V_v}{V}\right) \quad \text{...}(\because V_s = V - V_v)$$

$$= G \times \gamma_w \left(1 - \frac{V_v}{V}\right)$$

$$= G \times \gamma_w (1 - n) \quad \text{...}\left(\because \frac{V_v}{V} = n\right)$$

6. *Relation between saturated unit weight (γ_{sat}), specific gravity (G), and void ratio (e) or porosity (n)*

We know that $$\gamma_{sat} = \frac{W_{sat}}{V} = \frac{W_s + W_w}{V} = \frac{W_s + W_v}{V} \quad \text{...}(W_w = W_v)$$

$$= \frac{\gamma_s \times V_s + \gamma_w \times V_v}{V} \quad \ldots(i)$$

$$= \gamma_s \times \frac{V_s}{V} + \gamma_w \times \frac{V_v}{V}$$

Since $G = \gamma_s / \gamma_w$ or $\gamma_s = G \times \gamma_w$ and $V = V_s + V_v$, therefore,

$$\gamma_{sat} = G \times \gamma_w \left(\frac{V_s}{V_s + V_v}\right) + \gamma_w \left(\frac{V_v}{V_s + V_v}\right)$$

$$= G \times \gamma_w \left(\frac{1}{1 + V_v / V_s}\right) + \gamma_w \left(\frac{1}{V_s / V_v + 1}\right)$$

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$$= \frac{G \times \gamma_w}{1+e} + \gamma_w \left(\frac{1}{\frac{1}{e}+1} \right)$$

$$= \frac{G \times \gamma_w}{1+e} + \frac{\gamma_w \times e}{1+e} = \frac{\gamma_w}{1+e}(G+e)$$

From equation (*i*), $\gamma_{sat} = \frac{\gamma_s \times V_s + \gamma_w \times V_v}{V}$

$$= \gamma_s \left(\frac{V - V_v}{V} \right) + \gamma_w \times \frac{V_v}{V}$$

$$= \gamma_s (1-n) + \gamma_w \times n = G \times \gamma_w (1-n) + n \times \gamma_w$$

7. *Relation between submerged or buoyant unit weight (γ_{sub}), specific gravity (G) and void ratio (e)*

We know that $\gamma_{sub} = \gamma_{sat} - \gamma_w$

We have already discussed that

$$\gamma_{sat} = \frac{\gamma_w}{1+e}(G+e)$$

$$\gamma_{sub} = \frac{\gamma_w}{(1+e)}(G+e) - \gamma_w$$

$\therefore$

$$= \gamma_w \left(\frac{G+e}{1+e} - 1 \right) = \frac{\gamma_w}{1+e}(G-1)$$

Note : The similar relations as discussed above may be obtained in terms of densities by replacing γ to ρ.

11.6 Determination of Properties of Soils

The methods of determining those properties of soils which are used in their identification and classification are as follows :

1. *Determination of water content.* The water content of a soil sample may be determined by the following methods :

(*a*) *Oven drying method.* This is the most accurate method of determining the water content. According to this method, water content is calculated from the following equation :

$$w = \frac{M_2 - M_3}{M_3 - M_1} \times 100\ \%$$

where M_1 = Mass of container with lid,

M_2 = Mass of container with lid and wet soil, and

M_3 = Mass of container with lid and dry soil.

(*b*) *Sand bath method.* This is a field method of determining rough value of the water content, where the facility of an oven method is not available.

(*c*) *Calcium carbide method.* This method is specially suited where water content is to be quickly determined for the purpose of proper field control, such as in the compaction of an embankment.

(*d*) *Pycnometer method.* This method is also a quick method of determining the water content of those soils whose specific gravity is accurately known. This method is suitable for coarse grained soils only.

2. *Determination of specific gravity.* The specific gravity of soil solids may be determined either by a density bottle method or by a pycnometer method. The density bottle method is the most

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accurate and is suitable for all types of soils. The pycnometer method is used only for coarse grained soils. According to this method, the specific gravity (G) of the soil solids is given by

$$G = \frac{M_2 - M_1}{(M_2 - M_1) + (M_4 - M_3)}$$

where
M_1 = Mass of pycnometer,
M_2 = Mass of pycnometer and dry soil,
M_3 = Mass of pycnometer, soil solids and water, and
M_4 = Mass of pycnometer and water.

3. *Determination of particle-size distribution.* The percentage of various sizes of particles in a given dry soil sample is found by the mechanical analysis which is performed is two stages, *i.e.* sieve analysis and sedimentation analysis. The *sieve analysis* is done if all particles do not pass through square opening of 75 micron (0.075 mm). The sieving is performed by arranging the various sieves one over the other in the order of their mesh openings. The largest aperture sieve being kept at the top and the smallest aperture size at the bottom. The smallest sieve size according to Indian standards, is 45 micron (0.045 mm). According to Indian standards, the sieves are designated by the size of the aperture in mm. For example, in a 2 mm sieve, each hole is a square with its side 2 mm. It may be noted that sieving is not practicable for grain sizes smaller than about 75 micron (0.075 mm).

The *sedimentation analysis* (which is based on the *Stoke's law) is used to determine the grain size distribution of those soils whose grain size is finer than 75 micron (0.075 mm). The sedimentation analysis is done either with the help of a hydrometer or a pipette. The analysis is based on the assumptions that the

(*a*) soil particles are spherical.

(*b*) particles settle independent of other particles and the neighbouring particles do not have any effect on its velocity of settlement, and

(*c*) walls of the jar, in which the suspension is kept, also do not affect the settlement.

The sedimentation analysis gives the particle size equivalent or effective diameter. The upper limit of particle size for the validity of the Stoke's law is about 0.2 mm and the lower limit of particle size is about 0.0002 mm. For particle smaller than 0.0002 mm effective diameter, Stoke's law no longer remains valid.

The hydrometer method of sedimentation analysis is used to determine the density of soil suspension. The hydrometers are generally calibrated at 27° C. If the temperature of the soil suspension is not 27°C, a correction for temperature should be applied to the observed hydrometer reading. In addition to the correction for temperature (may be positive or negative), two more corrections are to be applied to the hydrometer reading *i.e.* correction for meniscus (always positive) and correction for dispersing agent (always negative).

The pipette method is the standard sedimentation method used in the laboratory. In order to have proper dispersion of soil, a dispersing agent is added to the soil. According to Indian standards, the dispersing solution used in the pipette method, for the determination of size of particle consists of 7 g sodium carbonate, 33g sodium hexameta phosphate and 1 litre distilled water.

A soil sample may be *well graded* or *poorly graded* or *uniformly graded*. A soil is said to be well graded when it has good representation of particles of all sizes. A soil is said to be poorly graded if it has an excess of certain particles and deficiency of other or if it has most of the particles of about the same size (known as uniformly graded soil).

For coarse grained soil, certain particle sizes such as D_{10}, D_{30} and D_{60} are important. The D_{10}

* According to Stoke's law, the velocity at which grains settle out of suspension, all other factors being equal, is dependent upon the shape, weight and size of the grain.

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resents a size in mm such that 10 % of the particles are finer than this size. Similarly, the soil ticles finer than D_{60} size are 60 % of the total mass of the sample. The size D_{10} is sometimes called *effective size* or *effective diameter*. The *uniformity coefficient* is a measure of the particle size ge and is given by the ratio of the D_{60} to D_{10} sizes. The uniformity coefficient for a uniformly ded soil is nearly unity. The soil is said to be well graded soil, when the uniformity coefficient is re than 10.

4. *Determination of consistency of soils.* The term consistency denotes the degree of firmness he soil which may be termed as soft, firm , stiff or hard. The term is mostly used for fine grained ls of which the consistency is related to a large extent to water content. The fine grained soil may nixed with water to form a plastic state which can be moulded into any form by pressure. The lition of water reduces the cohesion making the soil still easier to mould. Further addition of water uces the cohesion until the material no longer retains its shape under its own weight, but flows as quid. According to Swedish agriculturist Atterberg, the soil passes through the four stages or es of consistency with the appropriate consistency limits. The four states are solids state, semi id state, plastic state and liquid state.

The Atterberg limits which are most useful for engineering purposes are liquid limit, plastic it and shrinkage limit. These limits are expressed as per cent water content.

The *liquid limit* is defined as the minimum water content at which the soil is still in the liquid te and just develops the shear strength against flowing.

The *plastic limit* is defined as the minimum water content which makes the soil to be rolled o 3 mm diameter threads. The shear strength of a soil in the plastic limit is higher than that in the uid limit.

The *shrinkage limit* is defined as the maximum water content of a saturated soil at which a duction in its moisture does not cause a decrease in volume of the soil mass. When the water ntent in a soil is reduced beyond the shrinkage limit, the soil will be in a *solid state*.

tes: (*a*) The difference between the liquid limit and plastic limit of a soil is termed as *plasticity index*. When plastic limit is equal to or greater than liquid limits, then the plasticity index is zero.

(*b*) The difference between the liquid limit and the shrinkage limit is called *shrinkage index*.

(*c*) The ratio of the liquid limit (w_L) minus the natural water content (w) to the plasticity index (I_P) is lled *consistency index* or *relative consistency* (I_C). Mathematically,

$$I_C = \frac{w_L - w}{I_P}$$

A soil with $I_C = 0$ is at its liquid limit and if $I_C = 1$, it is at the plastic limit. If I_C exceeds unity, the soil in a semi solid state and will be stiff.

(*d*) The ratio of the natural water content (w) minus its plastic limit (w_P) to the plasticity index (I_P) is alled *liquidity index* (I_L). Mathematically,

$$I_L = \frac{w - w_P}{I_P}$$

(*e*) The *flow index* in soils indicates the shear strength variation with water content. The ratio of the lasticity index to the flow index is called *toughness index* of the soil.

(*f*) The ratio of the plasticity index to the clay fraction is known as *activity of clay*.

11.7 Sensitivity of Clays

The ratio of the unconfined compressive strength of the natural or undisturbed soil to the unconfined compressive strength of soil in a remoulded state, without change in the water content, is known as *sensitivity*. The sensitivity of most clays is 1 to 8. For normal clays, the sensitivity is from 2 to 4.

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Notes: (*a*) The property of a soil which enables to regain its strength lost on remoulding in a short time, without change in water content, is called *thixotropy*.

(*b*) The unconfined compressive strength of a very soft clay is 10 to 25 kN/m^2 and of a hard clay, it is above 400 kN/m^2.

11.8 Soil Structure

The arrangement and state of aggregation of soil particles in a soil mass is called a *soil structure*. The following are the different types of soil structure :

1. *Single grained structure.* It is an arrangement composed of individual soil particles.
2. *Honey combed structure.* It is an arrangement of soil particles having a comparatively loose, stable structure resembling a honey comb.
3. *Flocculent structure.* It is an arrangement composed of flocs of soil particles instead of individual soil particles. The particles of soil are oriented 'edge-to-edge' or 'edge-to-face' with respect to one another.
4. *Dispersed structure.* It is an arrangement composed of particles having 'face-to-face' or parallel orientation.
5. *Coarse-grained skeleton structure.* It is an arrangement of coarse grains forming a skeleton with its interstices partly filled by a relatively loose aggregation of the finest soil grains.
6. *Cohesive matrix structure.* It is an arrangement in which a particle-to-particle contact of coarse fraction is not possible.

Note: The single grained structure is found in coarse grained soils. The honeycombed, flocculent and dispersed structures are found in fine-grained soils. The skeleton and matrix structures represent composite soils.

11.9 Permeability

The property of the soil mass which permits the seepage of water through its interconnecting voids, is called *permeability*. A soil having continuous voids is called *permeable soil*. The gravels are highly permeable while stiff clay is the least permeable and hence a clay is termed as impermeable soil for all practical purposes.

The flow of water through soil was first studied by Darcy who demonstrated experimentally that for laminar flow conditions in a saturated soil, *the rate of flow or the discharge per unit time is proportional to the hydraulic gradient.*

The average velocity of flow that will take place through the total cross-sectional area of soil under unit* hydraulic gradient, is known as *coefficient of permeability*. Its unit is same as that of velocity *i.e.* m/s.

The permeability of a soil sample may be determined by the falling head permeameter and constant head permeameter.

Notes : (*a*) The value of permeability depends upon the direction of flow of water through the soil mass.

(*b*) The permeability of a given soil is directly proportional to the square of the average size and inversely proportional to its viscosity.

(*c*) The quantity of seepage of water in a soil medium is directly proportional to the coefficient of permeability.

(*d*) The coefficient of permeability of silt is less than that of clay.

11.10 Seepage Pressure

The pressure exerted by water on the soil through which it percolates, is known as *seepage pressure*. It is this seepage pressure that is responsible for the phenomenon known as *quick sand* and is of vital importance in the stability analysis of earth structures subjected to the action of seepage.

* The loss of head or dissipation of the hydraulic head per unit distance of flow through the soil is called *hydraulic gradient.*

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The seepage pressure always acts in the direction of flow. The vertical effective pressure may be decreased or increased, due to the seepage pressure depending upon the direction of flow. If the flow occurs in the downwards direction, the seepage pressure also acts in the downward direction and the effective pressure is increased. When the flow takes place in an upward direction, the seepage pressure also acts in the upward direction and the effective pressure is decreased. If the seepage pressure becomes equal to the submerged weight of the soil, the effective pressure is reduced to zero. In such a case, a cohesionless soil loses all its shear strength and the soil particles have a tendency to move up in the direction of flow. This phenomenon of lifting soil particles is called *quick condition* or *quick sand*.

The hydraulic gradient at which quick condition occurs, is called *critical hydraulic gradient* (i_c).

Mathematically,

$$i_c = \frac{G-1}{1+e}$$

where
G = Specific gravity of soil particles, and
e = Void ratio.

Notes: (*a*) The critical hydraulic gradient for all soils is normally equal to unity.
(*b*) The critical hydraulic gradient increases with the increase in specific gravity of the soil and the decrease in void ratio.

11.11 Flow Lines and Equipotential Lines

The flow net in the seepage of water through a soil medium is a network of flow lines and equipotential lines. The flow net is used to determine the seepage flow, hydrostatic pressure, seepage pressure and exit gradient. A *flow line* or *stream line* in a seepage through a soil medium is defined as the path of particles of water through a saturated soil mass. The *equipotential line* in a seepage through a soil mass is defined as the line connecting the points of equal head of water. The direction of seepage is always perpendicular to the equipotential lines. The flow lines and equipotential lines are intersecting lines at 90° to each other.

Notes: 1. The portion between any two successive flow lines is known as *flow channel*. The portion enclosed between two successive equipotential lines and successive flow lines is known as *field*.

2. The discharge (Q) passing through a flow net for isotropic soils is given by

$$Q = KH \times \frac{N_F}{N_D}$$

where
K = A constant,
H = Total hydraulic head causing flow,
N_F = Number of flow channels, and
N_D = Number of potential drops.

11.12 Exit Gradient

The hydraulic gradient provided at the downstream side of a hydraulic structure such as a dam, is called *exit gradient* or *downstream gradient* or *tail water gradient*. It is defined as the ratio of the head loss to the length of seepage. The maximum permissible exit gradient is the critical gradient divided by the factor of safety.

11.13 Stress Conditions in Soil

The total stress or unit pressure, at any plane in a soil mass, is the total load per unit area. The total stress consists of effective stress or intergranular pressure and neutral stress or pore water pressure. The *effective stress* on the soil is due to the external load acting on the soil and the self weight of the soil particles. This stress is effective in decreasing the void ratio of the mass and in mobilising its shear strength. The neutral stress or pore water pressure on the soil is due to the weight of water present in soil pores. It is transmitted to the soil base through the pore water. This stress does not

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have any measurable influence on the voids ratio or any other mechanical property of the soil such as shearing resistance.

Notes: (*a*) The decrease in effective stress is accompanied by increase in the neutral stress.

(*b*) The effective stress is increased if the water is flowing from upward on the soil mass.

(*c*) The neutral stress is decreased if the water is flowing from downward on the soil mass.

11.14 Compressibility and Consolidation

When a compressive load is applied to soil mass, a decrease in its volume takes place. The decrease in volume of soil mass under stress is known as *compression* and the property of soil mass pertaining to its susceptibility to decrease in volume under pressure is known as *compressibility*. In a saturated soil mass having its voids filled with incompressible water, the decrease in volume takes place due to the* expulsion of water out of the voids under an applied load. Such a compression resulting from gradual reduction of pore space under steady load is called *consolidation*. According to Terzaghi, every process involving a gradual decrease of water content of a saturated soil at constant load is called a *process of consolidation*.

Note: In case of coarse grained sand having high permeability and low plasticity, 95 % of consolidation occurs within 1 minute after the application of load.

11.15 Coefficient of Compressibility

The coefficient of compressibility is defined as the decrease in voids ratio per unit increase of pressure. If the pressure on a clay layer increases slightly from p to $p + \delta p$ and the voids ratio decreases from e_0 to e, then the coefficient of compressibility (a_v) is given by

$$a_v = \frac{e_0 - e}{\delta p}$$

For a given difference in pressure, the value of coefficient of compressibility decreases as the pressure increases. The unit of coefficient of compressibility is inverse of pressure.

The change in volume of a soil per unit of initial volume due to a given increase in the pressure, is called the *coefficient of volume change* or *coefficient of volume compressibility* (m_v). Mathematically,

$$m_v = \frac{a_v}{1 + e_0}$$

The coefficient of volume compressibility is directly proportional to coefficient of compressibility. It decreases with the increase in pressure and the void ratio.

11.16 Coefficient of Consolidation

The coefficient of consolidation is adopted to indicate the combined effects of permeability and compressibility of soil on the rate of volume change. It is expressed by C_v and its unit is cm^2/s. Mathematically,

$$C_v = \frac{k}{m_v \cdot \gamma_w} = \frac{k\,(1 + e_0)}{a_v \cdot \gamma_w}$$

where

k = Coefficient of permeability,

m_v = Coefficient of volume change or coefficient of volume compressibility,

e_0 = Void ratio, and

γ_w = Unit weight of water.

11.17 Degree of Consolidation

The downward movement of the surface of a consolidating layer at any time (t) during the

* The rate of expulsion of water is directly dependent on the permeability of the soil.

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process of consolidation is called *consolidation settlement*. The ratio of the settlement (ρ) of the fully thickness of the clay to the ultimate or final settlement (ρ_f) when the process of consolidation is complete, is known as *degree of consolidation* (U). It is expressed as a percentage. The degree of consolidation is a function of time factor (T_v) such that

$$T_v = \frac{C_v \cdot t}{d^2} \quad ...(i)$$

where
C_v = Coefficient of consolidation, and
d = Drainage path. It is the maximum distance which the layer particles have to travel for reaching the free drainage layer.

The time factor (T_v) contains the physical constants of soil layer influencing its time-rate of consolidation. The equation (i) may be written as

$$T_v = \frac{k \cdot t}{m_v \gamma_w d^2} = \frac{k (1 + e_0) t}{a_v \gamma_w d^2}$$

The time-factor and hence the degree of consolidation depends upon the following factors :

(*a*) Thickness of clay layer,
(*b*) Number of drainage faces,
(*c*) Coefficient of permeability (k),
(*d*) Coefficient of consolidation (C_v), and
(*e*) Magnitude of consolidating pressure and the manner of its distribution across the thickness of the layer.

The equation (i) may also be written as

$$t = \frac{d^2 \cdot T_v}{C_v}$$

Since T_v is constant for a given degree of consolidation and given boundary conditions of the problem under consideration, the time (t) required to attain a certain degree of consolidation is directly proportional to the square of its drainage path and inversely proportional to the coefficient of consolidation.

Note: When the degree of consolidation (U) is less than 60 %, then the time factor (T_v) is given by

$$T_v = \frac{\pi}{4}\left(\frac{U}{100}\right)^2$$

When U is greater than 60 %, then

$$T_v = -0.9332 \log\left(1 - \frac{U}{100}\right) - 0.0851$$

11.18 Shear Strength of Soils

The shear strength of soil is the resistance to deformation by continuous shear displacement of soil particles due to the action of shear stress. The shear strength is a most important characteristic of the soil. The shearing strength of soil is due to the following components :

(*a*) *Structural resistance.* The structural arrangement of soil particles affects the shear stress because of the interlocking of the particles. The same soil may exhibit remarkably different shear strength at different void ratio and also at different rate of loading.

(*b*) *Frictional resistance.* The internal friction between soil particles resists the shearing friction of soil mass. The friction may be either sliding friction or a rolling friction or a combination of the two.

(*c*) *Cohesion.* The property of the soil holding its soil particles together is called cohesion. The soil which does not possess any cohesion is called cohensionless soil such as dry sand. The soil

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which possesses actual cohesion is called cohesion soil such as clays. It is an important property of fine grained soils. The coarse grained soils do not exhibit any cohesion. The shear strength of cohesionless soils results from intergranular friction alone, while in all other soils it results from both internal friction as well as cohesion.

11.19 Angle of Internal Friction

The measure of the shearing resistance of soil to sliding along a plane is termed as *angle of internal friction* or *friction angle* (ϕ). It depends upon the shape of the particles, surface roughness, type of interlocking, lateral pressure and the state of packing. The angle of internal friction varies with the normal direct pressure and the density of sand. The angle of internal friction of rounded grained loose sand and dense sand is about 25° to 30° and 32° to 37° respectively.

11.20 Coulomb's Law

According to Coulomb's law, the shearing strength of soil consists of cohesion and friction between the soil particles. Mathematically, shearing strength of soil,

$$\tau = c + \sigma \tan \phi$$

where

c = Cohesion (apparent or actual),

σ = Normal stress on the plane of shear, and

ϕ = Angle of internal friction or angle of shearing resistance.

11.21 Earth Pressure

A structure used for maintaining the ground surfaces at different elevations on either side of it is called a *retaining wall*. The material retained or supported by the structure is called *backfill* which may have its top surface horizontal or inclined. If the position of the backfill lies above the horizontal plane at the elevation of the top of the structure, it is called the *surcharge* and the inclination of the surcharge to the horizontal is called *surcharge angle*.

The lateral pressure exerted by the soil when the retaining wall has no movement relative to the backfill, is called *earth pressure* at rest. The earth pressure may be active earth pressure and passive earth pressure. The lateral pressure exerted by the soil when the retaining wall tends to move away from the backfill due to excessive pressure of the retained soil, is called *active earth pressure*. It is the minimum earth pressure exerted by the soil on the retaining wall. The lateral pressure exerted by the soil when the retaining wall moves towards the backfill due to any natural cause, is known as *passive earth pressure*. It is maximum earth pressure due to the maximum shear stress on the retaining wall.

Note: The value of earth pressure at rest is higher than the active earth pressure but less than the passive earth pressure.

11.22 Coefficient of Earth Pressure

The ratio of the horizontal stress (σ_h) to the vertical stress (σ_v) is called the *coefficient of earth pressure* (K). When the soil is in the *active state* of plastic equilibrium, the coefficient of active earth pressure (K_a) is given by

$$K_a = \frac{\sigma_h}{\sigma_v} = \cot^2 (45° + \phi/2) = \frac{1}{\tan^2 (45° + \phi/2)}$$

$$= \left[\frac{1 - \tan \phi/2}{1 + \tan \phi/2}\right]^2 = \left[\frac{\cos \phi/2 - \sin \phi/2}{\cos \phi/2 + \sin \phi/2}\right]^2$$

$$= \frac{\cos^2 \phi/2 + \sin^2 \phi/2 - 2 \cos \phi/2 \times \sin \phi/2}{\cos^2 \phi/2 + \sin^2 \phi/2 + 2 \cos \phi/2 \sin \phi/2}$$

$$= \frac{1 - 2 \sin \phi/2 \times \cos \phi/2}{1 + 2 \sin \phi/2 \times \cos \phi/2} = \frac{1 - \sin \phi}{1 + \sin \phi}$$

...($\because \sin \phi = 2 \sin \phi/2 \times \cos \phi/2$)

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where σ_v = Vertical pressure or Major principal stress,
σ_h = Horizontal pressure or Minor principal stress, and
ϕ = Angle of internal friction.

Similarly, in the passive state of plastic equilibrium, the coefficient of passive earth pressure (K_p) is given by

$$K_p = \frac{\sigma_v}{\sigma_h} = \tan^2 (45^\circ + \phi/2) = \frac{1 + \sin \phi}{1 - \sin \phi}$$

The value of K_a is always less as compared to K_p.

When the soil is at elastic equilibrium (*i.e.* at rest), then the coefficient of earth pressure at rest (K_0) is given by

$$K_0 = \frac{\mu}{1 - \mu}$$

where μ = Poisson's ratio of the soil.

The value K_0 for loose sand is 0.4, for hard clay 0.5, for soft clay and dense sand, it is 0.6. When the sand is compacted in layers and for stiff clay, the value of K_0 is 0.8.

Note: The earth pressure at rest can be calculated by using the theory of elasticity assuming the soil to be semi-infinite, homogeneous, elastic and isotropic.

11.23 Active Earth Pressure of Cohesive Soils

Consider a retaining wall with a smooth, vertical back retaining a horizontal backfill. At any depth z, lateral pressure (p_a) of cohesive soils is given by

$$p_a = \gamma z \cot^2 \alpha - 2c \cot \alpha \quad ...(i)$$

where γ = Dry weight of the soil,
c = Cohesion, and
$\alpha = 45^\circ + \phi/2$

At $z = 0$, equation (i) becomes

$$p_a = -2c \cot \alpha$$

and when $p_a = 0$,

$$z = z_0 = \frac{2c \tan \alpha}{\gamma}$$

...[From equation (i)]

This shows that negative pressure (*i.e.* tension) is developed at the top level of the retaining wall. This tension decreases to zero at a depth $z_0 = \dfrac{2c \tan \alpha}{\gamma}$

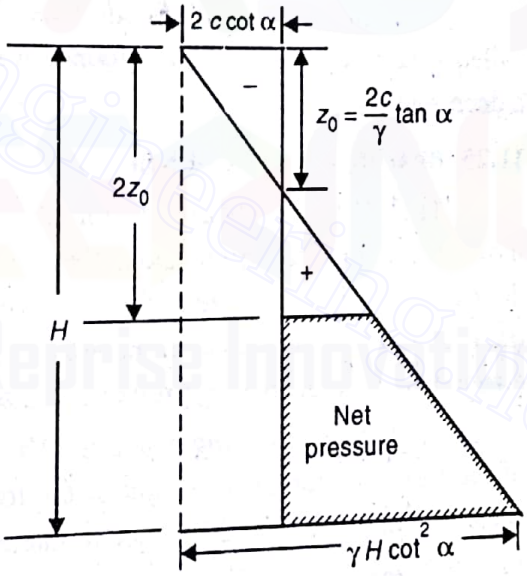

Fig. 11.2

At $z = H$, $p_a = \gamma H \cot^2 \alpha - 2c \cot \alpha$

The variation of lateral pressure along the height of the retaining wall is shown in Fig. 11.2. If the soil is cohesionless (*i.e.* if $c = 0$), then the pressure at the base will be equal to $\gamma H \cot^2 \alpha$. Thus the effect of cohesion in soil is to reduce the pressure intensity by $2c \cot \alpha$.

The total net pressure is given by

$$P_a = \int_0^H p_a \, dz = \int_0^H (\gamma z \cot^2 \alpha - 2c \cot \alpha) \, dz$$

$$= \frac{1}{2} \gamma H^2 \cot^2 \alpha - 2c H \cot \alpha$$

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Due to the negative pressure, a tension crack is usually developed in the soil near the top of the wall upto a depth of z_0. The total net pressure upon a depth $2\,z_0$ is zero. This means that a cohesive soil should be able to stand with a vertical face upto a depth $2\,z_0$ without any lateral support. The critical height (H_c) of an unsupported vertical cut in cohesive soil is thus given by

$$H_c = 2\,z_0 = \frac{4c}{\gamma} \tan\alpha = \frac{4c}{\gamma} \tan\left(45° + \frac{\phi}{2}\right) \quad \ldots(\because \alpha = 45° + \phi/2)$$

11.24 Foundations

The foundation is the lower part of a structure which transmits load to the ground. The various types of foundations are as follows :

1. *Footings.* A portion of the foundation of a structure which transmits load directly to the soil, is called footing.

2. *Combined footings.* The combination of two or more footings joined together to form a small mat, is called combined footing.

3. *Strip foundations.* The foundation whose length is considerably greater than its width, is called strip or continuous foundation.

4. *Raft foundation.* The foundation which supports a large number of loads of a single row and covers the whole loaded area even more, is called raft foundation.

5. *Pile foundation.* The foundation which is provided in soils incapable to transmit the structural load to suitable stratum by inserting relatively slender structural elements (called piles) is known as pile foundation.

6. *Shallow and deep foundations.* The foundation whose depth is not more than its width, is called a shallow foundation. The foundation whose depth is many times more than its width, is called a deep foundation.

11.25 Bearing Capacity of Soil

The load or pressure developed under the foundation without introducing any damaging movement in the foundation and in the supporting structure, is called *bearing capacity of the soil.* It depends upon the grain size of the soil, size and shape of the footing. The bearing capacity of a soil increases with the decrease in the area of the footing. The term bearing capacity is defined after attaching certain qualifying prefixes, as discussed below :

1. *Ultimate bearing capacity.* The total pressure at the base of the footing due to the weight of the superstructure, self weight of the footing and weight of the earth fill, if any, is called *gross pressure intensity.* The difference in intensities of the gross pressure due to the construction of the structure and the original overburden pressure, is known as *net pressure intensity.*

The minimum gross pressure intensity at the base of the foundation at which the soil fails in shear, is called *ultimate bearing capacity.*

2. *Net ultimate bearing capacity.* It is the minimum net pressure intensity at the base of the foundation at which the soil fails in shear.

3. *Net safe bearing capacity.* It is the net ultimate bearing capacity divided by the factor of safety.

4. *Safe bearing capacity.* It is the maximum pressure which the soil can carry safely without any risk of shear failure.

5. *Allowable bearing capacity.* It is the net loading intensity at which neither the soil fails in shear nor there is excessive settlement detrimental to the structure.

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11.16 Terzaghi's Analysis

The analysis of the condition of complete bearing capacity failure, usually termed as general shear failure, can be made by assuming that the soil behaves like an ideally plastic material. According to Dr. K. Terzaghi,

(*a*) The ultimate bearing capacity (q_f) per unit area of a cohesive soil for general shear failure (when the water table is below the base of footing) is given by

$$q_f = c.\,N_c + 0.5\,\gamma\,B\,N_\gamma + \gamma\,D_f N_q \quad ...(i)$$

where

c = Cohesion,

γ = Unit weight of soil,

B = Width of footing,

D_f = Depth of footing, and

N_c, N_q and N_γ = Bearing capacity factors which are functions of internal friction angle.

(*b*) The ultimate bearing capacity (q_f) per unit area of sands (cohesionless soil) for general shear failure is given by

$$q_f = 0.5\,\gamma\,B\,N_\gamma + \gamma\,D_f\,N_q \quad ...(ii)$$

(*c*) The ultimate bearing capacity (q_f) per unit area of clays (*i.e.* purely cohesive soils) for general shear failure is given by

$$q_f = 5.7\,c + \gamma\,D_f \quad ...(iii)$$

(*d*) The net ultimate bearing capacity (q_{nf}) per unit area of a cohesive soil is given by

$$q_{nf} = c\,N_c + 0.5\;\gamma\,BN_\gamma + \gamma\,D_f(N_q - 1) \quad ...(iv)$$

For cohesionless soil, $c = 0$

$$\therefore \quad q_{nf} = 0.5\,\gamma\,BN_\gamma + \gamma\,D_f(N_q - 1)$$

(*e*) The ultimate bearing capacity (q_f) per unit area of a frictional cohesive soil for square footing,

$$q_f = 1.3\,c\,N_c + \gamma\,D_f N_q + 0.4\,\gamma\,BN_\gamma$$

For rectangular footing, $$q_f = c\,N_c\left(1 + \frac{0.3B}{L}\right) + \gamma\,D_f\,N_q + 0.4\,\gamma\,BN_\gamma$$

and for circular footing, $$q_f = 1.3\,c\,N_c + \gamma\,D_f N_q + 0.3\,\gamma\,B\,N_\gamma$$ ...(Here B is diameter of footing)

(*f*) The ulitmate bearing capacity (q_f) per unit area of a cohesive soil for square and rectangular footing,

$$q_f = c\,N_c\left(1 + \frac{0.3\,B}{L}\right) + \gamma\,D_f$$

and for circular footing, $$q_f = 7.4\,c + \gamma\,D_f$$

(*g*) The ultimate bearing capacity (q_f) per unit area of non cohesive soil for square and rectangular footing,

$$q_f = 0.4\,\gamma\,B\,N_\gamma + \gamma\,D_f(N_q - 1)$$

and for circular footing, $$q_f = 0.3\,\gamma\,B\,N_\gamma + \gamma\;D_f(N_q - 1)$$

OBJECTIVE TYPE QUESTIONS

1. The term Soil Mechanics was coined by Dr. Karl Terzaghi.
   (*a*) True (*b*) False
2. The soil transported by running water is called
   (*a*) aeolian soil (*b*) marine soil
   (*c*) alluvial soil (*d*) lacustrine soil

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3. The soil transported by wind is called
   (a) aeolian soil (b) marine soil
   (c) alluvial soil (d) lacustrine soil
4. Lacustrine soils are those soils which are
   (a) deposited in sea water (b) deposited at the bottom of the lakes
   (c) transported by running water (d) transported by wind
5. Glacial soils are those soils which are
   (a) deposited in sea water (b) deposited at the bottom of the lakes
   (c) transported by running water (d) none of these
6. For engineering purposes, soil is defined as
   (a) the loose mantle at the surface of the earth which favours the growth of plant
   (b) a natural aggregate of mineral grains, loose or moderately cohesive, inorganic or organic nature
   (c) a disintegrated rock
   (d) all of the above
7. According to a geologist, soil is defined as a disintegrated rock.
   (a) Agree (b) Disagree
8. By an agriculturist, soil is defined as
   (a) the loose mantle at the surface of the earth which favours the growth of plant
   (b) a natural aggregate of mineral grains, loose or moderately cohesive, inorganic or organic nature
   (c) a disintegrated rock
   (d) none of the above
9. Which of the following soil is transported by wind ?
   (a) Talus (b) Loess (c) Drift
10. 'Talus' is a soil transported by glacial water.
   (a) Right (b) Wrong
11. Soils are derived from
   (a) igneous rocks (b) sedimentary rocks
   (c) metamorphic rocks (d) any one of these
12. Chemical weathering of soil is caused due to
   (a) oxidation (b) hydration
   (c) carbonation and leaching (d) all of these
13. The soil transported by glaciers either by ice or water is called
   (a) talus (b) loess (c) drift (d) none of these
14. Mechanical weathering of soils is caused by
   (a) periodical temperature changes (b) splitting action of flowing water
   (c) splitting action of ice (d) all of these
15. When the soils are carried away by force of gravity, they are known as ..... soils.
   (a) transported (b) residual
16. Residual soils are
   (a) sands (b) silts (c) clays (d) all of these

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17. A civil engineer is concerned mainly with ..... top mantle of soil in dealing with small and medium sized projects.
(a) 2 to 5 m (b) 5 to 8 m (c) 8 to 10 m (d) 10 to 15 m

18. Cohesionless soils are
(a) sands (b) clays (c) silts (d) silts and clays

19. The maximum size of grains of silts is about
(a) 0.06 mm (b) 0.2 mm (c) 0.5 mm (d) 1 mm

20. Silt is a
(a) material deposited by a glacier
(b) soil composed of two different soils
(c) fine grained soil with little or no plasticity
(d) clay with a high percentage of the clay mineral

21. Black cotton soil
(a) is inorganic in nature (b) contains large percentage of clay mineral
(c) exhibits high compressibility (d) all of these

22. Black cotton soils are ..... soils.
(a) expensive (b) residual

23. A fine grained soil
(a) has low permeability (b) has high compressibility
(c) may or may not be plastic (d) all of these

24. Consolidation and compressibility of soil
(a) is a measure of the ability of soil to allow the water to pass through its pores
(b) is a measure of the ability of soil to bear stresses without failure
(c) deals with changes in volume of pores in a soil under load
(d) any one of the above

25. The minimum size of grains of silts is about
(a) 0.0002 mm (b) 0.002 mm (c) 0.02 mm (d) 0.2 mm

26. The property of a soil which is of great importance in finding settlement of structures, is
(a) permeability (b) shear strength (c) consolidation (d) compressibility

27. Sand is almost non-compressible.
(a) Correct (b) Incorrect

28. The maximum size of the particles of clay is about
(a) 0.0002 mm (b) 0.002 mm (c) 0.02 mm (d) 0.2 mm

29. If the pores of a soil are completely full of air only, the soil is said to be
(a) wet soil (b) dry soil
(c) fully saturated soil (d) partially saturated soil

30. The moist soil is ..... saturated soil.
(a) fully (b) partially

31. The ratio of the volume of voids to the total volume of soil mass is called
(a) water content ratio (b) porosity
(c) void ratio (d) degree of saturation

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32. The ratio of the unit weight of soil solids to that of water is called
(a) void ratio (b) porosity
(c) specific gravity (d) degree of saturation

33. The degree of saturation of a soil is
(a) $\frac{V_w}{V_a + V_w}$ (b) $\frac{V_a}{V_a + V_w}$ (c) $\frac{V_s}{V_a + V_v}$ (c) $\frac{V_a + V_v}{V_s}$
where V_a = Volume of air in the voids, V_w = Volume of water in the voids,
V_s = Volume of solids, and V_v = Total volume of voids.

34. The unit weight of a soil at zero air voids depends upon
(a) unit weight of water (b) water content
(c) specific gravity (d) all of these

35. If W is the total weight of the soil mass and W_s is the weight of solids, then water content is equal to
(a) $1 + \frac{W}{W_s}$ (b) $1 - \frac{W}{W_s}$ (c) $\frac{W}{W_s} - 1$ (d) $\frac{W_s}{W} + 1$

36. The relation between porosity (n) and void ratio (e) is given by
(a) $n = \frac{1+e}{e}$ (b) $n = \frac{e}{1+e}$ (c) $e = \frac{n}{1-n}$ (d) $e = \frac{1-n}{n}$

37. The relation between void ratio (e), degree of saturation (s), water content (w) and specific gravity of solids (G) is given by
(a) $e + s = w + G$ (b) $e \times s = w \times G$ (c) $\frac{e}{s} = \frac{w}{G}$ (d) $\frac{s+e}{w} = \frac{G+e}{s}$

38. The relation between the air content (a_c) and the degree of saturation (s) is
(a) $a_c = s$ (b) $a_c = 1 - s$ (c) $a_c = 1 + s$ (d) $a_c = 1/s$

39. The degree of saturation for fully saturated soil is
(a) 0.25 (b) 0.50 (c) 0.75 (d) 1

40. The void ratio for saturated soil is equal to the ..... of water content and specific gravity of solids.
(a) sum (b) difference (c) product (d) ratio

41. The ratio of the volume of air voids to the volume of voids, is called
(a) void ratio (b) air content
(c) degree of saturation (d) porosity

42. For a perfectly dry soil mass, the degree of saturation is zero.
(a) Yes (b) No

43. The difference between maximum void ratio and minimum void ratio of a sand sample is 0.2. If the relative density of this sample is 66.6 % at a void ratio of 0.40, then the void ratio of this sample at its loosest state will be
(a) 0.40 (b) 0.60 (c) 0.70 (d) 0.75

44. The dry density of a soil is 1.5 g / cm^3. If the saturation water content is 50 %, then its saturated density and submerged density will respectively be
(a) 1.5 g / cm^3 and 1.0 g / cm^3 (b) 2.0 g / cm^3 and 1 g / cm^3
(c) 2.25 g / cm^3 and 1.25 g / cm^3 (d) 2.50 g / cm^3 and 1.50 g / cm^3

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45. A soil sample is having a specific gravity of 2.60 and a void ratio of 0.78. The water content in percentage required to fully saturate the soil at that void ratio will be
(a) 10 (b) 30 (c) 50 (d) 70

46. The specific gravity of a soil is the ratio of unit weight of soil solids to that of water at a temperature of
(a) 4° C (b) 17° C (c) 27°C (d) 36°C

47. A dry soil sample weighing 100 g has volume of 60 ml and specific gravity 2.5. Its void ratio is
(a) 0.4 (b) 0.5 (c) 0.6 (d) 0.8

48. For a given soil mass, the void ratio is 0.60, water content is 18 % and specific gravity of the soil particles is 2.6. The degree of saturation of the soil is
(a) 30 % (b) 50 % (c) 78 % (d) 82.5 %

49. The ratio of the difference between the void ratio in its loosest state and its natural void ratio to the difference between the voids ratio is the loosest and the densest state, is called
(a) density index (b) relative density (c) degree of density (d) any one of these

50. The submerged or buoyant unit weight of soil is equal to the ..... of unit weight of saturated soil and unit weight of water.
(a) sum (b) difference (c) product (d) ratio

51. The water content is the ratio of weight of water to the weight of solids
(a) Yes (b) No

52. The void ratio of a soil is defined as the ratio of the
(a) weight of water to the weight of solids
(b) volume of water to the volume of voids in the soil mass
(c) total volume of voids to the volume of soil solids
(d) total volume of voids to the total volume of soil

53. The water content ratio of a soil is defined as the ratio of the
(a) weight of water to the weight of solids
(b) volume of water to the volume of voids in the soil mass
(c) total volume of voids to the volume of soil solids
(d) total volume of voids to the total volume of soil

54. The degree of saturation for the moist soil is about
(a) 0 % (b) 1 to 25 % (c) 25 to 50 % (d) 50 to 75 %

55. The approximate void ratio in sandy soils is
(a) 0.2 (b) 0.6 (c) 0.8 (d) 1.2

56. When the soil particles are less than 0.002 mm, the force of gravity on each particle is ..... as compared to electric surface charges.
(a) less (b) more (c) negligible

57. Which of the following clay mineral gives maximum swelling ?
(a) Kalonite (b) Montmorillonite (c) Illite (d) all of these

58. Gravel and sand is a
(a) cohesive coarse grained soil (b) cohesive fine grained soil
(c) non-cohesive coarse grained soil (d) non-cohesive fine grained soil

59. The specific gravity of sandy soils is
(a) 1.2 (b) 1.8 (c) 2.2 (d) 2.7

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60. Which of the following gives the correct decreasing order of the densities of a soil sample?
(a) Saturated, submerged, wet, dry (b) Saturated, wet, submerged, dry
(c) Saturated, wet, dry, submerged (d) Wet, saturated, submerged, dry

61. Bulk density of a soil is defined as the ratio of
(a) total mass of soil to the total volume of soil
(b) weight of water to the weight of solids
(c) unit weight of solids to the unit weight of water
(d) weight of solid grains to the volume of solids

62. The unit weight of soil mass is expressed in
(a) kg/m^2 (b) kg/m^3 (c) N/m^2 (d) N/m^3

63. The dry density of a soil is same as the unit weight of solids.
(a) True (b) False

64. Submerged soils are ..... saturated soils.
(a) partially (b) fully

65. The density of soil mass is expressed in
(a) kg/m^2 (b) kg/m^3 (c) N/m^2 (d) N/m^3

66. If the volume of voids is equal to the volume of soil solids, then the values of porosity and void ratio are respectively
(a) 0 and 0.5 (b) 0 and 1 (c) 0.5 and 1 (c) 1 and 0.5

67. If w is the water content and γ is the unit weight of soil mass, then the unit weight of dry soil (γ_d) is equal to

(a) $\frac{w}{\gamma}+1$ (b) $\frac{\gamma}{w}+1$ (c) $\frac{\gamma}{1+w}$ (d) $\frac{1+w}{\gamma}$

68. The relation between dry unit weight (γ_d), specific gravity (G), void ratio (e) or porosity (n) is

(a) $\gamma_d = \frac{G.\gamma_w}{1+e}$ (b) $\gamma_d = \frac{G.\gamma_w}{1+e}$ (c) $\gamma_d = G.\gamma_w(1-n)$ (d) $\gamma_d = G.\gamma_w(1+n)$

69. The unit weight of a completely saturated soil (γ_{sat}) is given by

(a) $\frac{(G+e)\gamma_w}{1+e}$ (b) $\frac{(1+e)\gamma_w}{G+e}$ (c) $\frac{(G-1)\gamma_w}{1+e}$ (d) $\frac{(1-e)\gamma_w}{G+e}$

where G = Specific gravity of soil, e = Void ratio, and γ_w = Unit weight of water.

70. The relation between the saturated unit weight (γ_{sat}), specific gravity (G) and porosity (n) is given by
(a) $\gamma_{sat} = G.\gamma_w(1+n)$ (b) $\gamma_{sat} = n\gamma_w(1-n)$
(c) $\gamma_{sat} = G.\gamma_w(1-n)+n\gamma_w$ (d) $\gamma_{sat} = G.\gamma_w(1+n)+n\gamma_w(1-n)$

71. The submerged unit weight for completely saturated soil is given by

(a) $\frac{(G+e)\gamma_w}{1+e}$ (b) $\frac{(1+e)\gamma_w}{G+e}$ (c) $\frac{(G-1)\gamma_w}{1+e}$ (d) $\frac{(1-e)\gamma_w}{G+e}$

72. The water content of soils can be accurately determined by
(a) sand bath method (b) calcium carbide method
(c) oven drying method (d) Pycnometer method

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73. The specific gravity of soil solids is determined by
(a) Pycnometer method (b) hydrometer analysis
(c) sieve analysis (d) all of these

74. According to Pycnometer method, the specific gravity of soil solids (G) is given by
(a) $G = \dfrac{M_1 + M_2}{M_1 - M_2 + M_3 - M_4}$ (b) $G = \dfrac{M_1 + M_3}{M_1 + M_2 - M_3 - M_4}$
(c) $G = \dfrac{M_2 - M_1}{M_2 + M_4 - M_1 - M_3}$ (d) $G = \dfrac{M_1 + M_2}{M_2 + M_4 - M_1 - M_3}$

where M_1 = Mass of Pycnometer,
M_2 = Mass of Pycnometer and dry soil,
M_3 = Mass of Pycnometer, soil solids and water, and
M_4 = Mass of Pycnometer and water.

75. Stoke's law is used to determine the
(a) specific gravity of soil solids (b) density of soil suspension
(c) grain size distribution of those soils whose grain size is finer than 0.075 mm
(d) all of the above

76. Hydrometer analysis is used to determine the density of soil suspension.
(a) Agree (b) Disagree

77. The standard temperature at which the hydrometer is calibrated is
(a) 10° C (b) 15° C (c) 20° C (d) 27° C

78. When the hydrometer analysis is performed, it requires correction for
(a) temperature only (b) meniscus only
(c) dispersing agent only (d) all of these

79. According to Stoke's law, the velocity at which grains settle out of suspension, all other factors being equal, is dependent upon
(a) shape of the grain (b) weight of the grain
(c) size of the grain (d) all of these

80. According to Indian standards, the dispersing solution used in pipette method, for the determination of size of particle consists of
(a) 7 g sodium carbonate, 43 g sodium hexameta-phosphate and 1 litre distilled water
(b) 7 g sodium carbonate, 33 g sodium hexameta-phosphate and 1 litre distilled water
(c) 7 g sodium carbonate, 23 g sodium hexameta-phosphate and 1 litre distilled water
(d) any one of the above

81. The smallest sieve size according to Indian standards is
(a) 0.0045 mm (b) 0.045 mm (c) 0.45 mm (d) 0.154 mm

82. According to Indian standards, in a 2 mm sieve
(a) there are two holes
(b) each sieve is circular and its diameter is 2 mm
(c) each hole is a square and its side is 2 mm
(d) there are two holes per cm length of the mesh

83. Sieving is not practicable for grain sizes smaller than about
(a) 0.075 mm (b) 0.095 mm (c) 0.15 mm (d) 0.2 mm

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84. The effective size of a soil is
(a) D_{10} (b) D_{20} (c) D_{40} (d) D_{60}

85. The uniformity co-efficient of soil is defined as the ratio of
(a) D_{40} to D_{10} (b) D_{40} to D_{20} (c) D_{50} to D_{10} (d) D_{60} to D_{10}

86. The particle size range is measured by
(a) effective size (b) curvature coefficient
(c) uniformity coefficient (d) none of these

87. A soil having particles of nearly the same size is known as
(a) uniform soil (b) poor soil (c) well graded soil (d) coarse soil

88. A soil having uniformity co-efficient more than 10, is called
(a) uniform soil (b) poor soil (d) well graded soil (d) coarse soil

89. The uniformity coefficient for a uniformly graded soil is nearly unity.
(a) Agree (b) Disagree

90. Stoke's law is applicable to particles upto ..... effective diameter.
(a) 0.0002 mm (b) 0.002 mm (c) 0.02 mm (d) 0.2 mm

91. Sieve analysis is done if all particles do not pass through square opening of 0.075 mm.
(a) Correct (b) Incorrect

92. The ratio of the unconfined compressive strength of undisturbed soil to the unconfined compressive strength of soil in a remoulded state, is called
(a) sensitivity (b) thixotropy (c) relative density (d) bulk density

93. The property of a soil which enables to regain its strength lost on remoulding in a short time without change of moisture content, is called
(a) unconfined compressive strength (b) sensitivity
(c) thixotropy (d) relative density

94. The unconfined compressive strength of a very soft clay is
(a) 10 to 25 kN/m^2 (b) 25 to 150 kN/m^2
(c) 150 to 400 kN/m^2 (c) above 400 kN/m^2

95. The unconfined compressive strength of a hard clay is
(a) 10 to 25 kN/m^2 (b) 25 to 150 kN/m^2
(c) 150 to 400 kN/m^2 (d) above 400 kN/m^2

96. The sensitivity of a normal clay is about
(a) 2 to 4 (b) 4 to 8 (c) 8 to 15 (d) 15 to 20

97. The maximum water content of a saturated soil at which a reduction in its moisture does not cause a decrease in volume of the soil, is called
(a) liquid limit (b) plastic limit (c) elastic limit (d) shrinkage limit

98. When water content in a soil is reduced beyond the shrinkage limit, the soil will be in a
(a) solid state (b) liquid state (c) semi-solid state (d) plastic state

99. The water content in a soil at which just shear strength develops is called
(a) liquid limit (b) plastic limit (c) elastic limit (d) shrinkage limit

100. The plastic limit of a soil is defined as the
(a) limit of water that makes the soil to flow
(b) amount of water content which makes the soil to go into the liquid state
(c) amount of water content which makes the soil to go into the solid state from the liquid state
(d) minimum amount of water content which makes the soil to be rolled into 3 mm diameter threads

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101. The consistency index is given by
(a) $\frac{w_P - w}{I_P}$ (b) $\frac{w_L - w}{I_P}$ (c) $\frac{w_L - w_P}{I_P}$ (d) $\frac{w - w_P}{I_P}$

where w_P = Plastic limit, w_L = Liquid limit, I_P = Plasticity index, and
w = Natural water content of a soil.

102. The consistency index is also known as relative consistency.
(a) True (b) False

103. The liquidity index (in percentage) is given by
(a) $\frac{w_P - w}{I_P}$ (b) $\frac{w_L - w}{I_P}$ (c) $\frac{w_L - w_P}{I_P}$ (d) $\frac{w - w_P}{I_P}$

104. When the consistency index is zero, then the soil is at its
(a) elastic limit (b) plastic limit (c) liquid limit (d) semi-solid state

105. A soil is in a semi-solid state, if the consistency index is
(a) zero (b) one (c) more than unity (d) none of these

106. A soil with consistency equal to one is at its ..... limit.
(a) liquid (b) plastic

107. Toughness index is the ratio of
(a) flow index and plasticity index (b) plasticity index and flow index
(c) liquidity index and flow index (d) flow index and liquidity index

108. A sample of soil has liquid limit 45 %, plastic limit 25 %, shrinkage limit 17 % and natural moisture content 30 %. The consistency index of the soil is
(a) 15/20 (b) 13/20 (c) 8/20 (d) 5/20

109. The shear strength of a soil in the plastic limit is ..... than that in the liquid limit.
(a) higher (b) lower

110. The liquid limit exists in
(a) sandy soils (b) gravel soils (c) silty soils (d) clays

111. The plastic limit exists in
(a) sandy soils (b) gravel soils (d) silty soils (d) clays

112. The liquid limit *minus* plastic limit is termed as
(a) flow index (b) plasticity index (c) shrinkage index (d) liquidity index

113. When the plastic limit is equal to or greater than the liquid limit, then the plasticity index is
(a) negative (b) zero (c) one (d) more than one

114. The shrinkage index is equal to
(a) liquid limit + plastic limit (b) plastic limit – liquid limit
(c) liquid limit – shrinkage limit (d) shrinkage limit – liquid limit

115. The flow index in soils indicates the
(a) ratio of liquid limit to plastic limit (b) variation of liquid limit
(c) variation of plastic limit (d) shear strength variation with water content

116. The moisture contents of a clayey soil is gradually decreased from a large value. The correct sequence of the occurrence of the limits will be
(a) liquid limit, plastic limit and shrinkage limit
(b) plastic limit, liquid limit and shrinkage limit
(c) shrinkage limit, plastic limit and liquid limit
(d) plastic limit, shrinkage limit and liquid limit

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117. The clays which exhibit high activity
(a) contain montmorillonite (b) have high plasticity index
(c) both (a) and (b) (d) none of these

118. The activity of clay is defined as the ratio of
(a) liquid limit to plastic limit (b) liquidity index to plasticity index
(c) plasticity index to clay fraction (d) plasticity index to shrinkage index

119. The plasticity index is the ratio of liquidity index and flow index.
(a) Right (b) Wrong

120. Match the correct answer from *Group B* for the statements given in *Group A*.

Group A	*Group B*
(a) The soil transported by water is	(A) aeolian soil
(b) The soil transported by wind	(B) alluvial soil
(c) The smallest sieve size is	(C) 0.002 mm
(d) The maximum size of the particles of clay is	(D) 0.045 mm

121. The ratio of the liquid limit *minus* the natural content of a soil to its plasticity index, is known as
(a) toughness index (b) liquidity index
(c) flow index (d) relative consistency

122. When the particles of soil are oriented 'edge to edge' or 'edge to face' with respect to one another, the soil is said to have
(a) single grained structure (b) double grained structure
(c) honey-combed structure (d) flocculent structure

123. A soil containing continuous voids is called ..... soil.
(a) permeable (b) impermeable

124. Which of the following is highly permeable ?
(a) Gravel (b) Sand mixture (c) Coarse sand (d) Clay

125. Which of the following is practically impermeable ?
(a) Gravel (b) Sand mixture (c) Coarse sand (d) Clay

126. A sample of clay and a sample of sand have the same specific gravity and void ratio. Their permeabilities will differ because
(a) their porosities will be different (b) their densities will be different
(c) their degrees of saturation will be different
(d) the size ranges of their voids will be different

127. The property of the soil mass which permits the seepage of water through its interconnecting voids, is called
(a) capillarity (b) permeability (c) porosity (d) none of these

128. The unit of coefficient of permeability is same as that of velocity.
(a) Yes (b) No

129. When applying Darcy's law to soils, it is assumed that the
(a) soil is incompressible (b) soil is homogeneous and isotropic
(c) flow conditions are laminar (d) all of these

130. The value of permeability ..... the direction of flow of water through the soil mass.
(a) depends upon (b) does not depend upon

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131. Which of the following have an influence on the value of permeability ?
(a) Grain size (b) Void ratio
(c) Degree of saturation (d) all of these

132. If the direction of flow of water is parallel to the planes of stratification, then the permeability is ..... times more than in a direction perpendicular to them.
(a) 2 to 10 (b) 2 to 15 (c) 2 to 20 (d) 2 to 30

133. The permeability of a given soil is
(a) directly proportional to the average grain size
(b) inversely proportional to the average grain size
(c) directly proportional to the square of the average grain size
(d) inversely proportional to the square of the average grain size

134. The coefficient of permeability of slit is ..... that of clay.
(a) same as (b) less than (c) more than

135. The coefficient of permeability ..... with the increase in temperature.
(a) decreases (b) increases

136. The quantity of seepage of water in a soil medium is
(a) directly proportional to the head of water at upstream
(b) inversely proportional to the head of water at upstream
(c) directly proportional to the coefficient of permeability
(d) inversely proportional to the coefficient of permeability

137. The average velocity of flow that will take place through the total cross-sectional area of soil under unit hydraulic gradient is called
(a) uniformity coefficient (b) Darcy's coefficient
(c) coefficient of permeability (d) terminal velocity

138. The pressure exerted by water on the soil through which it percolates, is known as
(a) hydrostatic pressure (b) effective pressure
(c) seepage pressure (d) none of these

139. A flow line in seepage through a soil medium is defined as the
(a) path of particles of water through a saturated soil mass
(b) line connecting points of equal head of water
(c) flow of movement of fine particles of soil
(d) direction of the flow particle

140. The equipotential line in a seepage through a soil medium is defined as the
(a) path of particles of water through a saturated soil mass
(b) line connecting points of equal head of water
(c) flow of movement of fine particles of soil
(d) direction of the flow particle

141. The seepage pressure always acts in the direction of flow.
(a) Right (b) Wrong

142. Quick sand is a
(a) moist sand containing small particles (b) condition which occurs in coarse sand
(c) condition in which a cohesionless soil loses all its strength because of upward flow of water
(d) none of the above

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143. Flow lines and equi-potential lines are
(a) perpendicular to each other (b) parallel to each other
(c) intersecting lines at 90° to each other (d) intersecting lines at 45° to each other

144. The flow net in the seepage of water through a soil medium is a network of
(a) flow lines (b) equi-potential lines
(c) flow lines and equi-potential lines (d) water particles and their movement in the soil

145. A flow net is used to determine the
(a) seepage flow (b) seepage pressure (c) exit gradient (d) all of these

146. Which of the following statement is correct ?
(a) The flow lines are perpendicular to equipotential lines.
(b) No two flow lines or equipotential lines start from the same point.
(c) No two flow lines cross each other.
(d) all of the above

147. The exit gradient of the seepage of water through a soil medium is the
(a) slope of the flow line (b) slope of the equi-potential line
(c) ratio of total head to the length of seepage
(d) ratio of the head loss to the length of seepage

148. The hydraulic gradient provided at the downstream side of a hydraulic structure such as a dam is called
(a) downstream gradient (b) tail water gradient
(c) exit gradient (d) any one of these

149. The critical gradient of the seepage of water in a soil medium is

(a) $\frac{1-G}{1+e}$ (b) $\frac{G-1}{1+e}$ (c) $\frac{1+e}{1-G}$ (d) $\frac{1+e}{G-1}$

where G = Specific gravity of soil, and e = Void ratio.

150. A deposit of fine sand has a porosity n and the specific gravity of soil solids is G. The hydraulic gradient of the deposit to develop boiling condition of sand is given by

(a) $(G-1)(1-n)$ (b) $(G-1)(1+n)$ (c) $\frac{G-1}{1-n}$ (d) $\frac{G-1}{1+n}$

151. The direction of seepage is always ..... to the equipotential lines.
(a) parallel (b) perpendicular

152. The critical gradient of the seepage of water
(a) directly proportional to void ratio
(b) increases with the decrease in void ratio
(c) inversely proportional to specific gravity
(d) increases with the decrease in specific gravity of soil

153. The critical gradient of the seepage of water ..... with the increase in specific gravity of soil.
(a) increases (b) decreases (c) does not change

154. The seepage force in soils is
(a) proportional to head loss (b) proportional to exit gradient
(c) perpendicular to the equi-potential lines (d) all of these

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155. The seepage pressure is independent of the coefficient of permeability.
(a) Correct (b) Incorrect

156. The critical gradient for all soils is normally
(a) 0.5 (b) 1 (c) 1.5 (d) 2.5

157. The maximum permissible exit gradient is the critical gradient divided by a factor of safety.
(a) True (b) False

158. The expression for the discharge (Q) through a flow net for isotropic soils is given by

(a) $Q = KH \times \frac{N_F}{N_D}$ (b) $KH \sqrt{\frac{N_F}{N_D}}$ (c) $Q = KH \left(\frac{N_F}{N_D}\right)^2$ (d) $KH \left(\frac{N_F}{N_D}\right)^3$

where
N_F = Number of flow channels,
N_D = Number of potential drops,
H = Total hydraulic head causing flow, and
K = A constant.

159. A flow net constructed to determine the seepage through an earth dam which is homogeneous but anisotropic, gave 4 flow channels and 16 equipotential drops. The coefficients of permeability in the horizontal and vertical directions are 4×10^{-7} m/s and 1×10^{-7} m/s respectively. If the storage head is 20 m, then the seepage per unit length of the dam in m^3/s, will be
(a) 5×10^{-7} (b) 10×10^{-7} (c) 20×10^{-7} (d) 40×10^{-7}

160. The permissible exit gradient for safety against piping which endanger the stability of a hydraulic structure, should be
(a) 0.2 (b) 0.4 (c) 0.6 (d) 0.8

161. The piping failure in a hydraulic structure can be prevented by
(a) diverting the seepage water into filter wells
(b) increasing the creep length of flow of water
(c) increasing the stress due to weight of the structure
(d) all of the above

162. The effective stress on the soil is due to the
(a) external load acting on the soil (b) weight of the soil particles
(c) weight of water present in soil pores (d) both (a) and (b)

163. The neutral stress on the soil is due to the
(a) external load acting on the soil (b) weight of the soil particles
(c) weight of water present in soil pores (d) both (a) and (b)

164. The effective stress is also called pore-water pressure.
(a) Agree (b) Disagree

165. The effective stress on the soil mass ..... void ratio.
(a) increases (b) decreases

166. The neutral stress is
(a) transmitted through the points of contact of the interconnected particles of soil.
(b) transmitted to the soil base through the pore water
(c) independent of the depth of water above the soil mass
(d) due to weight of soil particles

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167. Which of the following statement is wrong ?
(*a*) The neutral stress does not change the shearing resistance of the soil.
(*b*) The decrease in effective stress is accompanied by increase in the neutral stress.
(*c*) The neutral stress does not decrease the void ratio.
(*d*) none of the above

168. The removal of neutral pressure ..... the effective pressure.
(*a*) increases (*b*) decreases (*c*) does not change

169. The total stress is equal to the sum of the effective stress and pore water pressure.
(*a*) True (*b*) False

170. The effective stress is ..... if the water is flowing from upward on the soil mass.
(*a*) increased (*b*) decreased

171. The neutral stress is ..... if the water is flowing from downward on the soil mass.
(*a*) increased (*b*) decreased

172. The consolidation of a soil is defined as the
(*a*) process of compression by gradual reduction of pore space under steady load
(*b*) process which gives gradual decrease of water content at constant load
(*c*) change in volume of soil due to expulsion of pure water under an applied load
(*d*) any one of the above

173. The vertical deformation of soil mass consists of
(*a*) deformation of soil grains (*b*) compression of pore fluid
(*c*) reduction of pore space (*d*) all of these

174. The rate of expulsion of pore fluid is directly dependent on the ..... of the soil.
(*a*) shear strength (*b*) void ratio (*c*) permeability

175. In case of coarse grained sand having high permeability and low plasticity, 95 % of consolidation occurs within ..... after application of load.
(*a*) 1 minute (*b*) 30 minutes (*c*) 1 hour (*d*) 2 hour

176. If the pressure on a clay layer increases slightly from p to $p + \delta p$ and the void ratio decreases from e_0 to e, then the coefficient of compressibility is given by

(*a*) $\frac{e}{p}$ (*b*) $\frac{e_0}{\delta p}$ (*c*) $\frac{e}{\delta p}$ (*d*) $\frac{e_0 - e}{\delta p}$

177. The unit of coefficient of compressibility is inverse of pressure.
(*a*) Correct (*b*) Incorrect

178. The coefficient of compressibility ..... with increase in pressure.
(*a*) increases (*b*) decreases (*c*) does not change

179. The coefficient of volume of compressibility is given by

(*a*) $\frac{a_v}{1 + e_0}$ (*b*) $\frac{1 + e_0}{a_v}$ (*c*) $\frac{e_0}{a_v}$ (*d*) $\frac{e_0}{a_0}$

where a_v = Coefficient of compressibility, and e_0 = Void ratio.

180. The decrease in voids ratio per unit increase of pressure is called
(*a*) coefficient of permeability (*b*) coefficient of compressibility
(*c*) coefficient of volume compressibility (*d*) coefficient of curvature

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181. The coefficient of consolidation is measured in
(a) cm^2/g (b) cm^2/s (c) $g/cm^2/s$ (d) $cm^2/g/s$

182. The coefficient of consolidation is used for evaluating
(a) stress in the soil (b) total settlement
(c) over consolidation ratio (d) time rate of settlement

183. The rate of consolidation ..... with the increase in temperature.
(a) increases (b) decreases (c) does not change

184. The degree of consolidation is proportional directly
(a) to time and inversely to drainage path
(b) to drainage path and inversely to time
(c) to time and inversely to the square of drainage path
(d) to square of drainage path and inversely to time

185. The time factor for a clay layer is
(a) a dimensionless parameter (b) directly proportional to permeability
(c) directly proportional to drainage path (d) none of these

186. The relation between coefficient of consolidation (c_v), coefficient of volume change (m_v) and coefficient of permeability (k) is given by

(a) $c_v = \frac{k}{m_v \cdot \gamma_w}$ (b) $c_v = \frac{k \cdot m_v}{\gamma_w}$ (c) $c_v = \frac{\gamma_w}{k \cdot m_v}$ (d) $c_v = \frac{m_v \cdot \gamma_w}{k}$

187. The ratio of settlement at any time (t) to the final settlement is known as
(a) compression index (b) coefficient of consolidation
(c) degree of consolidation (d) none of these

188. The relation between coefficient of consolidation (c_v), time factor (T_v), drainage path (d) and time (t) is given by

(a) $c_v = \frac{d^2 \cdot T_v}{t}$ (b) $c_v = \frac{d^2 \cdot t}{T_v}$ (c) $c_v = \frac{T_v \cdot t}{d^2}$ (d) $c_v = \frac{T_v}{d^2 \cdot t}$

189. The time factor corresponding to 25 % degree of consolidation is given by

(a) $\frac{\pi}{8}$ (b) $\frac{\pi}{16}$ (c) $\frac{\pi}{32}$ (d) $\frac{\pi}{64}$

190. The coefficient of consolidation of a soil is affected by
(a) compressibility (b) permeability (c) both (a) and (b) (d) none of these

191. The change in volume of soil per unit of initial volume due to a given unit increase in pressure is called
(a) coefficient of permeability (b) coefficient of compressibility
(c) coefficient of volume compressibility (d) coefficient of curvature

192. The coefficient of volume compressibility is
(a) directly proportional to the void ratio
(b) inversely proportional to the void ratio
(c) directly proportional to the coefficient of compressibility
(d) inversely proportional to the coefficient of compressibility

193. The coefficient of volume compressibility ..... with the increase in pressure.
(a) increases (b) decreases (c) does not change

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194. The compression index of the soil
(a) increases with the increase in liquid limit
(b) decreases with the increase in liquid limit
(c) increases with the decrease in plastic limit
(d) decreases with the increase in plastic limit

195. The ultimate settlement of a soil
(a) is directly proportional to the compression index
(b) decreases with an increase in the initial void ratio
(c) is directly proportional to the depth of the compressible soil mass
(d) all of the above

196. The strength of a soil is usually identified by
(a) direct tensile stress (b) direct compressive stress
(c) ultimate shear stress (d) effective stress

197. The shear strength of a soil
(a) is proportional to the cohesion of the soil
(b) is proportional to the tangent of the angle of internal friction
(c) increases with the increase in normal stress of soil
(d) all of the above

198. The expansion of soil due to shear at a constant value of pressure is called
(a) apparent cohesion (b) true cohesion (c) dilatancy (d) consistency

199. If a shear stress is applied on a dense sand, the shear strain caused will ..... the volume of sand.
(a) increase (b) decrease (c) not effect

200. The density of sand at which there is no change in volume under the influence of shearing strain produced due to shear stress, is called
(a) relative density (b) apparent density (c) critical density (d) any one of these

201. The angle of internal friction
(a) varies with the density of sand (b) depends upon the amount of interlocking
(c) depends upon the particle shape and roughness
(d) all of the above

202. Which one of the following parameters can be used to estimate the angle of friction of a sandy soil ?
(a) Particle size (b) Roughness of particle
(c) Density index (d) Particle size distribution

203. The angle of internal friction of round-grained loose sand is about
(a) 5° to 25° (b) 25° to 30° (c) 30° to 35° (d) 32° to 37°

204. The angle of internal friction of round-grained dense sand is about
(a) 5° to 25° (b) 25° to 30° (c) 30° to 35° (d) 32° to 37°

205. The angle of shearing resistance for dry loose sand is same as that of angle of internal friction.
(a) Right (b) Wrong

206. According to Coulomb's law, the shearing strength of soil is
(a) $c - p \tan \phi$ (b) $p - c \tan \phi$ (c) $c + p \tan \phi$ (d) $p + c \tan \phi$

where
c = Cohesion (apparent or actual),
p = Normal stress on the plane of shear, and
ϕ = Angle of internal friction or angle of shearing resistance.

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207. The frictional resistance of clayey soil is ..... sandy soil.
(a) less than (b) more than (c) same as

208. The frictional resistance offered by sand is
(a) sliding friction (b) rolling friction
(c) resistance due to interlocking (d) all of these

209. The useful method of finding the shear strength of very plastic cohesive soils is by means of
(a) cone test (b) penetration test
(c) vane shear test (d) torsional shear test

210. A line showing the dry density as a function of water content for soil containing no air voids, is called
(a) saturation line (b) zero air void line
(c) liquid limit line (d) none of these

211. The earth pressure at rest is defined as the lateral pressure exerted by soil
(a) when it is at rest
(b) when the retaining wall has no movement relative to the back fill
(c) when the retaining wall tends to move away from the back fill
(d) when the retaining wall moves into the soil

212. The active earth pressure of a soil is defined as the lateral pressure exerted by soil
(a) when it is at rest
(b) when the retaining wall has no movement relative to the back fill
(c) when the retaining wall tends to move away from the back fill
(d) when the retaining wall moves into the soil

213. The effect of cohesion on a soil is to
(a) reduce both active and passive earth pressure intensities
(b) increase both active and passive earth pressure intensities
(c) reduce active earth pressure intensity but to increase passive earth pressure intensity
(d) increase active earth pressure intensity but to reduce passive earth pressure intensity

214. The lateral earth pressure exerted by the soil when the retaining wall moves into the soil, is known as
(a) earth pressure at rest (b) active earth pressure
(c) passive earth pressure (d) total earth pressure

215. The earth pressure at rest is calculated by using
(a) Euler's theory (b) Rankine's theory
(c) bending theory (d) theory of elasticity

216. The coefficient of earth pressure at rest is given by
(a) $\frac{\mu}{1+\mu}$ (b) $\frac{1+\mu}{\mu}$ (c) $\frac{\mu}{1-\mu}$ (d) $\frac{1-\mu}{\mu}$

where μ = Poisson's ratio.

217. The coefficient of earth pressure at rest for loose sand is ..... that of dense sand.
(a) more than (b) less than (c) same as

218. The coefficient of earth pressure at rest for stiff clay is about
(a) 0.4 (b) 0.5 (c) 0.6 (d) 0.8

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219. The coefficient of earth pressure at rest for sand compacted in layers is about the same as for stiff clay.

(*a*) Yes (*b*) No

220. The coefficient of active earth pressure for cohesionless granular soils is given by

(*a*) $\frac{1+\sin\phi}{1-\sin\phi}$ (*b*) $\frac{1-\sin\phi}{1+\sin\phi}$ (*c*) $\frac{1+\cos\phi}{1-\cos\phi}$ (*d*) $\frac{1-\cos\phi}{1+\cos\phi}$

221. The coefficient of passive earth pressure for cohesionless granular soils is given by

(*a*) $\frac{1+\sin\phi}{1-\sin\phi}$ (*b*) $\frac{1-\sin\phi}{1+\sin\phi}$ (*c*) $\frac{1+\cos\phi}{1-\cos\phi}$ (*d*) $\frac{1-\cos\phi}{1+\cos\phi}$

222. If the coefficient of passive earth pressure is 1/3, then the coefficient of active earth pressure is

(*a*) 1/3 (*b*) 1 (*c*) 3/2 (*d*) 3

223. The coefficient of active earth pressure for a loose sand having an angle of internal friction of 30°, is

(*a*) 1/2 (*b*) 1/3 (*c*) 1 (*d*) 3

224. The active earth pressure is proportional to

(*a*) $\tan^2\left(45°+\frac{\phi}{2}\right)$ (*b*) $\tan^2\left(45°-\frac{\phi}{2}\right)$ (*c*) $\cot^2\left(45°+\frac{\phi}{2}\right)$ (*d*) $\cot^2\left(45°-\frac{\phi}{2}\right)$

where ϕ = Angle of internal friction of soil.

225. The passive earth pressure is proportional to

(*a*) $\tan^2\left(45°+\frac{\phi}{2}\right)$ (*b*) $\tan^2\left(45°-\frac{\phi}{2}\right)$ (*c*) $\cot^2\left(45°+\frac{\phi}{2}\right)$ (*d*) $\cot^2\left(45°-\frac{\phi}{2}\right)$

226. For a sandy soil, the angle of internal friction is 30°. If the major principal stress is 50 kN/m² at failure, the corresponding minor principal stress will be

(*a*) 12.2 kN/m² (*b*) 16.66 kN/m² (*c*) 20.8 kN/m² (*d*) 27.2 kN/m²

227. A dry sand specimen is put through a triaxial test. The cell pressure is 50 kPa and the deviator stress at failure is 100 kPa. The angle of internal friction for the sand specimen is

(*a*) 15° (*b*) 30° (*c*) 35° (*d*) 40°

228. The Poisson ratios of soil samples 1 and 2 are μ_1 and μ_2 respectively and the coefficients of earth pressure at rest for soil samples 1 and 2 are k_1 and k_2 respectively. If $\mu_1/\mu_2 = 1.5$ and $(1-\mu_1)/(1-\mu_2) = 0.875$, then k_1/k_2 will be

(*a*) 1.3125 (*b*) 1.7143 (*c*) 1.8213 (*d*) 1.9687

229. The earth pressure at rest is proportional to $\mu / 1-\mu$, where μ = Poisson's ratio of the soil.

(*a*) Right (*b*) Wrong

230. The coefficient of active earth pressure is always ..... as compared to coefficient of passive earth pressure.

(*a*) more (*b*) less

231. If k_o is the coefficient of earth pressure at rest, k_a is the coefficient of active earth pressure, k_p is the coefficient of passive earth pressure and μ is Poisson's ratio, then the value of $(1-\mu)/\mu$ is given by

(*a*) k_a/k_p (*b*) k_o/k_a (*c*) k_p/k_o (*d*) $1/k_o$

232. The effect of cohesion is to ..... the active earth pressure all along the height of retaining wall.

(*a*) decrease (*b*) increase

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233. In case of cohesive soils, vertical cuts can be made (without any support) proportional to
(a) $\tan\left(45° + \frac{\phi}{2}\right)$ (b) $\tan\left(45° - \frac{\phi}{2}\right)$ (c) $\tan^2\left(45° + \frac{\phi}{2}\right)$ (d) $\tan^2\left(45° - \frac{\phi}{2}\right)$

234. For cohesive soils, the height of the retaining wall for zero active earth pressure will be
(a) $\frac{c}{\gamma}\tan\left(45° + \frac{\phi}{2}\right)$ (b) $\frac{2c}{\gamma}\tan\left(45° + \frac{\phi}{2}\right)$
(c) $\frac{3c}{\gamma}\tan\left(45° + \frac{\phi}{2}\right)$ (d) $\frac{4c}{\gamma}\tan\left(45° + \frac{\phi}{2}\right)$

where c = Cohesion value of soil, γ = Density of the soil, and ϕ = Angle of internal friction.

235. The net ultimate bearing capacity is the maximum net pressure intensity causing shear failure of soil.
(a) True (b) False

236. The lateral earth pressure is
(a) directly proportional to the depth of soil
(b) inversely proportional to the depth of soil
(c) directly proportional to the square of the depth of soil
(d) inversely proportional to the square of the depth of soil

237. The maximum unit pressure that a soil can withstand without rupture in shear or without excessive settlement of the structure, is called
(a) allowable bearing pressure (b) safe bearing capacity
(c) ultimate bearing capacity (d) bearing capacity

238. The bearing capacity of a soil depends upon
(a) grain size of the soil (b) size of the footing
(c) shape of the footing (d) all of these

239. The bearing capacity of a soil ..... with the decrease in the area of the footing.
(a) increases (b) decreases (c) does not change

240. The coefficient of passive earth pressure ..... with the increase of angle of shearing resistance.
(a) increases (b) decreases (c) does not change

241. The ultimate bearing capacity per unit area of a soil for general shear failure is
(a) $0.5\,\gamma\,BN_\gamma + \gamma\,D_f N_q$ (b) $c\,N_c + 0.5\,\gamma\,BN_\gamma + g\,D_f N_q$
(c) $1.3\,c\,N_c + \gamma\,D_f N_q + 0.6\,\gamma.r.N_\gamma$ (d) $1.3\,c\,N_c + \gamma\,D_f N_q + 0.4\,\gamma\,BN_\gamma$

where
c = Cohesion value,
r = Radius of footing,
B = Width of footing,
D_f = Depth of foundation,
γ = Density of soil, and
N_c, N_q and N_γ = Bearing capacity factors.

242. The ultimate bearing capacity per unit area of sands for general shear failure is given by
(a) $0.5\,\gamma\,D_f N_q + \gamma\,BN_\gamma$ (b) $0.5\,\gamma\,BN_\gamma + \gamma\,D_f N_q$
(c) $0.67\,\gamma\,D_f N_\gamma + \gamma\,BN_q$ (d) $0.67\,\gamma\,BN_q + \gamma\,D_f N_\gamma$

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243. The ultimate bearing capacity per unit area of clays for general shear failure is given by
(*a*) $1.54\,c + \gamma D_f$ (*b*) $4.15\,c + \gamma D_f$ (*c*) $c + 1.54\,\gamma D_f$ (*d*) $5.7\,c + \gamma D_f$

244. The bearing capacity factors N_c, N_q and N_γ are functions of
(*a*) cohesion of the soil (*b*) friction angle
(*c*) internal friction angle (*d*) both (*a*) and (*b*)

245. The ultimate net bearing capacity of clays depends upon the value of cohesion.
(*a*) Agree (*b*) Disagree

246. The dense sands have ..... bearing capacity.
(*a*) greater (*b*) lesser

247. The unit bearing capacity of footing in sand
(*a*) decreases with depth of footing (*b*) decreases with width of footing
(*c*) increases with depth of footing (*d*) increases with width of footing

248. A sand with greater relative density exhibits ..... angle of internal friction.
(*a*) smaller (*b*) larger

249. The ultimate unit bearing capacity for square footing is given by
(*a*) $0.4\,c\,N_c + \gamma D_f N_q + 1.2\,\gamma B N_\gamma$ (*b*) $0.4\,c\,N_c + 1.2\,\gamma D_f N_q + \gamma B N_\gamma$
(*c*) $1.3\,c\,N_c + \gamma D_f N_q + 0.4\,\gamma B N_\gamma$ (*d*) $0.5\,\gamma B N_\gamma + \gamma D_f N_q$

250. The net ultimate bearing capacity of a square footing in sand is given by
(*a*) $0.3\,\gamma B N_\gamma + \gamma D_f (N_q - 1)$ (*b*) $0.3\,\gamma B N_\gamma + \gamma D_f (N_q + 1)$
(*c*) $0.4\,\gamma B N_\gamma + \gamma D_f (N_q - 1)$ (*d*) $0.4\,\gamma B N_\gamma + \gamma D_f (N_q + 1)$

251. Match the correct answer from *Group B* for the statements given in *group A*.

Group A	*Group B*
(*a*) The net loading intensity at which neither the soil fails in shear nor there is excessive settlement	(*A*) Ultimate bearing capacity
(*b*) The maximum pressure which the soil can carry safely without any risk of shear failure	(*B*) Net safe bearing capacity
(*c*) The net ultimate bearing capacity divided by factor of safety.	(*C*) Safe bearing capacity
(*d*) The minimum gross pressure intensity at the base of the foundation at which soil fails in shear	(*D*) Allowable bearing capacity

252. According to I.S. code, the total settlement of isolated footings for cohesive soil should be
(*a*) 30 mm (*b*) 40 mm (*c*) 50 mm (*d*) 65 mm

253. In the design of footings on sand, if the angle of internal friction is equal to 36°, the bearing capacity factors for ..... shear failure are used.
(*a*) general (*b*) local

254. When the water table is close to the ground surface, the bearing capacity of a soil is reduced to
(*a*) one-fourth (*b*) one-half (*c*) two-third (*d*) three-fourth

255. When the water table is under the base of the footing at a depth equal to half of the width of the footing, the bearing capacity of a soil is reduced to
(*a*) one-fourth (*b*) one-half (*c*) two-third (*d*) three-fourth

256. The net soil pressure is obtained by multiplying the net ultimate bearing capacity of soil to the factor of safety.
(*a*) Right (*b*) Wrong

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257. If the soil below the base of the footing is dry or moist, the confining pressure is approximately ..... the confining pressure available when the water table is at the base of the footing.
(a) equal to (b) double (c) three times (d) four times

258. The settlement of a footing in sand depends upon the
(a) stress deformation characteristics of sand (b) relative density of the sand
(c) width of the footing (d) all of these

259. According to Terzaghi, the net ultimate bearing capacity of clay is given by
(a) $c N_q$ (b) $c N_\gamma$ (c) $c N_c$ (d) $1.3\, c N_c$

260. According to Terzaghi's equation, the bearing capacity of strip footing resting on cohesive soil ($c = 10$ kN/m^2) per unit depth and unit width (assume N_c as 5.7) is
(a) 47 kN/m^2 (b) 57 kN/m^2 (c) 67 kN/m^2 (d) 77 kN/m^2

261. In case of footings in sand, if the soil pressure distribution is triangular, the maximum soil pressure is ..... the average soil pressure.
(a) equal to (b) double (c) three times (d) four times

262. The settlement of a footing (S_F) in sandy soils is given by

(a) $\frac{S_P}{B_P} \times B_F$ (b) $\frac{S_P}{B_F} \times B_P$

(c) $\frac{S_P}{\left[\frac{B_P (B_F + 30.48)}{B_F (B_P + 30.48)}\right]^2}$ (d) $\frac{S_P (B_P + 30.48)^2}{(B_F + 30.48)^2}$

where S_P = Settlement of a plate in the bearing test,
B_P = Width of the plate, and
B_F = Width of the footing,

263. The settlement of a footing in clays (S_F) is given by

(a) $\frac{S_P}{B_P} \times B_F$ (b) $\frac{S_P}{B_F} \times B_P$

(c) $\frac{S_P}{\left[\frac{B_P (B_F + 30.48)}{B_F (B_P + 30.48)}\right]^2}$ (d) $\frac{S_P (B_P + 30.48)^2}{(B_F + 30.48)^2}$

264. Which of the following statement is correct ?
(a) The settlement of a flexible footing on cohesionless soil is less in the centre than at the edges.
(b) The settlement of a rigid footing on cohesionless soil is uniform throughout.
(c) The settlement of a flexible footing on cohesive soil is more in the centre than at the edges.
(d) all of the above

265. The contact pressure of flexible footing on non-cohesive soils is
(a) more in the centre than at the edges (b) less in the centre than at the edges
(c) uniform throughout (d) none of these

266. The contact pressure of rigid footing on cohesive soils is
(a) more in the centre than at the edges (b) less in the centre than at the edges
(c) uniform throughout (d) none of these

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267. The process of obtaining increased density of soil in a fill by reduction of its pore space by the expulsion of air, is known as
(a) soil exploration (b) soil stabilisation (c) soil compaction (d) consolidation

268. The process of maintaining or improving the performance of a soil as a constructional material usually by the use of admixtures, is known as
(a) soil exploration (b) soil stabilisation (c) soil compaction (d) consolidation

269. The high density of the soil placed in a fill is desired in order to
(a) increase its shear resistance (b) reduce future settlements
(c) reduce percolation through the fill (d) all of these

270. The critical height in the stability of soil is the
(a) minimum height at which it is possible for the sloped bank of soil to be stable
(b) maximum height at which it is possible for the sloped bank of soil to be stable
(c) minimum vertical height of the soil in an open excavation
(d) maximum vertical height of the soil is an open excavation

ANSWERS

1. (a)	2. (c)	3. (a)	4. (b)	5. (d)	6. (b)	7. (a)	8. (a)	9. (b)	10. (b)
11. (d)	12. (a)	13. (c)	14. (d)	15. (a)	16. (d)	17. (d)	18. (a)	19. (a)	20. (c)
21. (d)	22. (a)	23. (d)	24. (c)	25. (a)	26. (c)	27. (a)	28. (b)	29. (b)	30. (b)
31. (b)	32. (c)	33. (a)	34. (d)	35. (c)	36. (c)	37. (b)	38. (b)	39. (d)	40. (c)
41. (b)	42. (a)	43. (b)	44. (c)	45. (b)	46. (c)	47. (b)	48. (c)	49. (d)	50. (b)
51. (a)	52. (c)	53. (a)	54. (d)	55. (b)	56. (c)	57. (b)	58. (c)	59. (d)	60. (c)
61. (a)	62. (d)	63. (b)	64. (b)	65. (b)	66. (c)	67. (c)	68. (a)	69. (a)	70. (c)
71. (c)	72. (c)	73. (a)	74. (c)	75. (c)	76. (a)	77. (d)	78. (d)	79. (d)	80. (b)
81. (b)	82. (c)	83. (a)	84. (a)	85. (d)	86. (c)	87. (a)	88. (c)	89. (a)	90. (a)
91. (a)	92. (a)	93. (c)	94. (a)	95. (d)	96. (a)	97. (d)	98. (a)	99. (a)	100. (d)
101. (b)	102. (a)	103. (d)	104. (c)	105. (c)	106. (b)	107. (b)	108. (a)	109. (a)	110. (d)
111. (d)	112. (b)	113. (b)	114. (c)	115. (d)	116. (a)	117. (c)	118. (c)	119. (b)	120. (B), (A), (D), (C)
121. (d)	122. (d)	123. (a)	124. (a)	125. (d)	126. (d)	127. (b)	128. (a)	129. (d)	130. (a)
131. (d)	132. (d)	133. (c)	134. (b)	135. (b)	136. (c)	137. (c)	138. (c)	139. (a)	140. (b)
141. (a)	142. (c)								

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143. (c) 144. (c) 145. (d) 146. (d) 147. (d) 148. (d)
149. (b) 150. (a) 151. (b) 152. (b) 153. (a) 154. (d)
155. (a) 156. (b) 157. (a) 158. (a) 159. (b) 160. (a)
161. (d) 162. (d) 163. (c) 164. (b) 165. (b) 166. (b)
167. (d) 168. (a) 169. (a) 170. (a) 171. (b) 172. (d)
173. (d) 174. (c) 175. (a) 176. (d) 177. (a) 178. (b)
179. (a) 180. (b) 181. (b) 182. (d) 183. (a) 184. (c)
185. (b) 186. (a) 187. (c) 188. (a) 189. (d) 190. (c)
191. (c) 192. (c) 193. (b) 194. (a) 195. (d) 196. (c)
197. (d) 198. (c) 199. (a) 200. (c) 201. (d) 202. (c)
203. (b) 204. (d) 205. (a) 206. (c) 207. (a) 208. (d)
209. (c) 210. (a) 211. (b) 212. (c) 213. (c) 214. (c)
215. (d) 216. (c) 217. (b) 218. (d) 219. (a) 220. (b)
221. (a) 222. (c) 223. (b) 224. (c) 225. (a) 226. (b)
227. (b) 228. (b) 229. (a) 230. (b) 231. (d) 232. (a)
233. (a) 234. (d) 235. (a) 236. (c) 237. (b) 238. (d)
239. (a) 240. (a) 241. (b) 242. (b) 243. (d) 244. (c)
245. (a) 246. (a) 247. (c), (d) 248. (b) 249. (c) 250. (c)
251. (D), (C), (B), (A) 252. (d) 253. (a) 254. (b) 255. (d)
256. (b) 257. (b) 258. (d) 259. (c) 260. (b) 261. (b)
262. (c) 263. (a) 264. (d) 265. (a) 266. (b) 267. (c)
268. (b) 269. (d) 270. (b)

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16 Construction Management

16.1 Introduction

The construction management deals with the management in which group of people of different categories work together, to execute the project economically without affecting the quality in a well planned and organised manner. It is very essential for the following factors :

1. To check up the wastage of material and labour.
2. To complete the work in the shortest possible time.
3. To have less construction cost.
4. To improve the quality of work by using modern construction equipments.

16.2 Functions of Construction Management

The aim of construction management is to facilitate the execution of work in a planned and efficient manner as per designs and specifications within the prescribed time limit and with the greatest possible economy in construction cost. In order to achieve this, the construction management should have the following functions :

1. *Planning.* It is an administrative process which translates the policy into a method of achieving the desired objective. Each work should be planned with respect to the manner of execution of the work, urgency of work and the availability of resources.

2. *Organising.* The type of organisation depends upon the type and volume of work as well as the method of execution. An organisation set up should be kept simple and balanced.

3. *Directing.* The object of directing is that each employee should know exactly what he is supposed to do, how and when to do.

4. *Controlling.* In a construction work, the following are the main aims of controlling :
   (*a*) To keep a watch over the physical progress of each activity of the work.
   (*b*) To control the quality of work.
   (*c*) To control the expenditure on each item of work.
   (*d*) To control the use of machines.

5. *Co-ordinating.* The co-ordination is necessary so that proper information is made available at proper time to the correct person. The proper planning, design and execution of the work is called *modular co-ordination.*

16.3 Classification of Construction Works

The works, according to their cost, are classified as follows :

1. *Minor works.* The construction works costing below rupees twenty thousands, are known as minor works.

2. *Major works.* The construction works costing between rupees twenty thousand and one ac, are known as major works.

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3. *Project.* The construction works costing above rupees *one lac, are known as projects.

Note : If the cost of a construction work is less than rupees two thousand five hundred, it is then known as petty work.

The construction work may be further classified as follows :

(*a*) *Light construction.* It includes the works with light structural members, light foundations and light timber members. The construction of residential and commercial buildings, schools, villages and city roads, small water supply and sewage works, ware houses and light industrial sheds are considered as light construction.

(*b*) *Heavy construction.* It includes heavy structural members on massive foundations. The construction of tunnels, bridges, oil pipe lines, railways, air ports, dams, thermal and hydroelectric power generation plants, are considered as heavy construction.

(*c*) *Industrial construction.* It includes all the construction work related to industries producing commercial products. The construction of refineries, fertilizers, chemical plants and steel mills are considered as industrial constructions.

16.4 Construction Stages

The following are the various stages in every construction work :

1. Conception; 2. Study and evaluation; 3. Design, drawings and estimates; 4. Specifications; 5. Contractor realisation; 6. Procurement of materials; 7 Construction and supervision; and 8. Utilisation and maintenance.

16.5 Construction Team

It may be noted that a construction work can not be completed by a single person. It requires a team of workers with their specific duties. The construction team includes owner, engineer, architect, designer and contractor or builder.

The conception of idea for any construction work is the responsibility of the owner. He is both financer and the beneficiary of the work.

The engineer is a professional man and responsible for the economic and safe design and construction of the work under his supervision. The field of activities of an engineer includes designing, drawing estimation, approval of construction plans by the local authority, tendering, supply of material as per contract, control and inspection of quality and progress of work done by the contractor, measurement of work done and payment of it. The engineer is also consulted by the architect regarding design, estimation etc.

The contractor is responsible for the material not supplied by the owner, organising, planning and execution of the work as per given drawings and specifications laid down in the contract.

16.6 Resources in a Construction Project

The resources in a construction project are made up of the following things :

1. Money which is the first and foremost item required for any construction project.
2. Plant equipment and machinery required for the construction project.
3. Construction materials such as cement, bricks, steel etc.
4. Skilled and un-skilled manpower.

For building works costing rupees one lac, the drawings should be prepared by architect. The technical sanction is accorded by Executive Engineers and higher authorities according to the powers delegated to them. The limit of powers of some officers to accord technical sanction is as follows :

1. Chief Engineer–Full powers, 2. Superintendent Engineer–Five lac; 3. Executive Engineer–One lac; and 4. Assistant Engineer–Twenty five thousand only.

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16.7 Construction Planning

It may be defined as a rational, sequential and appropriate way of directing the construction activities. It is an administrative process which translates the policy into a method of achieving the desired goal.

The construction planning may be classified as follows :

1. *Pre-tender planning.* The pre-tender planning is the planning undertaken by the contractor after receipt of tender notice and before submitting a bid for the tender for the proposed work. The pre-tender stage of construction requires the following :

(*a*) selection of site; (*b*) acquisition of land; (*c*) finalisation of designs; (*d*) preparation of estimate; (*e*) availability of material, labour, machinery and equipment.

2. *Post-tender planning.* The aim of post-tender planning is to organise all aspects of construction work so that the work may proceed without any problems causing delay. The post-tender stage of construction consists of the following :

(*a*) assessment of work; (*b*) assessment of expenditure during execution; (*c*) detailed requirement of machinery and equipment; (*d*) necessary requirements of men, material, machines and finances at various stages; (*e*) finalisation of accounts.

3. *Technical planning.* The technical planning is carried out for the preparation of detailed drawings, estimate, planning resources and initiating procurement action.

16.8 Construction Scheduling

It is a mechanical process for setting up the sequential order of the various operations in a construction project by fixing the dates of starting and completing each operation of the work. In order to prepare a construction schedule, the following data is required:

1. Number of operations; 2. Number of activities; 3. Output of labour; and 4. Number of field workers.

16.9 Organisation

The organisation is a group of people which works under an executive leadership. It divides the work and responsibilities of the employees. It establishes a relationship between authority and responsibility and controls the efforts of groups. The organisation is a step towards the achievement of established goals. The following are the various types of organisations:

1. *Line organisation.* It is also called military type of organisation because it resembles to olden military organisation. Sometimes it is also called as the scalar type since it has straight flow of authority within a single unit. It is the simplest form of organisation in which responsibility of each individual is fixed, discipline is strong and quicker decisions are taken. The disadvantage of this organisation is that it overloads a few key executive and encourages dictatorial way of working.

The line organisation is suitable for small construction works such as a private residential building.

2. *Functional organisation.* This type of organisation was introduced by F.W. Taylor. In the functional organisation, the quality of work is better, wastage of material is minimum and specialised knowledge and guidance to individual worker is provided. This type of organisation is suitable for large sized construction works.

3. *Line and staff organisation.* This type of organisation possesses practically all the advantages of both the line and functional organisations. In the line and staff organisation, the quality of work is improved, and there is less wastage of material, man and machine hours. The expert advice from specialist staff executives can be made use of. This type of organisation is preferred for medium sized construction works.

16.10 Principles of Organisation

In order to have effective organisation, the following basic principles should be followed :

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1. Span of management; 2. Unity of command; 3. Delegation of authority; 4. Unity of assignment; 5. Division of work; 6. Separation of work; 7. Job definition; 8. Contact; and 9. Ultimate authority and responsibility.

16.11 Methods of Planning and Scheduling

The methods of planning and scheduling the construction of a project are as follows :

1. By Charts such as bar charts or Gantt chart and milestone charts.
2. By network technique such as programme evaluation review technique (P.E.R.T), critical path method (C.P.M.) and line of bolana system (L.B.S.)

These methods are discussed as follows:

16.12 Bar Chart or Gantt Chart

The bar chart or Gantt chart was developed by Henry Gantt for planning and scheduling the methods of construction. This chart is a graphical representation of various activities involved in a construction work. It consists of two co-ordinates. The horizontal ordinate or bar represents the various activities involved in a construction work and the duration of times required for completion of the activities. The vertical abscissa or bar represents the respective jobs to be performed. The length of the bar indicates the duration of activity or job for its completion. The various activities are shown parallel to each other along ordinates.

Since the various activities are shown by a number of parallel ordinates or bars, therefore it is called a *bar chart*. The duration of the activities are represented from the left to the right. Each bar is divided longitudinally into two portions. The top portion indicates the progress of completion of the activity and the bottom portion indicates the duration of the activity.

The use of bar chart is very popular in construction departments because of the following advantages :

(*a*) It is very simple to prepare and interpret.
(*b*) Each item of work or activity is shown separately.
(*c*) It is very easy to compare the progress and original schedule.
(*d*) It is easy to know the time for the resource of activities.
(*e*) The modifications to the chart, if required, can be carried out easily.

Notes : 1. The process of calculating the resource requirement of a project is known as *resource aggregation*.
2. In a bar chart method, the sequence of activities is not clearly defined.
3. The critical activities can not be shown by bar charts.

16.13 Milestone Chart

A milestone chart is a modification of a bar chart. In this chart, the key events are shown on the respective bars. Each event is numbered and an explanatory note is provided with it. These key events are known as milestones. These charts are restricted to small projects only.

16.14 Network Planning and Scheduling

Now-a-days, necessity for better planning and scheduling is increasing due to the increasing complexity of large projects. It is very essential for the success of any project that time schedules and objectives of various operations should be defined in a project. The network analysis helps designing, planning, co-ordinating, controlling and in decision making in order to accomplish the project economically in the minimum available time with the limited available resources. The net work techniques were developed from the milestone chart and bar chart. These conventional planning methods, because of their inherent limitations could not be utilised for planning large and complex projects. There are number of network techniques, but the most important are critical path method (C.P.M.) and programme evaluation review technique (P.E.R.T.).

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16.15 Terms used in Network Planning Methods

A network is a schematic representation of the entire project, consisting of number of activities. These activities are joined together in such a way as to form an integrated network, as shown in Fig. 16.1.

The following terms are commonly used in network planning methods :

1. *Activity.* Every project consists of a number of job operations or tasks which are called activities. An activity is shown by an arrow and it begins and ends with an event. An activity consumes time and resources. An activity may be performed by an individual or a group of individuals.

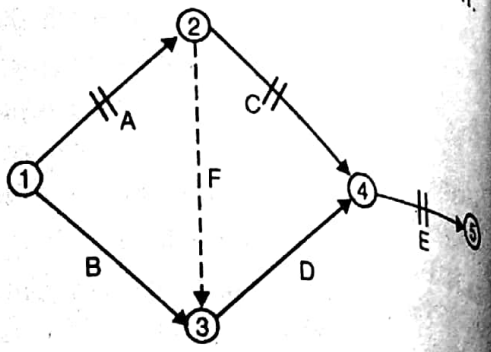

Fig. 16.1

The activity may be classified as critical activity, non-critical activity and dummy activity. The activity is called critical if its earliest start time (EST) plus the time taken by it, is equal to the latest finishing time (LFT). *A* critical activity (*e.g. A*, *C* or *E*) is marked either by a thick arrow or by two lines as shown in Fig. 16.1.

The non-critical activities have provision (float or slack) so that, even if they consume a specified time over and above the estimated time, the project will not be delayed. In Fig. 16.1, *B* and *D* are non-critical activities.

When two activities start at the same instant of times (like activities *C* and *D*), the head events are joined by a dotted arrow and this is known as dummy activity as shown by *F* in Fig. 16.1. The dummy activity does not consume time and resources.

2. *Event.* The event is a specific instant of time which makes the start and the end of an activity. The event consumes neither time nor resources. It is represented by a circle and the event number is written within the circle, as shown in Fig. 16.1.

3. *Critical path.* It is that sequence of activities which decide the total project duration. It is formed by critical activities. In Fig. 16.1, 1–2–4–5 is the critical path. *A* critical path consumes maximum resources. It is the longest path and consumes maximum time. *A* critical path has zero float or slack.

4. *Slack or Float.* The slack is with reference to an event and float is with respect to an activity. In other works, slack is used with PERT and float with CPM, but in general practice, they may be used interchangeably. The slack or float represents the difference between the earliest completion or finish time and the latest allowable time. The slack or float may be positive, negative or zero.

When the slack or float of an activity is positive, then it represents a situation where extra resources are available and the completion of project is not delayed.

When the slack or float of an activity is negative, then it represents that a programme falls behind schedule and additional resources are required to complete the project in time.

When the slack or float of an activity is zero, then the activity is critical and any delay in its performance will delay the completion of whole project.

The slack or float may be total float, free float, interfering and independent float.

The *total float* is the time available for an activity performance minus the duration of activity. It may be defined as the difference of the latest finish time (LFT) and earliest finish time (EFT). It is also equal to the difference of latest start time (LST) and earliest start time (EST).

The *free float* is defined as the earliest start time (EST) of its successor activity and the earliest finish time (EFT) of the activity in question.

The *interfering float* is the difference between the total float and free float of an activity.

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The *independent float* is the excess of minimum available time over the required activity duration :

Notes : (*a*) The earliest possible time at which an activity may start is called *earliest start time* (EST).

(*b*) The sum of the earliest start time (EST) of an activity and the time required for its completion, is called *earliest finish time* (EFT).

(*c*) The latest possible time at which an activity may start without delaying the completion of the project, is called *latest start time* (LST).

(*d*) The sum of the latest start time (LST) of an activity and the time required for its completion, is called *latest finish time* (LFT).

16.16 Critical Path Method (CPM)

The critical path method (CPM) is a network technique to deal with large and complex projects. It was first used by Morgan R. Walker in 1957. It helps in ascertaining time schedules, makes better and detailed planning possible, encourages discipline and provides a standard method for communicating project plan schedules and to time and cost performance.

16.17 Programme Evaluation Review Technique (PERT)

The programme evaluation review technique (PERT) is a project planning and control technique. It is an event oriented technique. It provides an approach for keeping planning up-to-date. It provides a way for management to require that planning be done on a uniform and logical basis. It permits management to foresee quickly the impact of variations from the plan. The programme evaluation review technique is applied for long-range planning, installation of machinery, research and development of products and marketing programmes and advertising programmes. The PERT analysis is based upon the following three time estimates :

(*a*) *Optimistic or best time*. It is the shortest possible time in which an activity can be completed if every thing goes exceptionally well.

(*b*) *Most probable or likely time.* It is the time in which the activity is normally expected to complete under normal contingencies.

(*c*) *Pessimistic or worst time.* It is the time which an activity will take to complete in case of difficulty. It is the longest of all the three time estimates.

If t_0 = Optimistic or best time,

t_n = Most probable or likely time, and

t_p = Pessimistic or worst time.

Then the probabilistic time (t_m) for completion of an activity is given by

$$t_m = \frac{t_0 + t_p + 4\,t_n}{6}$$

OBJECTIVE TYPE QUESTIONS

1. The main function of the construction management is
   (*a*) planning (*b*) organising (*c*) directing (*d*) all of these
2. Each work should be planned with respect to
   (*a*) manner of execution of the work (*b*) urgency of the work
   (*c*) availability of resources (*d*) all of these
3. In construction work, the controlling function aims at
   (*a*) keeping a watch over the physical progress of each activity of the work
   (*b*) controlling the expenditure on each item of work
   (*c*) controlling the use of machines and materials
   (*d*) all of the above

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4. A golden rule for the procurement of construction stores is that
   (a) half of the construction stores should be at work site and half under procurement
   (b) two-third of the construction stores should be at work site and one-third under procurement
   (c) three-fourth of the construction stores should be at work site and one-fourth under procurement
   (d) whole of the construction stores should be at work site
5. The proper planning, design and execution of the work is called modular co-ordination.
   (a) Right (b) Wrong
6. The construction works costing below rupees twenty thousand are classified as
   (a) minor works (b) major works (c) projects (d) none of these
7. The construction works costing above rupees one lac are classified as
   (a) minor works (b) major works (c) projects (c) none of these
8. When the construction cost of a work is between rupees twenty thousand and one lac, then it is said to be a major work.
   (a) Agree (b) Disagree
9. The construction of residential building are treated as
   (a) light construction (b) heavy construction
   (c) industrial construction (d) none of these
10. The construction of ..... belongs to industrial construction.
   (a) transit sheds (b) tunnels (c) dams (d) chemical plants
11. The construction of airports are treated as
   (a) light construction (b) heavy construction
   (c) industrial construction (d) none of these
12. Light construction includes works involving light structural members on massive foundation.
   (a) True (b) False
13. The final technical authority of a project is
   (a) Assistant Engineer (b) Executive Engineer
   (c) Superintending Engineer (d) Chief Engineer
14. An Assistant Engineer may have powers upto rupees
   (a) twenty five thousand (b) one lac (c) two lac (d) five lac
15. A Superintending Engineer may have powers upto rupees five lac.
   (a) True (b) False
16. When used in connection with the progress of a work, the term amount indicates the
   (a) total expenditure on a particular item (b) supplies made and services performed
   (c) value of the finished product in a manufacturing operation
   (d) none of the above
17. The term productivity denotes the output in any productive work in relation to the inputs.
   (a) Correct (b) Incorrect
18. The first stage of a large construction work to
   (a) contract (b) design
   (c) conception (d) study and evaluation
19. A construction team includes
   (a) owner (b) engineer (c) architect (d) all of these

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20. The conception of idea for any construction work is the responsibility of
(a) owner (b) engineer (c) contractor (d) all of these

21. The field of activities of an engineer includes
(a) estimation
(b) approval of construction plans by the local authority
(c) inspection and payment of work done by contractor
(d) all of the above

22. The contractor is responsible for
(a) procuring material which is not supplied by the owner
(b) organising and planning the work as per drawing
(c) executing the work as per specifications laid down in the contract
(d) all of the above

23. Match the correct answer from *Group B* for the statements given in *Group A*.

Group A	*Group B*
(a) Translates policy into a method of achieving the objective set/out	(A) Co-ordinating
(b) Consists of defining the responsibilities of employees	(B) Planning
(c) Transmits all the informations to the supervising staff	(C) Organising
(d) The organisational set up is aided to operate efficiently with flow of information, decisions and results in all directions	(D) Directing

24. In large works, construction is the responsibility of a contractor.
(a) Correct (b) Incorrect

25. The resources in a construction project are made up of
(a) plant equipment and machinery required for the project
(b) construction materials such as cement, bricks, steel etc.
(c) skilled and unskilled manpower
(d) all of the above

26. The pre-tender stage of construction requires
(a) selection of site (b) acquisition of land
(c) finalisation of designs (d) all of these

27. Technical planning is carried out for the
(a) preparation of detailed drawings
(b) preparation of detailed estimate
(c) planning resources and initiating procurement action
(d) all of the above

28. Planning of resources belongs to the ..... planning.
(a) pre-tender (b) post-tender

29. Pre-tender planning is undertaken by the contractor after receipt of tender notice and before submitting a bid.
(a) Yes (b) No

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30. The post-tender stage of construction consists of
(a) assessment of work
(b) finalisation of accounts
(c) assessment of expenditure during execution
(d) all of the above

31. For the preparation of a construction schedule, the data required is
(a) number of operations
(b) number of activities
(c) output of labour
(d) all of these

32. Military type of organisation is known as
(a) line organisation
(b) functional organisation
(c) line and staff organisation
(d) none of these

33. In a line organisation
(a) discipline is strong
(b) quick decisions are taken
(c) responsibility of each individual is fixed
(d) all of these

34. F.W. Taylor introduced a system of organisation known as
(a) line organisation
(b) functional organisation
(c) line and staff organisation
(d) none of these

35. Functional organisation system of working was introduced by
(a) Henry Gantt (b) F.W. Taylor (c) M.R. Walker (d) none of these

36. In a functional organisation
(a) quality of work is better
(b) wastage of material is minimum
(c) specialised knowledge and guidance to individual worker is provided
(d) all of the above

37. Line organisation is suitable for a big organisation.
(a) Agree
(b) Disagree

38. In functional organisation, responsibility..... directly on any individual.
(a) can be fixed
(b) can not be fixed

39. The salient feature of the organisation evolved by F.W. Taylor is
(a) strict adherence to specification
(b) separation of planning and design part for field work
(c) each individual maintains functional efficiency
(d) all of the above

40. The major principle of an organisation is
(a) span of management
(b) unity of command
(c) delegation of authority
(d) all of these

41. Time and progress chart are also known as
(a) bar chart
(b) modified milestone chart
(c) critical path method chart
(d) all of these

42. The process of calculating the resource requirement of a project is known as
(a) scheduling
(b) co-ordinating
(c) resource aggregation
(d) all of these

43. Bar chart is suitable for
(a) large project (b) major work (c) minor work (d) all of these

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44. The use of bar chart is very popular in construction departments because
(a) it is very simple to prepare and interpret
(b) each item of work or activity is shown separately
(c) modification to the chart, if required, can be carried out easily
(d) all of the above

45. In bar chart method, the sequence of activities is not clearly defined.
(a) Agree (b) Disagree

46. The chart which gives an estimate about the amount of materials handling between various work stations is known as
(a) flow chart (b) process chart (c) travel chart (d) operation chart

47. The bar chart is also known as
(a) flow chart (b) time chart (c) travel chart (d) Gantt chart

48. A bar chart is drawn for
(a) time versus activity (b) activity versus resources
(c) resources versus progress (d) progress versus time

49. A drawback of the bar chart is that
(a) all the activity are independent of each other
(b) it is difficult to judge whether an activity is completed or not
(c) the sequence of activities is not clearly defined
(d) all of the above

50. Which of the following statement is correct in bar chart planning ?
(a) The inter dependence of the operations can not be portrayed.
(b) The progress of work can be measured.
(c) The spare time of the activities can be determined.
(d) The schedule can not be updated.

51. A milestone chart
(a) depicts the delay of job
(b) shows the inter dependence of various jobs
(c) shows the events in chronological, but not in a logical sequence
(d) all of the above

52. Milestone chart is an improvement over
(a) bar chart (b) PERT (c) CPM (d) all of these

53. A Gantt chart indicates
(a) balance of work to be done
(b) efficiency of project work
(c) comparison of actual process with the scheduled progress
(d) progress cost of project

54. The jobs going ahead of schedule are conveniently shown in
(a) Gantt chart (b) milestone chart (c) pie chart (d) none of these

55. The earliest method used for planning of projects was
(a) CPM (b) PERT (c) bar chart (d) milestone chart

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56. Travel charts are used to
   (*a*) analyse material handling
   (*b*) determine inventory control difficulties
   (*c*) plan material handling procedure and routes
   (*d*) all of the above

57. PERT stands for
   (*a*) Programme Estimation and Reporting Technique
   (*b*) Process Estimation and Review Technique
   (*c*) Programme Evaluation and Review Technique
   (*d*) Planning Estimation and Resulting Technique

58. Actual performance of a task is called
   (*a*) an event (*b*) an activity (c) a duration (*d*) any one of these

59. The start or completion of task is called
   (*a*) an event (*b*) an activity (*c*) a duration (*d*) any one of these

60. An activity requires
   (*a*) events (*b*) resources (*c*) time and resources (*d*) energy

61. An event is a definite position of an activity.
   (*a*) Correct (*b*) Incorrect

62. An activity is
   (*a*) the beginning or end of a specified job
   (*b*) an element of work entailed in the project
   (*c*) the movement of heavy vehicles from one place to another
   (*d*) the progress of work upto a certain limit

63. PERT
   (*a*) provides an approach for keeping planning up-to-date
   (*b*) provides a way for management to require that planning be done on a uniform and logical basis
   (*c*) permits management to foresee quickly the impact of variations from the plan
   (*d*) all of the above

64. PERT is a project planning and control technique.
   (*a*) Yes (*b*) No

65. PERT is an event oriented technique.
   (*a*) Right (*b*) Wrong

66. CPM is
   (*a*) activity oriented (*b*) event oriented
   (*c*) time oriented (*d*) resource oriented

67. CPM stands for
   (*a*) Combined Process Method (*b*) Critical Path Method
   (*c*) Common Planning Method (*d*) Critical Process Method

68. CPM requires
   (*a*) single time estimate (*b*) double time estimate
   (*c*) triple time estimate (*d*) none of these

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69. PERT requires
(a) single time estimate (b) double time estimate
(c) triple time estimate (d) none of these

70. PERT analysis is based upon
(a) optimistic time (b) pessimistic time (c) most likely time (d) all of these

71. Probabilistic time for completion of any activity can be found out from
(a) optimistic time (b) pessimistic time (c) most likely time (d) all of these

72. The optimistic time represents the
(a) shortest possible time in which an activity can be completed if everything goes exceptionally well
(b) time in which the activity is normally expected to complete under normal contingencis
(c) time in which an activity will take to complete in case of difficulty
(d) none of the above

73. The time in which an activity will take to complete in case of difficulty, is called
(a) optimistic time (b) most likely time (c) pessimistic time (d) none of these

74. The most likely time is the time in which the activity is normally expected to complete under normal contingencies.
(a) Agree (b) Disagree

75. In CPM, the cost slope is determined by
(a) $\frac{\text{Crash cost}}{\text{Normal cost}}$ (b) $\frac{\text{Crash cost} - \text{Normal cost}}{\text{Normal time} - \text{Crash time}}$
(c) $\frac{\text{Normal cost}}{\text{Crash cost}}$ (d) $\frac{\text{Normal time} - \text{Crash time}}{\text{Crash cost} - \text{Normal cost}}$

76. Generally PERT is preferred over CPM for the purpose of project evaluation.
(a) True (b) False

77. The probabilistic time is given by
(a) $\frac{t_0 + t_p + t_n}{3}$ (b) $\frac{t_0 + 2t_p + t_n}{4}$ (c) $\frac{t_0 + 4t_p + t_n}{5}$ (d) $\frac{t_0 + t_p + 4t_n}{6}$
where t_0 = Optimistic time, t_p = Pessimistic time, and t_n = Most likely time.

78. Float or slack represents the difference between the
(a) earliest completion time and latest allowable time
(b) latest allowable time and earliest completion time
(c) earliest completion time and normal expected time
(d) latest allowable time and normal allowable time

79. The amount of time by which the activity completion can be delayed without interfering with the start of succeeding activity, is known as
(a) earliest completion time (b) total float
(c) free float (d) none of these

80. The early finish time of an activity is the ..... of early start time and duration of activity.
(a) sum (d) difference (c) product (d) ratio

81. The total activity slack is equal to
(a) Late start time – Early start time (b) Late finish time – Early finish time
(c) Latest allowable event occurrence time – Early finish time
(d) all of the above

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82. The free float is equal to

(*a*) Latest allowable event occurrence time + Early finish time

(*b*) Earliest event occurrence time + Early finish time

(*c*) Latest allowable event occurrence time – Early finish time

(*d*) Earliest event occurrence time – Early finish time

83. The difference between the total float and free float is called

(*a*) duration (*b*) interfering float (*c*) critical activity (*d*) none of these

84. The estimated time required to complete an activity is known as

(*a*) duration (*b*) float (*c*) restraint (*d*) all of these

85. Float or slack may be positive, zero or negative.

(*a*) Correct (*b*) Incorrect

86. When float or slack of an activity is positive

(*a*) it represents a situation where extra resources are available and the completion of project is not delayed

(*b*) it represents that a programme falls behind schedule and additional resources are required to complete the project in time

(*c*) the activity is critical and any delay in its performance will delay the completion of whole project

(*d*) any one of the above

87. Critical path method

(*a*) helps in ascertaining time schedules

(*b*) makes better and detailed planning possible

(*c*) provides a standard method for communicating project plans, schedules time and cost performance

(*d*) all of the above

88. Which of the following statement is correct ?

(*a*) When float of an activity is zero, it falls only on critical path.

(*b*) CPM technique is useful to minimise the direct and indirect expenses.

(*c*) Critical path of a net work represents the minimum time required for completion of project.

(*d*) all of the above

89. When float of an activity is zero, the activity is critical and any delay in its performance will lay the completion of the whole project.

(*a*) Agree (*b*) Disagree

90. When float of an activity is negative

(*a*) it represents a situation where extra resources are available and the completion of project is not delayed

(*b*) it represents that a programme falls behind schedule and additional resources are required to complete the project in time

(*c*) the activity is critical and any delay in its performance will delay the completion of whole project

(*d*) all of the above

91. An event is a function of two or more activities.

(*a*) True (*b*) False

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92. Which of the following statement is wrong ?
(a) An activity consumes time and resources whereas an event do not consume time or resources.
(b) The performance of a specific task is called an activity.
(c) An event is an instantaneous point in time at which an activity begins or ends.
(d) none of the above

93. A critical activity has
(a) maximum float (b) minimum float (c) zero float (d) average float

94. The graphical representation of activities and events of a project is known as net work.
(a) True (b) False

95. An activity of the project is graphically represented by ..... on the network.
(a) a circle (b) a straight line (c) an arrow

96. Which of the following statement is correct about the net work diagram ?
(a) The events are represented graphically by circles or nodes at the beginning and the end of activity by arrows.
(b) The tail end of the arrow represents the start of an activity.
(c) The head of the arrow represents the end of an activity.
(d) all of the above

97. A dummy activity in a net work
(a) is represented by a dotted line (b) is an artificial activity
(c) does not consume time or resources (d) all of these

98. The occurrence of the completion of an activity, is called its
(a) head event (b) tail event (c) dual role event (d) none of these

99. The occurrence of the starting of an activity, is called its
(a) head event (b) tail event (c) dual role event (d) none of these

100. Match the correct answer from *Group B* for the statements given in *Group A*.

Group A (*Description of activity floats*)	*Group B* (*Names of the floats*)
(a) The earliest start time of its successor activity *minus* earliest finish time of the activity in question	(*A*) Total float
(b) The time available for an activity performance *minus* the duration of activity	(*B*) Free float
(c) The excess of minimum available time over the required activity duration	(*C*) Interfering float
(d) The difference between total float and free float of an activity	(*D*) Independent float

101. In the critical path of construction planning, free float can be
(a) greater than total float (b) equal to total float
(c) greater than independent float (d) less than independent float

102. Which of the following is a dummy activity ?
(a) Excavation of foundations (b) Laying the foundation concrete
(c) Awaiting the arrival of concrete material (d) Curing the foundation concrete

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103. The essential condition for the decompression of an activity is that
(*a*) the project time should change due to decompression
(*b*) after decompression, the time of an activity invariably exceeds its normal time
(*c*) an activity could be decompressed to the maximum extent of its normal time
(*d*) none of the above

104. Dummy activities are used to
(*a*) determine the critical path
(*b*) determine the project completion time
(*c*) maintain the required net work
(*d*) none of these

105. *A* dummy activity becomes a critical activity when its earliest start time (EST) is same as its latest finishing time (LFT).
(*a*) Correct
(*b*) Incorrect

106. Which of the following are the guidelines for the construction of a network diagram?
(*a*) Each activity is represented by one and only arrow in the network.
(*b*) Dangling must be avoided in a network diagram.
(*c*) Dummy activity consumes no time or resource.
(*d*) all of the above

107. In a network shown in Fig. 16.2, the critical path is along
(*a*) 1–2–3–4–8–9
(*b*) 1–2–3–5–6–7–8–9
(*c*) 1–2–3–4–7–8–9
(*d*) 1–2–5–6–7–8–9

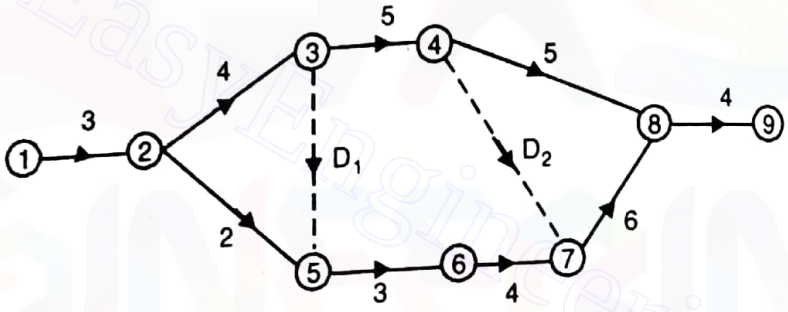
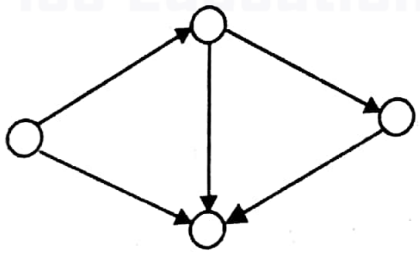


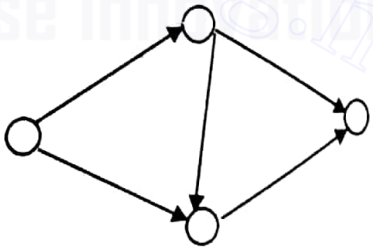
Fig. 16.2

108. Which of the following networks is correctly drawn ?

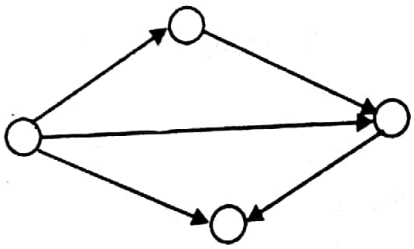
(*a*)



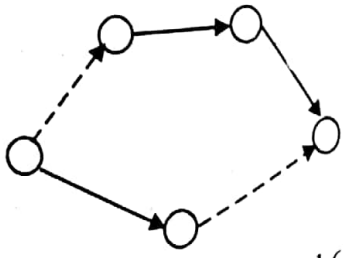
(*b*)



(*c*)



(*d*)



109. *A* PERT network has three activities on critical path with mean time 3,8 and 6 and standard deviations 1,2 and 2 respectively. The probability that the project will be completed in 20 days is
(*a*) 0.50
(*b*) 0.66
(*c*) 0.84
(*d*) 0.95

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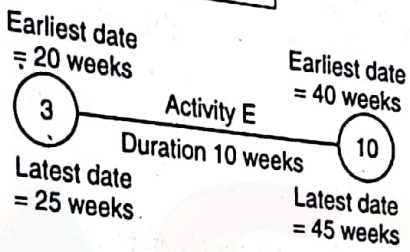
110. The network rules are common to all activity-on-arrow net working systems. The use of computers for making computations may impose certain rules. Which of the following basic rules of net work logic are correct ?
(a) Before an activity may begin, all the activities preceding it may be complete.
(b) Any two events may be directly connected by not more than one activity.
(c) The event numbers must not be duplicated in a net work.
(d) all of the above

111. Match the correct answer from *Group B* for the statements given *Group A*.

Group A (Item)	*Group B (Characteristic)*
(a) Activity	(A) Resourceless
(b) Event	(B) Resource consuming element
(c) Dummy	(C) Spare time
(d) Float	(D) Instantaneous stage

112. The earliest date and the latest date of events 3 and 10 are given in the figure. Activity *E* is connecting both the events and its duration is 10 weeks. The independent float of the activity is

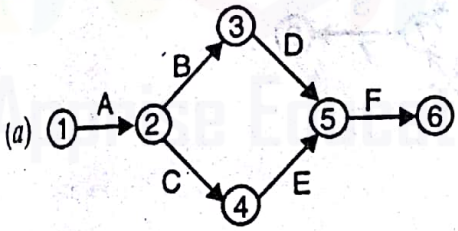


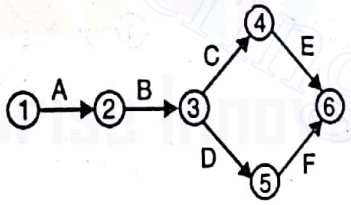
(a) 5 weeks (b) 10 weeks
(c) 15 weeks (d) 20 weeks

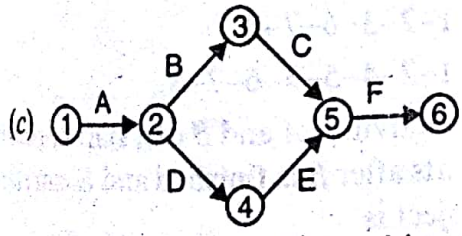
113. PERT is applied for long-time range planning.
(a) Right (b) Wrong

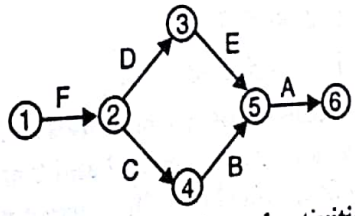
114. Which of the following is an activity ?
(a) Construction of foundation (b) Construction of roof
(c) Construction of super-structure (d) all of these

115. In a project, activities *B* and *C* follows *A*, activity *D* follows *B*, activity *E* follows *C* and activities *D* and *E* precede *F*. The correct net work for the project is

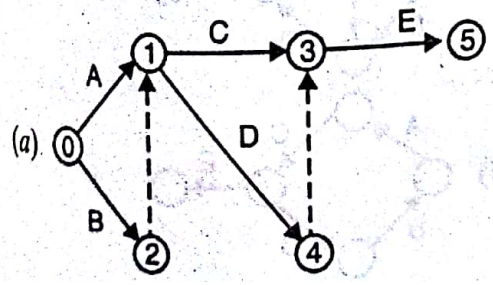
(a)


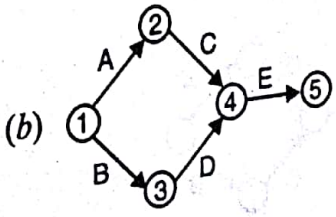
(b)


(c)


(d)


116. When it is required that activities *A* and *B* can be started independently and activities *C* and *D* being independent but can be started after *A* and *B* have been completed and activity *E* can be started only when all activities *A*, *B*, *C* and *D* have been completed, then the flow diagram will be

(a)


(b)


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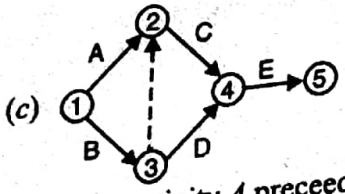
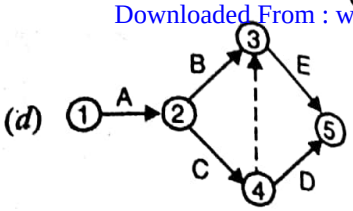
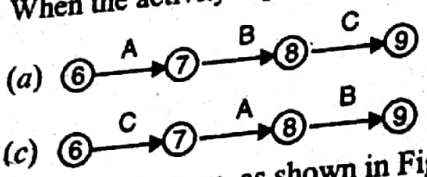
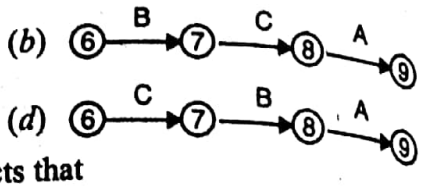




117. When the activity *A* preceeds *B* but succeeds *C*, then the net work is





118. The flow diagram, as shown in Fig. 16.3, depicts that

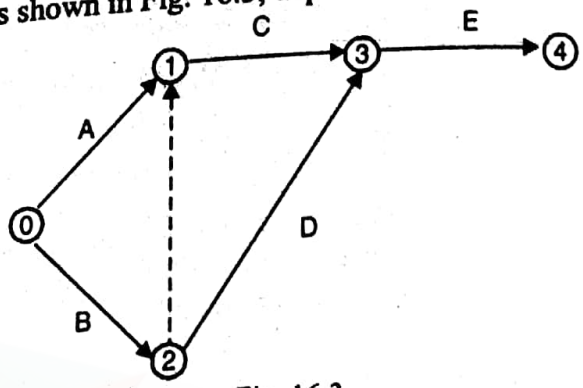


Fig. 16.3

(*a*) activity *C* can be started only after the completion of activities *A* and *B*

(*b*) activity *D* can be started only when activity *B* is completed

(*c*) activity *E* can be started only when activities *A*, *B*, *C* and *D* have been completed

(*d*) all of the above

119. The flow net of activities of a project is shown in Fig. 16.4. The duration of the activities are written along their arrows. The critical path of the activities is along

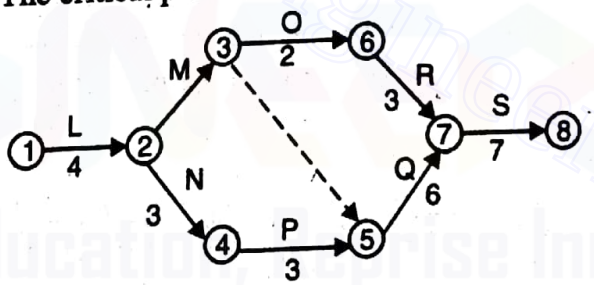


Fig. 16.4

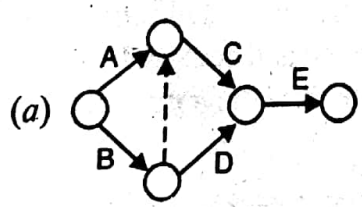
(*a*) 1–2–4–5–7–8

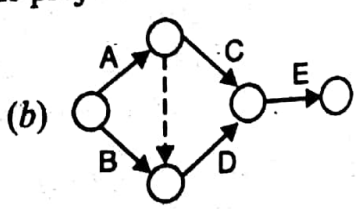
(*b*) 1–2–3–6–7–8

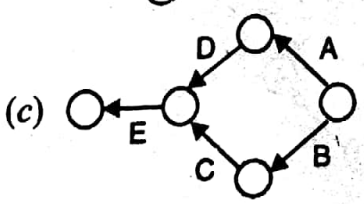
(*c*) 1–2–3–5–7–8

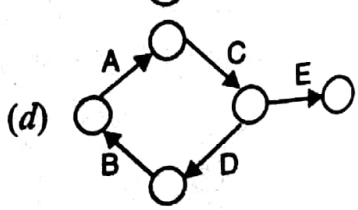
(*d*) 1–2–4–5–3–6–7–8

120. A job consists of five activities *A*, *B*, *C*, *D* and *E*. The activities *A* and *B* can start concurrently. The activity can start only after *A* and *B* are completed, *D* starts after *B* is finished and *E* can start only after *C* and *D* are finished. The correct network for the project is









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ANSWERS

1. (d) 2. (d) 3. (d) 4. (b) 5. (a) 6. (a)
7. (c) 8. (a) 9. (a) 10. (d) 11. (b) 12. (b)
13. (d) 14. (a) 15. (a) 16. (a) 17. (a) 18. (c)
19. (d) 20. (a) 21. (d) 22. (d) 23. (B), (C), (D), (A)
24. (a) 25. (d) 26. (d) 27. (d) 28. (a) 29. (a)
30. (d) 31. (d) 32. (a) 33. (d) 34. (b) 35. (b)
36. (d) 37. (b) 38. (b) 39. (d) 40. (d) 41. (d)
42. (c) 43. (c) 44. (d) 45. (a) 46. (c) 47. (d)
48. (a) 49. (c) 50. (a), (d) 51. (c) 52. (a) 53. (c)
54. (a) 55. (c) 56. (d) 57. (c) 58. (b) 59. (b)
60. (c) 61. (a) 62. (b) 63. (d) 64. (a) 65. (a)
66. (a) 67. (b) 68. (a) 69. (c) 70. (d) 71. (d)
72. (a) 73. (c) 74. (a) 75. (b) 76. (a) 77. (d)
78. (a) 79. (c) 80. (a) 81. (d) 82. (d) 83. (b)
84. (a) 85. (a) 86. (a) 87. (d) 88. (d) 89. (a)
90. (b) 91. (a) 92. (d) 93. (c) 94. (a) 95. (c)
96. (d) 97. (d) 98. (a) 99. (b) 100. (B), (A), (D), (C)
101. (c) 102. (c) 103. (c) 104. (c) 105. (a) 106. (d)
107. (a) 108. (a) 109. (b) 110. (d) 111. (B), (D), (A), (C)
112. (a) 113. (a) 114. (d) 115. (a) 116. (a) 117. (c)
118. (d) 119. (c) 120. (a)

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12 Building Construction

12.1 Introduction

A building has two main components, *i.e.* foundation or sub-structure and super structure. The *foundation* or *sub-structure* is the lowest part of the structure which transmits the load to the soil. The *super structure* is that part of the structure which is above the ground level. A part of the super structure, located between the ground level and the floor level is known as *plinth*. The level of the floor is usually known as *plinth level* and the built up covered area measured at the floor level is called *plinth area*.

The soil which is located immediately below the base of the foundation is called the *sub-soil* or *foundation soil*, while the lower most portion of the foundation which is in direct contact with the sub-soil is called *footing*. The basic function of the foundation is to transmit dead loads, super-imposed or live loads and wind loads from a building to the soil on which the building rests, in such a way that the settlements are within permissible limits, without causing cracks in the super-structure and the soil does not fail. Since the load of the structure is ultimately coming on the soil, therefore it is very important to know the strength and behaviour of the soil.

The ability of the sub-soil to support the load of the structure without yielding or displacement, is known as *bearing power* or *bearing value* or *bearing capacity of the soil*. It is defined as the maximum load per unit area which the soil can resist safely. The minimum load which will cause failure of a foundation is called *ultimate bearing power* of the soil. When the ultimate bearing power of the soil is divided by the factor of safety, we get *safe bearing capacity of the soil*. The bearing capacity of the soil can be improved by

(*a*) increasing the depth of footing,

(*b*) draining the sub-soil water,

(*c*) driving sand piles, and

(*d*) ramming the granular material like crushed stone in the soil.

Notes: 1. The maximum pressure which the soil can carry safely without any risk of shear failure, is called *safe bearing capacity*.

2. The net loading intensity at which neither the soil fails in shear nor there is excessive settlement is known as *allowable bearing capacity*. It is usually taken as 150 kN/m^2

3. The maximum safe bearing capacity of soil is generally more than allowable bearing capacity of soil.

12.2 Types of Foundations

The foundations may be broadly classified as shallow foundations and deep foundations. A foundation is said to be a shallow if its depth is equal to or less than its width. When the depth is equal to or greater than its width, the foundation is termed as deep foundation.

12.3 Types of Shallow Foundations

The shallow foundations are of the following types :

1. *Spread footing.* The spread footings are those which spread the super-imposed load of the structure over a large area. The spread footings may be of the following types :

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(a) Single footing for a column,
(b) Stepped footing for a column,
(c) Sloped footing for a column,
(d) Wall footing without steps and with steps, and
(e) Grillage foundation.

The base for the first three types of footings is made of concrete. When heavy structural loads from column are required to be transferred to a soil of low bearing capacity, the most economical foundation is grillage foundation. The depth of such a foundation is limited to 0.9 to 1.6 m.

2. *Combined footing*. The common footing which is constructed for two or more columns, is called combined footing. The shape of a combined footing is so proportioned that the centre of gravity of the supporting area is in line with the centre of gravity of the two column loads. The general shape of a combined footing is either rectangular or trapezoidal. A combined rectangular footing is provided where loading condition is such that either of the two columns are equally loaded or the interior column carries greater load. A trapezoidal combined footing is provided under any condition of loading.

3. *Strap footing*. When two or more footings are connected by a beam, it is called a strap footing. It may be used where the distance between the columns is so great that a combined trapezoidal footing becomes quite narrow, with high bending moments.

4. *Raft or mat foundation*. A foundation consisting of thick reinforced concrete slab covering the entire area of the bottom of the structure, is known as raft or mat foundation. When the allowable soil pressure is low or the building loads are heavy and if the required area of footing is more than half the total area of the structure, then it is more economical to use raft or mat foundation.

12.4 Types of Deep Foundations

The deep foundations are of the following types :

1. Pile foundation, 2. Pier foundation, and 3. Caisson or well foundation.

Out of these types, pile foundation is more commonly used in construction.

A pile is a long vertical load transferring member composed of either timber, steel or concrete. In pile foundations, a number of piles are driven in the base of the structure. The pile foundation is generally used when the soil is compressible, water-logged and made-up type. It is most suitable for bridges.

In pier foundations, hollow vertical shafts are sunk upto the hard bed and hollow portions are then filled up with inert material such as sand or lean concrete. The pier foundations are specially suitable for heavy structure such as flyovers in sandy soil or soft soil overlying hard bed at reasonable depth.

The open caisson (called well) is a box of timber, metal, reinforced concrete or masonry which is open both at the top and at the bottom and is used for building and bridge foundation. The well foundation form the most common type of deep foundation for bridges in India.

12.5 Classification of Piles

The piles may be classified as follows :

1. *Classification based on the function*. The piles based upon the function or use may be classified as follows :

(a) *Bearing piles*. The piles which do not support the load by themselves, but act as a medium to transmit the load from the foundation to the resisting sub-stratum, are known as bearing piles.

(b) *Friction piles*. The piles which are driven in the type of soil whose strength does not increase with depth or where the rate of increase in strength with depth is very slow, are known as friction piles.

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(*c*) *Compaction piles*. The piles which are driven in granular soil with the aim of increasing the bearing capacity of the soil, are known as compaction piles.

(*d*) *Batter piles*. The piles which are driven at an inclination to resist large horizontal or inclined force, are known as batter piles.

(*e*) *Fender piles*. The piles used to protect concrete deck or other water front structures from the abrasion or impact, are called fender piles.

(*f*) *Sheet piles*. These piles are commonly used as bulk heads or as impervious cut off to reduce seepage and uplift under hydraulic structures. These piles are not meant for carrying any vertical load. The sheet piles are made of wood, steel or concrete.

2. *Classification based on materials and composition*. The piles based on the materials and composition are as follows :

(*a*) *Concrete piles*. The concrete piles may be pre-cast piles and cast-in-situ piles. The *pre-cast concrete piles* are usually reinforced concrete or pre-stressed concrete piles. These piles require space for casting and storage, more time to set and cure before installations and heavy equipment for handling and driving. The precast concrete piles are generally used for a maximum design load of about 800 kN except for large pre-stressed piles. The length of precast concrete piles varies from 4.5 m to 30 m. The pre-stressed concrete piles as compared to pre-cast and reinforced concrete piles are lesser in weight, easy to handle, have high load carrying capacity and are extremely durable.

The *cast-in-situ concrete piles* are casted in position inside the ground and need not to be reinforced in ordinary cases. These piles are not subjected to handling or driving stresses. The cast-in-situ concrete piles are generally used for a maximum design load of 750 kN except for compacted pedestal piles.

The cast-in-situ piles are of two types, *i.e.* driven piles (cased or uncased) and bored piles (pressure piles, pedestal piles and under-reamed piles). The cased cast-in-situ piles are suitable in practically all ground conditions. The common types of cased cast-in-situ piles are Raymond standard pile, and step-taper pile, Mc-Arthur pile and sewage pile.

The *Raymond standard pile* is used primarily as a friction pile. The length of pile varies from 6 to 12 m and the diameter from 40 to 60 cm at the top and 20 to 30 cm at the base. The thickness of the outer shell depends upon the pile diameter and site conditions.

The *Mac-Arthur cased pile* is a pile of uniform diameter, using the corrugated steel shell which remains in place. The core and the casing are together driven into the ground to the required depth.

The *sewage piles* are used in some soils where driving is very hard or where it is designed to leave water tight shell for sometime before filling the concrete.

The *uncased cast-in-situ concrete piles* are cheaper but requires great skill in their construction. These piles have the advantage that they need no storage space, do not require cutting off excess lengths or building up short lengths, do not require special handling equipment and the concrete is not liable to damage from driving. The common type of uncased cast-in-situ concrete piles are simplex pile, Franki pile, Vibro pile and pedestal pile.

The *simplex pile* can be driven through soft or hard soils. In this pile, a stell tube filled with a cast iron shoe is driven into the ground upto the required depth. The reinforcement, if necessary, is put inside the tube. The concrete is then poured into the tube, and the tube is slowly withdrawn, without concrete being tamped, leaving behind the cast iron shoe.

The *Franki pile* has an enlarged base and a corrugated stem. This pile is more useful where a bearing stratum of limited thickness can be reached at reasonable depth. This pile is also suited to granular soil. The pile diameter in Franki piles vary from 500 to 600 mm, while the enlarged base may have a diameter of about 900 mm or more. The pile has a load carrying capacity of 600 to 900 kN.

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The *Vibro piles* are best suited for places where the ground is soft and offers little resistance to the flow of concrete. These piles are formed by driving a steel tube and shoe, filling with concrete and extracting the tube, using upward extracting and downward tamping blows alternately.

The *pedestal pile* is used where thin bearing stratum is reached with reasonable depth. The pedestal of the pile gives the effect of spread footing on this comparatively thin bearing. The pile uses a steel tube casing and a steel core, the lower end of the core being flush with the bottom of the casing and the end made flat.

(*b*) *Steel piles*. A steel pile may be a rolled section, a fabricated shape or a piece of sheet pile. The steel piles may be either H-piles, box piles or circular tube piles. The H-piles are suitably used in hard soil by driving to desired depth by hammering. These are generally used in retaining walls. These piles can withstand large lateral forces, require less space for shipping and storing, and do not require special care in handling.

The box piles are generally rectangular, square or octagonal in shape. These piles consist of deep beams which offer adequate frictional resistance. These piles can also be driven in hard strata where it is not possible to drive H-piles. The shoes can be provided at its bottom, if desired.

The circular tube piles are made of seamless or welded pipes, which may be driven either closed-ended or open ended. The choice between closed-end and open end type depends upon the soil conditions at the site.

(*c*) *Timber piles*. The timber piles are generally square or circular in cross-section, having cast iron shoe at its bottom. The size of square and circular pile may vary between 300 to 500 mm. The length of the pile should not be more than 20 times its top width. These piles are driven with a light pile driving equipment. In order to protect the head of the pile from brooning, an iron ring is fixed at the top. The timber piles can take a maximum load of 200 kN. The best spacing of timber piles from centre to centre is 900 mm.

(*d*) *Composite piles*. The composite piles are those which are made of two portions of two different materials driven one above the other. The two common types of composite piles in use are timber and concrete, and steel and concrete.

(*e*) *Screw piles*. A screw pile is made of a hollow cast iron or steel shaft. The external diameter of the shaft may vary from 150 to 300 mm, which may terminate into a helix or screw base at its base. The screw pile functions more efficiently in soft clay or loose sand. These piles are screwed into the soil manually using capstan bars or by motive power. These piles can be driven without disturbing adjacent structure.

(*f*) *Disc piles*. A disc pile consists of hollow cast iron pipe with a disc or casing of enlarged size at the bottom, to enlarge the bearing area to a very great extent. The diameter of the disc may vary from 0.6 m to 1.2 m. These piles are more useful in sub soil consisting of sand or sandy silt. These piles are used in marine structures.

12.6 Pile Driving

The pile driving is a process by which a pile is forced or driven into the ground without excavation or boring. The piles are commonly driven by means of a hammer supported by a crane or by a special device known as a pile driver. The driving hammer may be a drop hammer, steam hammer, diesel hammer or vibratory hammer.

12.7 Coffer Dams

A temporary structure constructed in a river, lake etc. for excluding water from a given site to enable the building operation to be performed on dry surface, is called a *coffer dam*. It may be made of earth materials, timber or steel sheet piling or a combination thereof. Some of the common types of coffer dams are as follows :

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1. Cantilever sheet pile coffer dam; 2. Braced coffer dam; 3. Embankment protected coffer dam; 4. Double wall coffer dam; and 5. Cellular coffer dam.

The cantilever sheet pile coffer dams are suitable for small heights. The braced coffer dams are economical for small to moderate heights. There is no height limitation for embankment type coffer dams. The double wall coffer dams are suitable for moderate height while the cellular coffer dams are suitable for moderate and large heights.

12.8 Caissons

A water tight structure (round or rectangular) constructed in connection with excavations for foundations of bridges, piers etc., is known as *caisson*. The caissons are of three types, *i.e.* box caissons, open caissons (or wells) and pneumatic caissons.

A *box caisson* is open at the top and closed at the bottom, and is made of timber, reinforced concrete or steel. Such a type of caisson is used where bearing stratum is available at shallow depth and where loads are not very heavy.

An *open caisson* is a box of timber, metal, reinforced concrete or masonry which is open both at the top and at the bottom. It is used for building and bridge foundations. The open caissons are called *wells*. The well foundation forms the most common type of deep foundation for bridges in India.

The *pneumatic caissons* are closed at the top and open at the bottom. The compressed air is used to remove water from the working chamber at the bottom, and the foundation work is thus carried out in dry conditions. The pneumatic caissons are useful where it is not possible to adopt open caissons (wells). These caissons are adopted when the depth of water is more than 12 metres or so. The maximum depth of water upto which pneumatic caissons can be used is limited from the consideration of health of the workers.

12.9 Design of Shallow Foundations

The design of shallow foundations involves the following two aspects :

1. *Width of foundation* : The width of foundation is obtained from the following relations:

(*a*) For walls, width of foundation

$$= \frac{\text{Total load per metre length}}{\text{Allowable bearing capacity of the soil}}$$

(*b*) For piers, width of foundation

$$= \frac{\text{Total load on the pier}}{\text{Allowable bearing capacity of the soil}}$$

Usually, the walls and piers are given footings such that the width at the base becomes equal to twice the width of wall at the plinth level.

2. *Depth of foundation* : According to Rankine's formula, the minimum depth (d) of foundation (in metres) is given by

$$d = \frac{p}{w}\left(\frac{1-\sin\phi}{1+\sin\phi}\right)^2$$

where p = Safe permissible pressure on base in kN/m^2,

w = Unit weight of soil in kN/m^3, and

ϕ = Angle of repose of the soil.

The minimum depth of foundation for the load bearing wall of a building is restricted to 900 mm.

12.10 Damp-proofing

In order to prevent the entry of damp or moisture in the building, the damp-proof courses (D.P.C.) are provided at various levels of entry of damp into a building. At present, practically all the

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The Vibro piles are best suited for places where the ground is soft and offers little resistance to ...e flow of concrete. These piles are formed by driving a steel tube and shoe, filling with concrete ...d extracting the tube, using upward extracting and downward tamping blows alternately.

The pedestal pile is used where thin bearing stratum is reached with reasonable depth. The ...edestal of the pile gives the effect of spread footing on this comparatively thin bearing. The pile ...es a steel tube casing and a steel core, the lower end of the core being flush with the bottom of the ...sing and the end made flat.

(b) Steel piles. A steel pile may be a rolled section, a fabricated shape or a piece of sheet pile. ...e steel piles may be either H-piles, box piles or circular tube piles. The H-piles are suitably used ...hard soil by driving to desired depth by hammering. These are generally used in retaining walls. ...ese piles can withstand large lateral forces, require less space for shipping and storing, and do not ...quire special care in handling.

The box piles are generally rectangular, square or octagonal in shape. These piles consist of ...eep beams which offer adequate frictional resistance. These piles can also be driven in hard strata ...here it is not possible to drive H-piles. The shoes can be provided at its bottom, if desired.

The circular tube piles are made of seamless or welded pipes, which may be driven either ...losed-ended or open ended. The choice between closed-end and open end type depends upon the ...oil conditions at the site.

(c) Timber piles. The timber piles are generally square or circular in cross-section, having ...st iron shoe at its bottom. The size of square and circular pile may vary between 300 to 500 mm. ...e length of the pile should not be more than 20 times its top width. These piles are driven with a ...ght pile driving equipment. In order to protect the head of the pile from brooning, an iron ring is ...ixed at the top. The timber piles can take a maximum load of 200 kN. The best spacing of timber ...iles from centre to centre is 900 mm.

(d) Composite piles. The composite piles are those which are made of two portions of two ...ifferent materials driven one above the other. The two common types of composite piles in use are ...mber and concrete, and steel and concrete.

(e) Screw piles. A screw pile is made of a hollow cast iron or steel shaft. The external ...iameter of the shaft may vary from 150 to 300 mm, which may terminate into a helix or screw base ...t its base. The screw pile functions more efficiently in soft clay or loose sand. These piles are ...crewed into the soil manually using capstan bars or by motive power. These piles can be driven ...ithout disturbing adjacent structure.

(f) Disc piles. A disc pile consists of hollow cast iron pipe with a disc or casing of enlarged ...ize at the bottom, to enlarge the bearing area to a very great extent. The diameter of the disc may ...ary from 0.6 m to 1.2 m. These piles are more useful in sub soil consisting of sand or sandy silt. ...These piles are used in marine structures.

12.6 Pile Driving

The pile driving is a process by which a pile is forced or driven into the ground without ...excavation or boring. The piles are commonly driven by means of a hammer supported by a crane or ...by a special device known as a pile driver. The driving hammer may be a drop hammer, steam ...hammer, diesel hammer or vibratory hammer.

12.7 Coffer Dams

A temporary structure constructed in a river, lake etc. for excluding water from a given site to ...enable the building operation to be performed on dry surface, is called a *coffer dam*. It may be made ...of earth materials, timber or steel sheet piling or a combination thereof. Some of the common types ...of coffer dams are as follows :

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1. Cantilever sheet pile coffer dam; 2. Braced coffer dam; 3. Embankment protected coffer dam; 4. Double wall coffer dam; and 5. Cellular coffer dam.

The cantilever sheet pile coffer dams are suitable for small heights. The braced coffer dams are economical for small to moderate heights. There is no height limitation for embankment type coffer dams. The double wall coffer dams are suitable for moderate height while the cellular coffer dams are suitable for moderate and large heights.

12.8 Caissons

A water tight structure (round or rectangular) constructed in connection with excavations for foundations of bridges, piers etc., is known as *caisson*. The caissons are of three types, *i.e.* box caissons, open caissons (or wells) and pneumatic caissons.

A *box caisson* is open at the top and closed at the bottom, and is made of timber, reinforced concrete or steel. Such a type of caisson is used where bearing stratum is available at shallow depth and where loads are not very heavy.

An *open caisson* is a box of timber, metal, reinforced concrete or masonry which is open both at the top and at the bottom. It is used for building and bridge foundations. The open caissons are called *wells*. The well foundation forms the most common type of deep foundation for bridges in India.

The *pneumatic caissons* are closed at the top and open at the bottom. The compressed air is used to remove water from the working chamber at the bottom, and the foundation work is thus carried out in dry conditions. The pneumatic caissons are useful where it is not possible to adopt open caissons (wells). These caissons are adopted when the depth of water is more than 12 metres or so. The maximum depth of water upto which pneumatic caissons can be used is limited from the consideration of health of the workers.

12.9 Design of Shallow Foundations

The design of shallow foundations involves the following two aspects :

1. *Width of foundation* : The width of foundation is obtained from the following relations :

(*a*) For walls, width of foundation

$$= \frac{\text{Total load per metre length}}{\text{Allowable bearing capacity of the soil}}$$

(*b*) For piers, width of foundation

$$= \frac{\text{Total load on the pier}}{\text{Allowable bearing capacity of the soil}}$$

Usually, the walls and piers are given footings such that the width at the base becomes equal to twice the width of wall at the plinth level.

2. *Depth of foundation* : According to Rankine's formula, the minimum depth (d) of foundation (in metres) is given by

$$d = \frac{p}{w}\left(\frac{1-\sin\phi}{1+\sin\phi}\right)^2$$

where

p = Safe permissible pressure on base in kN/m^2,

w = Unit weight of soil in kN/m^3, and

ϕ = Angle of repose of the soil.

The minimum depth of foundation for the load bearing wall of a building is restricted to 900 mm.

12.10 Damp-proofing

In order to prevent the entry of damp or moisture in the building, the damp-proof courses (D.P.C.) are provided at various levels of entry of damp into a building. At present, practically all the

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buildings are given the treatment of damp-proofing. Thus the provision of D.P.C. prevents the entry of moisture from walls, floors and basement of a building. Following are the various causes of dampness in a building :

(a) Rising of moisture from the ground.
(b) Rain travel from wall tops.
(c) Rain beating against external walls.
(d) Condensation.
(e) Poor drainage, imperfect orientation, imperfect roof slope, defective construction etc.

The ideal damp proofing material should have the following characteristics :

1. It should be perfectly impervious.
2. It should be durable.
3. It should be strong and capable of resisting superimposed loads coming on it.
4. It should be flexible, so that it can accommodate the structural movements without any fracture.
5. It should remain steady in its position when once applied.
6. It should not be costly.

The materials commonly used for damp-proofing are hot bitumen, mastic asphalt, bituminous or asphaltic felts, metal sheets, combination of sheets and felts, stones, bricks, mortar, cement concrete and plastic sheets.

The following general principles should be kept in mind while providing D.P.C.

1. The damp-proof course may be horizontal or vertical.
2. The horizontal damp-proof course should cover the full thickness of walls, excluding rendering.
3. The damp-proof course should be so laid that a continuous projection is provided.
4. At junctions and corners of walls, the horizontal damp-proof course should be laid continuous.
5. The mortar bed supporting the damp proof course should be even and levelled and should be free from projections so that the damp proof course is not damaged.
6. The damp proof course should not be kept exposed on the wall surface, otherwise it may get damaged during finishing work.
7. When a horizontal damp proof course (*i.e.* that of a floor) is continued to a vertical face, a cement concrete fillet of about 75 mm radius should be provided at the junction.

12.11 Cavity Wall

A *cavity wall* or *hollow wall* consists of two separate walls called *leaves* or *skins* with a cavity or gap in between. The cavity wall construction is an effective method of damp prevention, in which the main wall of a building is shielded by an outer skin wall, leaving a cavity between the two. The cavity walls are often constructed for giving better insulation to the building. It also prevents the dampness to enter and acts as sound insulation.

The cavity extends vertically all along the height of the wall, except at the openings, where it is discontinued. The cavity should terminate near coping in case of flat roofs with parapet walls and upto or near eaves level in case of sloping roof. In the foundations, the cavity should start near the ground level or 150 mm below the D.P.C. level.

12.12 Scaffolding

The scaffolding is a temporary structure (usually of timber) having platforms raised for the workers as the building increases in height. An ordinary scaffolding consists of standards, ledgers,

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putlogs, transoms, braces, bridle, guard rail, tee board. The various members of a scaffold are secured by means of devices such as rails, bolts, ropes etc. The various types of scaffolding are as follows :

1. *Single brick-layers scaffolding.* This is the most common type of scaffolding and is widely used in the construction of brick work. This type of scaffolding is, sometimes, known as *putlog scaffolding.*

2. *Double or mason's scaffolding.* This scaffolding is stronger than single scaffolding and it is used in the construction of stone work. This type of scaffolding is, sometimes, known as *independent scaffolding.*

3. *Cantilever or needle scaffolding.* This type of scaffolding is used under the following circumstances :

(*a*) When the ground is weak to support the standards,

(*b*) When the construction for the upper parts of a multi-storeyed building is to be carried out, and

(*c*) When the ordinary scaffolding will obstruct the traffic on road such as for a building on the side of a busy street.

4. *Suspended scaffolding.* This is a light weight scaffolding used for repair works such as painting, pointing, white washing, distempering etc. The working platform is suspended from the roof by means of wire ropes, chains etc. The platform can be raised or lowered at any desired level.

5. *Trestle scaffolding.* This type of scaffolding is used for painting and repair works inside the room, upto a height of 15 metres.

6. *Steel scaffolding.* It is similar to timber scaffolding except that wooden members are replaced by steel tubes and rope lashings are replaced by couplets or fittings. Such a scaffolding can be easily erected and dismantled. It is strong and more durable, but the initial cost is high.

7. *Patented scaffolding.* Now-a-days, the various patented scaffoldings made of steel, with special types of couplings and frames, are available. Usually, the working platform is supported on a bracket which can be adjusted to any suitable height.

12.13 Shoring

The shoring is the construction of a temporary structure required to support an unsafe structure. The shores may be of the following types :

1. *Raking or inclined shores.* In this method, inclined members called rakers are used to give temporary lateral support to an unsafe wall.

2. *Flying or horizontal shores.* In this method, horizontal temporary support is provided to two adjacent, parallel party walls of the two buildings where the intermediate building is to be pulled down and rebuilt.

3. *Dead or vertical shores.* In this system, vertical support is provided to walls, roofs, floors etc. when the lower part of a wall has to be removed for the purpose of providing an opening in the wall.

12.14 Underpinning

The underpinning is an arrangement of supports provided underneath the existing structure without disturbing its stability. The underpinning is required in the following situations :

1. When a building with deep foundation is to be constructed to an existing building.
2. When the settlement of existing foundation has taken place, resulting in serious cracks in the wall.
3. When the basement is to be provided to an existing building.
4. When the existing foundations are to be deepened so as to rest them on soil of higher bearing power.

The underpinning may be carried out by the pit method or pile method.

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2.15 Stone Masonry

The term masonry is used to indicate the art of building the structures in either stones or bricks. he former type is called *stone masonry* and the latter type is called *brick masonry*. Some important chnical terms used in masonry are as follows :

1. *Course*. A horizontal layer of stones or bricks is known as course. Its thickness is generally ual to the thickness of a stone or a brick plus the thickness of one mortar joint.
2. *Header*. A full stone unit or brick laid with its length perpendicular to the face of the wall, known as header.
3. *Stretcher*. A full stone unit or brick laid with its length parallel to the face of the wall, own as stretcher.
4. *Quoin*. The exterior angle or corner of a wall is known as quoin. The stones or bricks rming the quoins are known as quoin stones or quoin bricks.
5. *Hearting*. The inner portion of the wall between the facing and backing is known as arting.
6. *Closer*. The portion of a brick cut in such a way that its one long face remains uncut, is own as closer. Thus closer is a header of small width.

A brick which is cut in such a way that the width of its one end is half that of a full brick, is called *king closer*.

A brick which is half as wide as the full brick, is known as *queen closer*.

A brick whose whole length is bevelled in such a way that half width is maintained at one end and full width is obtained at the other end, is known as *bevelled closer*.

A brick whose one end is splayed or mitred for full length, is called *mitred closer*.

7. *Bat*. The portion of a brick cut across the width, is known as *bat*. Thus a bat is smaller in ngth than the full brick.
8. *Frog*. The indentation or depression at the top face of a brick, is called frog.
9. *Sill*. A horizontal member of stone, concrete or wood provided to give support for the rtical members of a wooden window, is called sill.
10. *String course*. The continuous horizontal course of masonry, projecting from the face of e wall for shedding rain water off the face, is called string course.
11. *Jamb*. The vertical sides of a finished opening for the door, window or fire place etc. are own as jambs.
12. *Reveal*. The exposed vertical surfaces left on the sides of an opening after the door or indow frame has been fitted in position, are known as reveals.
13. *Corbel*. A projecting stone which is usually provided to serve as support for joist, roof uss, weather shed etc., is known as corbel. The corbels should extend atleast two-third of their ngth into the wall.
14. *Cornice*. A horizontal moulded projection provided near the top of a building, is called rnice.
15. *Coping*. A covering of stone, concrete, brick of terracota placed on the exposed top of an ternal wall.
16. *Blocking course*. A course of stone masonry provided immediately above the cornice, is lled blocking course.
17. *Frieze*. A course of stone provided immediately below the cornice, is called frieze.
18. *Gable*. A triangular shaped portion of masonry at the end of a sloped roof, is called gable.

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19. *Lacing course.* A horizontal course of stone blocks provided to strengthen a wall made of irregular courses of small stones, is called lacing course.

20. *Spalls.* The chips or small pieces of stones obtained as a result of reducing big blocks of stones into the regular stone blocks, are called spalls.

21. *Buttress.* A sloping or stepped masonry projection from a tall wall intended to strengthen the wall against the thrust of a roof or arch, is called buttress.

22. *Setting.* The process of placing a stone in its position in masonry construction, is called setting.

12.16 Classification of Stone Masonry

The stone masonry may be classified as follows :

1. *Rubble masonry.* In rubble masonry, the stones of irregular sizes are used. The different types of rubble masonary are as follows :

   (*a*) *Coursed rubble masonry.* This is the roughest and cheapest form of stone walling. In this type of rubble masonry, the stones used are of widely different sizes (from 50 mm to 200 mm). This type of stone masonry is commonly used in the construction of public buildings, residential buildings etc.

   (*b*) *Uncoursed rubble masonry.* In this type of rubble masonry, the stones are not dressed. They are used as they are available from the quarry, except knocking out some corners. The courses are not maintained regularly. This type of rubble masonry, being cheaper, is used for the construction of compound walls, godowns, garages etc.

   (*c*) *Random rubble masonry.* In this type of rubble masonry, the stones of irregular sizes and shapes are used. The stones are arranged so as to have a good appearance. This type of masonry is used in residential buildings, compound walls, godowns, etc.

   (*d*) *Dry rubble masonry.* This type of rubble masonry is similar in construction to coursed rubble masonry except that no mortar is used in the joints. It is extensively used for compound walls, retaining walls, pitching on bridge approaches etc.

2. *Ashlar masonry.* In ashlar masonry, the square or rectangular blocks of stone are used. The courses are not necessarily of the same height . The height of stone varies from 250 mm to 300 mm. The length of stones should not exceed three times the height and the depth into the wall should be at least equal to half the height.

12.17 Brick Masonry

According to Indian standards, the nominal size of the modular brick is 200 mm × 100 mm × 100 mm while the actual size the brick is 190 mm × 90 mm × 90 mm. The nominal size includes the mortar thickness.

The arrangement of laying bricks and bonding them with mortar properly to form a unified mass which can transmit the super-imposed load safely to the foundation, is called *brick masonry.* Some important terms used in brick masonry are as follows :

1. *Stretcher.* The longest face of a brick as seen in the elevation of the wall is called stretcher.
2. *Header.* The shortest face of a brick as seen in the elevation of the wall, is called header.
3. *Arrises.* The edges formed by the intersection of plane surfaces of brick are called arrises.
4. *Bed.* The lower surface of the brick when laid flat is known as bed.
5. *Perpend.* An imaginary vertical line which includes the vertical joint separating two adjoining bricks, is called perpend.
6. *Lap.* The horizontal distance between the vertical joints of successive courses is termed as lap.

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7. *Closer.* A portion of a brick used to close up the bond at the end of the brick courses, is lled closer.

8. *Queen closer.* It is the portion of a brick obtained by cutting a brick lengthwise into two rtions. In other words, it is brick which is half as wide as full brick.

9. *King closer.* It is the portion of a brick which is so cut that the width of its one end is half that a full brick, while the width of the other end is equal to the full width. It is thus obtained by cutting riangular portion of the brick such that half header and half stretcher is obtained on joining the cut ces.

10. *Bevelled closer.* It is the portion of brick obtained by cutting the brick in such a way that half idth is maintained at one end and full width at the other end.

11. *Mitred closer.* It is the portion of brick obtained by cutting the triangular portion of the brick rough its width and making an angle of 45° to 60° with the length of the brick.

12. *Bat.* The portion of the brick cut across the width is called bat. Thus, a bat is smaller in ngth than the full brick.

13. *Bull nose.* A brick moulded with a rounded angle is called bull nose.

14. *Quoin.* The corner or external angle on the face side of a wall is known as quoin. The oins are, generally, at right angles, but may be greater than a right angle.

15. *Frog.* The indentation or depression at the top face of a brick to form a key for holding the rtar, is called frog.

2.18 Bonds in Brick Work

The arrangement of bricks in order to tie them together in a mass of brick work is called nding. Following are the types of bond provided in brick work :

1. *Stretching bond.* In this type of bond, all the bricks are laid as stretchers on the faces of alls. It is suitable for half brick walls only.

2. *Heading bond.* In this type of bond, all the bricks are laid as headers on the faces of walls. is suitable for one brick wall only.

3. *English bond.* This type of bond consists of alternate courses of headers and stretchers. his is the most commonly used bond for all wall thicknesses. This bond is considered to be the rongest bond.

otes : (*a*) The vertical joints in the header courses come over each other and vertical joints in the stretcher courses are also in the same line.

(*b*) The heading course should never start with a queen closer.

4. *Flemish bond.* In this type of bond, each course consists of alternate headers and stretchers. he alternate headers of each course are centrally supported over the stretchers below it. The every lternate course starts with a header at the corner (*i.e.* quoin header). The flemish bond are of two ypes, *i.e.* double flemish bond and single flemish bond. In the *double flemish bond*, each course resents the same appearance in the front face as well as in the back face. The *single flemish bond* onsists of double flemish bond facing and English bond backing and hearting in each course.

otes : (*a*) The flemish bond gives more pleasing appearance than the English bond.

(*b*) The English bond is stronger than flemish bond for walls thicker than 1½ brick.

5. *Facing bond.* This type of bond consists of heading and stretching courses so arranged at one heading course comes after several stretching courses. This bond is not structurally good nd load distribution is not uniform.

6. *Raking bond.* In this type of bond, the bonding bricks are laid at any angle other than zero 90°. The raking or inclination should be in opposite direction in alternate courses of raking bond. he raking bond is generally provided in the stretcher course of a wall having thickness equal to even umber of half-brick. This arrangement makes a raking bond more effective.

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The raking bonds are of three types, *i.e.* diagonal bond, herring bone bond, and zig-zag bond.

In *diagonal bond*, the bricks are laid diagonally. The angle of inclination is so selected that there is minimum breaking of bricks.

In *herring-bone bond*, the bricks are laid at an angle of 45° from the centre in both the directions.

The *zig-zag bond* is similar to herring-bone bond, except that the bricks are laid in zig-zag fashion.

7. *Dutch bond.* This bond is a modified form of English bond. In this bond, the corners of the wall are strengthened. The arrangement of bricks is similar to English bond, *i.e.* the alternate courses of headers and stretchers are provided as in English bond. The quoin of a stretcher course is a three-quarter bat. A header is introduced next to the three-quarter bat in every stretcher course.

12.19 Retaining Walls and Breast Walls

A *retaining wall* is a wall of increasing thickness, built to resist pressure of earth filling. A *breast wall* is similar to retaining wall, but it is built to protect natural sloping ground from the cutting action of weathering. A retaining wall is commonly required in the construction of hill roads, masonry dams and wing walls. It may be built in dry stone masonry, plain cement concrete and reinforced cement concrete.

Notes : 1. The retaining wall should be structurally capable of resisting the earth pressure applied to it.

2. The section of the wall should be so proportioned that it will not over turn by the lateral pressure.

3. The weight of the retaining wall and the force resulting from the earth pressure should not stress its foundation to a value greater than safe bearing capacity of the soil.

4. The weep holes are provided in the retaining walls to drain off the water from the filling behind.

5. The toal horizontal pressure (p) per metre length of retaining wall at a depth h metre is given by

$$p = \frac{wh}{2} \times \frac{1 - \sin \phi}{1 + \sin \phi}$$

where w = Weight of filling in kN/m^3, and

ϕ = Angle of repose of the soil.

6. The total horizontal pressure at the retaining wall will act at $h/3$ from the base.

12.20 Partition Wall

A thin internal wall constructed to divide the space within the building into rooms or areas, is known as *partition wall.* It may be either load bearing or non-load bearing. A partion wall is designed as a load bearing wall. It should be strong enough to carry its own load. It should be light, thin, cheap, fire resistant and easy to construct. A partition wall may be folding, collapsible or fixed.

Though there are many types of partition walls, yet the brick partitions are quite common because they are cheapest. The following are ttree types of brick partitions :

1. *Plain brick partition.* The plain brick partition walls are usually half brick thick. These are constructed by laying bricks as stretchers in cement mortar. The wall is then plastered on both sides.

2. *Reinforced brick partition.* These are stronger than the ordinary brick partitions. These are used when better longitudinal bond is required and when the partition wall has to carry other super-imposed loads.

3. *Brick nogging partition.* The brick nogging partition wall consists of brick work (half brick thickness) built within a frame work of wooden members. The wooden frame work consists of lower horizontal members called sills, upper horizontal members called heads, vertical members called studs and intermediate horizontal members called noggings. The vertical members or studs are spaced at 4 to 6 times the brick length. The nogging pieces are housed in the studs at a vertical distance of about 600 to 900 mm.

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Note: The pre-cast concrete slab units are commonly used for partitions. These slabs may be quite thin (25 mm to 40 mm) and secured to pre-cast posts.. The concrete mixture usually adopted is M 150 (1 : 2 : 4). The joints are filled with cement mortar.

12.21 Flooring

The exposed top surface of the floor is termed as *flooring* or *floor covering* or *floor finish*. The purpose of flooring is to provide a neat, clean and pleasing appearance. The following factors should be carefully considered before selecting the material for flooring :

(*a*) Initial cost; (*b*) Appearance; (*c*) Cleaniness; (*d*) Durability; (*e*) Damp resistance; (*f*) Sound insulation; (*g*) Thermal insulation; (*h*) Fire resistance; (*g*) Hardness; (*h*) Smoothness; (*i*) Slipperiness; (*j*) Maintenance.

Some of the commonly used flooring are as follows :

1. *Brick flooring*. This flooring is specially suited for godowns, stores, warehouses etc. The bricks are laid either flat or on edge arranged in herring-bone fashion or set at right angles to the wall or set at any other good looking pattern.

2. *Cement concrete flooring*. It is cheap, quite durable and easy to construct. This type of flooring is commonly used for residential, commercial and industrial buildings.

3. *Granolithic flooring*. When hard wearing surface is required, then granolithic finish is carried out over the cement concrete. The granolithic concrete consists of cement, sand and rich concrete made with very hard and tough quality coarse aggregate such as granite, basalt, quartzite etc.

4. *Terrazzo flooring*. The flooring made with special aggregate of marble chips mixed with white and coloured cement, is called terrazzo flooring. It is decorative and has good wearing properties. It is widely used in residential buildings, hospitals, offices, schools and other public buildings.

5. *Mosaic flooring*. The flooring made with small pieces of broken tiles of china glazed or of marble or of cement, arranged in different pattern, is known as mosaic flooring.

6. *Tiled flooring*. The flooring made from square, hexagonal or other shapes, made of clay (pottery), cement concrete or terrazzo, is called tiled flooring. These are available in different sizes and thicknesses. These are commonly used in residential houses, offices, schools, hospitals and other public buildings, as an alternative to terrazzo flooring.

7. *Marble flooring*. It is a superior type of flooring used especially where extra ordinary cleanliness is required as in case of hospitals, bath rooms, kitchens, temples, etc.

8. *Asphalt flooring*. This flooring is not favoured because of bad smell and ugly colour of the asphalt. But at present, the asphalt flooring can be carried out in a variety of colours and in different forms. The asphalt flooring is recommended for swimming pools, because it is non-slippery.

9. *Linoleum flooring*. Strictly speaking, it is a covering which is available in rolls and laid directly on concrete or wooden flooring. The linoleum tiles are also available which can be fixed or glued to concrete base or wooden floor. Since it is subjected to rotting when wet or moist for some time, therefore, it is not recommended for bathrooms, kitchens etc.

10. *Plastic or poly-vinyl-chloride (P.V.C.) flooring*. The plastic or P.V.C. tiles are now widely used for all residential and non-residential buildings. These tiles are laid on concrete base with an adhesive. The P.V.C. tile flooring is resilient, smooth, good looking and can be easily cleaned. However, it is costly and can be easily damaged when it comes into contact with burning objects.

12.22 Stairs

A stair is a sequence of steps provided to afford the means of ascent and descent between the floors or landing. The apartment or room of a building in which the stair is located, is known as a *stair case* and the opening or space occupied by the stair is known as *stairway*.

Following are the common technical terms used in connection with the stairs :

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1. *Tread.* The horizontal upper part of a step on which foot is placed in ascending a stairway, is called tread.

2. *Riser.* A vertical portion of a step providing a support to the tread, is called riser.

3. *Flier.* A straight step having a parallel width of tread, is called flier.

4. *Flight.* An unbroken series of steps between two landings, is called flight.

5. *Landing.* A horizontal platform at the top or bottom of a flight between the floors is called landing. It facilitates change of direction and provides an opportunity for taking rest during the use of the stair.

6. *Rise.* The vertical distance between two successive tread faces, is called rise.

7. *Going.* The horizontal distance between two successive riser faces, is called going.

8. *Nosing.* The projecting part of the tread beyond the face of riser, is called nosing.

9. *Scotia.* A moulding provided under the nosing to beautify the elevation of a step, and to provide strength to nosing, is called scotia.

10. *Soffit.* The under surface of a stair, is called soffit.

11. *Pitch or slope.* The angle which the line of nosing of the stair makes with the horizontal is called pitch or slope.

12. *Strings or stringers.* The sloping members which support the steps in a stair, are called strings or stringers.

13. *Baluster.* The vertical member of wood or metal to support the hand rail, is called baluster.

14. *Balustrade.* The combined frame work of handrail and balusters is known as balustrade.

15. *Hand rail.* The horizontal or inclined support provided at a convenient height, is called hand rail.

16. *Newel post.* The vertical member placed at the ends of flights connecting the ends of strings and hand rails, is called newel post.

Notes : **(*a*)** The size of a step commonly adopted for residential buildings is 250 mm × 160 mm. In hospitals etc., the comfortable size of step is 300 mm × 100 mm.

(*b*) The width of stairs depends upon its location in the building and the type of the building itself. In a residential building, the average value of stair width is 900 mm, while in a public building, 1.5 to 1.8 metres width may be required.

(*c*) The width of landing should be greater than the width of stair.

(*d*) The pitch of stair should never exceed 40°.

(*e*) In designing a stair, a comfortable slope is achieved when the sum of going (in cm) and twice the rise (in cm) should be equal to 60 approximately.

(*f*) In designing a stair, the product of going (in cm) and the rise (in cm) should be equal to 400.

(*g*) The clear distance between the tread and soffit of the flight immediately above it should not be less than 2 metres.

(*h*) An open-newel stair consists of two or more straight flights arranged in such a manner that a clear space occurs between the backward and forward flights.

(*i*) In wooden stairs, the thickness of tread is adopted as 38 mm.

12.23 Arches

An arch is a structure constructed to span across an opening. It generally consists of small wedge-shaped units which are joined together with mortar. The important technical terms (as shown in Fig. 12.1) used in arch work are as follows :

1. *Intrados.* It is the inner curve of an arch.

2. *Soffit.* It is the inner surface of an arch. Sometimes intrados and soffit are used synonymously.

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3. *Extrados.* It is the outer curve of an arch.
4. *Voussoirs.* These are wedge-shaped units of masonry forming an arch.
5. *Crown.* It is the highest point of the extrados.
6. *Skew back.* It is the inclined or splayed surface on the abutment on which the arch rests.
7. *Abutment.* It is the part of the wall on which the arch rests. In other words, it is the end pport of an arch.
8. *Key stone.* It is the wedge-shaped unit at the crown of an arch.
9. *Springer.* It is the voussoir next to skew back.
10. *Springing line.* It is an imaginary line joining the lowest parts of springers.

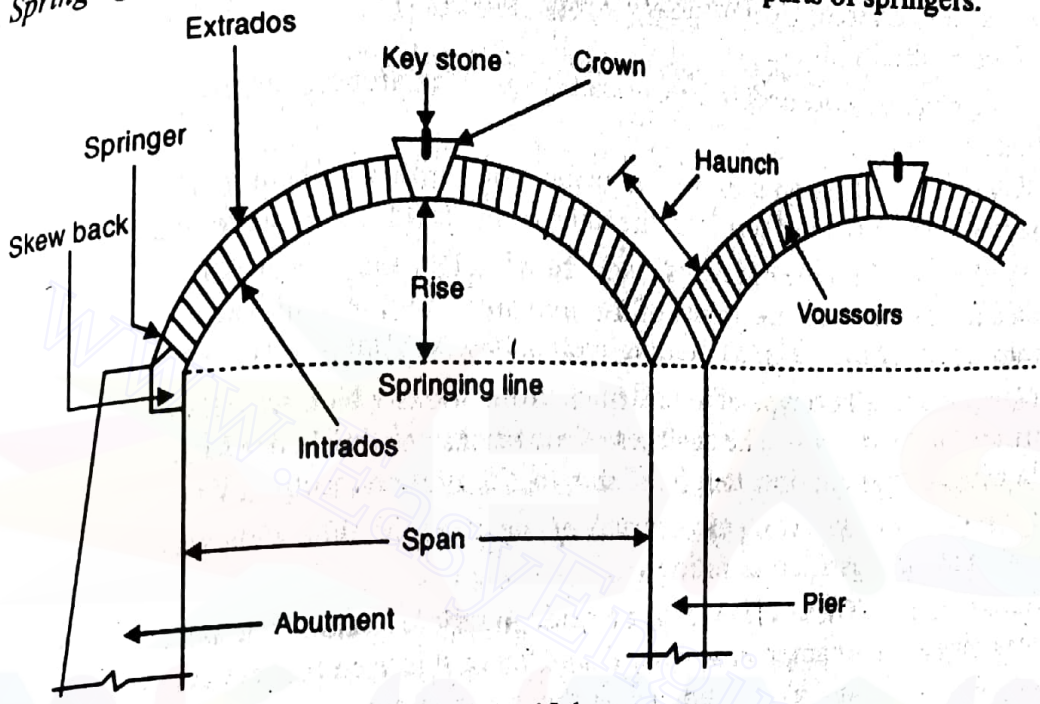

Fig. 12.1

11. *Haunch.* It is the bottom portion of an arch between the skew back and crown.
12. *Span.* It is the clear horizotnal distance between the supports.
13. *Pier.* It is an intermediate support of an arch.
14. *Rise.* It is the clear vertical distance between the springing line and the highest point on the rados.
15. *Depth or height.* It is the perpendicular distance between the intrados and extrados.
16. *Thickness or breadth of soffit.* It is the horizotnal distance measured perpendicular to the nt and back faces of an arch.

24 Classification of Arches

The arches may be classified according to shape, number of centres, workmanship and materials construction, as discussed below :

1. *Classification according to shape.* The arches, according to their shape, are classified as llows :

(*a*) *Flat arch.* In a flat arch, the skewback is made to rest in an inclined position so as to make an angle of 60° with the springing line, thus forming an equilateral triangle with intrados as the base. The intrados is given a slight rise or camber of about 10 mm to 15 mm per metre width of the opening to allow for small settlements. The extrados is kept perfectly horizontal and flat.

(*b*) *Segmental arch.* In a segmental arch, the centre of the arch lies below the springing line.

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(*c*) *Semi-circular arch.* In a semi-circular arch, the centre of the arch lies on the springing line and shape of the arch curve is that of a semicircle.

(*d*) *Semi-elliptical arch.* This type of arch has a shape of semi-ellipse and may have either three or five centres.

(*e*) *Pointed or Gothic arch.* This type of arch consists of two curves which meet at the apex of the triangle. The triangle formed may be equilateral or isosceles. The latter type is known as *Lancet arch*.

2. *Classification according to number of centres.* The arches, according to number of centres, may be classified as follows :

(*a*) One-centred arch; (*b*) Two-centred arch; (*c*) Three-centred arch; (*b*) Four-centred arch; and (*e*) Five-centred arch.

3. *Classification according to workmanship.* The arches, according to workmanship, may be classified as follows :

(*a*) *Rough arch.* This type of arch is made from ordinary uncut bricks. Since the bricks are rectangular in shape, therefore, the joints at the extrados are wider than those at the intrados.

(*b*) *Axed arch.* This type of arch is made from bricks which are cut to wedge-shape by means of an axe. In this case, the joints of the arch are of uniform thickness varying from 3 mm to 6 mm.

(*c*) *Gauged arch.* This type of arch is made from bricks which are cut to exact size and shape by means of a wire saw. The surfaces of the bricks are finished with a file. The joints formed in gauged arch are fine, thin (0.75 mm to 1.5 mm) and truly radial.

4. *Classification according to materials of construction.* The arches, according to materials of construction, may be classified as follows :

(*a*) *Stone arches.* These arches may be made in rubble masonry or ashlar masonry. The rubble masonry arch is comparatively weak and hence it is used for inferior type of work. The span of rubble masonry arch is limited to about one metre or so. These arches are also used as relieving arches, over wooden lintels.

The ashlar arches are made with stones which are cut to proper shape and are fully dressed.

(*b*) *Brick arches.* These arches are made from ordinary bricks or purpose made bricks or soft bricks.

(*c*) *Concrete arches.* These arches are made from pre-cast cement concrete blocks or monolithic concrete. The blocks are similar to stone and are prepared by casting cement concrete in specially prepared moulds.

12.25 Doors and Windows

A *door* is an openable barrier secured in an opening left in a wall for the purpose of providing access to the users of the structure.

A *window* is an opening made in a wall for the purpose of providing day light, vision and ventilation.

The following technical terms as applied to doors and windows are important :

1. *Frame.* It consists of a group of horizontal and vertical members which form a support for a door or a window.

2. *Head.* It is the top or uppermost horizontal part of a frame.

3. *Sill.* It is the bottom or lowermost horizontal part of a window frame.

Note : The door frames are normally not provided with sills.

4. *Horn.* It is a horizontal projection of head or sill beyond the face of frame.

5. *Style.* It is the vertical outside member of the shutter of a door or a window.

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6. *Jamb.* It is a vertical member which support the frame of the door and window.
7. *Reveal.* It is the external jamb of a door or widnow opening at right angles to the wall face.
8. *Rebate.* It is the depression or recess made inside the door frame, to receive the door shutter.
9. *Mullion.* It is a vertical member of a frame which is employed to sub-divide or window or door opening vertically.
10. *Transom.* It is a horizontal member of a frame which is employed to sub-divide a window opening horizontally.

12.26 Types of Doors and Windows

The doors, according to their movement, are as follows :

(*a*) Sliding doors ; (*b*) Rolling doors; (*c*) Folding doors; (*d*) Revolving doors; (*e*) Swinging doors; and (*f*) Collapsible doors.

The various important types of windows are as follows :

(*a*) *Corner window.* It is provided at the corner of a room. It has two faces in two perpendicular directions. Due to this, light and air enters from two directions. Such a window improves the elevation of the building also.

(*b*) *Gable window.* It is a vertical window provided in the gable end of a roof.

(*c*) *Dormer window.* It is a vertical window provided on the sloping roof with the object of providing light and air to the enclosed space below the roof.

(*d*) *Bay window.* This window projects outward from the walls of a room to provide an increased area of opening for admitting greater light and ventilation.

(*e*) *Clere-storey window.* This window is usually provided near the main roof of a room and opens above the adjoining verandah.

(*f*) *Casement window.* It is a common type of window usually provided in the building. The shutters of this type of window open like doors.

(*g*) *Sash or glazed window.* It is a type of casement window in which the panels are fully glazed.

12.27 Roofs

A roof is an uppermost part of a building which provides a structural covering, to give protection to the building against rain, sun, wind etc. The roofs are classified into the following three categories :

1. Pitched or sloping roofs; 2. Flat or terraced roofs; and 3. Curved roofs.

The choice of the type of roof depends upon the climatic conditions, shape of the building, availability of materials, importance of the building etc.

The *pitched roofs* have sloping top surface and these are useful at places where rainfall or snow fall is heavy.

The *flat roofs* are useful at places where rainfall is moderate. These roofs are equally applicable to buildings of any shape and size.

The *curved roofs* have their top surface curved in the form of shells and domes. Such roofs are more suitable for public buildings like libraries, theatres, recreation centres etc., to develop architectural effects.

12.28 Technical Terms Used in Pitched Roofs

The following technical terms used in connection with pitched roofs are important :

1. *Span.* It is the horizontal distance between the internal faces of walls or supports.
2. *Rise.* It is the vertical distance between the wall plate and top of the ridge.
3. *Pitch.* It is the inclination of the sides of a roof to the horizontal plane.

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4. *Ridge*. It is the apex line of the sloping roof.

5. *Hip*. It is the ridge formed by the intersection of two sloped surfaces having an exterior angle greater than 180°.

Note : The ridge formed by the intersection of two sloped surfaces having an exterior angle less than 180°, is called a *valley*.

6. *Eaves*. These are the lower edges of a roof which are resting upon or projecting beyond the supporting walls.

7. *Purlins*. These are horizontal wooden or steel members used to support the common rafters of a sloping roof when span is large.

8. *Gable*. It is a triangular upper part of a wall formd at the end of a pitched roof.

9. *Verge*. It is the edge of a gable, running between the eaves and ridge.

10. *Cleats*. These are small blocks of wood which are fixed on the rafters or ceiling.

11. *Template*. It is a square or rectangular block of stone or concrete provided under the end of the beam or truss to spread the load from the roof over a large area of bearing.

12. *Common rafters*. These are inclined wooden members laid from the ridge to the eaves.

13. *Hip rafters*. These are sloping rafters which forms the hip of a sloped roof. These are laid diagonally from the ridge to the corners of the wall to support roof coverings.

14. *Jack rafters*. These rafters are shorter in length than common rafter and are laid from hip or valley to the eaves.

15. *Valley rafters*. These rafters are sloping rafters and are laid diagonally from the ridge to the eaves for supporting valley gutters.

16. *Truss*. A roof truss is a frame work, usually of triangles, designed to support the roof covering or ceiling over rooms.

12.29 Types of Pitched Roofs

The pitched roofs are classified into three categories, *i.e.* single roofs, double or purlin roofs and trussed roofs. These roofs are discussed briefly as follows :

1. *Single roofs*. These roofs consist of only common rafters to each slope without any intermediate support. The single roofs are of the following four types :

   (*a*) *Lean-to roof or verandah roof or shed roof*. This is the simplest type of pitched roof in which rafters slope to one side only. It is also known as *Pent roof* or *Aisle roof*. It is suitable to a maximum span of 2.4 metres.

   (*b*) *Couple roof*. This type of roof is formed by the couple or pair of common rafters which slope to both the sides of the ridge of the roof. It is suitable for spans upto 3.5 metres.

   (*c*) *Couple close roof*. This roof is similar to couple roof except that the legs of the common rafter are connected by a tie beam. A couple close roof is economically suitable for spans upto 5 metres.

   (*d*) *Collar beam roof*. This roof is similar to couple close roof except that in the latter case, a tie beam is raised and placed at a higher level. The tie beam is then known as collar beam. This roof is suitable for spans upto 5 metres.

2. *Double or purlin roofs*. When the span exceeds about 2.4 metres, the necessary size for the rafters becomes uneconomical. Hence, in order to reduce the size of rafters to the economical range, the intermediate supports called *purlins* are provided under the rafters.

3. *Trussed roofs*. When the span of the roof exceeds 5 metres and when there are no inside supporting walls or partitions for the purlins, the framed structures known as *trusses* are used. Some of the usual forms of trusses are as follows :

   (*a*) *King-post truss*. In this type of truss, the central vertical post, known as king-post, forms a

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support for a tie beam. The inclined members, known as struts, prevent the principal rafters from bending in the middle. A king post truss is suitable for roofs of span varying from 5 to 8 metres.

(*b*) *Queen-post truss*. This truss differs from a king-post truss in having two vertical posts, known as queen posts. This truss is suitable for spans varying from 8 to 12 metres.

(*c*) *Mansard truss*. This truss is named after a French architect Francois Mansard. It is a combination of king-post and queen-post trusses. In other words, the Mansard truss is a two-storey truss with upper portion consisting of king-post truss and the lower portion of queen-post truss.

(*d*) *Truncated truss*. This truss is similar to Mansard truss except that the top is formed flat, with a gentle slope to one side. This truss is used when it is requird to provide a room in the roof.

(*e*) *Bel-fast roof truss*. It is also sometimes known as latticed roof truss or bow string truss. This truss is in the form of a bow. It consists of thin sections of timber with its top chord curved. This truss can be used for long spans of about 30 metres, provided the light roof covering is used.

(*f*) *Steel trusses*. The steel trusses are more economical for larger spans (greater than 12 metres). Most of the roof trusses are made from mild steel angle-sections because they can resist effectively both tension as well as compression.

OBJECTIVE TYPE QUESTIONS

1. The lowest part of a structure which transmits the load to the soil is known as
   (*a*) super-structure (*b*) plinth (*c*) foundation (*d*) basement
2. The foundation in a building is provided to
   (*a*) distribute the load over a large area (*b*) increase overall stability of the structure
   (*c*) transmit load to the bearing surface (sub soil) at a uniform rate
   (*d*) all of the above
3. The failure of foundation of a building is due to
   (*a*) withdrawl of subsoil moisture (*b*) unequal settlement of soil
   (*c*) lateral escape of the supporting material (*d*) all of these
4. The ability of sub-soil to support the load of the structure without yielding is konwn as
   (*a*) bearing value of soil (*b*) bearing power of soil
   (*c*) bearing capacity of soil (*d*) any one of these
5. The minimum load which will cause failure of a foundation is called ..... of the soil.
   (*a*) ultimate tensile strength (*b*) nominal strength
   (*c*) ultimate bearing power (*d*) ultimate compressive strength
6. The safe bearing capacity of the soil is equal to
   (*a*) Nominal strength × Factor of safety (*b*) $\frac{\text{Ultimate bearing power}}{\text{Factor of safety}}$
   (*c*) $\frac{\text{Ultimate tensile strength}}{\text{Factor of safety}}$ (*d*) $\frac{\text{Ultimate compressive strength}}{\text{Factor of safety}}$
7. The bearing capacity of soils can be improved by
   (*a*) increasing the depth of footing (*b*) draining the sub-soil water
   (*c*) ramming the granular material like crushed stone in the soil
   (*d*) all of the above

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8. The maximum bearing capcaity of soil is that of
(a) hard rocks (b) black cotton soil
(c) dry, coarse sandy soil (d) fine sandy soil

9. When the foundation is placed immediately beneath the lowest part of the super-structure, it is called ..... foundation.
(a) deep (b) shallow

10. The depth of the concrete bed placed at the bottom of a wall footing should never be less than its projection beyond the wall base.
(a) Agree (b) Disagree

11. When the walls are subjected to heavy loading and the bearing capacity of the soil is very low, then the wall is constructed on
(a) reinforced concrete footing (b) column footing
(c) lean concrete footing (d) none of these

12. The minimum depth of foundation for buildings on clays is
(a) 0.2 to 0.4 m (b) 0.4 to 0.6 m (c) 0.6 to 0.9 m (d) 0.9 to 1.6 m

13. When heavy structural loads from columns are required to be transferred to a soil of low bearing capacity, the most economical foundation is
(a) shallow foundation (b) deep foundation
(c) raft foundation (d) grillage foundation

14. The distance between the flanges of the beams in steel grillage foundation should not be more than twice the width of flange.
(a) True (b) False

15. A grillage foundation can be treated as a deep foundation.
(a) Right (b) Wrong

16. In order to protect the beam against corrosion, a minimum cover of ..... is kept on the outer sides of the external beams as well as above the upper flange of the top tier.
(a) 50 mm (b) 100 mm (c) 150 mm (d) 200 mm

17. In masonry construction, excessive tension is not permissible and hence in order that the supporting area is fully in compression, the width of footing is so adopted that the centre of gravity of the load falls
(a) at the centre of base (b) within the middle third of base
(c) within the middle fifth of base (d) any one of these

18. For a rectangular foundation of width b, the eccentricity of the load should not be greater than
(a) $b/3$ (b) $b/4$ (c) $b/5$ (d) $b/6$

19. Which of the following statement is correct ?
(a) A combined footing is so proportioned that the centre of gravity of the supporting area is in line with the centre of gravity of the two column loads.
(b) A combined rectangular footing is provided where loading condition is such that either the two columns are equally loaded or the interior column carries greater load.
(c) A trapezoidal shaped footing is provided under any condition of loading.
(d) all of the above

20. In made-up ground having a low value of its bearing power, heavy concentrated structural loads are generally supported by providing
(a) combined footing (b) strap footing (c) raft footing (d) all of these

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21. Which of the following foundation is used for weaker soil ?
(a) Column footing (b) Grillage footing (c) Raft footing (d) all of these

22. The raft foundations are generally used when the required area of footing is ....., the total area of the structure.
(a) more than one-fourth (b) less than one-fourth
(c) more than one-half (d) less than one-half

23. When two or more footings are connected by a beam, it is called
(a) beam footing (b) combined footing (c) strap footing (d) mat footing

24. A foundation consisting of thick reinforced concrete slab covering the entire area of the bottom of the structure, is known as
(a) pile foundation (b) pier foundation (c) raft foundation (d) machine foundation

25. A raft foundation is also known as mat foundation.
(a) Correct (b) Incorrect

26. A black cotton soil is unsuitable for foundations because it
(a) undergoes volumetric changes with the change of atmospheric conditions
(b) swells excessively when wet (c) shrinks excessively when dry
(d) all of the above

27. For providing safe and economical foundation in black cotton soil, the under-reamed piles are commonly recommended.
(a) Yes (b) No

28. When a heavy structure is to be constructed in sandy soil, the foundation used is
(a) pier foundation (b) strap foundation (c) raft foundation (d) any one of these

29. Pile foundation is generally used when the soil is
(a) compressible (b) water-logged (c) made-up type (d) all of these

30. The type of foundation most suitable for bridges is
(a) pier foundation (b) raft foundation (c) pile foundation (d) strap foundation

31. A combined footing is commonly used
(a) when two columns are spaced close to each other
(b) when two columns are spaced far apart (c) under a set of columns
(d) under a set of walls

32. The piles which do not support the load by themselves, but act as a medium to transmit the load from the foundation to the resisting sub-stratum, are known as
(a) friction piles (b) bearing piles (c) batter piles (d) compaction piles

33. The piles which are driven in the type of soil whose strength does not increase with depth or where the rate of increase in strength with depth is very slow, are known as
(a) friction piles (b) bearing piles (c) batter piles (d) compaction piles

34. In combined footing
(a) depth of footing varies (b) width of footing is uniform
(c) centre of gravity of the column loads must coincide with the centre of gravity of the footing
(d) all of the above

35. Pile foundations are used where the good bearing capacity is available near the ground.
(a) True (b) False

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36. Batter piles are
(*a*) used to function as retaining walls
(*b*) used to protect concrete deck or other water front structures from the abrasion or impact
(*c*) driven at an inclination to resist large horizontal inclined forces
(*d*) driven in granular soil with the aim of increasing the bearing capacity of the soil

37. Fender piles are
(*a*) used to function as retaining walls
(*b*) used to protect concrete deck or other water front structures from the abrasion or impact
(*c*) driven at an inclination to resist large horizontal inclined forces
(*d*) driven in granular soil with the aim of increasing the bearing capacity of the soil

38. The best spacing of timber piles from centre to centre is
(*a*) 600 mm (*b*) 700 mm (*c*) 800 mm (*d*) 900 mm

39. The maximum load on the wooden pile should not exceed
(*a*) 50 kN (*b*) 100 kN (*c*) 150 kN (*d*) 200 kN

40. Pre-cast concrete piles are usually
(*a*) reinforced concrete only (*b*) plain or reinforced concrete
(*c*) reinforced concrete or pre-stressed concrete
(*d*) plain, reinforced concrete or pre-stressed concrete

41. The length of pre-cast concrete piles varies from
(*a*) 3 m to 4.5 m (*b*) 4.5 m to 10 m (*c*) 4.5 m to 20 m (*d*) 4.5 m to 30 m

42. Cast-in-situ piles
(*a*) are cast in position inside the ground (*b*) need not be reinforced in ordinary cases
(*c*) are not subjected to handling or driving stresses
(*d*) all of the above

43. A type of cast-in-situ pile best suited for places where the ground is soft and offers little resistance to the flow of concrete, is
(*a*) simplex pile (*b*) Franki pile (*c*) vibro-pile (*d*) Raymond pile

44. A type of cast-in-situ pile which has an enlarged base and a corrugated stem, is
(*a*) simplex pile (*b*) Franki pile (*c*) vibro-pile (*d*) Raymond pile

45. The vibro-expanded pile ..... the bearing resistance of a vibro pile.
(*a*) increases (*b*) decreases

46. In a Raymond pile
(*a*) the length varies from 6 to 12 m
(*b*) the diameter at the top varies from 400 to 600 mm and the diameter at the base varies from 200 to 280 mm
(*c*) the thickness of the outer shell depends upon the pile diameter and site conditions
(*d*) all of the above

47. In a Mac Arthur pile, the core and the casting are together driven into the ground to the equired depth.
(*a*) Agree (*b*) Disagree

48. The diameter of the drilled piles should not exceed
(*a*) 200 mm (*b*) 400 mm (*c*) 600 mm (*d*) 800 mm

49. The pre-stressed concrete piles as compared to pre-cast and reinforced concrete piles
(*a*) are lesser in weight (*b*) have high load carrying capacity
(*c*) are extremely durable (*d*) all of these

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50. H-piles
(a) require large storage space (b) are difficult to handle
(c) cannot withstand large impact stress developed during hand driving
(d) none of the above

51. A steel pile which function more efficiently in soft clay or loose sand, is
(a) H-pile (b) pipe pile (c) screw pile (d) disc pile

52. A screw pile consists of cast iron or steel shaft of external diameter varying from
(a) 0 to 150 mm (b) 150 to 300 mm (c) 300 to 450 mm (d) 450 to 600 mm

53. Sheet piles are made of
(a) wood (b) steel (c) concrete (d) all of these

54. The coefficient of friction between the concrete and soil is
(a) 0.20 to 0.25 (b) 0.25 to 0.30 (c) 0.30 to 0.35 (d) 0.35 to 0.50

55. When the pile is required to penetrate beds of hard soil or soft rock to reach its required depth, the best method of driving the pile is by
(a) drop hammer (b) steam hammer (c) water jets (d) boring

56. When the pile is driven by means of water jets, water is forced through the jet pipe under a pressure of
(a) 0.2 to 0.5 N/mm^2 (b) 0.5 to 0.7 N/mm^2 (c) 0.7 to 1.75 N/mm^2 (d) 1.75 to 2.5 N/mm^2

57. The centre to centre spacing of lateral reinforcement in pre-cast reinforced concrete piles should not exceed ..... the least width of the pile.
(a) half (b) equal to (c) double (d) three times

58. For the pre-cast reinforced concrete piles, the quality of concrete recommended is
(a) M 100 to M 150 (b) M 150 to M 200 (c) M 200 to M 250 (d) M 250 to M 300

59. In the pre-cast reinforced concrete piles, the thickness of concrete covering the main bars should not be less than
(a) 40 mm (b) 55 mm (c) 75 mm (d) 100 mm

60. The minimum covering of the reinforcement for the pre-cast reinforced piles used in sea water, is
(a) 40 mm (b) 55 mm (c) 75 mm (d) 100 mm

61. A temporary structure constructed in a river for excluding water from a given site to enable the building operation to be performed on dry surface, is called
(a) caisson (b) cofferdam (c) well foundation (d) raft foundation

62. When the depth of water is from 4.5 to 6 m, the type of coefferdam used is
(a) earthen cofferdam (b) rockfill cofferdam
(c) single-walled cofferdam (d) double walled cofferdam

63. A watertight structure constructed in connection with excavations for foundations of bridges, piers etc., is known as
(a) caisson (b) cofferdam (c) well foundation (d) raft foundation

64. According to Rankine's formula, the minimum depth of foundation should be

(a) $\frac{p}{w}\left(\frac{1+\sin\phi}{1-\sin\phi}\right)^2$ (b) $\frac{p}{w}\left(\frac{1-\sin\phi}{1+\sin\phi}\right)^2$ (c) $\frac{p}{w}\left(\frac{1+\cos\phi}{1-\cos\phi}\right)^2$ (d) $\frac{p}{w}\left(\frac{1-\cos\phi}{1+\cos\phi}\right)^2$

where p = Safe permissible pressure on base in N/m^2,
w = Weight of soil in N/m^3, and
ϕ = Angle of repose of the soil.

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65. The minimum depth of foundation for the load bearing wall of a building is restricted to
(a) 600 mm (b) 700 mm (c) 800 mm (d) 900 mm

66. In order that the wall may be stable, the lowermost course of the wall footing is made ..... the width of the wall.
(a) half (b) equal to (c) twice (d) four times

67. The dampness in a building is due to
(a) ground moisture (b) rain water
(c) defective construction (d) all of these

68. The dampness on roof may be due to
(a) use of porous materials (b) insufficient lap of covering material
(c) bad workmanship in plumbing (d) all of these

69. The most commonly used material for damp proofing is
(a) bitumen (b) paraffin wax (c) cement solution (d) cement concrete

70. In case of buildings without basement, the best position for damp-proof course (D.P.C.) lies at
(a) plinth level (b) ground level
(c) 150 mm above plinth level (d) 150 mm above ground level

71. For D.P.C. at plinth level, the commonly adopted material is
(a) bitumen sheeting (b) plastic sheeting (c) mastic asphalt (d) cement concrete

72. A semi-rigid material which forms an excellent impervious layer for damp-proofing, is called
(a) bitumen (b) mastic asphalt (c) aluminal (d) bituminous felt

73. The damp-proof course
(a) may be horizontal or vertical (b) should be continuous
(c) should be of good impervious material (d) all of these

74. Which of the following statement is correct ?
(a) The cavity should start near the ground level.
(b) The cavity should terminate near eaves level in case of sloping roof.
(c) The cavity should terminate near coping in case of flat roof with parapet wall.
(d) all of the above

75. The damp-proof course for the two leaves of the cavity wall is laid separately although at the same level.
(a) Correct (b) Incorrect

76. The cavity wall is generally provided for
(a) preventing dampness (b) heat insulation
(c) sound insulation (d) all of these

77. In horizontal D.P.C. at plinth level, the thickness of cement concrete of 1 : 2 : 4 mix, is kept as minimum of 40 mm.
(a) Correct (b) Incorrect

78. A flexible material used for D.P.C. is
(a) bitumen sheeting (b) plastic sheeting (c) mastic asphalt (d) cement concrete

79. The construction of a temporary structure required to support an unsafe structure, is called
(a) underpinning (b) scaffolding (c) shoring (d) jacking

80. A temporary rigid structure having platforms raised up as the building increases in height, is called
(a) underpinning (b) scaffolding (c) shoring (d) jacking

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81. The arrangement of supports provided underneath the existing structure without disturbing its stability, is known as
(a) underpinning (b) scaffolding (c) shoring (d) jacking

82. A raking shore is a system of
(a) giving temporary lateral support to an unsafe wall
(b) providing temporary support to the party walls of two buildings where the intermediate building is to be pulled down and rebuilt
(c) providing vertical support to walls and roofs, floors etc. when the lower part of a wall has to be removed for the purpose of providing an opening in the wall
(d) all of the above

83. For a building on the side of a busy street where the ordinary scaffolding will obstruct the traffic on road, the type of scaffolding provided is
(a) brick layer's scaffold (b) mason's scaffold
(c) steel scaffold (d) needle scaffold

84. A horizontal layer of bricks laid in mortar is known as
(a) course (b) stretcher (c) header (d) closer

85. The brick laid with its length perpendicular to the face of the wall is called a
(a) course (b) stretcher (c) header (d) closer

86. The brick laid with its length parallel to the face of the wall is called a
(a) course (b) stretcher (c) header (d) closer

87. A system of providing temporary support to the party walls of two buildings where the intermediate building is to be pulled down and built, is called
(a) raking shore (b) dead or vertical shore
(c) flying or horizontal shore (d) none of these

88. A brick which is cut in such a way that the width of its one end is half that of a full brick, is called
(a) king closer (b) mitred closer (c) bevelled closer (d) queen closer

89. A brick which is half as wide as a full brick, is called
(a) king closer (b) mitred closer (c) bevelled closer (d) queen closer

90. The exterior angle or corner of a wall is known as quoin.
(a) Right (b) Wrong

91. Match the correct answer from *Group B* for the statements given in *Group A*.

Group A	*Group B*
(a) A raft foundation is also called	(A) pile foundation
(b) The foundation most suitable for bridges is	(B) stretcher
(c) The brick laid with its length perpendicular to the face of the wall is called	(C) mat foundation
(d) The brick laid to its length parallel to the face of the wall is called	(D) header

92. Frog is defined as a
(a) depression on the top face of a brick (b) topmost course of plinth
(c) brick whose one end is cut splayed or mitred for the full width
(d) brick used for the corner of a wall

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93. The most important purpose of frog in a brick is to
(a) emboss manufacture's name (b) reduce the weight of brick
(c) form keyed joint between brick and mortar (d) improve insulation by providing 'hollow'

94. The frog of the brick must be kept ..... while laying bricks in a wall.
(a) downward (b) upward

95. In brick masonry, for good bonding
(a) all bricks need not be uniform in size (b) bats must be used in alternate courses only
(c) vertical joints in alternate courses should fall in plumb
(d) cement mortar used must have surkhi as additive

96. King closers are related to
(a) king post truss (b) queen post truss
(c) brick masonry (d) doors and windows

97. Cornice is defined as a
(a) horizontal course of masonry projecting from the face of the wall
(b) horizontal moulded projection provided near the top of a building
(c) covering placd on the exposed top of an external wall
(d) triangular shaped portion of masonry at the end of a sloped roof

98. Coping is defined as a
(a) horizotnal course of masonry projecting from the face of the wall
(b) horizontal moulded projection provided near the top of a building
(c) covering placed on the exposed top of an external wall
(d) triangular shaped portion of masonry at the end of a sloped roof

99. Corbel is the extension of one or more course of bricks from the ..... of a wall.
(a) face (b) back

100. A horizontal member of stone, concrete or wood provided to give support for the vertical members of a wooden window, is called
(a) jamb (b) reveal (c) sill (d) quoin

101. The exposed vertical surface left on the sides of an opening after the door or window frame has been fitted in position, is called
(a) jamb (b) reveal (c) sill (d) quoin

102. A bat is the portion of a
(a) wall not exposed to weather (b) brick cut across the width
(c) wall between facing and backing
(d) brick cut in such a manner that its one long face remains uncut

103. Hearting is the portion of a
(a) wall not exposed to weather (b) brick cut across the width
(c) wall between facing and backing
(d) brick cut in such a manner that its one long face remains uncut

104. A course of stone provided immediately below a cornice, is called
(a) blocking course (b) coping (c) frieze (d) parapet

105. A course of stone masonry provided immediately above the cornice, is called
(a) blocking course (b) coping (c) frieze (d) parapet

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106. Match the correct answer from *Group B* for the statements given in *Group A*.

Group A	*Group B*
(*a*) The small pieces of stone broken off a larger block are termed as	(*A*) spalls
(*b*) A pier built in the wall to increase its stability is called	(*B*) gable
(*c*) A triangular shaped portion of masonry at the end of a sloped roof is known as	(*C*) coping
(*d*) A covering placed on the exposed top of an external wall is called	(*D*) buttress

107. The process of placing a stone in its position in masonry construction is termed as setting.
(*a*) Yes (*b*) No

108. The type of stone masonry commonly adopted in the construction of residential building is
(*a*) uncoursed rubble masonry (*b*) coursed rubble masonry
(*c*) random rubble masonry (*d*) dry rubble masonry

109. In the first class coursed rubble masonry
(*a*) all the coruses are of the same height
(*b*) minimum height of the course is limited to 150 mm
(*c*) the length of the quoin is generally kept 450 mm
(*d*) all of the above

110. The type of masonry in which the stones of irregular size and shapes are used and there are no regular courses, is known as
(*a*) uncoursed rubble masonry (*b*) coursed rubble masonry
(*c*) random rubble masonry (*d*) dry rubble masonry

111. The minimum thickness of a wall in stone masonry should not be less than
(*a*) 100 mm (*b*) 200 mm (*c*) 350 mm (*d*) 450 mm

112. A type of bond in a brick masonry consisting of alternate course of headers and stretchers, is called
(*a*) English bond (*b*) Flemish bond (*c*) stretching bond (*d*) heading bond

113. A type of bond in a brick masonry in which each course consists of alternate headers and stretchers, is called
(*a*) English bond (*b*) Flemish bond (*c*) stretching bond (*d*) heading bond

114. Which of the following statement is wrong ?
(*a*) In English bond, vertical joints in the header courses come over each other and vertical joints in the stretcher courses are also in the same line.
(*b*) In English bond, the heading course should start with a queen closer.
(*c*) In Flemish bond, the alternate headers of each course are centrally supported over the strechers in the course below.
(*d*) In Flemish bond, every alternate course starts with a header at the corner.

115. For walls thicker than 1½ brick, English bond is stronger than Flemish bond.
(*a*) True (*b*) False

116. In a stretching bond
(*a*) all the bricks are laid as headers (*b*) all the bricks are laid as stretchers
(*c*) the arrangement of bricks is similar to English bond
(*d*) the bonding bricks are laid at any angle other than zero or ninety degrees

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117. A type of bond in which all the bricks are laid as headers on the faces of walls, is known as
(*a*) raking bond (*b*) dutch bond (*c*) facing bond (*d*) heading bond

118. A bond consisting of heading and stretching courses so arranged that one heading course comes after several stretching courses, is called
(*a*) raking bond (*b*) dutch bond (*c*) facing bond (*d*) heading bond

119. A stretcher bond is usually used for
(*a*) half brick wall (*b*) one brick wall
(*c*) one and half brick wall (*d*) two brick wall

120. The heading bond is usually used for
(*a*) half brick wall (*b*) one brick wall
(*c*) one and half brick wall (*d*) two brick wall

121. The most commonly used bond for all wall thicknesses is
(*a*) English bond (*b*) Flemish bond (*c*) stretching bond (*d*) heading bond

122. In English bond, the queen's closer should be placed next to the quoin header.
(*a*) Yes (*b*) No

123. Herring-bone bond is commonly used for
(*a*) brick paving (*b*) very thick walls
(*c*) partition walls (*d*) footings in foundations

124. The filling in cavities with cement slurry is known as
(*a*) coping (*b*) beam-filling (*c*) grouting (*d*) gunniting

125. In a raking bond,
(*a*) all the bricks are laid as headers (*b*) all the bricks are laid as stretchers
(*c*) the arrangement of bricks is similar to English bond
(*d*) the bonding bricks are laid at any angle other than zero or ninety degree

126. The arrangement of bricks is similar to English bond in
(*a*) raking bond (*b*) dutch bond (*c*) facing bond (*d*) heading bond

127. A wall built to resist the pressure of earth filling, is known as
(*a*) breast wall (*b*) retaining wall (*c*) parapet wall (*d*) buttress

128. A retaining wall may be built in
(*a*) dry stone masonry (*b*) stone masonry
(*c*) plain cement concrete (*d*) all of these

129. A retaining wall is commonly required in the construction of
(*a*) hill roads (*b*) masonry dams (*c*) wing walls (*d*) all of these

130. Weep holes are provided in the retaining walls to drain off the water from the filling behind.
(*a*) Agree (*b*) Disagree

131. A stone wall provided to protect the slopes of cutting in natural ground from the action of weather, is known as
(*a*) retaining wall (*b*) breast wall (*c*) parapet wall (*d*) buttress

132. The total horizontal pressure (p) per metre length of retaining wall at a depth h metre is

(*a*) $wh \times \frac{1+\sin\phi}{1-\sin\phi}$ (*b*) $wh \times \frac{1-\sin\phi}{1+\sin\phi}$ (*c*) $\frac{wh}{2} \times \frac{1+\sin\phi}{1-\sin\phi}$ (*d*) $\frac{wh}{2} \times \frac{1-\sin\phi}{1+\sin\phi}$

where w = Weight of filling in N/m^3, and
ϕ = Angle of repose of the soil.

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133. The total horizontal pressure at the retaining wall acts at ..... from the base.
(a) $\frac{h}{2}$ (b) $\frac{h}{3}$ (c) $\frac{h}{4}$ (d) $\frac{h}{5}$

134. Which of the following statement is correct ?
(a) The retaining wall should be structurally capable of resisting the earth pressure applied to it.
(b) The section of the wall should be so proportioned that it will not overturn by the lateral pressure.
(c) The weight of the retaining wall and the force resulting from the earth pressure should not stress its foundation to a value greater than safe bearing capacity of the soil.
(d) all of the above

135. A partition wall may be
(a) folding (b) collapsible (c) fixed (d) any one of these

136. A partition wall is designed as a no load bearing wall.
(a) Right (b) Wrong

137. Plain brick type of partition wall is constructed by
(a) laying bricks as stretchers in cement mortar
(b) laying bricks as headers in cement mortar
(c) reinforcing the brick wall with iron straps
(d) brick work built within a frame-work of wooden members

138. Brick nogging type of partition wall is constructed by
(a) laying bricks as stretchers in cement mortar
(b) laying bricks as headers in cement mortar
(c) reinforcing the brick wall with iron straps
(d) brick work built within a frame-work of wooden members

139. In a brick nogging type of partition wall, the vertical wooden members are called
(a) noggings (b) studs (c) sills (d) templates

140. The sill in a wooden partition wall is the .....wooden member.
(a) vertical (b) lower horizontal
(c) upper horizontal (d) intermediate horizontal

141. The nogging, in a brick nogged partition wall, is a intermediate horizontal wooden member.
(a) Correct (b) Incorrect

142. The nogging pieces are housed in the studs at a vertical distance of about
(a) 100 to 200 mm (b) 200 to 400 mm (c) 400 to 600 mm (d) 600 to 900 mm

143. In constructing concrete partition wall, the concrete mixture usually adopted is
(a) M 100 (b) M 150 (c) M 200 (d) M 250

144. The brick flooring may be done with bricks
(a) laid flat (b) set at right angle to the walls
(c) laid on edge arranged in herring-bone fashion
(d) all of the above

145. A type of flooring made with special aggregate of marble chips mixed with white and coloured ement, is called
(a) granolithic flooring (b) terrazzo flooring (c) mosaic flooring (d) asphalt flooring

146. The asphalt type of flooring is recommended for swimming pools because it is non-slippery.
(a) Yes (b) No

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147. The moulding provided under nosing to beautify the elevation of a step of stair, is called
(a) flier (b) soffit (c) scotia (d) tread

148. The horizontal upper part of a step on which foot is placed in ascending or descending a stairway, is called
(a) riser (b) tread (c) flight (d) nosing

149. A series of steps without any platform, break or landing in their direction, is called
(a) riser (b) tread (c) flight (d) nosing

150. The vertical distance between the upper surface of the successive treads is known as 'going of step
(a) True (b) False

151. The brick flooring is used in
(a) workshops (b) godowns (c) verandahs (d) none of these

152. The flooring made with small pieces of broken tiles of china glazed or of marble arranged in different pattern, is known as
(a) asphalt flooring (b) mosaic flooring
(c) terrazo flooring (d) granolithic flooring

153. In stairs, the flier is
(a) a vertical portion of a step providing a support to the tread
(b) a straight step having a parallel width of tread
(c) the under surface of a stair
(d) the angle which the line of nosing of the stair makes with the horizontal

154. In stairs, the soffit is
(a) a vertical portion of a step providing a support to the tread
(b) a straight step having a parallel width of tread
(c) the under surface of a stair
(d) the angle which the line of nosing of the stair makes with the horizontal

155. The projecting part of the tread beyond the face of riser is called
(a) pitch (b) nosing (c) baluster (d) stringer

156. In a public building, the stairs should be located near the ..... of building.
(a) entrance (b) centre (c) end (d) toilet

157. The angle which the line of nosing of the stair makes with the horizontal, is called
(a) riser (b) flier (c) soffit (d) pitch or slope

158. In stairs, the vertical portion of a step providing a support to the tread, is known as
(a) riser (b) flier (c) soffit (d) pitch or slope

159. The size of a step commonly adopted for residential buildings is
(a) 250 mm × 160 mm (b) 270 mm × 150 mm
(c) 300 mm × 130 mm (d) 350 mm × 100 mm

160. In residential building, the average value of stair width is
(a) 600 mm (b) 700 mm (c) 800 mm (d) 900 mm

161. The width of landing should be ..... the width of stair.
(a) equal to (b) less than (c) greater than

162. The pitch of stair should never exceed
(a) 20° (b) 25° (c) 30° (d) 40°

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163. In designing a stair, the sum of going (in cm) and twice the rise (in cm) should be equal to
(a) 40 (b) 50 (c) 60 (d) 70

164. In designing a stair, the product of going (in cm) and the rise (in cm) should be equal to
(a) 300 (b) 350 (c) 400 (d) 450

165. An open-newel stair consists of two or more straight flights arranged in such a manner that a clear space occurs between the backward and forward flights.
(a) Agree (b) Disagree

166. In wooden stairs, the thickness of tread is adopted as
(a) 28 mm (b) 38 mm (c) 48 mm (d) 58 mm

167. The inner surface of an arch is called
(a) extrados (b) intrados (c) crown (d) voussoir

168. The surface of the abutment on which the arch rests, is known as
(a) span (b) keystone (c) skew back (d) crown

169. The intermediate support of an arch is known as pier.
(a) Right (b) Wrong

170. The depth of arch is the
(a) vertical distance between the springing line and the highest point on the intrados
(b) vertical distance between the springing line and the highest point on the extrados
(c) perpendicular distance between the intrados and extrados
(d) horizontal distance between the supports

171. The highest point on the extrados is called
(a) skew back (b) crown (c) voussoir (d) keystone

172. The vertical distance between the springing line and the highest point on the intrados is called ..... of the arch.
(a) depth (b) rise (c) haunch (d) extrados

173. Which of the following statement is wrong ?
(a) The part of the wall on which the arch rests, is called abutment.
(b) Soffit is the under surface of an arch (c) Crown is the highest point of the intrados
(d) all of the above

174. The wedge shaped unit (voussoir) placed at the crown of an arch, is called
(a) skew back (b) intrados (c) extrados (d) keystone

175. The perpendicular distance between the intrados and extrados of an arch, is called
(a) pitch of an arch (b) depth of an arch
(c) width of an arch (d) thickness of an arch

176. In rough brick arches, the joints at the extrados are wider than those at the intrados.
(a) Correct (b) Incorrect

177. In axed brick arches, the joints of the arch are not of uniform thickness.
(a) Right (b) Wrong

178. The arch consisting of fully dressed stones, is called
(a) axed arch (b) gauged arch (c) ashlar arch (d) rubble arch

179. In a flat arch, the skew back is made to rest in an inclined position so as to make an angle of ..... with the springing line.
(a) 30° (b) 40° (c) 50° (d) 60°

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180. The intrados of the flat arch is horizotnal but the extrados has a straight camber or upward curvature.
(*a*) Yes (*b*) No

181. The span of an arch is
(*a*) vertical distance between the springing line and the highest point on the intrados
(*b*) vertical distance between the springing line and the highest point on the extrados
(*c*) perpendicular distance between the intrados and extrados
(*d*) horizontal distance between the supports

182. The lower portion of an arch between the skew back and crown is called
(*a*) depth (*b*) rise (*c*) haunch (*d*) intrados

183. The vertical members which support the door frame are called
(*a*) reveals (*b*) styles (*c*) posts (*d*) jambs

184. The external jamb of a door or window opening at right angles to the wall face, is called
(*a*) reveal (*b*) style (*c*) post (*d*) horn

185. A horizontal member of a frame employed to sub-divide a window opening horizontally is called
(*a*) sill (*b*) mullion (*c*) transom (*d*) horn

186. The bottom or lowermost horizontal part of a window frame is known as
(*a*) sill (*b*) mullion (*c*) transom (*d*) horn

187. The width of jambs is
(*a*) 57 mm to 76 mm (*b*) 76 mm to 114 mm
(*c*) 114 mm to 138 mm (*d*) 138 mm to 152 mm

188. The depth of jambs is
(*a*) 57 mm to 76 mm (*b*) 76 mm to 114 mm
(*c*) 114 mm to 138 mm (*d*) 138 mm to 152 mm

189. Which of the following statement is correct ?
(*a*) The flat members connecting the jambs at the top is called head.
(*b*) The head is of the same size as the jamb.
(*c*) The jamb are tennoned into the head and wedged.
(*d*) all of the above

190. The projections which help in securing the head of a door frame to the masonry, are called
(*a*) reveals (*b*) stops (*c*) horns (*d*) styles

191. The window which projects outward from the walls of a room to provide an increased area of opening for admitting greater light and ventilation, is called
(*a*) dormer window (*b*) corner window (*c*) bay window (*d*) clerestorey window

192. The window used with the object of providing light and air to the enclosed space below the roof, is called
(*a*) dormer window (*b*) corner window
(*c*) bay window (*d*) clerestorey window

193. The window usualy provided near the main roof of a room and opens above the adjoining verandah, is called
(*a*) dormer window (*b*) corner window
(*c*) bay window (*d*) clerestorey window

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194. In air conditioned building, a door has to serve both purposes of opening and closing. The st suitable type of door for this purpose is
(a) sliding door (b) swinging door (c) revolving door (d) none of these

195. For ordinary Portland cement, the initial setting time should not be more than
(a) 30 minutes (b) 1 hour (c) 5 hours (d) 10 hours

196. The cement which is commonly used in all types of structures and require no special nsideration, is called
(a) rapid hardening cement (b) normal setting cement
(c) quick setting cement (d) white cement

197. The ultimate strength of rapid hardening cement is just the same as that of normal setting ment.
(a) True (b) Flase

198. High alumina cement is
(a) made by fusing together a mixture of lime-stone and bauxite
(b) highly resistant to heat, chemical and other corrosive acids
(c) used for structures subjected to the action of sea water
(d) all of the above

199. High early strength of cement is obtained as a result of
(a) fine grinding (b) burning at high temperatures
(c) decreasing the lime content (d) increasing the quantity of gypsum

200. The addition of *surfactants in the concrete mix results in
(a) decrease in the water cement ratio (b) increase in the strength of concrete
(c) increase in the density of concrete (d) all of these

201. A fine aggregate is one whose particles are of size
(a) 4.75 mm (b) below 4.75 mm (c) 6.75 mm (d) above 6.75 mm

202. A coarse aggregate is one whose particles are of size
(a) 4.75 mm (b) below 4.75 mm (c) 6.75 mm (d) above 6.75 mm

203. If the water-cement ratio is low, the strength of the mix is high.
(a) Agree (b) Disagree

204. The higher water cement ratio in concrete results in
(a) a weak mix (b) a stronger mix (c) better workable mix (d) less bleeding

205. The slump commonly adopted for concrete for road works is
(a) 12 to 25 (b) 20 to 28 (c) 25 to 50 (d) 50 to 100

206. The slump commonly adopted for concrete for columns is
(a) 25 to 50 (b) 50 to 100 (c) 75 to 175 (d) 175 to 200

207. The vertical distance between the wall plate and top of the ridge is called ..... of roof.
(a) rise (b) pitch (c) template (d) gable

208. A ridge formed by the intersection of two sloped surfaces having an exterior angle greater than 180°, is called
(a) gable (b) hip (c) verge (d) template

209. A block of stone or concrete provided under the end of tie beam to spread the load from the roof over a large area of bearing, is called
(a) gable (b) hip (c) verge (d) template

* The substance which reduces surface tension is called surfactant.

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210. The horizontal members of wood or steel used to support the common rafter of a sloping roof are called
(*a*) purlins (*b*) cleats (*c*) hip rafters (*d*) valley rafters

211. In a sloping roof, the inclined wooden members laid from the ridge to the eaves are known as
(*a*) hip rafters (*b*) jack rafters (*c*) common rafters (*d*) valley rafter

212. In pitched roofs, the term gable is defined as the
(*a*) apex line of the sloping roof
(*b*) inclination of the sides of a roof to the hoizontal plane
(*c*) horizontal distance between the internal faces of the walls
(*d*) triangular upper part of a wall formed at the end of a pitched roof

213. The term pitch in connection with pitched roofs is defined as the
(*a*) apex line of the sloping roof
(*b*) inclination of the sides of a roof to the horizontal plane
(*c*) horizontal distance between the internal faces of the walls
(*d*) triangular upper part of a wall formed at the end of a pitch roof

214. A pitched roof in which rafters slope to one side only is called
(*a*) lean-to roof (*b*) Pent roof (*c*) Aisle roof (*d*) any one of these

215. The combination of a king-post truss and queen post truss is known as
(*a*) couple roof (*b*) collar beam roof (*c*) mansard roof (*d*) purlin roof

216. The coupled roof is suitable for spans upto
(*a*) 3.5 m (*b*) 5 m (*c*) 6.5 m (*d*) 8 m

217. The type of truss commonly used for spans varying from 5 to 9 metre is
(*a*) queen post truss (*b*) king post truss (*c*) mansard truss (*d*) composite truss

218. In a king post truss, one vertical post is used.
(*a*) Correct (*b*) Incorrect

219. In a queen post truss, ... vertical posts are used.
(*a*) two (*b*) three (*c*) four (*d*) six

220. A queen post truss is commonly used for spans
(*a*) upto 3.5 m (*b*) from 3.5 to 5 m (*c*) from 5 to 8 m (*d*) from 8 to 12 m

221. A couple-close roof is used for spans upto
(*a*) 3.5 m (*b*) 5 m (*c*) 9 m (*d*) 14 m

222. The pointing which is extensively used in brick work and stone masonry face work, is
(*a*) flush poining (*b*) struck pointing (*c*) V-grooved pointing (*d*) tuck pointing

223. The type of pointing in which the mortar is first pressed into the raked joints and then finished off flush with the edges of the bricks or stones, is called
(*a*) flust pointing (*b*) struck pointing (*c*) V-grooved pointing (*d*) tuck pointing

224. The type of pointing in which the mortar is first pressed into the raked joint and then finished off flush with the face of the bricks or stones is called
(*a*) flush pointing (*b*) struck pointing (*c*) V-grooved pointing (*d*) tuck pointing

225. The process of filling up all nail holes, cracks etc. with putty is known as
(*a*) knotting (*b*) priming (*c*) stopping (*d*) finishing

ANSWERS

1. (*c*)	**2.** (*d*)	**3.** (*d*)	**4.** (*d*)	**5.** (*c*)	**6.** (*b*)
7. (*d*)	**8.** (*a*)	**9.** (*b*)	**10.** (*a*)	**11.** (*a*)	**12.** (*d*)

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13. (d) 14. (a) 15. (b) 16. (b) 17. (b) 18. (d)
19. (d) 20. (c) 21. (d) 22. (c) 23. (c) 24. (c)
25. (a) 26. (d) 27. (a) 28. (a) 29. (d) 30. (c)
31. (a) 32. (b) 33. (a) 34. (c) 35. (b) 36. (c)
37. (b) 38. (d) 39. (d) 40. (c) 41. (d) 42. (d)
43. (c) 44. (b) 45. (a) 46. (d) 47. (a) 48. (c)
49. (d) 50. (d) 51. (c) 52. (b) 53. (d) 54. (c)
55. (d) 56. (c) 57. (a) 58. (b) 59. (a) 60. (b)
61. (b) 62. (c) 63. (a) 64. (b) 65. (d) 66. (c)
67. (d) 68. (d) 69. (a) 70. (a) 71. (d) 72. (b)
73. (d) 74. (d) 75. (a) 76. (d) 77. (a) 78. (a)
79. (c) 80. (b) 81. (a) 82. (a) 83. (d) 84. (a)
85. (c) 86. (b) 87. (c) 88. (a) 89. (d) 90. (a)
91. (C), (A), (D), (B) 92. (a) 93. (c) 94. (b) 95. (c)
96. (c) 97. (b) 98. (c) 99. (a) 100. (c) 101. (b)
102. (b) 103. (c) 104. (c) 105. (a) 106. (A), (D), (B), (C)
107. (a) 108. (b) 109. (d) 110. (a) 111. (c) 112. (a)
113. (b) 114. (b) 115. (a) 116. (b) 117. (d) 118. (c)
119. (a) 120. (b) 121. (a) 122. (a) 123. (a) 124. (c)
125. (d) 126. (b) 127. (b) 128. (d) 129. (d) 130. (a)
131. (b) 132. (d) 133. (b) 134. (d) 135. (d) 136. (a)
137. (a) 138. (d) 139. (b) 140. (b) 141. (a) 142. (d)
143. (b) 144. (d) 145. (b) 146. (a) 147. (c) 148. (b)
149. (c) 150. (b) 151. (b) 152. (b) 153. (b) 154. (c)
155. (b) 156. (a) 157. (d) 158. (a) 159. (a) 160. (d)
161. (c) 162. (d) 163. (c) 164. (c) 165. (a) 166. (b)
167. (b) 168. (c) 169. (a) 170. (c) 171. (a) 172. (b)
173. (c) 174. (d) 175. (b) 176. (a) 177. (b) 178. (c)
179. (d) 180. (b) 181. (d) 182. (c) 183. (d) 184. (a)
185. (c) 186. (a) 187. (b) 188. (a) 189. (d) 190. (c)
191. (c) 192. (a) 193. (d) 194. (b) 195. (d) 196. (b)
197. (a) 198. (d) 199. (a), (b) 200. (d) 201. (b) 202. (a)
203. (a) 204. (a), (c) 205. (b) 206. (c) 207. (a) 208. (b)
209. (d) 210. (a) 211. (c) 212. (d) 213. (b) 214. (d)
215. (c) 216. (a) 217. (b) 218. (a) 219. (a) 220. (d)
221. (b) 222. (a) 223. (a) 224. (d) 225. (c)

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13.1 Introduction

The concrete is obtained by mixing cement, aggregates and water in required proportions, with or without a suitable admixture. The subject which deals with the fundamental principles of concrete is known as *Concrete Technology*. The practical utility of Concrete Technology for civil engineers is to enable them to know how to stock properly the materials required for concrete and to perform different tests for concrete.

13.2 Properties of Concrete

The concrete, in the plastic state (*i.e.* freshly mixed concrete) should have the following properties :

(*a*) *Workability.* The concrete should have good workability. It is defined as the ease with which it can be mixed, transported and placed in position in a homogeneous state. It depends upon the quantity of water, grading of aggregate and percentage of fine materials in the mix.

(*b*) *Segregation.* The concrete should be free from segregation. It is defined as the breaking up of cohesion (separation of coarse aggregate) in a mass of concrete. It results in honey combing, decrease in density, and ultimately loss of strength of hardened concrete.

(*c*) *Bleeding.* The concrete should have no bleeding. It is defined as the separation of water or water-cement mixture from the freshly mixed concrete. It causes the concrete porous and weak.

(*d*) *Harsh.* It is the resistance offered by concrete to its surface finishing. The surface of harsh concrete remains rough and porous.

The concrete, in the hardened state, should have the following properties :

1. *Strength.* The hardened concrete should have high compressive strength so that it can resist the heavy loads of the structures. It should not be less than 15.5 N/mm^2.

2. *Durability.* The hardened concrete must be durable to resist the effects of rain, frost action etc. This property is mainly affected by water-cement ratio.

3. *Impermeability.* The hardened concrete should have sufficient impermeability or water tightness so that it can resist the entry of water inside the structure.

4. *Shrinkage.* The hardened concrete should exhibit minimum shrinkage. This property is guided by water-cement ratio.

5. *Creep.* The hardened concrete should be subjected to minimum creep. It is the continuous strain, which the concrete undergoes due to application of external loads.

6. *Thermal expansion.* The hardened concrete should have minimum thermal expansion so as to provide good resistance to fire.

13.3 Classification of Concrete

The concretes are classified as follows :

1. *Plain cement concrete.* The plain cement concrete consists of cement, sand and a coarse aggregate mixed in suitable proportions in addition to water. The cement is used as a binding material, sand as fine aggregate and shingle, gravel, broken brick or crushed stone as coarse aggregates.

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The usual proportions of ingredients in plain cement concrete are : Portland cement (1 part), ean sand (1½ to 8 parts) and coarse aggregate (3 to 16 parts).

The plain cement concrete is strong in taking compressive stress.

2. *Lime concrete.* The lime concrete consists of lime, a fine aggregate and a coarse aggregate, ixed in suitable proportions, in addition to water. The hydraulic lime is used as a binding material, nd, surkhi and cinder as fine aggregates and broken bricks, broken stones etc. as coarse aggregates.

The usual proportions of ingredients in lime concrete are : Lime (1 part), sand (2 to 3 parts) d coarse aggregates (3 to 4 parts).

The lime concrete is cheaper and has less strength than plain cement concrete.

3. *Reinforced cement concrete (R.C.C.).* The reinforced cement concrete (also called ferro-ncrete) is a cement concrete in which reinforcement is embedded. The usual proportions of gredients in reinforced cement concrete are : Portland cement (1 part), clean sand (1 to 2 parts) and arse aggregates (2 to 4 parts).

The reinforced cement concrete is equally strong for taking tensile, compressive and shear esses.

4. *Pre-stressed cement concrete (P.C.C.).* The pre-stressed cement concrete is a cement ncrete in which high compressive stresses are artificially induced before its actual use. This type of ncrete can take up high tensile and compressive stresses without development of cracks.

5. *Light-weight concrete.* The light-weight concrete is prepared by using coke-breeze, cinder slag as aggregate in the cement concrete. This type of concrete possesses high insulating property. is used in making precast structural units for partition and wall lining purposes.

6. *Cellular or aerated concrete.* The cellular or aerated concrete (also called air-entrained ncrete) is prepared by mixing aluminium in the cement concrete. It is light in weight and spongy structure. It is used for roof slab and precast units in partitions etc. for heat and sound insulation.

7. *Saw dust concrete.* The saw dust concrete is prepared by mixing portland cement with saw st in specified proportions in the concrete. It is used as a heat and sound insulating material.

8. *Vacuum concrete.* The vacuum concrete is the cement concrete from which entrained air d excess water are removed with a vacuum pump, after placing it in position. The removal of xcess air after placing concrete helps in increasing the strength of concrete by 15 to 20 percent. It is sed for all reinforced concrete works.

3.4 Functions of Ingredients of Cement

The functions of various ingredients of an ordinary portland cement, as mentioned above, are follows :

1. *Lime.* It makes the cement sound and strong. The lime in excess quantity makes the ement unsound and causes the cement to expand and disintegrate.

2. *Silica.* It provides strength to the cement due to the formation of dicalcium and tricalcium ilicates. The silica in excess quantity causes the cement to set slowly.

3. *Alumina.* It provides quick setting property to the cement and lowers the clinkering temperature.

4. *Iron oxide.* It provides colour, hardness and strength to the cement. It also helps the fusion f raw materials during the manufacture of cement.

5. *Magnesium oxide.* It provides hardness and colour to the cement, when present in small uantity. The magnesium oxide in excess quantity makes the cement unsound.

6. *Sulphur trioxide.* It makes the cement sound, when present in very small quantity. The ulphur trioxide in excess quantity makes the cement unsound.

7. *Alkalies.* These should be present in small quantities. The alkalies in excess quantity will ause efflorescence.

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13.5 Composition of Cement Clinker

The cement clinkers (which are formed when calcareous and agrillaceous raw materials are mixed and burned in rotary kilns) consist of the following major compounds :

1. *Tricalcium silicate (40%).* The presence of tricalcium silicate in cement hydrates more rapidly. It generates more heat of hydration. It develops high early strength and possesses less resistance to sulphate attack.

2. *Dicalcium silicate (32%).* The presence of dicalcium silicate in cement hydrates slowly. It generates less heat of hydration. It hardens more slowly and offers more resistance to sulphate attack. It provides good ultimate strength to cement.

3. *Tricalcium aluminate (10.5%).* The presence of tricalcium aluminate causes initial setting of cement. It reacts fast with water and generates large amount of heat hydration. It is the first compound which reacts with water when mixed with cement.

4. *Tetra calcium alumino ferrite (9%).* The presence of tetracalcium alumino ferrite in cement has poor cementing value. If reacts slowly with water and generates small amount of heat hydration.

Notes : (*a*) The high percentage of tricalcium silicate and low percentage of dicalcium silicate in cement results in rapid hardening, high early strength, high heat of generation and less resistance to chemical attack.

(*b*) The low percentage of tricalcium silicate and high percentage of dicalcium silicate in cement results in slow hardening, much more ultimate strength, less heat of generation and greater resistance to chemical attack.

13.6 Setting and Hardening of Cement

The chemical reaction between cement and water is called *hydration of cement* or simply *cement hydration.* The phenomenon by virtue of which the plastic cement changes into a solid mass is known as *setting of cement.* The phenomenon by virtue of which the cement paste sets and develops strength is known as *hardening of cement.*

The rate of setting and hardening of cement, the rate of evolution of heat and resistance to sulphate attack are affected by the proportions of different cement compounds. The sum of percentage of tricalcium silicate and dicalcium silicate for Portland cement varies from 70 to 80%. The tricalcium silicate hydrates more rapidly than dicalcium silicate and develops strength in cement for the first 7 days. The tricalcium aluminate and tetracalcium alumino ferrite compounds are responsible for the initial setting of cement.

13.7 Types of Cements

The various types of cements available in the market are as follows :

1. *Ordinary Portland cement.* This is the common type of cement in use. It has adequate resistance to dry shrinkage and cracking, but has less resistance to chemical attack. It should not be used for construction work exposed to sulphates in the soil.

2. *Rapid hardening Portland cement.* It is also known as high early strength cement. It is lighter than ordinary Portland cement. Since the curing period for this cement is short, therefore it is economical. It is used where high early strength is desired, for constructing road pavements, for cold weather concreting and where form work is to be removed as early as possible. It should not be used for massive concrete structures.

3. *Low heat Portland cement.* It contains a low percentage of tricalcium silicate which hydrates quickly and a higher percentage of dicalcium silicate which hydrates slowly. It contains less lime than ordinary Portland cement. It possesses less compressive strength. This cement is widely used in retaining walls. It should not be used for thin concrete structures.

4. *Sulphate resisting Portland cement.* In this cement, the percentage of tricalcium aluminate is kept below 5% and it results in the increase in resisting power against sulphates. It is used for structures which are likely to be damaged by severe alkaline conditions such as canal linings, culverts etc.

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5. *High alumina cement.* It contains about 35% of alumina. It sets quickly and attains higher ultimate strength in a short period. It is used for a structure subjected to the action of sea water, chemical plants and furnaces.

6. *Blast furnace slag cement.* It is made by intergrinding of ordinary Portland cement clinker and granulated blast furnace slag. It is cheaper than ordinary Portland cement. It develops low heat of hydration and has less early strength. This cement is frequently used in dams, bridge abutments and retaining walls.

7. *Coloured cement.* It is prepared by adding 5 to 15% of a suitable colouring pigment before the cement is finally ground. The commercial term used for a coloured cement is *Colocrete*. It is widely used for finishing of floors, external surfaces etc.

8. *Pozzolana cement.* It is made by intergrinding of ordinary Portland cement clinker and pozzolana. The pozzolana is essentially a silicious material containing clay upto 80%. In the manufacture of pozzolana cement, about 30% of pozzolana material is added to the ordinary Portland cement clinkers. It is widely used for hydraulic structures such as dams, wiers etc.

13.8 Testing of Portland Cement

The following important tests are carried out for ordinary Portland cement :

1. *Fineness test.* This test is carried to check the proper grinding of cement. It may be noted that the finer cement has quicker action with water and gain early strength. The fineness of cement is tested either by sieve method or air permeability method. In the sieve method, the fineness of cement is measured in terms of percentage weight retained on IS sieve number 9 (*i.e.* 90 micron IS sieve). According to Indian standards (IS : 269-1967 and 1975), the percentage of residue left after sieving a good Portland cement through IS sieve number 9, should not exceed 10%.

In air permeability method, the fineness of cement is measured in terms of surface area in cm^2 per gram of cement. A good Portland cement should not have specific surface less than 2250 cm^2/g of cement.

2. *Consistency test.* This test is conducted to determine the percentage of water required for preparing cement pastes of standard consistency for other tests (*e.g.* setting time, soundness and compressive strength tests). This test is performed with the help of Vicat's apparatus which consists of a plunger having 10 mm diameter and 40 to 50 mm length. The Vicat's apparatus determines the initial and final setting time and normal consistency of cement.

Notes : (*a*) In order to make a cement paste of normal consistency, the percentage of water varies from 25 to 35%.

(*b*) In order to perform the initial setting time test, the water is added to the cement at the rate of 0.85 *P* by weight of cement, where *P* is the percentage of water required for normal consistency paste.

(*c*) In order to perform the soundness test, the cement paste is prepared by adding water to the cement at the rate of 0.72 *P* by weight of cement, where *P* is the percentage of water required for normal consistency paste.

(*d*) In order to perform the compressive test, the cement paste is prepared by adding water at the rate of (*P* + 3% of water), where *P* is the percentage of water required for normal consistency paste.

(*e*) The initial setting time of ordinary and rapid hardening cement should not be less than 30 minutes.

(*f*) The final setting time of ordinary and rapid hardening cement should not be less than 10 hours.

3. *Soundness test.* This test is carried out to detect the presence of uncombined lime and magnesia in cement which causes the expansion of cement. The soundness of cement is tested with Le-chatelier apparatus. According to Indian standard specifications, the expansion should not exceed 10 mm for any type of Portland cement.

4. *Tensile strength test.* This test is carried out on standard briquettes made of good Portland cement and standard sand mortar in the ratio of 1 : 3, to determine the tensile strength of cement. The

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average tensile strength after 3 and 7 days of curing should not be less than 2 N/mm^2 and 2.5 N/mm^2 respectively.

5. *Compressive strength test.* This test is carried out on standard cubes made of good Portland cement and standard sand mortar in the ratio of 1 : 3, to determine the compressive strength of cement. The size of cube mould should be 70.6 mm. The cubes should be kept at a temperature of 27° ± 2°C in an atmosphere of at least 90% relative humidity for 24 hours.

According to Indian standard specifications, the average compressive strength for three cubes should not be less than 11.5 N/mm^2 and 17.5 N/mm^2 after 3 and 7 days of curing respectively.

Note : During field test, the cement is said to be pure and of good quality when

(*a*) the colour of cement is uniformly greenish grey,

(*b*) a handful of cement, thrown into a bucket of water, floats,

(*c*) hand is thrusted into a bag of cement, it feels cool, and

(*d*) rubbed in between fingers, it feels smooth.

13.9 Aggregate

The aggregate is an inert mineral material used for the manufacture of mortars and concretes. According to Indian standards (IS : 383-1970), a good aggregate for concrete construction should be sufficiently strong, chemically inert, sufficiently hard and durable. The aggregates may be natural and artificial aggregates. The natural aggregates such as sand, gravel and crushed rock are used for reinforced concrete. The artificial aggregates such as furnace clinker, coke breeze, saw dust and foamed slag are used for the manufacture of concrete of low density.

The aggregates, according to their size, shape and unit weight are classified as follows :

The aggregates, according to their size, are classified as fine aggregate, coarse aggregate, cyclopean aggregate and all-in-aggregate.

The aggregate which pass through 4.75 mm IS sieve and entirely retain on 75 micron IS sieve is called *fine aggregate.* It may be natural sand, crushed stone sand or crushed gravel sand. The minimum particle size of fine aggregate is 0.075 mm and the maximum particle size is 4.75 mm. The material having particle size varying from 0.002 to 0.06 mm is termed as silt and still smaller particles are called clay.

The aggregate which pass through 75 mm IS sieve and entirely retain on 4.75 mm IS sieve is known as *coarse aggregate.* It may be crushed gravel or stone, uncrushed gravel or stone or partially crushed gravel or stone. The minimum particle size of coarse aggregate is 4.75 mm and the *maximum particle size is 75 mm. If the size is more than 75 mm, then the aggregate is called *cyclopean aggregate.*

The *all-in-aggregate* consists of different fractions of fine and coarse aggregates. These aggregates are not generally used for making high quality concrete.

The aggregates, according to their shape, are classified as rounded aggregate, irregular aggregate, angular aggregate, flaky and elongated aggregate.

The aggregates of rounded shape (river or sea shore gravel) have minimum voids ranging from 32 to 33%. It gives minimum ratio of surface area to the volume thus requiring minimum cement paste to make good concrete.

The aggregates of irregular shape (pit sand and gravel) have higher percentage of voids ranging from 35 to 38. It requires more cement paste for a given workability.

The aggregates of sharp, angular and rough shape (crushed rock) have maximum percentage of voids ranging from 38 to 40. The aggregate requires more cement paste to make workable concrete of high strength than that required by rounded shape.

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* The maximum size of coarse aggregate should not exceed one-fourth of the minimum dimension of the plain concrete member and one-fifth of the minimum dimension of the reinforced concrete member.

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The aggregate is said to be flaky when its least dimension (thickness) is three-fifth of its mean dimension. The mean dimension of the aggregate is the average of the sieve sizes through which the particles pass and retained, respectively. The aggregate is said to be elongated when its greatest dimension (length) is greater than 1.8 times its mean dimension.

The aggregates, according to their unit weights, are classified as normal-weight aggregate, heavy weight aggregate and light weight aggregate.

The commonly used aggregates *i.e.* sands and gravels, crushed rocks such as granite, basalt, quartz, sandstone and limestone which have specific gravities between 2.5 and 2.7 produce concrete with unit weight ranging from 23 to 26 kN/m^3. Some heavy weight aggregates (such as magnetite, barytes and scrap iron) having specific gravities ranging from 2.8 to 2.9 and unit weights from 28 to 29 kN/m^3, are used in the manufacture of heavy weight concrete which is more effective as a radiation shield. The light weight aggregates having unit weight upto 12 kN/m^3 are used to manufacture the structural concrete and masonry bricks for reduction of the self-weight of the structure.

The aggregates, depending upon the moisture contents, are classified as dry aggregate, very dry aggregate, saturated surface dry aggregate and moist aggregate.

The aggregate which may contain some moisture in the pores but having dry surface is known as *dry aggregate.*

The aggregate which do not contain any moisture either in the pores or on the surface, is known as *very dry aggregate.*

The aggregate having all the pores filled completely with water but having its surface just dry, is known as *saturated surface dry aggregate.*

The aggregate whose all the pores are filled with water and also having its surface wet, is known as *moist aggregate.*

13.10 Specific Gravity and Bulk Density of Aggregate

Since the aggregate generally contains pores, therefore there are two types of specific gravities *i.e.* apparent specific gravity and bulk specific gravity.

The *apparent specific gravity* of an aggregate is defined as the weight of oven dry aggregate divided by its absolute volume, excluding the natural pores in the aggregate particles.

The *bulk specific gravity* of an aggregate is defined as the weight of oven dry aggregate divided by its absolute volume, including the natural pores in the aggregate particles.

The specific gravity is required for the calculation of the yield of concrete or the quantity of aggregate required for a given volume of concrete. The specific gravity of an aggregate gives valuable information on its quality and properties. The higher the specific gravity of an aggregate, the harder and stronger it will be. The specific gravity of majority of natural aggregates lie between 2.6 and 2.7.

The *bulk density* of an aggregate is defined as the mass required to fill a container of unit volume. It is expressed in kilograms per litre. The bulk density of an aggregate depends upon the shape, size, specific gravity, grading of the aggregate and moisture content.

13.11 Properties of Aggregate

Following are some important properties of aggregate :

1. *Crushing value.* It is the resistance of an aggregate to crushing under a gradually applied compressive forces.

2. *Impact value.* It is the resistance of an aggregate to sudden shock or impact. It is, sometimes, used as an alternative to its crushing value, to know the quality of aggregate.

3. *Abrasion value.* It is the resistance of an aggregate to wear when it is rotated in a cylinder along with some abrasive charge, by using the Los Angeles machine.

4. *Soundness.* It is the resistance of an aggregate to the effect of hydration of cement and weather.

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13.12 Bulking of Sand

The increase in the volume of sand due to the presence of moisture upto certain extent, is called *bulking of sand*. The ratio of the volume of moist sand to the volume of dry sand is known as *bulking factor*. It may be noted that fine sand bulks more than coarse sand.

13.13 Deleterious Materials in Aggregates

The deleterious materials are those whose presence in the aggregate prevent normal hydration of cement, reduce the strength and durability of concrete, modify the setting action and cause efflorescence. The sum of percentages of all deleterious materials in the aggregate shall not exceed 5%.

13.14 Fineness Modulus

The fineness modulus is a numerical index of fineness, giving some idea of the average size of the particles in the aggregate. The value of fineness modulus is higher for coarser aggregate. For fine aggregate, its value varies from 2.2 to 2.6, for coarse aggregate from 2.9 to 3.2. It may be noted that fineness of sand should not be less than 2.5 and not more than 3.

The percentage of fine aggregate to be combined with coarse aggregate (x) is determined by

$$x = \frac{F_2 - F}{F - F_1} \times 100$$

where

F = Fineness modulus according to the specified grading,

F_1 = Fineness modulus of fine aggregate, and

F_2 = Fineness modulus of coarse aggregate.

13.15 Water

It is the most important and least expensive ingredient of concrete. A part of the mixing water is utilised in the hydration of cement to form the binding matrix in which the inert aggregates are held in suspension until the matrix has hardened. The remaining water serves as a lubricant between the fine and coarse aggregates and makes the concrete workable.

The water used for the mixing and curing of concrete should be free from deleterious materials. The potable water is generally considered satisfactory for mixing concrete. The quantity of water used should be just sufficient for hydration and suitable workability of concrete. The insufficient quantity of water makes the concrete mix harsh and unworkable. The excess quantity of water causes bleeding and segregation in concrete. The strength and durability of concrete is reduced due to the presence of impurities in the mixing water. The presence of sodium carbonate and bicarbonates in water has an adverse effect on the setting time of cement. The presence of calcium chloride in water accelerates setting and hardening of cement. The quantity of calcium chloride is restricted to 1.5% by weight of cement.

13.16 Admixtures

The admixtures are the materials other than the basic ingredients of concrete (*i.e.* cement, water and aggregates) and are added to the concrete mix immediately before or during mixing. These are used to improve or give special properties to the concrete in the fresh or hardened state. The use of admixture should accelerate the rate of setting and hardening of cement. It should also make the concrete water proof, acid proof etc. and should reduce the bleeding and segregation of concrete mix. The admixtures may be broadly classified as follows :

(*a*) Air-entraining admixtures ; (*b*) Retarding and water reducing admixtures; (*c*) Accelerating admixtures; (*d*) Water proofing admixtures; (*e*) Pozzolanic admixtures; and (*f*) Colouring admixtures or pigments.

13.17 Water Cement Ratio

It is the ratio of water and cement (by weight or by volume) in a concrete mix. It is usually expressed in litres of water per bag of cement (50 kg). After carrying out a number of experiments by

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Duff Abrahms, he established a relationship between water and cement, which is known as *water cement ratio law.* This law is valid only when the concrete is of workable plasticity. According to this law, the strength of concrete wholly depends upon the amount of water used in the preparation of concrete mix and is quite independent of the proportion of cement and aggregates. The strength of concrete is inversely proportional to the water cement ratio. In other words, the strength of concrete decreases as the water cement ratio increases. It may be noted that when the water cement ratio becomes less than 0.45, the concrete is not workable and causes honey-combed structure containing a large number of voids. If the water cement ratio is more, then the capillary voids will be more in the physical structure of hydrated cement. The strength and durability of concrete will also be less.

13.18 Workability

It is defined as that property of freshly mixed concrete or mortar which determines the ease and homogeneity with which it can be mixed, placed, compacted and finished. The concrete mix is said to be workable, if it has mixability, stability, flowability or movability, compatability and finishability. The optimum workability of fresh concrete varies from situation to situation.

Sometimes, the terms consistency and plasticity are used to denote the workability of concrete mix. Following are the factors which affect the workability :

(*a*) *Water content.* The workability of concrete largely depends upon its water content. It increases with increase in water content on account of greater lubrication.

(*b*) *Size of aggregates.* The concrete having large size aggregates is more workable than that containing small size aggregates because the smaller size aggregates require more quantity of water for lubrication.

(*c*) *Shape of aggregates.* The round shape aggregates increase the workability whereas the angular, flaky and elongated aggregates reduce the workability considerably.

(*d*) *Surface texture of aggregates.* The smooth surface aggregates increase the workability because less quantity of water is required for lubrication. On the other hand, rough surface aggregates reduce the workability because more quantity of water is required for lubrication.

(*e*) *Grading of aggregates.* The grading of aggregates affect the workability and should be continuous lean concrete mix.

(*f*) *Air entraining agents.* The air bubbles produced due to adding air entraining agents in the concrete mix, act as rollers and thus increase the workability.

(*g*) *Temperature.* The workability of concrete mix reduces at higher temperature.

13.19 Measurement of Workability

A number of different empirical tests are available for measuring the workability of fresh concrete, but none of these is fully satisfactory. Each test provides only useful information within a range of variation in workability. Following are the empirical tests widely used :

1. *Slump test.* The slump test is essentially a measure of consistency or the wetness of the concrete mix. This test is carried out with a steel mould in the form of a frustrum of a cone whose top diameter is 100 mm, bottom diameter is 200 mm and the height is 300 mm. According to Indian standard specifications, the maximum size of the aggregate should not exceed 38 mm in the slump test. This method is suitable only for the concretes of medium to high workability. The slump value for high degree of workability should vary between 80 to 100 mm. It may be noted that as the slump value increases, the workability of concrete also increases.

2. *Compaction factor test.* The compaction factor test is carried out to measure the compactability of concrete which is an important aspect of workability. This test works on the principal of measuring the amount of compaction achieved by a standard amount of work done by allowing the concrete to fall through a standard height. This test is more accurate than slump test, especially for concrete mixes of medium and low workabilities *i.e.* compacting factor of 0.9 to 0.8. The compaction

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factor test is more popular to determine the workability of concrete mix in laboratories. The compaction factor is the ratio of weight of partially compacted concrete to the weight of fully compacted concrete.

3. *Vee-Bee test.* The Vee-Bee test is suitable for stiff concrete mixes having low and very low workability. In this test, the time required for complete remoulding in seconds is the required measure of the workability and it is expressed as the number of Vee-Bee seconds.

There is no rigid correlation between workabilities of concrete as measured by different test methods. The workability measured by different test methods are given in the following table :

Table 13.1. Recommended workability values.

Degree of workability	*Slump, in mm*	*Compacting factor*	*Vee-Bee time in seconds*
Very low	0 – 25	0.75 – 0.80	20-10
Low	25 – 50	0.80 – 0.85	10-5
Medium	50 – 75	0.85 – 0.92	5-2
High	75 – 150	> 0.92	2-0

13.20 Concrete Grades

According to Indian standard specifications (IS : 456-1978 and IS : 1343-1980), the concrete mixes are designated into the following seven grades :

M10, M15, M20, M25, M30, M35, M40

In the designation of a concrete mix, the letter M refers to the mix and the number to the specified characteristic compressive strength of a 150 mm cube at 28 days expressed in MPa (N/mm^2). For example, a concrete mix of grade M25 means that the compressive strength of 150 mm cube at 28 days after mixing is 25 MPa (N/mm^2).

The concretes are mainly divided into two categories *i.e.* ordinary concrete and controlled concrete. The concrete in which no preliminary tests are performed for designing the mix is called *ordinary concrete*. The ordinary concrete is used for M10, M15, M20 and M25 grades of concrete mixes. The concrete in which preliminary tests are performed for designing the mix, is called *controlled concrete*. The controlled concrete is used for all the seven grades of concrete mixes.

The proportions of different ingredients (cement, sand and aggregate) in the concrete mix are as follows :

S. No.	*Grade*	*Concrete mix*	*Uses*
1.	M10	1 : 3 : 6	Mass concrete in piers, abutments, massive reinforced concrete members.
2.	M15	1 : 2 : 4	Normal R.C.C. works *i.e.* slabs, columns, beams, walls, small span arches.
3.	M20	1 : 1½ : 3	Water retaining structures *i.e.* reservoirs, columns and piles.
4.	M25	1 : 1 : 2 1 : 4 : 8	Long span arches and highly loaded columns.
5.	M30	1 : 5 : 10 1 : 6 : 12	Mass concrete foundations.
6.	M35	.....	Post tensioned prestressed concrete.
7.	M40	.....	Pre tensioned prestressed concrete.

3.21 Methods of Proportioning Concrete

The process of determining the proportion of cement to fine aggregate and coarse aggregate

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concrete mix is called proportioning of concrete. The various methods of proportioning concrete
e as follows :

1. *Arbitrary method.* In this method, one part of cement to M parts of fine aggregate and $2M$
rts of coarse aggregate are taken as the basis. The quantity of water required for mixing is determined
cording to the desired workability. In order to obtain the required workability, the minimum quantity
water to be added to fine and coarse aggregates is determined by the following relation :

$$\frac{W}{C} \times p = 0.3\,p + 0.1y + 0.01z.$$

here
W/C = Water-cement ratio,
p = Quantity of cement by weight,
y = Quantity of fine aggregate by weight, and
z = Quantity of coarse aggregate by weight.

2. *Minimum voids method.* This method is based on the principle that the concrete which has
e minimum voids is the densest and strongest. In this method, it is assumed that the voids in the
arse aggregate are filled by the fine aggregates and the voids in the fine aggregate are filled by the
ment paste. In order to allow for additional voids created by wedging action, the volume of fine
gregates required for 1 m^3 of coarse aggregate is equal to the total voids in coarse aggregate *plus*
% aggregate extra and the volume of cement paste required for 1 m^3 of coarse aggregate is equal to
e total volume of voids in the fine aggregate *plus* 15% aggregate extra.

3. *Fineness modulus method.* This method is based on a factor known as fineness modulus of
gregates. The fineness modulus is used to indicate an index number which is roughly proportional
the average size of the particle in the entire quantity of aggregates. The percentage of fine aggregate
the combined aggregate (P) is obtained by the following relation :

$$P = \frac{X - Z}{Z - Y} \times 100$$

here
X, Y and Z = Fineness modulii for coarse, fine and combined aggregates respectively.

3.22 Storing of Ingredients of Concrete

The ingredients of concrete should be stored in a warehouse whose walls are of water proof
sonry construction and the roof is leak proof. The importance of storing the various ingredients of
ncrete is to maintain the uniformity of grading and moisture. The capacity of a warehouse depends
on the floor area occupied by one cement bag and the height to which the cement bags are piled. In
signing a warehouse, it is assumed that each bag contains 50 kg of cement and the floor area
cupied by one bag of cement is 0.3 m^2. The height of each cement bag containing 35 litres of
ment is 0.18 m. In order to prevent the cement bags from any possible contact with moisture, the
ment bags should be placed closed together in the piles and the space between the exterior walls
d piles should be 300 mm. The width and height of the pile should not exceed 3 m and 2.7 m
spectively. The cement bags should be rolled on the floor when it is taken out for use. The 'first-in,
st-out' rule should be applied when cement bags are to be removed from the warehouse. It may be
oted that the strength of cement decreases with the passage of time.

3.23 Production of Concrete

The production of concrete of uniform quality involves the following stages :

1. *Batching or measurement of materials.* The process of proper and accurate measurement
f all concrete materials for uniformity of proportions and aggregate grading is called batching. The
portance of batching is to obtain strength, workability, durability and economy. For most of the
rge and important jobs, the batching of materials is done by weighing. The weight batching is done
y spring dial scale, platform weighing machine or portable weigh batchers.

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The weighing machine should be levelled before placing the material and the bucket in which the material is to be weighed should be cleaned thoroughly. The chart should be prepared indicating the weight of each material used for different strengths of concrete.

For most of the small jobs, volume batching is adopted. The volume of one bag of cement is taken as 35 litres. The wooden gauge boxes (known as farmas) are used for measuring the fine and coarse aggregates. For measuring 50 litres of aggregate, the inner dimensions of a farma should be 31cm × 31cm × 52 cm. The batch volume for some of the commonly used mixes are given in the following table :

Table 13.2. Batch Volume of materials for various mixes.

Grade	*Concrete mix*	*Cement, kg*	*Fine aggregate, litres*	*Coarse aggregate, litres*
M 10	1 : 3 : 6	50	105	210
M 15	1 : 2 : 4	50	70	140
M 20	1 : 1½ : 3	50	52.5	105
M 25	1 : 1 : 2	50	35	70

2. *Mixing.* The thorough mixing of the materials is essential for the production of uniform concrete. The concrete mixing is normally done by mechanical means called mixer, but sometimes, the mixing of concrete is done by hand. The machine mixing is more efficient and economical as compared to hand mixing. The mixers are classified as follows :

(*a*) Tilting type mixer ; (*b*) Non-tilting type mixer ; and (*c*) Reversing mixer.

According to Indian standards (IS : 1791-1968), concrete mixers are designated by a number representing its nominal mixed batch capacity in litres. The following are the standard sizes of the three types :

Tilting (T) : 85 T, 100 T, 140 T, 200 T

Non tilting (NT) : 200 NT, 280 NT, 340 NT, 400 NT, 800 NT

Reversing (R) : 200 R, 280 R, 340 R, 400 R

The concrete mixers are generally designed to run at a speed of 15 to 20 revolutions per minute. For proper mixing, about 25 to 30 revolutions are required in a well designed mixer.

3. *Transporting.* The concrete can be transported by a variety of methods and equipments. For small jobs, the concrete is transported in *iron pans, wheel barrows* or *two wheel carts* by manual labour. For large and massive works, the concrete is transported by buckets or by pumps which are operated mechanically. The concrete is transported by pumps for concreting of tunnel lining. The concrete can be lifted by pumps through a maximum vertical distance of 50 m. In transportation of concrete by pumps, the water-cement ratio should remain between 0.5 to 0.65. The slump should not be less than 50 mm and more than 80 mm. The number of bends in a pipe line should be as small as possible.

For large concrete works, particularly for concrete to be placed at ground level, trucks and dumpers or ordinary open steel body tipping lorries can be used. The skip and hoist is one of the widely adopted methods for transporting concrete vertically up for multistorey building construction.

4. *Placing.* It is very important that the concrete must be placed in position in a proper manner as early as possible within the initial setting time of cement. The following precautions be taken while placing the concrete :

(*a*) The concrete should not be thrown from a height of more than 1 m, to prevent segregation.

(*b*) The placement of concrete should be discontinued during rainy periods.

(*c*) The placing of concrete should start width wise in reinforced cement concrete slabs from one end.

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(*d*) The concrete should be laid continuously in order to prevent the formation of irregular and unsightly lines.

5. *Compaction.* It is the process of consolidating concrete mix after placing it in position. The main aim of consolidation of concrete is to eliminate air bubbles and thus to give maximum density to concrete. The proper consolidation ensures intimate contact between the concrete and the surface of reinforcement. The compaction of concrete may be carried out either manually or mechanically. The concrete is compacted manually by using hand tools such as rammers, templates or tamping and spading rod. The concrete is compacted mechanically by jets of compressed air or by vibrators. The various types of vibrators used are as follows :

(*a*) Internal or immersion or needle vibrator ; (*b*) Surface or screed vibrator ;

(*c*) Form or shutter or external vibrator ; and (*d*) Table vibrator.

In case of large sections of mass concrete in structures, the concrete is compacted by internal vibrator. The external or screed vibrator is used for compacting plain concrete or one-way reinforced concrete floors.

When vibrators are used for compaction, the consistency of concrete depends upon the type of mix, placing conditions and efficiency of vibrator. The slump should not exceed 50 mm when compacting concrete with vibrators. It may be noted that when the slump of the concrete mix is less than 50 mm, the segregation will not take place while compacting it with vibrators. The vibrator should also not touch the form surface.

6. *Finishing.* The finishing of concrete surfaces is an important process from the engineering point of view. The results of finishing are good if slump is about 50 mm. The finishing may be achieved by the following operations :

(*a*) *Screeding.* It is the levelling operation that removes humps and hollows and give a true and uniform concrete surface.

(*b*) *Floating.* It is the process of removing the irregularities from the surface of concrete left after screeding.

(*c*) *Trowelling.* It is final operation of finishing the concrete surface. It is performed where smooth and dense surface is required.

7. *Curing.* It is the process of hardening the concrete mixes by keeping its surface moist for a certain period, in order to enable the concrete to gain more strength. The object of curing is to prevent the loss of water by evaporation ; to reduce the shrinkage of concrete and to preserve the properties of concrete. The concrete gains strength upto 100 percent after the curing of 28 days. The proper curing of cement concrete is good for its volume stability, strength and wear resistance.

13.24 Stripping of Forms

The removal of forms after the concrete has set is termed as stripping of forms. The period upto which the forms must be left in place before they are stripped is called stripping time. Under normal circumstances, the vertical sides of columns may be stripped after 1 to 2 days and the beam soffits may be removed after 2 days.

OBJECTIVE TYPE QUESTIONS

1. The practical utility of concrete technology for civil engineers is to
   (*a*) enable them to know how to stock properly the materials required for concrete
   (*b*) enable them to perform different tests concerning concrete
   (*c*) make them conversant with the fundamental principles of concrete
   (*d*) all of the above

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2. The strength and durability of concrete depends upon
   (a) size of aggregates (b) grading of aggregates
   (c) moisture contents of aggregates (d) all of these
3. The breaking up of cohesion in a mass of concrete is called
   (a) workability (b) bleeding (c) segregation (d) creep
4. The workability of concrete is defined as the
   (a) ease with which it can be mixed, transported and placed in position in a homogeneous state
   (b) breaking up of cohesion in a mass of concrete
   (c) separation of water or water-cement mixture from the freshly mixed concrete
   (d) none of the above
5. The separation of water or water-cement mixture from the freshly mixed concrete is known as bleeding.
   (a) True (b) False
6. The continuous strain, which the concrete undergoes due to application of external loads, is called
   (a) workability (b) bleeding (c) segregation (d) creep
7. A good concrete should be subjected to ..... creep.
   (a) maximum (b) minimum
8. Segregation in concrete results in
   (a) honey combing (b) porous layers (c) surface scaling (d) all of these
9. Harshness in concrete is due to the excess of
   (a) water (b) finer particles
   (c) middle sized particle (d) coarser particles
10. In order to avoid segregation, the concrete should not be thrown from a height.
    (a) Agree (b) Disagree
11. In lime concrete, lime is used as
    (a) coarse aggregate (b) fine aggregate (c) binding material (d) admixture
12. The type of lime used in lime concrete is
    (a) fat lime (b) poor lime (c) slaked lime (d) hydraulic lime
13. A good concrete should have minimum thermal expansion.
    (a) Yes (b) No
14. The lime concrete has ..... strength as compared to cement concrete.
    (a) less (b) more (c) same
15. The usual proportion of ingredients in plain cement concrete is
    (a) Portland cement (1 part), clean sand (1½ to 8 parts) and coarse aggregate (3 to 16 parts)
    (b) Portland cement (1 part), clean sand (3 to 16 parts) and coarse aggregate (1½ to 8 parts)
    (c) Portland cement (1 part), clean sand and coarse aggregate (1½ to 8 parts)
    (d) any one of the above
16. The usual proportion of ingredients in reinforced cement concrete is
    (a) Portland cement (1 part), clean sand (2 to 4 parts) and coarse aggregate (1 to 2 parts)
    (b) Portland cement (1 part), clean sand (1 to 2 parts) and coarse aggregate (2 to 4 parts)
    (c) Portland cement (1 part), clean sand and coarse aggregate (2 to 4 parts)
    (d) any one of the above

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17. Ferro-concrete is another name given to
(a) plain cement concrete (b) reinforced cement concrete
(c) prestressed cement concrete (d) none of these

18. Reinforced cement concrete is equally strong in taking
(a) tensile and compressive stresses (b) compressive and shear stresses
(c) tensile, compressive and shear stresses (d) tensile and shear stresses

19. Plain cement concrete is strong in taking
(a) tensile stress (b) compressive stress
(c) shear stress (d) all of these

20. In flooring of building, prestressed cement concrete is commonly used.
(a) Right (b) Wrong

21. The cement concrete in which high compressive stresses are artificially induced before its actual use, is called
(a) plain cement concrete (b) reinforced cement concrete
(c) prestressed cement concrete (d) lime concrete

22. The prestressed cement concrete can take up high tensile and compressive stresses without development of cracks.
(a) Correct (b) Incorrect

23. For heat and sound insulation purposes, we shall use
(a) vacuum concrete (b) air-entrained concrete
(c) saw dust concrete (d) both (a) and (b)

24. The cement concrete, from which entrained air and excess water are removed after placing it in position, is called
(a) vacuum concrete (b) light weight concrete
(c) prestressed concrete (d) sawdust concrete

25. The removal of excess air after placing concrete helps in increasing the strength of concrete by
(a) 15 to 20% (b) 20 to 30% (c) 30 to 50% (d) 50 to 70%

26. The cement concrete prepared by mixing aluminium in it, is called
(a) air-entrained concrete (b) cellular concrete
(c) aerated concrete (d) any one of these

27. The light-weight concrete is prepared by
(a) mixing Portland cement with sawdust in specified proportion in the concrete
(b) using coke-breeze, cinder or slag as aggregate in the concrete
(c) mixing aluminium in the concrete
(d) none of the above

28. The sound absorption coefficient of light weight concrete is nearly ..... than that of ordinary concrete.
(a) twice (b) three times (c) four times (d) six times

29. In making precast structural units for partition and wall lining purposes, the concrete should be
(a) sawdust concrete (b) air-entrained concrete
(c) light-weight concrete (d) vacuum concrete

30. Cement concrete is ..... to moisture.
(a) permeable (b) impermeable

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31. Which of the following statement is wrong ?
(a) The concrete can not be pumped.
(b) The concrete should have maximum creep.
(c) The concrete structures can be put to use immediately after their construction.
(d) all of the above

32. The characteristic, which makes the concrete a versatile and widely used material of modern construction, is the possibility of
(a) controlling the properties of concrete by using appropriate ingredients
(b) moulding the concrete in any desired shape
(c) complete mechanisation of concrete preparation and its placing process
(d) all of the above

33. The concrete without any reinforcement has ..... tensile strength.
(a) low (b) high

34. Segregation of concrete increases the strength of concrete.
(a) Yes (b) No

35. The material used as an ingredient of concrete is usually
(a) cement (b) aggregate (c) water (d) all of these

36. A suitable admixture added at the time of preparing the concrete mix, makes the concrete
(a) water-proof (b) acid proof (c) highly strong (d) all of these

37. The function of aggregates in concrete is to serve as
(a) binding material (b) filler (c) catalyst (d) all of these

38. Calcareous material used in the manufacture of cement consists of
(a) lime stone (b) chalk (c) shells (d) all of these

39. In the manufacture of cement, the dry or wet mixture of calcareous and argillaceous materials burnt in a
(a) country kiln (b) continuous flare kiln
(c) rotary kiln (d) all of these

40. In the manufacture of cement, the dry or wet mixture of calcareous and argillaceous materials burnt at a temperature between
(a) 900°C to 1000°C (b) 1000°C to 1200°C
(c) 1200°C to 1500°C (d) 1500°C to 1600°C

41. Argillaceous materials contain ..... as their major constituent.
(a) calcium (b) lime (c) alumina

42. Hydration of cement evolves heat.
(a) True (b) False

43. The proportion of lime, silica, alumina and iron oxide in a good Portland cement should be
(a) 63 : 22 : 6 : 3 (b) 63 : 22 : 3 : 6 (c) 22 : 63 : 6 : 3 (d) 22 : 63 : 3 : 6

44. The chemical ingredient of cement which provides quick setting property to the cement is
(a) lime (b) silica (c) alumina (d) iron oxide

45. The presence of lime in cement
(a) makes the cement sound (b) provides strength to the cement
(c) lowers the clinkering temperature (d) all of these

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46. The gypsum is added to the cement for
(a) providing high strength to the cement
(b) controlling the initial setting time of cement
(c) lowering the clinkering temperature of cement
(d) all of the above

47. Which of the following ingredient of cement when added in excess quantity, causes the cement set slowly ?
(a) Lime (b) Silica (c) Alumina (d) Iron oxide

48. Lime when added in excess quantity
(a) makes the cement unsound
(b) causes the cement to expand and disintegrate
(c) lowers the clinkering temperature of cement
(d) both (a) and (b)

49. The magnesium oxide and sulphur dioxide when added in excess quantity makes the cement unsound.
(a) Correct (b) Incorrect

50. In order to provide colour, hardness and strength to the cement, the ingredient used is
(a) lime (b) silica (c) alumina (d) iron oxide

51. Alumina in the cement lowers the clinkering temperature.
(a) Agree (b) Disagree

52. After the final grinding, the cement is sieved through IS sieve number
(a) 9 (b) 12 (c) 24 (d) 48

53. The change of state of cement paste from fluid to solid is called hardening.
(a) Right (b) Wrong

54. Efflorescence in cement is caused due to the excess of
(a) silica (b) lime (c) alkalies (d) iron oxide

55. The presence of tricalcium silicate in cement
(a) hydrates the cement rapidly (b) generates less heat of hydration
(c) offers high resistance to sulphate attack (d) all of these

56. The presence of dicalcium silicate in cement
(a) hydrates the cement slowly (b) generates less heat of hydration
(c) has more resistance to sulphate attack (d) all of these

57. The tricalcium aluminate in cement has the property of
(a) reacting fast with water (b) causing initial setting of cement
(c) generating large amount of heat hydration (d) all of these

58. The tetra calcium alumino ferrite in cement has ..... cementing value.
(a) good (b) poor

59. High percentage of tricalcium silicate and low percentage of dicalcium silicate in cement results in
(a) rapid hardening (b) high early strength
(c) high heat generation (d) all of these

60. Low percentage of tricalcium silicate and high percentage of dicalcium silicate in cement results in
(a) rapid hardening (b) high early strength
(c) high heat generation (d) none of these

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61. The first compound which reacts with water when mixed with cement is tricalcium aluminate.
(a) Correct (b) Incorrect

62. Tricalcium silicate develops strength in cement for first 7 days.
(a) Yes (b) No

63. Which of the following statement is correct ?
(a) The high early strength is obtained by adding tricalcium silicate in cement.
(b) The dicalcium silicate provides good ultimate strength to cement.
(c) The tetra calcium alumino ferrite has poor cementing value.
(d) all of the above

64. The sum of the percentage of tricalcium silicate and dicalcium silicate for Portland cement varies from
(a) 50 to 60% (b) 60 to 70% (c) 70 to 80% (d) 80 to 90%

65. Ordinary Portland cement should not be used for construction work exposed to sulphates in the soil.
(a) Agree (b) Disagree

66. The rate of hydration is ..... proportional to the generation of heat.
(a) directly (b) inversely

67. Rapid hardening cement is used
(a) where high early strength is desired
(b) where form work is to be removed as early as possible
(c) for constructing road pavements
(d) all of the above

68. Low heat cement is used in ..... structures.
(a) thin (b) thick

69. The cement, widely used in retaining walls, is
(a) rapid hardening cement (b) low heat cement
(c) sulphate resisting cement (d) ordinary Portland cement

70. Blast furnace slag cement is used for
(a) dams (b) bridge abutments
(c) retaining walls (d) all of these

71. Blast furnace slag cement concrete requires ..... time for shuttering and curing.
(a) less (b) more

72. Low heat cement contains more lime than ordinary Portland cement.
(a) True (b) False

73. Blast furnace slag cement
(a) develops low heat of hydration (b) has less early strength
(c) develops high heat of hydration (d) has high early strength

74. Which of the following cements is expected to have the highest compressive strength after 3 days ?
(a) ordinary Portland cement (b) rapid hardening cement
(c) high alumina cement (d) sulphate resisting cement

75. For a structure subjected to the action of sea water, the cement used is
(a) rapid hardening cement (b) low heat cement
(c) high alumina cement (d) sulphate resisting cement

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76. The strength of concrete using air entraining cement gets reduced by
(a) 5 to 10% (b) 10 to 15% (c) 15 to 20% (d) 20 to 25%

77. "Colocrete" is the commercial term for
(a) high alumina cement (b) coloured cement
(c) low heat cement (d) rapid hardening cement

78. Pozzolana is essentially a silicious material containing clay upto
(a) 20% (b) 40% (c) 60% (d) 80%

79. In the manufacture of pozzolana cement, the amount of pozzolana material added to ordinary Portland cement clinkers is about
(a) 20% (b) 30% (c) 40% (d) 50%

80. Which of the following statement is correct ?
(a) Sulphate resisting cement is particularly used for canal lining.
(b) Low heat cement should not be used for thin concrete structures.
(c) Rapid hardening cement should not be used for massive concrete structures.
(d) all of the above

81. Match the correct answer from *Group B* for the statements given in *Group A*.

Group A	*Group B*
(a) Bhakra dam was constructed with	(A) blast furnace slag cement
(b) The cement used for chemical plants is	(B) sulphate resisting cement
(c) The cement not to be used in thin R.C.C. structures is	(C) pozzolana cement
(d) The cement used for marine works is	(D) high alumina cement

82. The degree of grinding of cement is called
(a) fineness (b) soundness (c) impact value (d) bulking

83. The hardening is the phenomenon by virtue of which
(a) the cement does not undergo large change in volume when treated with water
(b) the plastic cement paste changes into hard mass
(c) the cement paste sets and develops strength
(d) none of the above

84. The phenomenon by virtue of which the cement does not undergo large change in volume when treated with water, is known as
(a) fineness (b) soundness (c) setting time (d) none of these

85. The fineness of cement is measured in terms of
(a) percentage weight retained on IS sieve number 9
(b) surface area in cm^2 per gram of the cement
(c) either (a) or (b) (d) none of these

86. Too much fineness of cement
(a) results cracks in concrete (b) generates greater heat
(c) develops early strength (d) both (a) and (b)

87. The setting time of cement is the governing factor for
(a) mixing of concrete (b) placing of concrete
(c) compaction of concrete (d) all of these

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88. According to IS : 269–1976, the requirement of an ordinary Portland cement is that
(*a*) the residue does not exceed 10% when sieved through IS sieve No. 9
(*b*) its expansion is not more than 10 mm for unaerated cement
(*c*) its initial setting time is not less than 30 minutes
(*d*) all of the above

89. The compressive strength of an ordinary Portland cement (1 : 3 cement mortar cube) after 7 days test should not be less than
(*a*) 11 N/mm^2 (*b*) 17.5 N/mm^2 (*c*) 22 N/mm^2 (*d*) 27.5 N/mm^2

90. Vicat's apparatus is used to perform
(*a*) fineness test (*b*) soundness test
(*c*) consistency test (*d*) compressive strength test

91. The knowledge of a standard consistency of a cement paste is essential to perform
(*a*) setting time test (*b*) soundness test
(*c*) compressive strength test (*d*) all of these

92. In Vicat's apparatus, the diameter of Vicat plunger is
(*a*) 5 mm (*b*) 10 mm (*c*) 15 mm (*d*) 20 mm

93. The length of Vicat plunger in Vicat's apparatus varies from
(*a*) 20 to 30 mm (*b*) 30 to 40 mm (*c*) 40 to 50 mm (*d*) 50 to 60 mm

94. The percentage of water for making a cement paste of normal consistency varies from
(*a*) 15 to 25% (*b*) 25 to 35% (*c*) 35 to 50% (*d*) 50 to 60%

95. To perform the initial setting time test, the water is added to the cement at the rate of ..... by weight of cement.
(*a*) 0.72 *P* (*b*) 0.78 *P* (*c*) 0.85 *P* (*d*) 0.95 *P*
where *P* = Percentage of water required for normal consistency paste.

96. Le-chatelier apparatus is used to perform
(*a*) fineness test (*b*) soundness test
(*c*) consistency test (*d*) compressive strength test

97. To perform the soundness test, the water is added to the cement at the rate of 0.72 *P* by weight of cement, where *P* is the percentage of water required for normal consistency paste.
(*a*) Correct (*b*) Incorrect

98. To perform the compressive strength test of cement, water is added at the rate of
(*a*) 0.72 *P* + 3% of water (*b*) 0.85 *P* + 4% of water
(*c*) *P* + 3% of water (*d*) *P* + 4% of water
where *P* = Percentage of water required for normal consistency paste.

99. Initial setting time of ordinary Portland cement is
(*a*) 15 min (*b*) 30 min (*c*) 60 min (*d*) 10 h

100. For performing the compressive strength test of cement, the size of cube mould should be 7.06 cm side.
(*a*) Right (*b*) Wrong

101. According to Indian standard specifications for the compressive strength test of cement, the cement and standard sand mortar in the ratio of ..... is used.
(*a*) 1 : 1 (*b*) 1 : 2 (*c*) 1 : 3 (*d*) 1 : 4

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102. The cubes of cement prepared for compressive strength test should be kept at a temperature of ..... in an atmosphere of at least 90% relative humidity for 24 hours.
(a) $15° \pm 2°C$ (b) $21° \pm 2°C$ (c) $27° \pm 2°C$ (d) $30° \pm 2°C$

103. During field test, the cement is said to be pure and of good quality when
(a) the colour of cement is uniformly greenish grey
(b) a handful of cement, thrown into a bucket of water, floats
(c) hand is thrusted into a bag of cement, it feels cool
(d) all of the above

104. The inert mineral material used for the manufacture of mortars and concretes is
(a) cement (b) water (c) aggregate (d) admixture

105. According to IS :383–1970, a good aggregate for concrete construction should be
(a) chemically inert (b) sufficiently strong
(c) sufficiently hard and durable (d) all of these

106. For reinforced concrete, the aggregate used is
(a) sand (b) gravel (c) crushed rock (d) all of these

107. For the manufacture of concrete of low density, the aggregate used is
(a) furnace clinker (b) coke breeze (c) saw dust (d) all of these

108. The material having particle size varying from 0.002 to 0.06 mm is termed as
(a) silt (b) clay (c) sand (d) none of these

109. An aggregate is said to be ..... aggregate if its size is more than 75 mm.
(a) coarse (b) fine (c) cyclopean

110. The aggregate which pass through 75 mm IS sieve and entirely retain on 4.75 mm IS sieve is known as
(a) cyclopean aggregate (b) coarse aggregate
(c) fine aggregate (d) all-in-aggregate

111. The maximum particle size of coarse aggregate is
(a) 45 mm (b) 55 mm (c) 65 mm (d) 75 mm

112. The maximum particle size of fine aggregate is
(a) 2.5 mm (b) 4.75 mm (c) 5.85 mm (d) 6.5 mm

113. The aggregate which pass through 4.75 mm IS sieve and entirely retain on 75 micron IS sieve is called
(a) cyclopean aggregate (b) coarse aggregate
(c) fine aggregate (d) all-in-aggregate

114. The minimum particle size of coarse aggregate is
(a) 2.5 mm (b) 4.75 mm (c) 5.85 mm (d) 6.5 mm

115. The minimum particle size of fine aggregate is
(a) 0.0075 mm (b) 0.075 mm (c) 0.75 mm (d) 0.95 mm

116. The aggregates of ..... shape have minimum voids.
(a) irregular (b) angular (c) rounded (d) flaky

117. The aggregates of ..... shape have maximum voids.
(a) irregular (b) angular (c) rounded (d) flaky

118. The size of an aggregate is determined by length gauge.
(a) Yes (b) No

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119. The aggregates of rounded shape require minimum cement paste to make good concrete.
(a) True (b) False

120. Which of the following statement is correct ?
(a) The maximum size of coarse aggregate should not exceed one-fourth of the minimum dimension of the plain concrete member.
(b) The maximum size of coarse aggregate should not exceed one-fifth of the minimum dimension of the reinforced concrete member.
(c) The aggregates of 40 mm, 20 mm and 10 mm sizes are commonly used for concrete works.
(d) all of the above

121. The aggregate is said to be flaky when
(a) its least dimension is three-fifth of its mean dimension
(b) its least dimension is equal to its mean dimension
(c) its length is equal to its mean dimension
(d) its length is equal to 1.8 times its mean dimension

122. The aggregate is said to be elongated when
(a) its least dimension is three-fifth of its mean dimension
(b) its least dimension is equal to its mean dimension
(c) its length is equal to its mean dimension
(d) its length is equal to 1.8 times its mean dimension

123. If the aggregate completely passes through a 50 mm sieve and retained on 40 mm sieve, then the particular aggregate is said to be flaky if its least dimension is less than
(a) 27 mm (b) 37 mm (c) 47 mm (d) 57 mm

124. In the above question, the particular aggregate is said to be elongated if its length is not less than 81 mm.
(a) True (b) False

125. Bulk specific gravity of an aggregate is defined as
(a) the weight of oven dry aggregate divided by its absolute volume, excluding the natural pores in the aggregate particles
(b) the weight of oven dry aggregate divided by its absolute volume, including the natural pores in the aggregate particles
(c) the weight of aggregate required to fill a container of unit volume
(d) the difference in weight of the aggregate in saturated surface dry condition and in moist condition

126. The apparent specific gravity of an aggregate is defined as
(a) the weight of oven dry aggregate divided by its absolute volume, excluding the natural pores in the aggregate particles
(b) the weight of oven dry aggregate divided by its absolute volume, including the natural pores in the aggregate particles
(c) the weight of aggregate required to fill a container of unit volume
(d) the difference in weight of the aggregate in saturated surface dry condition and in moist condition

127. The bulk density of an aggregate is the weight required to fill a container of unit volume.
(a) Agree (b) Disagree

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128. The value of bulk density for angular and flaky aggregates is ..... as compared to graded aggregates.
(a) same (b) less (c) more

129. The value of bulk density of the aggregate depends upon
(a) size distribution of aggregate (b) shape of aggregate
(c) specific gravity of aggregate (d) all of these

130. An aggregate which may contain some moisture in the pores but having dry surface is known as
(a) very dry aggregate (b) dry aggregate
(c) saturated surface dry aggregate (d) moist aggregate

131. An aggregate having all the pores filled with water but having dry surface is called
(a) very dry aggregate (b) dry aggregate
(c) saturated surface dry aggregate (d) moist aggregate

132. A moist aggregate is one
(a) whose all the pores are filled with water and also having its surface wet
(b) whose all the pores are filled with water but having its surface dry
(c) which do not contain any moisture either in the pores or on the surface
(d) which may contain some moisture in the pores but having dry surface

133. The surface moisture of aggregates increases the water-cement ratio in the mix and thus ..... the strength.
(a) increases (b) decreases

134. Which of the following statement is correct ?
(a) Larger the size of coarse aggregate, lesser is the quantity of fine aggregate and of cement required.
(b) If very dry aggregates are used, the workability of the mix is likely to be reduced.
(c) Bulking is caused due to the formation of thin film of surface moisture around the sand particles.
(d) all of the above

135. The deleterious materials present in the aggregate
(a) prevent normal hydration of cement
(b) reduce the strength and durability of concrete
(c) modify the setting action and cause efflorescence
(d) all of the above

136. The sum of percentages of all deleterious materials in the aggregate shall not exceed
(a) 5% (b) 10% (c) 15% (d) 20%

137. The resistance of an aggregate to compressive forces is known as
(a) crushing value (b) impact value (c) abrasion value (d) none of these

138. The resistance of an aggregate to sudden compressive forces is called impact value.
(a) Correct (b) Incorrect

139. The resistance of an aggregate to wear is known as
(a) shear value (b) crushing value (c) abrasion value (d) impact value

140. The resistance of an aggregate to the effect of hydration of cement and weather is called
(a) crushing value (b) impact value (c) abrasion value (d) soundness

141. Los Angeles machine is used to perform the abrasion resistance test of an aggregate.
(a) Right (b) Wrong

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142. The impact value of an aggregate is generally used as an alternative to its crushing value, to know the quality of aggregate.
(a) Yes (b) No

143. Bulking of sand is
(a) compacting of sand (b) segregating sand of particular size
(c) increase in volume of sand due to presence of moisture upto certain extent
(d) none of the above

144. With the moisture content of 5 to 10% by weight, the bulking of sand is increased by
(a) 20% (b) 30% (c) 40% (d) 50%

145. When the sand is fully saturated, its volume is ..... the volume of dry and loose sand.
(a) equal to (b) less than (c) more than

146. The ratio of the volume of moist sand to the volume of dry sand is known as
(a) crushing value (b) impact value (c) bulking factor (d) none of these

147. Fine sand bulks ..... than coarser sand.
(a) less (b) more

148. The fineness modulus of an aggregate is roughly proportional to
(a) specific gravity of the aggregate (b) shape of the aggregate
(c) average size of particles in the aggregate (d) grading of the aggregate

149. The coarser the aggregate, the ..... is the fineness modulus.
(a) higher (b) lower

150. The value of fineness modulus for fine sand may range between
(a) 1.1 to 1.3 (b) 1.3 to 1.6 (c) 1.6 to 2.2 (d) 2.2 to 2.6

151. If the fineness modulus of sand is 3, then the sand is graded as
(a) very fine sand (b) fine sand (c) medium sand (d) coarse sand

152. The percentage of fine aggregate to be combined with coarse aggregate (x) is determined by

(a) $x = \frac{F + F_1}{F + F_2} \times 100$ (b) $x = \frac{F + F_2}{F + F_1} \times 100$

(c) $x = \frac{F_2 - F}{F - F_1} \times 100$ (d) $x = \frac{F - F_1}{F_2 - F} \times 100$

where F = Fineness modulus according to the specified grading,
F_1 = Fineness modulus of fine aggregate, and
F_2 = Fineness modulus of coarse aggregate.

153. The presence of ..... in water has an adverse effect on the setting time of cement.
(a) sodium carbonate and bicarbonate (b) calcium chloride
(c) sodium chloride (d) sodium sulphate

54. The presence of calcium chloride in water
(a) accelerates setting of cement (b) accelerates hardening of cement
(c) causes little effect on quality of concrete (d) all of these

55. The admixtures are added in concrete to
(a) accelerate the rate of setting and hardening of cement
(b) make the concrete water proof, acid proof etc.
(c) reduce the bleeding and segregation of concrete mix
(d) all of the above

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156. Water cannot be used as a lubricant in concrete mix.
(a) True (b) False

157. If sea water is used for preparing concrete mix, it
(a) reduces strength (b) corrodes steel reinforcement
(c) causes efflorescence (d) all of these

158. If mineral oil is present in mixing water for concrete, it increases strength for a concentration upto 2 percent.
(a) Yes (b) No

159. Which of the following statement is wrong ?
(a) The coarse sand produces a harsh and unworkable mix.
(b) An admixture cannot increase the workability of concrete without increasing water content.
(c) Salts of manganese cause a considerable reduction in the strength of concrete.
(d) all of the above

160. The standard sand now used in India is obtained from
(a) Ennore (Chennai) (b) Mumbai (c) Orissa (d) Jaipur

161. Insufficient quantity of water
(a) makes the concrete mix harsh (b) makes the concrete mix unworkable
(c) causes segregation in concrete (d) causes bleeding in concrete

162. Excess quantity of water
(a) makes the concrete mix harsh (b) makes the concrete mix unworkable
(c) causes segregation in concrete (d) causes bleeding in concrete

163. Water cement ratio may be defined as the ratio of
(a) volume of water to that of cement in a concrete mix
(b) weight of water to that of cement in a concrete mix
(c) volume of water to that of concrete in a concrete mix
(d) weight of water to that of concrete in a concrete mix

164. The rule of water cement ratio was established by
(a) Duff Abram (b) Plowman
(c) W. Simms (d) Dr. Karl Terzaghi

165. According to the rule of water cement ratio, the strength of concrete wholly depends upon
(a) the quality of cement
(b) the quality of cement mixed with aggregate
(c) the amount of water used in preparation of concrete mix
(d) all of the above

166. The strength of cement concrete increases with the increase of water cement ratio.
(a) Agree (b) Disagree

167. The cement concrete having water-cement ratio less than 0.45 by weight, causes honey-comb structure.
(a) Correct (b) Incorrect

168. Hydration of cement is due to the chemical action of water with
(a) dicalcium silicate (b) tricalcium silicate
(c) tricalcium aluminate (d) all of these

169. The development of first 28 days strength is on account of the hydration of
(a) dicalcium silicate (b) tricalcium silicate
(c) tricalcium aluminate (d) tetra calcium alumino ferrite

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170. If the water cement ratio is more, then the
(a) strength of concrete will be less (b) durability of concrete will be less
(c) capillary voids will be more in the physical structure of hydrated cement
(d) all of the above

171. Water-cement ratio is, usually, expressed in
(a) litres of water required per bag of cement (b) litres of water required per kg of cement
(c) both (a) and (b) (d) none of these

172. High temperature ..... the setting time of cement in concrete.
(a) increases (b) decreases

173. The concrete mix is said to be workable if it has
(a) compatibility (b) movability (c) stability (d) all of these

174. Which of the following statement is correct ?
(a) Duff Abram's law is valid only when the concrete is of workable plasticity.
(b) If the water-cement ratio is less, the strength of concrete will be less.
(c) The strength of concrete decreases with age.
(d) A rich mix of concrete provides low strength than a lean mix.

175. At freezing point, the concrete sets easily.
(a) Right (b) Wrong

176. The internal friction between the ingredients of concrete is minimised by
(a) adopting coarse aggregates (b) using more water
(c) reducing the surface area (d) all of these

177. For the improvement of workability of concrete, the shape of aggregate recommended is
(a) irregular (b) angular (c) round (d) flaky

178. Smaller size aggregates require less quantity of water for lubrication.
(a) Yes (b) No

179. Grading of aggregates should be continuous for ..... mixes.
(a) lean (b) rich

180. The use of air-entraining agents in concrete
(a) increases workability of concrete (b) decreases bleeding
(c) decreases strength (d) all of these

181. The workability of concrete is expressed by
(a) water-cement ratio (b) slump value
(b) compaction factor (d) both (a) and (b)

182. The workability of concrete can be improved by adding
(a) hydrated lime (b) flyash (c) calcium chloride (d) all of these

183. The steel mould used for slump test is in the form of a
(a) cube (b) cylinder (c) frustrum of a cone (d) none of these

184. The top diameter, bottom diameter and height of the mould used for slump test are respectively
(a) 100 mm, 200 mm, 300 mm (b) 200 mm, 100 mm, 300 mm
(c) 200 mm, 300 mm, 100 mm (d) 100 mm, 300 mm, 200 mm

185. In the slump test, the maximum size of the aggregate should not exceed 38 mm.
(a) Correct (b) Incorrect

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186. For high degree of workability, the slump value should vary between
(a) 0 to 25 mm (b) 25 to 50 mm (c) 50 to 80 mm (d) 80 to 100 mm

187. For high degree of workability, the compaction factor is
(a) 0.65 (b) 0.75 (c) 0.85 (d) 0.95

188. Workability of concrete mix having very low water-cement ratio should be obtained by
(a) flexural strength test (b) slump test
(c) compaction factor test (d) any one of these

189. Vibrated concrete needs ..... slump values.
(a) less (b) high

190. Concrete with higher compaction factor has less workability.
(a) True (b) False

191. The workability of concrete by slump test is expressed as
(a) minutes (b) mm / h (c) mm^2 / h (d) mm

192. The slump test of concrete is used to measure its
(a) consistency (b) mobility (c) homogeneity (d) all of these

193. The compaction factor is the ratio of weight of partially compacted concrete to the weight of fully compacted concrete.
(a) Yes (b) No

194. If the slump of concrete mix is 70 mm, its workability is considered to be
(a) very low (b) low (c) medium (d) high

195. A compaction factor of 0.88 indicates that the workability of concrete mix is
(a) very low (b) low (c) medium (d) high

196. The Vee-Bee test is suitable for concrete mixes of low and very low workabilities.
(a) True (b) False

197. Which of the following statement is correct ?
(a) Harshness in concrete mix increases if finer aggregates to fill the voids in coarse aggregates are less.
(b) As the internal friction of aggregates increases, the workability of concrete decreases.
(c) As the slump value increases, the workability of concrete also increases.
(d) all of the above

198. More water should not be added in the concrete mix, as to increase
(a) strength (b) durability (c) water-cement ratio (d) all of these

199. The main object of proportioning concrete is to obtain
(a) required strength and workability (b) desired durability
(c) water tightness (d) all of these

200. As per IS : 459–1978, the concrete mixes are designated into
(a) 4 grades (b) 5 grades (c) 6 grades (d) 7 grades

201. Which of the following grade is not recommended by IS 456–1978 ?
(a) M 10 (b) M 20 (c) M 40 (d) M 55

202. The concrete mix of grade M 25 means that the compressive strength of 15 cm cubes at 28 days after mixing is
(a) 15 N/mm^2 (b) 20 N/mm^2 (c) 25 N/mm^2 (d) 30 N/mm^2

203. The test conducted in the laboratory on the specimen made out of trial concrete mix is called
(a) preliminary test (b) slump test (c) works test (d) none of these

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204. In performing preliminary test
(*a*) the moulds required for test specimens should be rigid
(*b*) the mix should be stored in air-tight containers
(*c*) the aggregates should be dry
(*d*) all of the above

205. After moulding, the test specimens of trial mix are placed at a temperature of
(*a*) $10 \pm 2°C$ (*b*) $15 \pm 2°C$ (*c*) $23 \pm 2°C$ (*d*) $27 \pm 2°C$

206. In order to prepare a test specimen, it is necessary to
(*a*) mix the cement and fine aggregate (sand) by dry hand
(*b*) mix the coarse aggregate
(*c*) mix water to the cement, fine aggregate and coarse aggregates
(*d*) all of the above

207. The ratio of different ingredients (cement, sand and aggregate) in concrete mix of grade M 20 is
(*a*) 1 : 1 : 2 (*b*) 1 : 1.5 : 3 (*c*) 1 : 2 : 4 (*d*) 1 : 3 : 6

208. The preliminary test is always conducted in the field.
(*a*) Agree (*b*) Disagree

209. In preliminary test, the concrete is placed in the mould in ..... layers of equal volume.
(*a*) two (*b*) three (*c*) four (*d*) five

210. Each layer of concrete placed in the mould, in preliminary test, is compacted 25 times with a 20 mm diameter rod and 60 cm in length.
(*a*) Right (*b*) Wrong

211. The preliminary test should be repeated if the difference of compressive strength of three test specimens exceeds
(*a*) 0.5 N/mm^2 (*b*) 1 N/mm^2 (*c*) 1.5 N/mm^2 (*d*) 2 N/mm^2

212. For mass concrete in piers and abutments, the grade of concrete mix used, is
(*a*) 1 : 1 : 2 (*b*) 1 : 1.5 : 3 (*c*) 1 : 2 : 4 (*d*) 1 : 3 : 6

213. In performing the works test
(*a*) the mould for test specimen should be made of non-absorbent material
(*b*) the mould should be constructed in such a way that there is leakage of water from test specimen during moulding
(*c*) the base plate of the mould should be of non-absorbent material
(*d*) all of the above

214. For highly loaded columns, the concrete mix used is of proportion
(*a*) 1 : 1 : 2 (*b*) 1 : 1.5 : 3 (*c*) 1 : 2 : 4 (*d*) 1 : 3 : 6

215. The correct proportioning of various ingredients of concrete largely depends upon
(*a*) bulking of sand (*b*) water content (*c*) absorption (*d*) all of these

216. If the proportions of different ingredients (cement, sand and aggregate) are in the ratio of 1 : 2 : 4, then the grade of concrete is
(*a*) M 10 (*b*) M 15 (*c*) M 20 (*d*) M 25

217. If 30% excess water is added, the strength of concrete is reduced by
(*a*) 30% (*b*) 40% (*c*) 50% (*d*) 60%

218. The finer the sand, greater is the bulkage.
(*a*) Correct (*b*) Incorrect

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219. The concrete in which preliminary tests are performed for designing the mix is called
(a) rich concrete (b) controlled concrete
(c) lean concrete (d) ordinary concrete

220. The maximum quantity of aggregate per 50 kg of cement should not exceed
(a) 100 kg (b) 200 kg (c) 350 kg (d) 450 kg

221. The minimum quantity of cement to be used in controlled concrete is specified as
(a) 120 kg / cm^3 (b) 160 kg / cm^3 (c) 220 kg / cm^2 (d) 280 kg / cm^2

222. The concrete in which no preliminary tests are performed for designing the mix is called
(a) rich concrete (b) controlled concrete
(c) lean concrete (d) ordinary concrete

223. The ordinary concrete is not used for ..... grade of concrete mix.
(a) M 10 (b) M 20 (c) M 25 (d) M 40

224. The controlled concrete is used for
(a) one grade of concrete mix (b) three grades of concrete mix
(c) five grades of concrete mix (d) all the seven grades of concrete mix

225. The water used for ordinary concrete is equal to 5% by weight of aggregate *plus* ..... by weight of cement.
(a) 10% (b) 20% (c) 30% (d) 40%

226. For reinforced cement concrete lintels and slabs, the nominal size of coarse aggregate should not exceed
(a) 10 mm (b) 15 mm (c) 20 mm (d) 40 mm

227. Which of following proportion of different ingredients of concrete mix confirm to the arbitrary method of mixing ?
(a) 1 : 2 : 5 (b) 1 : 3 : 7 (c) 1 : 4 : 8 (d) 1 : 5 : 9

228. The factor which effects the design of concrete mix is
(a) fineness modulus (b) water-cement ratio
(c) slump (d) all of these

229. In arbitrary mix method, the coarse aggregates are taken twice the fine aggregates.
(a) True (b) False

230. The percentage of fine aggregate to the combined aggregate (P) is obtained by the relation

(a) $P = \frac{X+Y}{X+Z} \times 100$ (b) $P = \frac{X-Y}{X-Z} \times 100$

(c) $P = \frac{X-Z}{Z-Y} \times 100$ (d) $P = \frac{Z-Y}{X-Z} \times 100$

where X, Y, and Z = Fineness modulii for coarse, fine and combined aggregates respectively.

231. In order to obtain the required workability, the minimum quantity of water to be added to fine and coarse aggregates is determined by the relation
(a) $W/C \times p = 0.3\,p + 0.1\,y + 0.01\,z$ (b) $W/C \times p = 0.1\,p + 0.3\,y + 0.001\,z$
(c) $W/C \times p = 0.001\,p + 0.1\,y + 0.3\,z$ (d) $W/C \times p = 0.3\,p + 0.001\,y + 0.1\,z$

where W/C = Water-cement ratio,
p = Quantity of cement by weight,
y = Quantity of fine aggregate by weight, and
z = Quantity of coarse aggregate by weight.

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232. If 50 kg of fine aggregates and 100 kg of coarse aggregates are mixed in a concrete whose water-cement ratio is 0.6, the weight of water required for harsh mix is
(*a*) 8 kg (*b*) 10 kg (*c*) 12 kg (*d*) 14 kg

233. The number of bags of cement required per cubic metre of 1 : 2 : 4 concrete will be approximately
(*a*) 2 to 3 (*b*) 3 to 4 (*c*) 4 to 5 (*d*) 5 to 6

234. A mix with water-cement ratio of 0.78 is termed as wet mix.
(*a*) Yes (*b*) No

235. The Indian standard code specifies that the crushing strength for which the mix should be designed in the laboratory should be ..... times the strength actually required.
(*a*) 1.25 (*b*) 1.5 (*c*) 2 (*d*) 2.5

236. In voids method of determining the quantity of cement paste, it is assumed that the
(*a*) voids in the coarse aggregate are filled by the fine aggregates
(*b*) volume of fine aggregates required for 1 m^3 of coarse aggregate is equal to total voids in coarse aggregate *plus* 10% aggregate extra to allow for additional voids created by wedging action
(*c*) volume of cement paste required for 1 m^3 of coarse aggregate is equal to total volume of voids in the fine aggregate *plus* 15% aggregate extra to allow for additional voids created by wedging action
(*d*) all of the above

237. The workability of concrete mix increases with the increase in moisture content.
(*a*) Agree (*b*) Disagree

238. The importance of storing the various ingredients of concrete is
(*a*) to maintain the uniformity of grading (*b*) to maintain the uniformity of moisture
(*c*) to maintain the strength of materials (*d*) both (*a*) and (*b*)

239. The main requirement, which a ware-house should fulfil is that
(*a*) its walls should be water proof masonry construction
(*b*) its roof should be leak-proof
(*c*) it must have large number of windows
(*d*) its plinth should be very high

240. The term 'ware-house pack' means
(*a*) the total capacity of ware-house (*b*) packing of ware-house
(*c*) pressure compaction of bags on lower layers
(*d*) pressure exertion of bags on upper layers

241. To prevent the cement bags from any possible contact with moisture, the main point that should be kept in mind is that the
(*a*) space between the exterior walls and piles should be 30 cm
(*b*) cement bags should be placed closer together in the piles
(*c*) width and height of the pile should not exceed 3 m and 2.70 m respectively
(*d*) all of the above

242. In designing a ware-house, it is assumed that
(*a*) each bag contains 50 kg of cement
(*b*) floor area occupied by one bag of cement is 0.3 m^2
(*c*) height of each cement bag containing 35 litres of cement is 0.18 m
(*d*) all of the above

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243. The 'first-in, first-out' rule should be applied when cement bags are to be removed from the ware-house.
(a) True (b) False

244. Which of the following statement is wrong ?
(a) If the height of pile exceeds 1.44 m, the cement bags should be arranged in header and stretcher fashion.
(b) The cement bags should be rolled on the floor when it is taken out for use.
(c) The strength of cement decreases with the passage of time.
(d) none of the above

245. The capacity of a ware-house depends upon the
(a) floor area occupied by one cement bag (b) height to which the cement bags are piled
(c) either (a) and (b) (d) both (a) and (b)

246. If the effective plan area of a warehouse is 54 m^2, and the maximum height of pile permitted is 2.7 m, then the number of cement bags to be stored is
(a) 2000 (b) 2200 (c) 2500 (d) 2700

247. The process of proper and accurate measurement of all concrete materials for uniformity of proportions and aggregate grading is called
(a) proportioning (b) grading (c) mixing (d) batching

248. The importance of batching is to obtain
(a) strength (b) workability (c) durability (d) all of these

249. Weight batching is done by
(a) spring dial scale (b) platform weighing machine
(c) portable weigh batchers (d) all of these

250. When the batching of material is done by weight
(a) the bucket in which the material is to be weighed should be cleaned thoroughly
(b) the weighing machine should be levelled before placing the material
(c) the chart should be prepared indicating the weight of each material used for different strengths of concrete
(d) all of the above

251. For batching 1 : 2 : 4 concrete mix by volume, the ingredients required per bag of cement are
(a) 50 kg of cement : 70 kg of fine aggregate : 140 kg of coarse aggregate
(b) 50 kg of cement : 70 litres of fine aggregate : 140 litres of coarse aggregate
(c) 50 kg of cement : 100 kg of fine aggregate : 200 kg of coarse aggregate
(d) 50 kg of cement : 100 litres of fine aggregate : 140 litres of coarse aggregate.

252. For measuring aggregates by volume, wooden batch boxes known as farmas are used.
(a) Correct (b) Incorrect

253. The measuring 50 litres of aggregate, the inner dimensions of a farma should be
(a) 25 cm × 25 cm × 40 cm (b) 29 cm × 29 cm × 48 cm
(c) 30 cm × 30 cm × 50 cm (d) 31 cm × 31 cm × 52 cm

254. The finished concrete is measured in litres.
(a) Right (b) Wrong

255. The mixer, which produces a steady stream of concrete as long as it is in operation, is known as
(a) non-tilling batch mixer (b) tilting type batch mixer
(c) continuous mixer (d) none of these

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256. The process of mixing, transporting, placing and compacting the cement concrete should not take more than
(*a*) 30 minutes (*b*) 60 minutes (*c*) 90 minutes (*d*) 120 minutes

257. For continuous transportation of concrete, the method used is
(*a*) transport of concrete by pans
(*b*) transport of concrete by wheel barrows
(*c*) transport of concrete by belt concrete conveyors
(*d*) transport of concrete by pumps.

258. For concreting of tunnel lining, the concrete is transported by
(*a*) pumps (*b*) pans (*c*) wheel barrows (*d*) containers

259. The concrete can be lifted by pumps through a maximum vertical distance of
(*a*) 10 m (*b*) 20 m (*c*) 30 m (*d*) 50 m

260. In transportation of concrete by pumps
(*a*) the slump should not be less than 50 mm and more than 80 mm
(*b*) the water cement ratio should remain between 0.5 to 0.65
(*c*) the number of bends in a pipe line should be as small as possible
(*d*) all of the above

261. The diameter of the pipe line used for transportation of concrete by pumps should not exceed
(*a*) 10 cm (*b*) 20 cm (*c*) 30 cm (*d*) 40 cm

262. To prevent segregation, the concrete should not be thrown from a height of more than
(*a*) 1/2 m (*b*) 1 m (*c*) 1.5 m (*d*) 2 m

263. The placement of concrete should be discontinued during rainy periods.
(*a*) Yes (*b*) No

264. The concrete ..... be laid continuously in order to prevent the formation of irregular and unsightly lines.
(*a*) should (*b*) should not

265. The placing of concrete should start width-wise in reinforced cement concrete slabs from one end.
(*a*) True (*b*) False

266. The process of consolidating concrete mix after placing it in position is termed as
(*a*) curing (*b*) wetting (*c*) compaction (*d*) none of these

267. When the concrete mix is too wet, it causes
(*a*) segregation (*b*) low density
(*c*) excess laitance at the top (*d*) all of these

268. The object of compaction is to
(*a*) eradicate air holes (*b*) give maximum density
(*c*) ensure intimate contact between the concrete and the surface of reinforcement
(*d*) all of the above

269. The factor which effect the quality of compaction, is
(*a*) density of concrete (*b*) strength of concrete
(*c*) durability of concrete (*d*) all of these

270. For compacting large sections of mass concrete in structures, the type of vibrator used is
(*a*) internal vibrator (*b*) screed vibrator
(*c*) form vibrator (*d*) all of these

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271. For compacting plain concrete or one-way reinforced concrete floors, the vibrator used is
(a) internal vibrator (b) screed vibrator
(c) form vibrator (d) all of these

272. The slump should not exceed 50 mm when compacting concrete with vibrators.
(a) Agree (b) Disagree

273. When vibrators are used for compaction, the consistency of concrete depends upon the
(a) type of mix (b) placing conditions
(c) efficiency of vibrator (d) all of these

274. If the slump of the concrete mix is less than 50 mm, then while compacting it with vibrators, the segregation will not take place.
(a) Right (b) Wrong

275. Which of the following statement is correct while compacting concrete with vibrators ?
(a) The vibrator should be inserted horizontally.
(b) The vibrator should not be immersed through a full depth of freshly laid concrete.
(c) The vibrator should not touch the form surface.
(d) all of the above

276. The levelling operation that removes humps and hollows and give a true, uniform concrete surface is called
(a) screeding (b) floating (c) trowelling (d) compacting

277. The final operation of finishing the concrete surface is called
(a) screeding (b) floating (c) trowelling (d) none of these

278. The process of removing the irregularities from the surface of concrete left after screeding is called floating.
(a) Correct (b) Incorrect

279. Trowelling should be finished on the same day of its laying operation.
(a) Yes (b) No

280. The process of hardening the concrete mixes by keeping its surface moist for a certain period is called
(a) floating (b) curing (c) screeding (d) none of these

281. The object of curing is to
(a) prevent the loss of water by evaporation (b) reduce the shrinkage of concrete
(c) preserve the properties of concrete (d) all of these

282. After the curing of 28 days, the concrete gains strength upto
(a) 40% (b) 67% (c) 100% (d) 122%

283. Proper curing of cement concrete, is good for its
(a) volume stability (b) strength (c) wear resistance (d) all of these

284. Under normal circumstances, the beam soffits may be removed after
(a) 2 days (b) 7 days (c) 14 days (d) 21 days

285. Vertical sides of columns may be stripped after
(a) 1 to 2 days (b) 7 days (c) 14 days (d) 21 days

286. In concrete walls, construction joints should be provided at the
(a) floor level (b) soffit level of lintels
(c) sill level of windows (d) all of these

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287. The construction joints in cement concrete
(a) should be located where bending moment is large
(b) should be located where shear force is large
(c) should not be provided at the corners
(d) should be spaced at a distance of 3 m apart in case of huge structures

288. The construction joints are generally provided in concrete
(a) roads (b) retaining walls (c) lining of tunnels (d) all of these

289. The most useless aggregate is, whose surface texture is
(a) smooth (b) glossy (c) granular (d) porous

290. The bulk density of aggregates depends upon its
(a) shape (b) grading (c) compaction (d) all of these

ANSWERS

1. (d)	2. (d)	3. (c)	4. (a)	5. (a)	6. (d)
7. (b)	8. (d)	9. (c)	10. (a)	11. (c)	12. (d)
13. (a)	14. (a)	15. (a)	16. (b)	17. (b)	18. (c)
19. (b)	20. (b)	21. (c)	22. (a)	23. (b), (c)	24. (a)
25. (a)	26. (d)	27. (b)	28. (a)	29. (c)	30. (b)
31. (d)	32. (d)	33. (a)	34. (b)	35. (d)	36. (d)
37. (b)	38. (d)	39. (c)	40. (d)	41. (c)	42. (a)
43. (a)	44. (c)	45. (a), (b)	46. (b)	47. (b)	48. (d)
49. (a)	50. (d)	51. (a)	52. (a)	53. (b)	54. (c)
55. (a)	56. (d)	57. (d)	58. (b)	59. (d)	60. (d)
61. (a)	62. (a)	63. (d)	64. (c)	65. (a)	66. (a)
67. (d)	68. (b)	69. (b)	70. (d)	71. (b)	72. (b)
73. (a), (b)	74. (c)	75. (c)	76. (b)	77. (b)	78. (d)
79. (b)	80. (d)	81. (C), (D), (A), (B)		82. (a)	83. (c)
84. (b)	85. (c)	86. (d)	87. (d)	88. (d)	89. (b)
90. (c)	91. (d)	92. (b)	93. (c)	94. (b)	95. (c)
96. (b)	97. (a)	98. (c)	99. (b)	100. (a)	101. (c)
102. (c)	103. (d)	104. (c)	105. (d)	106. (d)	107. (d)
108. (a)	109. (c)	110. (b)	111. (d)	112. (b)	113. (c)
114. (b)	115. (b)	116. (c)	117. (b)	118. (b)	119. (a)
120. (d)	121. (a)	122. (d)	123. (a)	124. (a)	125. (b)
126. (a)	127. (a)	128. (b)	129. (d)	130. (b)	131. (c)
132. (a)	133. (b)	134. (d)	135. (d)	136. (a)	137. (a)
138. (a)	139. (c)	140. (d)	141. (a)	142. (a)	143. (c)
144. (d)	145. (a)	146. (c)	147. (b)	148. (c)	149. (a)
150. (d)	151. (d)	152. (c)	153. (a)	154. (a), (b)	155. (d)
156. (b)	157. (d)	158. (a)	159. (b)	160. (a)	161. (a), (b)

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162. (c), (d) 163. (a), (b) 164. (a) 165. (c) 166. (a) 167. (b)
168. (d) 169. (b) 170. (d) 171. (a) 172. (b) 173. (d)
174. (a) 175. (b) 176. (d) 177. (c) 178. (b) 179. (a)
180. (d) 181. (d) 182. (d) 183. (c) 184. (a) 185. (a)
186. (d) 187. (d) 188. (c) 189. (a) 190. (a) 191. (d)
192. (a) 193. (a) 194. (c) 195. (c) 196. (a) 197. (d)
198. (c) 199. (d) 200. (d) 201. (d) 202. (c) 203. (a)
204. (d) 205. (d) 206. (d) 207. (b) 208. (b) 209. (b)
210. (b) 211. (c) 212. (d) 213. (d) 214. (a) 215. (d)
216. (b) 217. (c) 218. (a) 219. (b) 220. (d) 221. (c)
222. (d) 223. (d) 224. (d) 225. (c) 226. (b) 227. (c)
228. (d) 229. (a) 230. (c) 231. (a) 232. (c) 233. (d)
234. (a) 235. (a) 236. (d) 237. (a) 238. (d) 239. (a), (b)
240. (c) 241. (d) 242. (d) 243. (a) 244. (d) 245. (d)
246. (d) 247. (d) 248. (d) 249. (d) 250. (d) 251. (b)
252. (a) 253. (d) 254. (b) 255. (c) 256. (a) 257. (c)
258. (a) 259. (d) 260. (d) 261. (c) 262. (b) 263. (a)
264. (a) 265. (a) 266. (c) 267. (d) 268. (d) 269. (d)
270. (a) 271. (b) 272. (a) 273. (d) 274. (a) 275. (c)
276. (a) 277. (c) 278. (a) 279. (a) 280. (b) 281. (d)
282. (c) 283. (d) 284. (b) 285. (a) 286. (d) 287. (c)
288. (d) 289. (b) 290. (d)

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17.1 Introduction to Geology

17.1.1 Geology as a Science

Geology (Greek, *Ge* = Earth, *logos* = science) is that branch of natural science which deals with the earth as a whole, regarding its history, composition, structure and day-to-day changes which are visible on the earth's surface, as well as those beneath the ground. Geology is important and useful as well as it reveals the hidden treasures of the earth *i.e.*, presence of minerals which form invaluable raw materials for different types of industries. As a matter of fact minerals form an important natural wealth of a country. It is, therefore, essential that their study should be pursued in a most systematic and scientific manner so that maximum benefit may be derived out of them.

17.1.2 Geology and Engineering

As a matter of fact, the progress in a certain branch of science enriches the other branches of the bordering sciences. Similarly, with the passage of time, the concepts of Geology, aided by other branches of physical sciences, started contributing and proved beneficial to Engineering regarding the problems arising from the conditions near the earth's surface.

Today, the knowledge of Geology has become an essential feature for a Civil Engineer, and in this connection certain aspects of Geology have become of much importance to an engineer. Compilation of all such aspects has given birth to Engineering Geology. Thus Engineering Geology, as the name indicates, is that branch of earth science or Geology which is of a particular interest for an engineer. It may be noted, that its complete knowledge is essential in planning and carrying out various engineering projects safely and successfully.

17.1.3 Sub-divisions of Geology

The science of Geology is a very vast subject. But if it is seen from an engineering point of view, we find that the Engineering Geology can be sub-divided into the following main heads:

1. General Geology,
2. Petrology,
3. Civil Engineering Geology,
4. Indian Geology.

17.1.4 General Geology

It includes the study of Geology, in general, the knowledge of which is very essential to study he subject systematically. It includes the following topics:

1. The Earth,
2. Palaeontology,
3. Mineralogy.

1. The Earth. It deals with the necessary background of our Solar system, and the importance f our planet (*i.e.*, earth) in it. It also deals with the history of the earth, *i.e.*, origin and age of the earth, longwith its different parts *i.e.*, atmosphere, crust and interior of the earth.

2. Palaeontology. It deals with study of ancient events of a region, which is done by the ystematic study of fossils (*i.e.*, remains or traces of living organisms of the past). It also deals with ıe various factors, which help in preserving the fossils.

3. Mineralogy. It deals with the various properties and uses of minerals. A mineral may be

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fined as an inorganic substance having, usually, a definite chemical composition and homogeneous character.

The study of mineralogy is purely of economic and geologic interest.

7.1.5 Petrology

This branch of Geology deals with the formation, composition and uses of rock (*i.e.*, stones). e rocks are broadly classified, on the basis of their mode of origin, into the following three catego-es:

1. Igneous rocks 2. Sedimentary rocks 3. Metamorphic rocks.

1. **Igneous rocks.** These are the rocks which are formed by the direct solidification of magma ther on the surface or below it.

2. **Sedimentary rocks.** These are the rocks which are formed by the consolidation of sediments f the pre-existing rocks under the mechanical, chemical or organic activities of the wind, running ater etc.

3. **Metamorphic rocks.** These are the rocks which are formed under the influence of heat, ressure or both from the pre-existing rocks.

The study of petrology is most important for a Civil Engineer, in the selection of suitable rocks r building stones, road metal etc.

7.1.6 Engineering Geology

It includes that part of the science of Geology, the knowledge of which is very essential for rious branches of Engineering; namely civil engineering, mining engineering, metallurgical gineering, etc. Since the science of Engineering Geology is more related to Civil Engineering, as mpared to other branches, therefore, in this part, a particular stress has always been laid for Civil gineers. It includes the following topics:

1. Physical Geology,
2. Structural Geology,
3. Field Geology,
4. Hydrology,
5. Earth Movements and Volcanic Activities,
6. Civil Engineering Geology.

1. **Physical Geology.** It deals with the various processes of physical agents, such as wind, nning water, glaciers and sea waves. These agents go on modifying the surface of the earth ntinuously. It includes the study of their erosion, transportation and deposition.

The study of Physical Geology is most useful for a Civil Engineer, as it reveals the constructive d destructive processes of various physical agents at a particular site. It helps in selecting a suitable e for different types of projects, to be undertaken after studying the effects of the physical agents, hich go on modifying the surface of the earth physically, chemically, and mechanically.

2. **Structural Geology.** It deals with the arrangement or architecture of the rocks, which form e earth's crust. It also includes the factors, which lead to such an arrangement *i.e.*, folds, faults and ints.

The study of Structural Geology is most useful for a Civil Engineer, as the arrangement of the cks always plays an important role for the selection of suitable suites for all types of projects such dams, tunnels, multi-storeyed buildings etc.

3. **Field Geology.** It deals with the study of rocks, alongwith their structural behaviour and neralogical composition in the field. It has the following two main features:

(*i*) Geological survey in the field, and

(*ii*) Interpretation in the laboratory.

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4. Hydrology. It deals with the study of quality and quantity of water present in the rocks and in different states. It also includes the study of atmosphere water, surface water and underground water.

5. Earth Movements and Volcanic Activities. It deals with the earth movements *i.e.*, earthquakes, landslides and volcanic activities, with a particular stress on their mode of origin. It also includes the damages they are likely to cause, alongwith suitable treatments to improve the situation according to the requirements.

6. Civil Engineering Geology. This, perhaps, is the youngest branch of Geology, which deals with all the geological implications alongwith suitable treatments arising in the field of a Civil Engineer. It also includes such details in the construction of dams, tunnels, mountain roads; selecting suitable sites for reservoirs and suitable rocks for building stones and road metals.

17.1.7 Indian Geology

This branch of Geology, as the name indicates, deals with the Geology of our motherland. Though, the study of Indian Geology is of much importance for the students of Geology, yet its few applications are important from the subject point of view. It includes the following topics:

1. Physiography of India
2. Stratigraphy of India
3. Coal and petroleum in India
4. Economic minerals of India.

1. Physiography of India. It deals with the various physiographic features of India. It also includes the study of mountains, valleys and lakes, alongwith a particular stress on their mode of formation.

2. Stratigraphy of India. It deals with stratigraphy (*i.e.*, study of the stratified rocks) of India. It also includes the correlation of Indian rock systems with that of standard stratigraphical scale.

3. Coal and Petroleum in India. It deals with mode of origin of coal and petroleum. It also includes the quantity and amount of coal and petroleum available in India. Though the subject-matter is purely of geologic interest, yet in this modern age of thermo-nuclear warfare, coal and petroleum behave as a nerve-centre of the strategic industries.

4. Economic minerals of India. It deals with the importance of minerals (which form the natural wealth) of a country. It also includes the amount of minerals available in India.

17.2 The Earth

17.2.1 Our Solar System

With the present planetary knowledge, we can only say that our Solar system consists of a central body, the Sun, around which there are nine major planets (including the earth) which in the order of distance from the Sun are:

1. Mercury.	2. Venus.	3. Earth
4. Mars.	5. Jupiter.	6. Saturn.
7. Uranus.	8. Neptune.	9. Pluto.

17.2.2 The Earth

Following is the chart of the diameter and the area of the earth, according to the present state of knowledge about it.

Equatorial diameter	12757 km	7926.7 miles
Polar diameter	12714 km	7900.0 miles
Floor area of the sea 70.78%	361 million square km	139.4 million square miles
Area of the land 29.22%	149 million square km	57.5 million square miles

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Total	510 million square km	196.9 million square miles.

17.2.3 Parts of the Earth

The outer envelops of the gaseous material, surrounding the earth, is called atmosphere. Under the **atmosphere** is our earth, on which we live. That part of the earth, which is in the form of land is known as the **earth's crust**. It also includes the highest peaks of mountains and floors of the oceans; part of the land which is visible on the globe is called **lithosphere**. (Greek, *Lithos* = stone).

We know that nearly 3/4 of the whole surface on the earth is covered with natural waters like oceans, seas, lakes, rivers etc. which is in the form of more or less a continuous envelop around the earth. This envelop of water is called **hydrosphere** (Greek, *Hudour* = water).

Under the earth's crust is the interior of the earth. It is further sub-divided into three shells depending upon the nature in the materials it is made up of as in Fig. 17.1.

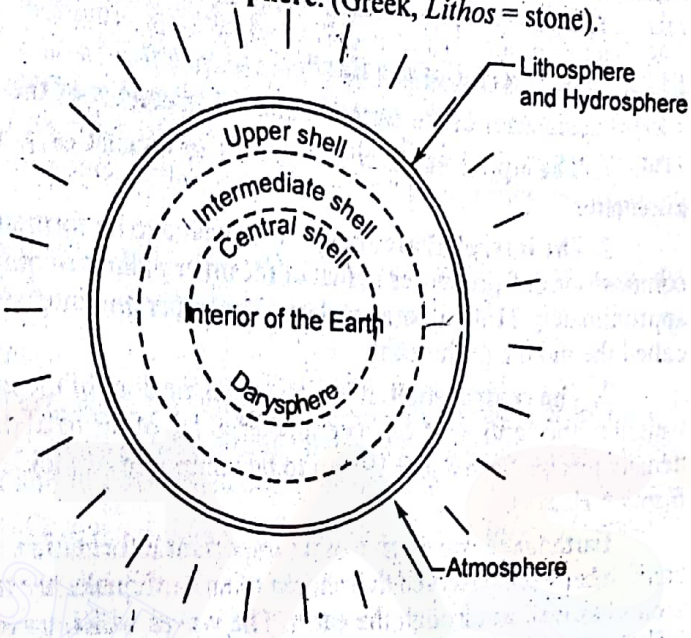

Fig. 17.1

17.2.4 The Earth's Crust

As already explained, it is the outer casing of our planet, on which we live. It also includes highest peaks of mountains and floors of the oceans.

The earth's crust is composed of different rocks. In an ordinary sense the term 'rock' means something hard and resistant, but in Geology, the term rock not only means something hard and resistant, but the meaning of this word has been extended so as to include all natural substances of the earth's crust, which may be hard like granite or soft like clay and sand. It has been estimated that maximum (95%) of the earth's crust is made up of primary *i.e.* first formed (igneous) rocks which is mostly composed of granite having felspar, quartz and mica in varying proportions. The remaining 5% of the crust is made up of secondary (sedimentary and metamorphic) rocks, which are formed from igneous rocks due to constant wearing down or breaking up chemically, mechanically or otherwise.

The earth's crust is in the form of a very thin layer of solidified rocks and is heterogeneous in nature. These rocks may be classified on the basis of their density into the following two groups:

1. Sial (*Si* = Silicon and *al* = aluminium) having density 2.75 to 2.90.
2. Sima (*Si* = Silicon and *ma* = magnesium) having density 2.90 to 4.75.

It has been estimated that sial rocks are about 70% of the earth's crust, which include chiefly granite and silica. These rocks are generally on the upper regions of the crust.

Sima rocks include heavy and dark coloured rocks like basalts. In these rocks, the percentage of silica is reduced and magnesium attains the next importance in the place of aluminium of sial rocks. These rocks are generally found on the floors of the oceans and beneath sial rocks.

It has been observed in deep wells, borings and mines etc. that the temperature increases with depth. The amount with which the temperature increases is not constant all over the world, but varies from place to place depending upon the type of the rocks and its distance from the equator.

Generally there is an increase of 1°C for every 40 metres depth. It is still an uncertain and a geological problem, as to how far downward this increase of temperature continues. If it may be

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assumed that this temperature gradient remains the same, as it is near the earth's surface, there will be a stage within the earth, which will have a temperature above the melting point of all the rocks. Such a stage is believed to be at a depth of about 40 kilometres (25 miles). Temperature at this depth is believed to be about 1000°C. That is why, sometimes we say that depth of the crust is about 40 kilometres only.

This depth is quite insignificant as compared to the radius of the earth which is 6378 kilometres. The outermost surface of the crust, which is in the form of thin layers, is called soil. It is mainly composed of a very thin veneer of secondary (sedimentary and metamorphic) rocks. The soil is made up of loose and consolidated matter, which differs from the underlying rocks in colour, texture, structure and physical as well as chemical properties. It may be noted that engineering is directly or indirectly related to it, and the processes involved in its change.

17.2.5 The Interior of the Earth

The interior of the earth is believed to consist of the following 3 shells:

1. The upper shell. It is believed to consist of granite and olivine up to a depth of 1000 kilometres.

2. The intermediate shell. It is believed to be formed of stony meteorites *i.e.*, having the same composition and properties as that of the other planets of our Solar system. This shell is believed to be approximately 2100 kilometres deep. The upper and intermediate shells in a combined form are also called the mantle of the earth.

3. The central shell. It is also called the core of the earth. It is believed to have 1/3 of the total weight of the earth, whereas its diameter is 1/2 of the total diameter of the earth. It is believed that its density lies between 8 and 19 and to be composed of nickle and iron. It is called barysphere (Greek. *Baros* = Heavy).

Earthquake waves give us an important information regarding the nature of the interior of the earth. It has been observed that shocks of an earthquake are transmitted from its focus in all directions, around as well as through the earth. The waves which travel through the earth have been classified into the following two categories:

1. Transverse waves 2. Longitudinal waves

We know that the velocity of earthquake waves depends upon the resistance offered by the rocks, or in other words on the elasticity of the rocks, through which they pass. It means that more the elasticity of rocks, greater will be the velocity of waves. It may also be noted that the transverse waves do not pass through the liquids.

It has been observed from the record of seismic (Greek, *Seismos* = Earthquake) activity, that the transverse waves vibrate through the earth up to a depth of about 3150 kilometres. That is why we say that the outer shell having a thickness of about half the radius of the earth is in a solid state. It has also been observed that beyond this depth transverse waves disappear whereas the longitudinal waves travel, but with a lesser velocity. Thus we may say that the central core of about 3150 kilometres radius is in a liquid state.

Temperature of the centre of the core is believed to be 6000°C, which is the same as the temperature of the Sun.

17.3 Palaeontology

The systematic study of ancient events and their interpretation on the basis of stratified rocks is known as palaeontology.

Fossils are the remains or traces of the living organisms, such as plants or animals. The process of preservation of fossils depends upon the following factors:

(*i*) The fossils of harder parts like shells, skeletons, bones etc: are better preserved than the softer parts.

(*ii*) The fossils are better preserved, if there are suitable environments at the time of burial (*i.e.*, absence of the destructive chemical agents).

(*iii*) The fossils are better preserved, if their dead bodies are immediately buried.

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During the last hundred years much importance has been attached to the fossils, since they are considered to be the most reliable evidence for studying the past history of region, and correlating the different series of rocks with that of the standard stratigraphical scale. The important uses of the fossils are:

(*i*) In the study of evolution and migration of animals and plants through ages.
(*ii*) In establishing the geological age of rock beds and their correct order of succession.
(*iii*) In the study of ancient geography of an area.
(*iv*) In the study of ancient climate of an area.

17.4 Mineralogy

17.4.1 Introduction

A mineral may be defined as an inorganic substance, having usually a definite chemical composition, which can be expressed by a chemical formula and physical properties. It is always homogeneous in nature, even if minutely examined under a microscope. As a matter of fact, minerals form an invaluable raw material for different types of industries and also form an important natural wealth of a country. A detailed study of minerals, regarding their properties and uses, is known as mineralogy.

Though the subject matter is purely of economic and geologic interest, yet its few applications are important from the subject point of view.

17.4.2 Physical Properties of a Mineral

It has been observed that every mineral has a set of physical as well as chemical properties. A careful study of these properties is essential for its identification. In general, following properties are studied for the identification of a mineral and to distinguish one from another.

1. Structure 2. Crystal system 3. Colour 4. Lustre 5. Streak. 6. Hardness 7. Specific gravity.
8. Cleavage 9. Fracture.

1. Structure. The structure of a mineral may be defined as the property, which indicates the order, in which the atoms of a mineral are arranged. It is an important criterion for the identification of a mineral. The terms used are:

Fibrous	...	When a mineral has a thread like structure.
Columnar	...	When a mineral has a thick or thin column like structure.
Granular	...	When a mineral has numerous grains, coarse or fine, packed together.
Crystalline	...	When a mineral has fine crystals packed together.
Massive	...	When a mineral has an irregular structure.
Bladed	...	When a mineral appears to be composed of the blade like structure.

2. Crystal system. A crystal of a mineral may be defined as a regular polyhedral form, bounded by smooth surfaces, which is acquired under the action of intermolecular forces. It is an important property, of a mineral, for its identification. There are 32 classes of the crystals, based on the symmetry and internal structure. But in common practice, there are 6 groups or crystal systems and a given crystal must belong to any one of them. These may be summarised as below:

(*i*) *Cubic (Isometric) system.* This system includes all those crystals which have three equal axes, and at right angles to each other. The most common examples of cubic system crystals are cube and octahedron.

(*ii*) *Tetragonal system.* This system includes all those crystals, which have three axes at right angles to each other. Two of these axes are equal and horizontal and the third one, which is vertical, is either longer or shorter than the horizontal ones.

The most common examples of tetragonal system crystals are regular prisms and pyramids.

(*iii*) *Hexagonal system.* This system includes all those crystals which have four axes. Three of these axes are equal, horizontal and meet at an angle of 60° with each other.

The most common examples of hexagonal crystal system are regular hexagonal prisms and hexagonal pyramids.

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(*iv*) *Orthorhombic system.* This system includes all those crystals, which have three axes, at right angles to each other. But all the three axes are essentially unequal

(*v*) *Monoclinic system.* This system includes all those crystals, which have three essentially unequal axes. Two of these axes are horizontal and are inclined at certain angle (but not at right angle) and the third one is vertical.

(*vi*) *Triclinic system.* This system includes all those crystals, which have three unequal axes, and none of them is at right angles to the other.

3. Colour. For some minerals, their colour is considered to be an important property for identification. But for others it is of little significance, as a mineral may occur in a variety of colours; whereas several different minerals may occur in the same colour. Thus, due to the presence of impurities in the minerals, the colour is not a reliable test, which would have been the important criterion otherwise. In spite of the above mentioned apparent difficulties the colour is still considered to be an important property of a mineral. Sometimes, an experienced and skilled observer can identify a mineral by observing its colour only.

4. Lustre. The lustre of mineral may be defined as its appearance in a reflected light, or in other words the radiant beauty of a shining surface is called its lustre. It depends upon the amount of reflection at the surface. It may be noted that this property of a mineral is independent of its colour. The terms used, in order of decreasing amount of lustre, are:

Adamantine	...	When a mineral has lustre like diamonds.
Vitreous	...	When a mineral has a lustre like a broken glass.
Resinous	...	When a mineral has a lustre like greese.
Pearly	...	When a mineral has a lustre like pearls.
Metallic	...	When a mineral has a lustre like metal.
Dull	...	When a mineral has no lustre.

5. Streak. The streak of a mineral may be defined as the colour of its fine powder, which is obtained by scratching or rubbing the mineral on a piece of an unglazed porcelain plate called streak plate. It may be noted that the streak of a mineral is fairly constant in colour and is considered to be an important criterion for its identification.

6. Hardness. The hardness of a mineral may be defined as the resistance offered to abrasion. This property of a mineral is fairly constant, and is considered to be an important criterion for its identification. The hardness of a mineral is determined by observing the comparative case or difficulty in scratching it with another mineral of known hardness. It is always expressed in Moh's scale of hardness, given below:

1. Talc 2. Gypsum 3. Calcite 4. Fluorite 5. Apatite 6. Orthoclase 7. Quartz 8. Topaz 9. Corundum 10. Diamond.

It has been observed that a soft mineral like talc and gypsum can be scratched even with a finger nail, a steel knife can cut apatite and orthoclase but not quartz.

7. Specific gravity. The specific gravity of a mineral may be defined as the ratio of its weight to an equal volume of water at 4°C. (39.2°F.) and is always expressed in numbers. The specific gravity of a mineral depends upon the weight and spacing of its atoms. A mineral consisting of heavier and closly spaced atoms will have a high specific gravity and a mineral consisting of lighter and widely spaced atoms will have a low specific gravity.

The specific gravity of a mineral is often considered to be an important property for its identification. All minerals have been found to range in specific gravity from 1 to 20. But most of them lie between 2 to 7.

8. Cleavage. Several minerals have a tendency to split up easily along certain parallel planes producing more or less a smooth surface. This habit or tendency of a mineral, in which it tends to split up, is known as cleavage. It is also an important criterion for the identification of a mineral. The terms used are:

Perfect, good or distinct ... when a mineral can split up with great ease and gives a smooth surface.

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Poor, imperfect or none ... when a mineral does not split up evenly with an average force.

9. **Fracture.** The fracture of a mineral may be defined as the appearance of its broken surface. is also an important criterion for the identification of a mineral. The terms used are:

Conchoidal ... when a mineral breaks up with a curved surface.

Even ... when a mineral breaks up with almost a smooth and flat surface.

Uneven ... when a mineral breaks up with an irregular and rough surface.

Hackly ... when a mineral breaks up with an irregular surface having sharp edges.

1.5 Petrology

1.5.1 Introduction

Petrology (Greek, *Petra* = Rock, *logos* = science) is that branch of Geology which deals with e study of rocks, with a particular stress on their mode of formation, composition and uses for all pes of engineering works.

1.5.2 Rocks

A rock may be defined as an aggregate of mineral constituents, which form the earth's crust. In ordinary sense, the term *'rock'* means 'something hard and resistant', but, in Geology, the term ck not only means something hard and resistant, but the meaning of this term has been extended so to include all natural substances of the earth's crust, which may be hard like granite or soft like clay sand.

Thus, combining the definitions of rocks in Geology and ordinary sense, the hard and resistant bstances like granite, marble sandstone etc., may be called stones. Now, a little consideration will, ow, that all the stones are rocks, but at the same time, all the rocks are not necessarily stones.

1.5.3 Classification of Rocks

The rocks may be broadly classified on the basis of their mode of origin, into the following ree groups:

1. Igneous Rocks 2. Sedimentary rocks 3. Metamorphic Rocks.

1.5.4 Igneous Rocks

Primary or first formed rocks are called igneous (Latin, *Ignis* = Fire) rocks. It has been observed deep wells, borings, mines etc. that the temperature increases with the depth. Generally, there is an crease of 1°C for every 40 meters depth. It is still an uncertain geological problem, as to how far ownward this increase of temperature continues. If, it may be assumed that this temperature gradient mains the same, as it is near the earth's surface, there will be a stage in the interior of the earth, hich will have a temperature above the melting point of all the rocks. Such a stage is believed to be a depth of about 40 kilometres (25 miles) where the temperature is believed to be about 1000°C. At is depth, all the rocks are believed to exist in a molten state. This molten material or liquid rock hen existing below the earth's surface is called *magma* but when forced out on the earth's surface, is lled *lava*.

When the magma comes out on the earth's surface, the gases contained in it escape into the here, and the remaining is called lava. Magma and lava differ from one another, roughly in the ase as soda water differs from ordinary water.

The magma remains in the molten state, so long its physical and chemical environments remain changed. But whenever some change (pressure, temperature etc.) takes place, the magma no longer mains in molten state; but is changed into a solid state called rock. All these rocks, which are rmed directly by the solidification of magma on the earth's surface or below it are called igneous cks.

1.5.5 Formation of Igneous Rocks

We have discussed that at about a depth of 40 kilometres in the earth, the rocks are believed to e in a molten state. Due to enormous heat and pressure, this molten material always has a tendency

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to penetrate into the cracks and lines of weakness of the thin solid crust of the earth, and thus tries to make its way out on the surface of the earth.

Sometimes, the magma, during its endeavour to come out on the earth's surface, is successful in coming out. But sometimes the magma is held up by strong and massive rock masses, below the earth surface, during its upward journey. If the magma is successful in coming out on the earth's surface, it is erupted out from a weak point with a great force, and spreads out on the surface of the earth. This spread out lava solidifies due to cool temperature of the atmosphere. But, if the magma is held up below the earth's surface, during its upward journey, it is then unable to descend. This magma then slowly cools down, and ultimately solidifies. The process of solidification of the lava or magma (as the case may be) gives birth to igneous rocks.

17.5.6 Classification of Igneous Rocks

The igneous rocks have been classified, by different scientists, on different basis. But there is no definite classification, which may be accepted universally. The following two classifications are important from the subject point of view:

1. Classification Based on the Proportion of the Main Constituent i.e., Silica

Igneous rocks may be classified on the basis of the proportion of main constituent *i.e.* silica into the following two types:

(a). Acidic rocks. Acidic rocks are those, which contain a high percentage of silica (generally more than 2/3). Acidic rocks are generally light in colour and weight.

(b). Basic rocks. Basic rocks are those which contain a low percentage of silica (generally less than 1/2). Basic rocks are comparatively darker in colour and heavier, in weight, than acidic rocks.

2. Classification Based on the Mode of Solidification of Magma

Igneous rocks may also be classified on the basis of the mode of solidification of magma into the following three types:

(a). Plutonic rocks. Plutonic (Greek, *Pluto* = God of the under-world) rocks are those which are formed beneath the surface of the earth or in other words the molten material of the liquid rock is consolidated under the earth's crust. Plutonic rocks are also called intrusive rocks.

As the plutonic rocks are formed after the solidification of magma, under the earth's crust and cool very slowly, thus these are coarsely crystallined rocks. Crystals of the plutonic rocks can be easily distinguished, even with a naked eye.

(b). Hypabyssal rocks. Hypabyssal rocks are those which are formed below the earth's surface at a short distance. This happens when the magma solidifies in the form of thin sheets or wall like structure in the earth's crust.

As the hypabyssal rocks are formed below the earth's surface and cool slowly, thus these are usually crystallined rocks, though the crystals may be small.

(c). Volcanic rocks. Volcanic (Roman, *Vulcan* = God of fire) rocks are those, which are formed on the surface of the earth. This happens when the magma is forced out on the surface of the earth, due to a sudden change of pressure or temperature of the under ground. The magma breaks into the earth's crust along the line of least resistance. This magma, when forced out on the earth's surface, is called lava. The lava, which is a molten state, spreads on the earth's surface in all directions, comes in contact with air and is ultimately consolidated into rock. Volcanic rocks are also called extrusive rocks. As the volcanic rocks are consolidated very rapidly, thus are fine grained rocks.

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17.5.7 Forms of Igneous Rocks

We have discussed that the magma *i.e.*, the liquid rock, has a tendency to penetrate into the cracks and lines of weakness of the thin solid crust of the earth, and tries to make its way out on the surface of the earth. Sometimes, this magma is held up below the earth's surface and is consolidated there in different shapes, known as forms of igneous rocks.

The forms of igneous rocks, in general, may be studied under the following two headings:

1. Concordant bodies
2. Discordant bodies.

17.5.8 Structure of Igneous Rocks

The structure of a rock may be defined as its conspicuous appearance, which is well developed in a rock. A rock can be easily recognised, on a visual inspection of its structure. Though the igneous rocks exhibit many types of structures, yet the following are important from the subject point of view:

1. **Flow structure.** Sometimes the lava, during its flow, solidifies on the already solidified layers of igneous rocks more or less in parallel layers. Such a structure is known as *flow structure.*
2. **Pillow structure.** Sometimes the upper surface of the lava, during its flow, is consolidated while the lava below the surface remains liquid and is still capable of flowing. This liquid lava breaks through the already solidified layer and is consolidated on the solidified layer. Such a structure is known as a *pillow structure.* (This name is given, as the structure generally looks like a pillow on a bed).
3. **Vesicular structure.** Sometimes the lava is rich in gases (*i.e.*, it contains a huge quantity of gaseous material) at the time of its eruption. When this lava is in process of solidification, the gaseous material escapes leaving cavities behind in the cooling lava. Sometimes these cavities remain, even after the solidification of lava. Such a structure is known as a *vesicular structure.*

17.5.9 Texture of Igneous Rocks

The texture of a rock may be defined as the mutual relationship of its component grains. It depends upon the mode of occurrence and is determined by the size, shape and arrangement of component grains of a rock. The texture of igneous rocks depends entirely on the mode formation of the rock, *i.e.*, the rate of cooling of the magma. Thus all the plutonic and hypabyssal rocks are coarsely crystalline; whereas all the volcanic rocks are finely crystalline.

17.5.10 Engineering Properties of Igneous Rocks

Many of the igneous rocks, specially plutonic, have high crushing and shearing strengths, and are thus considered to be the most satisfactory rocks for all types of engineering purposes. Basalts and dark, coloured rocks are largely used as road metals and concrete aggregates.

Almost all the igneous rocks, being crystalline compact and impervious, are always considered to be safe for use as foundation rocks, abutment of dams, walls and roof of tunnels.

17.5.11 Description of Igneous Rocks

Though there are many types of igneous rocks, yet a few of them which are important from the subject point of view are discussed as below:

1. **Granite.** It is a plutonic rock of light colour, with a white or pink tint colour. It is found in batholiths, dykes and sills. Granite is the commonest type of igneous rock, having coarse to medium grained crystals.

Essential minerals are felspar and quartz. A few varieties also contain mica, hornblende, zircon, garnet, magnetite etc. All the varieties of the granite are named according to the presence of mineral except felspar and quartz e.g., muscovite granite (containing a good amount of muscovite *i.e.*, white mica), biotite granite (containing a good amount of biotite), hornblende-granite etc.

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Granite is one of the most important building stones, specially used for decorative, monumental and architectural purposes. It can take a fine polish and is the strongest stone among all the varieties of the building stones. It is also extensively used as a road metal.

2. Gabbro. Gabbro is a plutonic rock, having dark colour from grey to black (usually greenish black) due to high proportion of mafic minerals. Being a plutonic rock it is medium to coarsely crystalline. Essential minerals are plagioclase and monoclinic pyroxene. Gabbro is generally free from quartz and orthoclase.

Gabbro can take fine polish and is used for all types of structural work. It is not used for most important buildings because of its black colour and irregular joints.

3. Basalt. Basalt is a volcanic igneous rock, having dark brown colour. It has been estimated that basalt is about 5/6 of all the volcanic igneous rocks of the world.

Being a volcanic rock, it is fine crystallined. Essential minerals are plagioclase and augite. The crushed basalt is used as road metal and concrete aggregate. Basalt is mainly used for the construction of bridges and other engineering works. It is not used for very important buildings because of its dark colour and the quality of not taking a good polish.

4. Dolerite. Dolerite is a hypabyssal rock, found in sills and dykes, having a dark and grey and sometimes black colour. Its mineral composition is the same as that of gabbro. Dolerite is an intermediate rock between gabbro and basalt. As the texture increases in coarseness, it approaches gabbro; as the texture becomes finer, it approaches basalt.

Due to interlocking of crystals, the rock is very tough and is widely used as a road metal, because of its special qualities of holding a firm grip of coal tar. It is also widely used as an aggregate of concrete work.

5. Diorite. Diorite is a hypabyssal rock, found in dykes and sills, having a dark colour. Essential minerals are plagioclase and hornblende. A few varieties also contain iron oxide, apatite and sphene. The mafic minerals vary from 15 to 40 percent of the rock.

Due to interlocking of mineral constituents and high compressive strength, it is widely used as road metal and for rubble masonry.

6. Syenite. Syenite is a plutonic rock of light colour having a coarse grained texture. Essential minerals are orthoclase plagioclase and mafic minerals. A few varieties also contain hornblende biotite, augite, zircon etc. Orthoclase is the chief constituent occurring in more than 50% of the whole rock. Varieties of syenite are named according to the presence of chief mafic constituents, such a hornblende-syenite, augite-syenite, quartz-syenite etc.

Though syenite is not so common, yet it can be used instead of granite. Presence of felspar shows beautiful blue and green effects, which improves its appearance, and hence is used for decorative purposes. Syenite can also take a fine polish.

7. Pegmatite. Pegmatite is a plutonic rock having exceptionally coarse grained texture, found in dykes and veins. Pegmatites are composed of variable mineralogical composition, but similar to those of parent igneous body. Mica, which is used in the industry, is obtained from pegmatites. Thus it is considered to be the best known source rock of white mica.

17.6 Sedimentary Rocks

17.6.1 Introduction

The sedimentary rocks, as the name indicates, are those rocks which are derived from the consolidation of sediments of the pre-existing rocks (igneous, sedimentary or metamorphic) under the influence of mechanical, chemical or organic activities of the denuding agents (*i.e.*, wind, running water, glacier etc.).

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7.6.2 Formation of Sedimentary Rocks

The sedimentary rocks are formed, from the pre-existing rocks, through the following stages:

1. **Erosion of the existing rocks.** We know that the surface of the earth is exposed everywhere, for the direct and indirect actions of the physical agents. These agents continuously go on causing wear and tear of the rocks, as a result of which the massive rocks are converted into fine sediments. This process is known as rock weathering, or erosion of the existing rocks.
2. **Transportation of the eroded material.** The material, eroded by the physical agents, may or may not remain at the place of its erosion. Sometimes, a part of the eroded material, manages to evade the transporting agents and hence accumulates at the site of its erosion for a certain length of time. Another insoluble part, of the eroded material, is readily transported to new places, depending upon the circumstances. The soluble substances of the eroded material are carried in solution, to far off places. If the transporting agent is running water, then the finer insoluble material carried in suspension and soluble material carried in solution, is capable of travelling variable distances; sometimes even to reach their peaceful home in the sea.
3. **Deposition of the material.** The eroded material, which is transported, by the transporting agents, is deposited sooner or later depending upon the circumstances. These sediments continue to accumulate in suitable basins of sedimentation.
4. **Transformation of the deposited material into thick and massive rocks.** After some time, when the accumulation is sufficient, the loose rock particles are subjected to compaction (sometimes due to either overlying sediments or earth movements) and finally conversion into sedimentary rocks, under favourable circumstances. The process of transformation of loose rock particles, into hard and massive sedimentary rocks, is achieved through the following two ways:
   (a) **Welding.** Sometimes, the sediments are compacted under the influence of pressure. As a result of the compaction, the water present in the sediments is squeezed out. This process invariably results in a very dense packing of the sediments, which are firmly held together; as if they were subjected to welding.
   (b) **Cementation.** Sometimes, the sediments are held together by a foreign binding or cementing materials (as the stone chips are held together by the cement mortar). This cementing materials is generally supplied by the percolating waters. The most common cementing materials are carbonates of calcium and magnesium as well as oxides of iron and silicon.

It may be noted that the formation of sedimentary rocks, which involves processes of disintegration, transportation, deposition and compaction, is a never-ending geological phenomenon.

7.6.3 Classification of Sedimentary Rocks

The sedimentary rocks have been classified by different scientists on different bases. But there is no definite classification, which may be accepted universally. The following two classifications are important from the subject point of view:

1. Classification based on the grain size of the sediments of the rocks.

Sedimentary rocks may be classified on the basis of grain size of their sediments into the following three groups:

(a). **Argillaceous.** Argillaceous (Latin, *Argilla* = clay) are those sedimentary rocks, which are made up from the finest clay particles.

(b). **Arenaceous.** Arenaceous (Latin, *Arena* = sand) are those sedimentary rocks, which are made of particles, having grain size between 1/10 mm. and 2 mm. in diameter.

(c). **Rudaceous.** Rudaceous (Latin, *Rudnus* = rubble) are those sedimentary rocks, which are made up of particles, having grain size more than 2 mm in diameter.

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2. Classification based on the mode of formation or origin of the rocks. Sedimentary rocks may also be classified on the basis of their mode of origin into the following three groups:

(a). **Mechanical origin.** All those sedimentary rocks, which are derived from the pre-existing rocks by the mechanical action (disintegration *i.e.,* fracture and abrasion, transportation, deposition and consolidation) of the denuding agents, without any change in their chemical composition, are called sedimentary rocks of *mechanical origin.*

(b). **Chemical origin.** All those sedimentary rocks which are derived from the pre-existing rocks by the chemical action (decomposition, precipitation, crystallization etc.) of the denuding agents are called sedimentary rocks of *chemical origin.*

(c). **Organic origin.** All those sedimentary rocks, which are derived from the pre-existing rocks by the activities of the organisms (both plants and animals) are called sedimentary rocks of *organic origin.*

17.6.4 Texture of Sedimentary Rocks

The texture of a rock may be defined as the mutual relationship of its component grains. It depends upon the mode of occurrence, and is determined by the size, shape and arrangement of the component grains of a rock. The texture of a sedimentary rock depends upon:

1. **Origin of grains.** A sedimentary rock of mechanical origin has course grains; whereas a sedimentary rock of chemical origin or organic origin has fine grains.
2. **Size of grains.** The size of grains, in a sedimentary rock, varies within wide limits (ranging from finest clay particles to 25 mm. diameter). The size of grains, in a sedimentary rock, depends upon the type of weathering, nature of the parent rocks and duration of the transportation of the eroded sediments.
3. **Shape of grains.** The shapes of grains, in a sedimentary rock, also vary within wide limits; *i.e.,* round, smooth, angular etc. The shape of grains depends upon the type of weathering, nature of the parent rocks and duration of the transportation of the eroded material. A little consideration will show, that the roundness of the grains will indicate a greater amount of abrasion and a larger amount of transportation; whereas the angularity of the grains will indicate a less amount of abrasion and a little or no amount of transportation.
4. **Packing of grains.** The grains, in a sedimentary rock, may be loosely packed or densely-packed. A little consideration will show, that loosely packed grains will indicate that the rocks have been compacted with a little pressure; whereas the densely packed grains will indicate that rocks have been compacted with a greater pressure.

17.6.5 Engineering Properties of Sedimentary Rocks

The strength of a sedimentary rock depends upon the strengths of its grains or sediments (constituting the rock) and cementing material. Thus the selection of a sedimentary rock, for any building or project, should be carefully based on the strength, colour and appearance of its grains as well as the cementing material.

17.6.6 Description of Sedimentary Rocks

Though there are many varieties of sedimentary rocks, yet a few of them, which are important from the subject point of view, are described here with a particular stress on their mode of formation, composition and uses etc.

1. Breccias. Breccias are mechanically formed sedimentary rocks, consisting of angular fragments as shown in Fig. 17.2. These sediments are heterogeneous in nature; cemented together by clay, iron oxide, silica or calcium carbonate and are generally more than 2 mm. in size.

Breccias show a wide range of colours and are not in use as building stones because of their heterogeneous character and appearance. But some of the compacted varieties, which are susceptible to polish, can be used for ornamental work.

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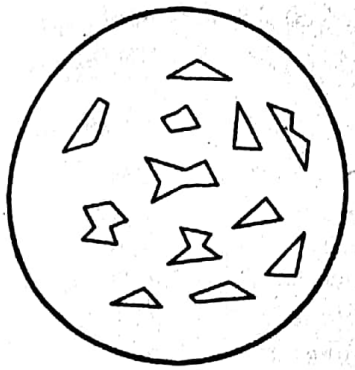

Fig. 17.2

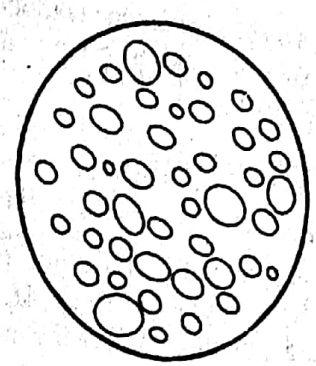

Fig. 17.3

2. Conglomerates. Conglomerates (Latin, *Cum* = Together, *lumos* = ball) are mechanically formed sedimentary rocks consisting of rounded pebbles, gravels, boulders etc. cemented together as shown in Fig. 17.3. These pebbles are generally heterogeneous in nature and are more than 2 mm. in diameter.

The pebbles are, usually, of hard and more resistant rocks such as quartz, granite and gneiss. Conglomerates are named after the fragments *i.e.*, quartz conglomerate (containing fragments of quartz), granite-conglomerate (containing fragments of granite), gneiss-conglomerate etc. A few harder and tougher varieties of conglomerates are used in foundation concrete and railway ballast.

3. Sandstone. Sandstone is a mechanically formed sedimentary rock. It is formed by the cementation of sand particles between 1/10 mm to 2 mm. in diameter. Sandstone is, perhaps, the most familiar of all the rocks, as it is easily quarried and used more than any other rock, for all types of buildings.

The sandstones are found in a variety of colours, depending upon the cementing material (which is usually silica, iron oxide or carbonates). The various varieties of sandstones are named after the cementing material *e.g.*

(*i*) *Siliceous sandstone.* It has a cement of quartz. It is a very hard and resistant rock, which is widely used for all types of important buildings.

(*ii*) *Ferruginous sandstone.* It has a cement of iron oxide and is available in red and brown colour. It is a popular building stone.

(*iii*) *Calcareous sandstone.* It has a cement of calcite. It is a weak rock and is easily affected by acids in rain water.

(*iv*) *Argillaceous sandstone.* Argillaceous (Latin, *Argilla* = clay) sandstone has a clay bond and thus is a weak rock. It is unsuitable for building purposes.

4. Shales. Shales are mechanically formed sedimentary rocks. These are formed by the compaction of the finest grained (not visible even under microscope) clays, muds or silts. Shales are characterized by a distinct fissility (Latin, *Fissilis* = Split) which may be defined as the tendency to split up into flat shell like fragments. Shales are usually soft and brittle rocks, which are used for brick and tile manufacture.

5. Limestones. Limestones are sedimentary rocks formed by the chemical as well as organic processes. These are very important and widely distributed rocks. Pure limestones are composed of calcium carbonate. But a few varieties also contain impurities such as clay, silica, quartz, felspar, pyrite etc. Varieties of limestones are named four on the basis of their mineralogical composition, into the following types:

(*i*) *Chalk.* It is a fine-grained, soft and porous variety of limestone consisting of microscopic shells of foraminifera. It is the purest form of limestone and is usually white in colour.

(*ii*) *Argillaceous limestone.* Limestones, containing clay in a considerable proportion, are known as argillaceous (Latin, *Argilla* = clay) limestones. These are used in cement industry.

(*iii*) *Shelly limestones.* Limestones, composed of shells or remains of organisms are known as shelly limestones. These are not useful for engineering purposes.

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(*iv*) *Kankar.* Limestone containing more than 30% of clay and sand is known as kankar. It is grey or khaki in colour and has a porous structure. A few varieties of kankar are used as a road metal.

17.7 Metamorphic Rocks

17.7.1 Introduction

The rocks formed from the pre-existing rocks (igneous, sedimentary or metamorphic) by the processes of metamorphism (Greek, *Meta* = Change, *morphe* = form). It is a process, by which the existing rocks are modified under the influence of heat, pressure or both.

17.7.2 Formation of Metamorphic Rocks

It has been observed that the rocks, of the earth's crust, remain in the same state so long as their temperature and pressure does not change. But whenever some change in the temperature or pressure or both takes place, the equilibrium of the rocks is disturbed and consequently a change in texture, structure or mineralogical composition takes place.

It has been observed in deep wells, borings, mines etc. that the temperature increases with the depth. In a similar manner, the pressure also increases with the depth, due to increasing load of the superimposed rocks. Thus the rocks, at a considerable depth, are subjected to a high temperature and pressure. Whenever a slight change in temperature or pressure or both takes place, due to magmetic movement or earth movement, the original minerals become unstable and there occurs a rearrangement, resulting in the formation of new minerals; which are stable under the changed conditions of temperature, pressure or both. Sometimes, the new minerals also change the texture and structure of the new rocks, under the influence of changed stress conditions.

A little consideration will show, that during the process of the transformation of the existing rocks, into the metamorphic rocks, the rocks do not melt. It is therefore obvious, that no foreign material can be added to, or subtracted from the existing rocks. Therefore the bulk chemical composition of the rocks does not change. But the new minerals, with different chemical compositions, are formed.

17.7.3 Metamorphism

The process of transforming the existing rocks (igneous, sedimentary or metamorphic) into the new metamorphic rocks under the influence of temperature, pressure or both is called *metamorphism.* Following are the three types of metamorphisms, depending upon the factors, which have been dominating during the process of transformation:

1. **Contact (thermal) metamorphism.** It is a process of formation of the metamorphic rocks, in which temperature is the dominating factor, with a negligible change in pressure. This results in recrystallisation of the rocks and new minerals are formed.
2. **Dynamic metamorphism.** It is a process of formation of the metamorphic rocks, in which temperature is the dominating factor, with a negligible change in pressure. This results in recrystallisation of the rocks and new minerals are formed.
3. **Thermodynamic metamorphism.** It is a process of formation of the metamorphic rocks, in which pressure is the dominating factor, with a negligible change in temperature. This results in deformation of the rocks and the particles get compacted and cemented.

17.7.4 Classification of Metamorphic Rocks

Metamorphic rocks have been variously classified on the basis of :

1. Texture of the rocks.
2. Structure of the rocks.
3. Degree of metamorphism.
4. Mode of origin.
5. Mineralogical composition.

But a most common way of classification of the metamorphic rocks is based on the presence of foliation. (Latin, *Folium* = Leaf) *i.e.* the property to split up into thin sheets, into the following two groups :

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(*i*) **Foliated rocks.** This group includes the rocks, that can be split up into thin sheets.

(*ii*) **Non foliated rocks.** This group includes the rocks, that cannot split up into thin sheets.

17.7.5 Engineering Properties of Metamorphic Rocks

The metamorphic rocks are extensively used as building stones. The foliated rocks like slate, gneiss and schist are used as a roofing material, table tops, stair case etc. The non foliated rocks are used as building stones and road metal. The most important non foliated rock is marble. It is considered to be an excellent building material for important monumental, historical and architectural buildings. Marble is extensively used, in modern buildings also, for decorative purposes in columns, staircases, floor etc.

17.7.6 Description of Metamorphic Rocks

Though there are many varieties of metamorphic rocks, yet a few of them which are important from the subject point of view are described, here with a particular stress on their mode formation, composition, uses etc.

1. Slate. Slate is a very fine grained metamorphic rock, formed by the dynamic metamorphism of shale. It is always characterised by a perfect cleavage and is available mostly in a bluish black colour.

Essential minerals are mica, chlorite and hornblende. Slate is widely used as roofing material, table tops, staircases, switch board etc. It is seldom used as a building stone and road metal, because of its low crushing strength and perfect cleavage.

2. Gneiss. Gneiss (pronounced as 'nis') is a coarse grained foliated rock, formed by the dynamic metamorphism of sandstones, conglomerates and granites. It is available in a great variety of colours.

Essential minerals are quartz, felspar and mica. A few varieties also contain hornblende and chlorite. Harder varieties of gneisses are used as road metal and concrete aggregates.

3. Schist. Schist (Greek, *Schizo* = Split) is a metamorphic rock, formed by the dynamic metamorphism of shale. It differs from gneiss in having closely spaced foliation planes.

Essential minerals are mica, chlorite, talc, hornblende and tourmaline. The varieties of schists are named according to the presence of the dominating mineral e.g., muscovite schist (containing a good amount of muscovite *i.e.* white mica), biotite schist (containing a good amount of biotite), tourmaline schist etc. Schists, being weak rocks, are not suitable for important works.

4. Marble. Marble is a crystallined metamorphic rock, formed by the contact metamorphism of limestone. It is available in a variety of colours e.g. white, grey, red, blue, green and yellow. Marble is chiefly composed of calcite. But a few varieties also contain olivine, serpentine, garnet and amphiboles.

Marble is sufficiently hard and can take a fine polish. It is extensively used as a building stone specially for the decorative purposes in columns, pilasters, staircases and floors etc. Coarse grained marbles are used for all types of important monumental, historical and architectural buildings; whereas fine grained pure white marbles are used for status.

5. Quartzite. Quartzite is a fine grained metamorphic rock, formed by thermodynamic metamorphism of sandstone. It is characterised by the tendency of the rock to fracture through the grains and not through the cementing material (as in the case of sandstone) as shown in Fig. 17.4.

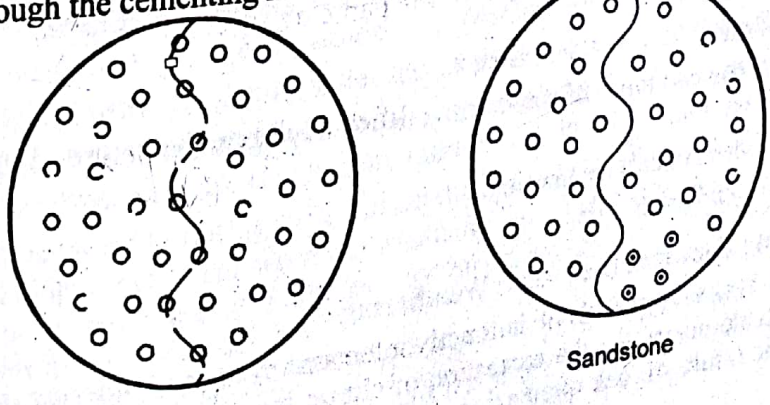

Fig. 17.4

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Essential minerals are quartz mica, felspar, garnet and amphibole. Quartzites are extensively used as road metal and concrete aggregates.

6. Phyllite. Phyllite is a fine grained metamorphic rock, formed by the thermodynamic metamorphism of shale and sometimes by the further metamorphism of slate. It is characterized by a shining cleavage. Essential minerals are mica, chlorite, hornblende and quartz. It is not used as a building stone for important buildings, because of perfect cleavage.

7. Serpentine. Serpentine is a coarse grained metamorphic rock, formed by the thermal metamorphism of gabbro and granite. It is available in green, yellowish green and dark green colours. It is used in the superior buildings for interior decorative purposes. Serpentine is a soft rock and can be cut with a knife.

8. Soapstone. Soapstone is a fine grained metamorphic rock, formed by the thermal metamorphism of impure limestone or dolomite in the presence of water. It is available in pale green to dark green colour and has a greasy feel.

It is used in the manufacture of soap and paint. It is very soft rock and can be cut with a knife.

17.8 Physical Geology

17.8.1 Introduction

The earth's crust is exposed everywhere for direct and indirect attacks of rain, wind, running water, glaciers etc. (called physical agents) which tirelessly attack the exposed surface of the earth and go on modifying it constantly. The study of such constructive and destructive processes of physical agents is called *Physical Geology*.

17.8.2 Technical Terms

Before entering into the details of the work done by the physical agents, a few technical terms which are of common usage, should be clearly understood at this stage.

(i) **Disintegration.** It may be defined as the process of breaking up of rocks into small pieces by the mechanical actions of the physical agents.

(ii) **Decomposition.** It may be defined as the process of breaking up of mineral constituents, to form new compounds, by the chemical actions of the physical agents.

(iii) **Denudation.** Denudation (Latin, *denudo* = to wear away) is a general term used when the surface of the earth is worn away by chemical as well as mechanical actions of physical agents and the lower layers are exposed. This happens when the rocks are exposed for a sufficient length of time to the attacks of physical agents.

17.8.3 Rock Weathering

In a broad sense, the term 'weathering' means the process of physical breaking up (*i.e.*, disintegration) and chemical rotting up (*i.e.*, decomposition) of rocks occurring simultaneously. As a result the rocks, at or near the surface of earth, are broken into large and small fragments which tend to become finer and finer with the passage of time. When the topmost material of the earth surface is mixed into the decayed vegetation and other organic matter, it forms the soil, which is very essential for our existence on the earth. The process of weathering depends upon the following two factors :

1. Nature of rocks, and
2. Length of time.

Following are the two types of weathering, depending upon the nature of the physical agents involved in its process:

1. Physical (Mechanical) weathering.
2. Chemical weathering.

17.8.4 Engineering Importance of Rock Weathering

An engineer is always directly or indirectly interested in rock weathering, specially when he has to select a suitable quarry for the extraction of stones for structural and decorative purposes. Strictly speaking the results of rock weathering, or its probabilities at a later stage, is one of the most

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important points to be considered before giving a final decision regarding the selection of a quarry for the extraction of stones to be used in any major construction work. The extent of weathering, or its probabilities at a later stage, is also an important factor during the selection of site for important projects such as a dam or a tunnel; as the process of weathering always causes a loss in the strength of the rocks or soil.

17.8.5 Geological Work

In a broad sense, geological work means the process of disintegration of rocks by the action of physical agents, followed by transportation of the rock material to considerable distances, where it is deposited sooner or later depending upon the circumstances. Thus the geological work can be sub-divided into the following three stages:

1. Erosion 2. Transport 3. Deposition.

Geological work of a few physical agents, which are important from the subject point of view, is described here.

17.8.6 Geological Work of Wind

The air in motion is called wind. It is the only physical agent which can carry rock particles, even against the normal force of gravity, for long distances. Like other agents, the work of wind can also be divided into the following three headings:

1. Erosion 2. Transport 3. Deposition.

The work of erosion, by wind, takes place by the following two processes :

(*a*) Deflation (*b*) Abrasion.

17.8.7 Engineering Considerations of Wind

In general, no site is selected for any type of important work on the moving dunes because such dunes are always a source of trouble to an engineer. It has been experienced that sometimes the moving dunes damage certain important works, if left uncontrolled. But if an engineer is compelled by the environments to select such a site, special methods should be adopted to check the motion of the moving dunes, *e.g.* either to construct wind breaks or growing vegetation on the surrounding areas.

17.8.8 Geological Work of Running Water

Rain falling on the dry ground first moistens the soil before any water may be evaporated or absorbed into the earth. Once the overlying soil takes its share from the rain water, the excessive water runs off superficially *i.e.*, starts flowing on the surface of the earth. This water goes on increasing, in volume, till it gathers some strength and enough volume to from a rill (very small stream). This will after joining with other rills forms a small stream, and ultimately the union of such small and large streams forms a river.

The geological work done by the running water or river is very important. Moreover, it is considered to be the most powerful agent, specially in times of flood. Like other agents, the work of running water can also be placed under the following three heads :

1. Erosion 2. Transport 3. Deposition.

The work of erosion, by running water, takes place by the following three processes :

(*a*) Hydraulic action (*b*) Abrasion (*c*) Corrosion.

The geological work of running water results in the formation of the following :

1. **Potholes.** Potholes are circular holes in the beds of streams or rivers, which are drilled down by stones or boulders in rotary motion imparted by eddies in the water.
   The boulders act as boring tools and get themselves rounded up in the process. Sometimes, these bolders which are worn out gradually, are replaced by new ones and the potholes continue to grow in size. Potholes may vary from several centimeters to a few metres in diameter as well as in depth.
2. **Waterfalls.** When a stream flows over rocks of different hardnesses, a softer layer is rapidly eroded away than a harder one. As a result of this unequal erosion, gradient of the river is increased, which ultimately increases the velocity of water.

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If it happens in a place where a softer rock is below a harder one, then the softer material is undercut by the eddies of the falling water. The gradual development of this process forms a waterfall.

The height, from which the water falls, is called drop or depth of waterfall which goes on increasing gradually.

In the famous Niagara falls of U.S.A., the water falls from a height of 50 metres.

These days power is being generated from waterfalls, by setting hydro-electric power generating plants in certain countries.

3. **Meanders.** When a stream does not flow in a straight line, but follows a zigzag path, it is said to meander. The process of development of the zig-zag route is called meandering and the curvature of the route is called meanders.

The meanders are developed when the velocity of a stream is such that it can perform the work of erosion and deposition side by side.

The zig-zag path of a stream helps in the development of meanders. Water goes on impacting on the concave side of the curve and causes erosion. But the velocity of the water as mentioned, is not sufficient to carry away the eroded material which is deposited on the convex side of the curve.

4. **Ox-Bow Lake.** Sometimes, the meandering streams detach loops and change their path along the shortest route. Such detached loops are called Ox-Bow lakes.

An Ox-Bow lake is generally formed when the neck of a meander is reduced very much, and during floods, the steam shortens its course by cutting directly across the neck of the meander.

5. **Deltas.** Delta is characterized by a triangular shape resembling the Greek letter D. Deltas vary extremely in size, shape and composition. It is formed when a stream or a river enters a body of standing water such as a lake or a sea where the velocity of the stream or river is checked and reduced to a great extent. As already mentioned the reduction in velocity results in separating out the rock particles which are carried in suspension by the water. These separated out particles are deposited near the shore line.

This deposition near the shore line partially chokes or blocks the mouth of the stream and divides it into two main branches or distributories. Similarly, when these distributaries are also partially blocked, these are further sub-divided into branches and each branch will begin to form a new bank of its own.

Principally, every river cannot form a delta higher than its own water level. But during floods, the material deposited may raise the delta higher than the water level and vegetation may grow on its flooded plains at higher elevations.

17. 8.9 Relation Between Velocity of Stream, Erosion and Transport

We know that the velocity of a stream increases with the increase in gradient as well as discharge. It has been experimentally found that if the velocity of a stream be doubled its erosive power is increased 4 times or even more : and its capacity to carry load is increased as much as 32 times; and its competence (*i.e.,* volume of the largest rock fragment that it can move by pushing or rolling) is increased up to 64 times. It has also been observed that if the gradient of the bed is increased 4 times, the velocity is about doubled.

17.8.10 Engineering Considerations of Running Water and Rivers

Generally any site for an engineering project is selected away from the path of a river or running water. But in the case of dams any bridges, where the site has to be within the path of the running water, suitable measures are adopted to stop or minimise the adverse effects of the running water. In such cases, foundations of the dam or piers of the bridges are made to rest on some firm strata and suitable measures are also adopted to strengthen the sides and the bed of the river by stone-pitching both upstream and downstream of the bridge or dam to stop erosion.

As already mentioned, the running water is the most powerful agent of erosion. Thus a detailed study of the soil and velocity of the running water constitutes an essential data to provide adequate

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safeguards in the design for the smooth and successful work of project.

Sometimes, an engineer has to deal with improvement and regulation of navigable rivers. The general trouble in such cases arises when the rocks met with are soft in nature. Suitable steps, like stone pitching in the bed and growing vegetation on the side slopes, are taken to guard against the scouring action of the water during floods.

17.8.11 Glaciers

The glaciers may be defined as the slow moving masses of ice away from their place of accumulation. These are formed by the accumulation of snow on very high altitudes. Glaciers vary in size from a fraction of square kilometre to thousands of square kilometres. It is an important agent of erosion, transport and deposition on very high mountain ranges, where climate is very cold and takes active part in shaping the mountanous regions.

The glaciers are not of great importance to an engineer though they are of scientific of economic interest; as sometimes glacier deposits contain many minerals of economic interest. But the work done by several glaciers, in the past and their resulting deposits, have been of considerable importance for engineers, as the glacier deposits have been creating a number of troubles during the construction of their projects such as dams, tunnels etc.

17.8.12 Geological Work of Glaciers

Like other agents, the work of glaciers can also be placed under the following three heads :

1. Erosion 2. Transport 3. Deposition.

The work of erosion, by glaciers, takes place by the following two processes :

(*a*) Plucking (*b*) Abrasion.

The work of glacial deposits takes place by the following two processes :

(*i*) Glacial drift or till (*ii*) Fluvio glacial deposit.

17.8.13 Comparison between the Geological Work of a Glacier and Running Water

Both, glaciers as well as rivers, move and carry the materials under the force of gravity. But the transport work of a glacier differs from that of a river in the following respects :

1. In the case of a glacier there is no limit of rock size that it can carry. But in the case of river it can not carry heavy boulders.
2. In the case of a glacier the velocity of a dust particle is the same as that of a rock fragment weighing many tonnes. But in the case of running water finer particles are lifted up by the water and are carried in suspension, whereas the coarser and heavier fragments are pushed and rolled along the bed of the channel. But their movement is much slower than that of the suspended particles.
3. In the case of glaciers U-shaped valleys are formed as a result of erosion. But in the case of running water V-shaped valleys are formed.
4. In the case of glaciers the deposit is poorly sorted *i.e.,* big boulders are deposited along with the dust particles. But in the case of running water the deposit is well stored *i.e.,* all the material is deposited according to the size of particles *e.g.,* heavier and bigger particles are deposited near the heads, whereas finest particles are carried to the farthest points.

17.8.14 Engineering Considerations of Glaciers

Strictly speaking any site of the construction of an important work is not selected either on a glacier or in the path of a glacier. The engineer may have to come across such a site where the deposition of boulder clay might have taken place in the recent past.

It has been experienced that deposits of boulder clay are more difficult to handle, because these are treacherous deposits due to their heterogeneous character. Such a site should preferably be avoided. But if such a site is unavoidable then the boulder clay should be removed and the foundations of the project should be laid on some firm strata.

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17.8.15 Geological Work of Sea

The oceans occupy nearly 71% of the surface of the earth and are major bodies of water. The seas are minor ones and are parts or extensions of the oceans towards the land areas; being bordered on one side or both by land areas. It has been observed that the sea water contains about 3.5% of salt by weight. Oceans or seas are the restless bodies of water and are never quiet. Following are the movements in the waters of an ocean :

1. Waves 2. Tides 3. Currents.

The geological work of the sea is done mostly by the waves, and is seen only near the sea shores.

17.8.16 Geological Work of Waves

In addition to the role of the sea for supporting abundant organic life, seas are also important agent of :

1. Erosion 2. Transport 3. Deposition.

The work of erosion, by waves, takes place by the following processes :

(*i*) Hydraulic action (*ii*) Abrasion (*iii*) Undertow current (*iv*) Corrosion.

The eroded rock particles are carried by the sea waves in following two ways:

1. In suspension.
2. In solution.

17.8.17 Coral Reefs

A coral reef is a particular type of sea deposit, originated by the accumulation of dead parts of sea organisms, among which the corals are prominent.

It is a small organism which grows in sea water and lives in groups comprising millions of these small organisms.

The growth of corals takes place under sea water in favourable circumstances (*i.e.*, at a depth 50 to 60 metres from the sea level and a temperature of 68° to 78° F). The dead bodies of the organisms go on accumulating in sea and their deposit is called coral reef.

17.8.18 Engineering Consideration of Waves

Engineers engaged on harbour maintenance or improvement, or those who are carrying out their work near the sea-shore face either of the following two problems as a result of the wave action:

1. Erosion of sea shore or harbour structures.
2. Silting up of harbours.

Strictly speaking the protective measures, for the erosion, to be adopted depend upon the direction and strength of the waves as well as nature of the coast at a particular site. When the waves erode the harbour structures, protection walls are provided in order to prevent the erosion and destruction of the harbour structures.

When waves carry load particles towards the shore, thus silting up the harbour, barries are constructed in the sea which considerably reduce the velocity of the waves and the rock particles are deposited beyond the barriers; and are carried back towards the sea when the waves going towards the sea attain sufficient powers as a transporting agent.

17.9 Structural Geology

17.9.1 Introduction

Since the dawn of civilization, the man has been curious to know, as to why water bubbles up from a spring? Why one well yields water in abundance, whereas another of the same depth is dry?

The man's curiosity had led him to seek answers to such riddles. He found that the interior of the earth is shrinking day by day. This shrinkage may be either due to loss of heat or reorganization of molecules under enormous pressure or high temperature. As the interior of the earth is getting

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condensed and recondensed, the earth's crust must shorten its circumference to adjust the shrunken interior. Due to this shrinkage, the rocks, which form the earth's crust, are subjected to a number of stresses. Under a certain set of conditions the stresses, which are developed within or on the earth's surface, disturb the layers of the earth's crust and ultimately some structural changes take place; such as folds, faults, joints etc. A detailed study of such structural features or architectural pattern of the rocks is known as structural geology.

17.9.2 Technical Terms

The following technical terms, which will be mostly used in this chapter and are important from the subject point of view, should be clearly understood at this stage.

1. Dip 2. Strike 3. Outcrop 4. Outlier 5. Inlier

6. Unconfirmity 7. Overlap 8. Cross-bedding 9. Folds 10. Faults 11. Joints

Inclination of the bedding planes with the horizontal is called a dip, and the direction of the intersection of the bedding planes with the horizontal is called a strike. The area actually occupied by a series of beds on the earth's surface is called an outcrop.

Outlier is a patch of younger rocks surrounded by geologically older rocks and inlier is a patch of older rocks surrounded by geologically younger rocks.

Unconfirmity is a junction, which separates two series and indicates a break in the process of deposition in the area. Overlap is a particular type of an unconfirmity in which the overlying strata extends so as to overlap the underlying strata.

Folds, Faults and Joints

Stresses are believed to be developed with the earth's crust, due to shrinkage of the interior of the earth. These stresses first buckle the layers, such buckles are called folds. When these stresses exert more pressure and cause the layers to fracture, such fractures are called joints. If these stresses are strong enough so that one of the fractured blocks moves with respect to the other, such fractures are called faults. It has been observed that time plays an important role in the formation of folds or faults, as a plastic material like wax will break when the force is applied suddenly but will bend when the same force is applied gradually.

17.9.3 Folds

Sometimes strata of the earth's crust is tilted out of the horizontal and is bent into folds such a fold may range from a microscopic crinkle to great arches and troughs even up to 100 kilometres across.

A set of such arches and troughs is called a fold.

17.9.4 Engineering Considerations of Folds

It has been observed that the folded rocks are always under a considerable strain, and the same is released whenever the folds are disturbed by some external force or whenever excavation is done through them. This release of energy may damage the site in many ways, depending upon the nature and intensity of the deformational stresses as well as nature of the rocks.

Thus for a major project like a tunnel, a dam, a railway siding etc., a site which is highly folded should be avoided because the engineer may have to face much troubles sooner or later; as the folds are easily fractured even due to a slight disturbance at a later stage. But if the project is of a fattered nature like electric or telegraphic poles, the work can be carried out without much of a risk.

It has also been observed that stones obtained from synclinal formations are harder and tougher than those obtained from anticlinal formations, as the latter are usually fractured. If a stone of tougher and harder variety is required, special care should be taken to obtain it from synclinal formations. This type of duty is slightly difficult to perform, as the labourers would always like to quarry stones from anticlinal formation, because quarrying is much easier from anticlinal formations than synclinal formations.

Folds are also important to a water supply engineer, specially when he has to select a suitable site for digging wells for water supply purposes. It has been observed that if the excavation of a well

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is done through an impervious strata, it will not yield any amount of water. (As in the case of well 'A'). If another well is excavated through a pervious strata (As in the case of well 'B') which may be of the same depth as that of 'A', it will yield water in abundance. Other factors, of course, also play a dominant role, which will be discussed in the later pages of the book.

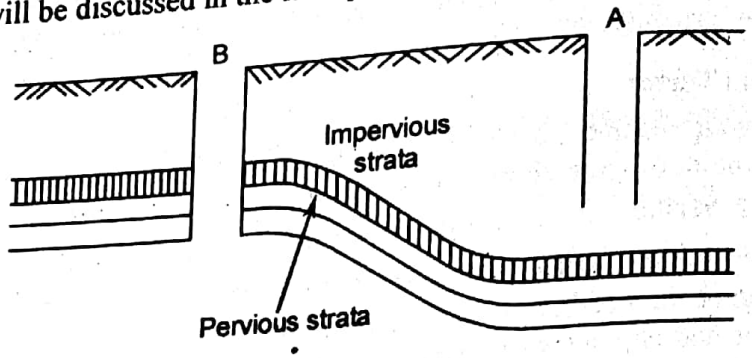

Fig. 17.5

17.9.5 Faults

Faults are fractures, along which the movement of one block with respect to other, has taken place. This movement may vary from a few centimetres to many kilometres depending upon the nature and magnitude of the stresses and the resistance offered by the rocks.

17.9.6 Engineering Considerations of Faults

Strictly speaking, no site should be selected on a fault for any major project and the least in an area where the fault or faults are 'active' due to recent earth movements; because movement along the existing fault plane is much easier than any other plane or along a crack. Even a slight disturbance is sufficient for a movement to take place and to damage the structure, built on it. Sometimes an engineer is unable to avoid faults, as in the case of a reservoir. In such cases a fault effects the side adversely in two ways.

Faults cause leakage in the water, and after sometime when the strata under the fault becomes sufficiently moistened, it loses its cohesive power which causes more displacement of blocks or new blocks to displace. Such displacements make the position from bad to worse. In such cases the faults should be thoroughly improved either by grouting or removing the loose material and refilling it with cement concrete, whichever is possible, depending upon the intensity of the fault and nature of the rocks.

If the project is very important like a dam, a tunnel or a multi-storeyed building, and at the same time the extent to which the fault has taken place is large, it is evident that the structure is not safe, if constructed on such a fault. The structure may collapse at any moment even due to a slight disturbance. It is therefore advisable that such a site should be avoided.

If the project is of a scattered nature like electric or telegraphic poles, the work can be carried out without much of a risk.

If general,a few safety factors should be provided in any building constructed over a fault by suitable modifications in the architectural and engineering design of the building to bear the initial shocks of an earthquake of low intensity.

17.9.7 Joints

We see that irregular and polygonal joints are frequently developed, when mud at the bottom of a temporary pond dries out. It has been observed that loss of either heat or moisture, from a solid mass, results in shrinkage of its volume. This shrinkage is always in all directions towards the centre of the mass. Sometimes, the shrinkage of the mass as a whole does not take place, but contraction starts around many points in the mass. When sufficient tensile stress is developed between two successive points, a crack is developed at right angle to the direction of the stress. Such cracks are called joints.

It has been observed that most rocks are brittle and tend to fail by fractures, whenever rocks are subjected to tensile or shearing stresses. If there is no movement of one fractured or separated

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block with respect to the other, such cracks are called joints. It may be noted that the joints may be vertical, horizontal or even in an intermediate position depending upon the direction of the stress and the resistance offered by the rocks.

The term 'joint' is said to have been originated in the British coalfields. The miners thought that the rocks were joined together along the fractures just as the bricks are put together in a wall.

17.9.8 Master Joints

It has been observed that the joints always occur in sets and groups. A set of joints means, joints occurring in the same dip or strike. A group of joints means a few sets of joints having almost the same trend. If a few sets or groups of joints appear for a considerable length in a rock, such joints are called *major joints* or *master joints*.

17.9.9 Engineering Considerations of Joints

Study of joints in a rock is always essential for an engineer, which is helpful to him in many ways. It may be noted that joints always play a major role in the geological survey of a site. Following are the engineering problems, directly or indirectly related to the joints :

1. Quarrying operations 2. Tunnelling 3. Reservoir site

1. **Quarrying operations.** Quarrying is a manual or mechanical process of taking out stones, of various sizes from an earth depression or open from one side. It has been experienced that joints always facilitate the extraction of stones, and cut down the expenses involved in the quarrying operations. This charming and attractive property of joints sometimes concentrates and attracts mind of an engineer to select such a quarry, for the extraction of stones, specially when the stones are required for road metal or other forms of crushed stones.

   Sometimes a jointed quarry has to be rejected, specially when the stones of large sizes are required, and the joints are closely spaced in the quarry under consideration.

2. **Tunnelling.** It has been experienced that if the joints are in abundance or closely spaced, it practically makes the rocks insecure and lot of grouting is required to hold the rock in its original position. Grouting is a process of filling up the joints, by injecting a thin mixture of cement and water, under high pressure. Sometimes when grouting does not seem to be sufficiently safe, heavy lining has to be provided. It is therefore advisable that a rock, which is heavily jointed, should preferably be avoided for a tunnel to be driven through. It may be noted that if the tunnel is required for the conduction of water, badly or heavily jointed may permit considerable leakage of water.

3. **Reservoir site.** It has been experienced that the joints always permit considerable leakage of water. If joints in a reservoir site are in abundance, it makes the site sometimes worthless. In limestone-formations joints may be enlarged by solution.

   The only remedy, that can be done at the best is grouting. But such a cure is hardly practicable unless the joints are local in character or the area affected is small, in such cases grouting improves the site and may be relied upon.

17.10 Field Geology

17.10.1 Introduction

The study of rocks, alongwith their structural behaviour, and mineralogical composition in the field is known as *Field Geology*. It is very essential for the successful study and proper understanding of the subject. The field Geology has the following two main features :

1. Geological survey in the field,
2. Interpretation in the laboratory.

17.10.2 Geological Survey

The scientist should, first of all, locate the stratigraphical formations likely to be encountered in the field from the available topographic maps and sections. After this, he should take his tools kit

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to the field for surveying.

The geological surveying is the systematic examination of a region for geologic information. A. geologic mapping requires (*i*) examination of rocks, (*ii*) location of outcrops and points where observations are made, and (*iii*) plotting the field data on a map. A little consideration will show, that for the above mentioned requirements the geologic notes should always be taken in full and accurate. The significant geological features should be clearly illustrated with the help of sketches and diagrams. All the photographs and rock specimens should be clearly numbered and indexed.

17.11 Hydrology

17.11.1 Introduction

The science, which deals with the study of quality and quantity of water in rocks and in different states is called *hydrology* (Greek. *Hudour* = Water, *logos* = science). The water of the earth may be, divided into the following three parts :

1. Water of the atmosphere,
2. Water on the surface of the earth, and
3. Water below the surface of the earth.

The water below the surface of the earth is sometimes, divided into two parts : (a) water near the earth's surface, which can be used by drilling wells, tube walls etc. (b) water in the interior of the earth, which cannot be used.

17.11.2 The Hydrologic Cycle

We know that the water falls from the atmosphere on the earth in the form of rain, snow, dew or fog. A part of this water is evaporated, which forms clouds and again falls on the ground. Another part of the falling water percolates into the ground, which can be obtained by digging wells or tube wells. A larger part of the falling water flows over the surface in the form of streams and rivers, from where a part of it is again evaporated to form clouds. The transformation of water, from one state to another, is known as *hydrologic cycle.*

17.11.3 Atmospheric Water

The amount of water present in the atmosphere (*i.e.* air) in the form of clouds, depends upon the weather, temperature, altitude and position of the area from the equator. This water is not available for useful work, unless it falls on the ground. It is only of academic interest, and gives us some idea of time and place when it will fall on the ground in the form of rain, snow, dew or fog.

17.11.4 Surface Water

The sources of surface water are:

(*a*) Lakes (*b*) Streams and rivers (*c*) Reservoirs.

(*a*) Lakes. The lakes are natural depressed basins, and are formed mostly in mountains (sometimes in plains also). Rain water, spring water and sometimes water from small streams gets collected in these basins and lakes are formed. The quantity of water stored in a lake depends upon the size of the basin and the source of water.

(*b*) Streams and rivers. The streams and rivers are formed by the surface run off. The discharge in a stream or a river varies greatly throughout the year. In dry season, the discharge in streams becomes very small, and sometimes they go dry also.

(*c*) Reservoirs. A reservoir is an artificial lake formed by the construction of a dam or weir across a river. The surplus water, during rainy season, is stored in an impounded reservoir. Care should always be taken to develop the reservoir at such a place where submergence of the area is low, and the basin formed is cup-shaped.

The quality of lake water is generally pure and does not need any purification. Large lakes provide comparatively more pure water than the smaller ones. It has been observed that the lakes situated in mountains generally provide pure water. The only drawback in lakes is their quantity, which is limited. It depends upon the capacity of the basin, catchment area, annual rainfall and poros-

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ip of the ground. The quality of stream water is generally safe, except in the first rainy discharge and floods. But the quality of river water is, generally, not reliable. It is, therefore, advisable to treat the river water before supplying to the public. Streams and rivers are the major sources of water supply all over the world.

17.11.5 Underground Water

The sources of underground water are:

(*a*) Well (*b*) Tube wells (*c*) Spring.

(*a*) **Well.** A well is a hole of 2.5 m to 5 m in diameter, made in the ground, for the purpose of getting underground water. It is a popular source for water supply (sometimes for irrigation also) in small villages, who can not develop their own water supply system because of high cost. The wells may be classified into shallow wells (which are dug up to the first water bearing strata) and deep wells (which are dug up to the second or third water bearing strata). Both the shallow wells and deep wells are lined from inside by brick or stone masonry.

(*b*) **Tube well.** In case of a tube well a hole of 15 cm to 50 cm. in diameter is drilled and a steel pipe line is inserted into it. This pipeline consists of perforated pipes which are put in the previous or water bearing layers, whereas blind pipes are put in the impervious or non water bearing layers. The water enters into the pipe line through perforations from where it is pumped out. The perforated pipes are also called strainer pipes.

(c) **Spring.** A spring is a natural flow of water from the ground at some point. The water from springs is, generally, so limited that it can be hardly used for any purpose. Some springs supply mineralized hot water which has medicinal value. Sometimes, these springs are developed into picnic places for tourists.

The quality of shallow well water depends upon surface conditions near the well. The area closer to the population is, generally, contaminated. Its quality can be improved to some extent if the wells are constructed away from the contaminated sites. The quality of water from deep wells and tube wells is generally better than shallow wells, and does not require any treatment. But, sometimes, some salts get dissolved in water while it flows through the strata and make it hard. In such cases, some treatment becomes essential to make it soft. The quality of spring water varies greatly from one to another, and is highly influenced by the geology of rocks through which the water flows.

17.11.6 Engineering Considerations

The most important point in the design of a water supply project is the required quantity of water of suitable quality. If sufficient quantity of water of suitable quality. If sufficient quantity of water is available from a surface source, then the same should be adopted. The water can be supplied to the public after its purification. But if there is no suitable surface source, then the water supply engineer has to depend upon underground source.

It may be noted that the surface source requires less initial cost but good running cost. The underground source requires heavy initial cost but less running cost.

17.11.7 Porosity

The consolidated or unconsolidated rocks always contain some voids. The ratio of the volume of voids in a formation to its total volume is called porosity, and is a measure of its ability to contain water. It is more in case of unconsolidated rocks than consolidated ones. The porosity of a rock depends upon:

1. Shape and arrangement of the rock particles.
2. Degree of mixture of various sizes of the particles.
3. Degree of compaction or consolidation of the rock formation.
4. Number of joints or fissures in the formation.

The porosity for a few types of rock formations are given below :

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S. No.	Type of formation	Porosity
1.	Uniform sand	48%
2.	Medium to fine sand	38%
3.	Coarse sand and gravel	34%
4.	Sandy clay	21%
5.	Clay	18%

17.11.8 Permeability

We have already discussed that the underground water flows from one place to another. This movement of water takes place because of the difference of water levels and depends upon the capacity of the porous medium to transmit water. The capacity of a rock formation to transmit water is known as its *permeability*. It is different than the porosity, and depends more upon the size of the pore openings than on the percentage space. The permeability of a rock formation is an important factor for determining the yield of a well.

Note: There is no direct relation between the porosity and permeability of a rock formation. A gravel with 20% porosity is much more permeable than clay with 35% porosity.

17.11.9 Aquifers

A body of rock or loose surface material, which is permeable as well as porous, and yields abundant water is called an *aquifer*. Most aquifers are sheets of sand, gravel or beds of sand stone.

17.11.10 Wells

A well is a hole, made in the ground, for the purpose of getting underground water. It will be interesting to known that the construction of wells is one of the oldest trades known to the man. He learnt the art of digging wells, by various methods, in the quest for water. The credit for the development of the art of drilling and casing of wells goes to the Chinese, who were probably the first to dig up the wells manually and provide lining by bamboos. The depth of water table, being very low, the digging well was often started by one generation and finished by another.

Before sinking a well (or boring a tube well) the site should be thoroughly examined for assured supply of water and its freedom from the possibility of pollution. A highly jointed and pervious rocky surface is not a favourable site. If the surface is less fissured, then there is a possibility of getting water at a moderate depth. The wells sunk into an old river terrace may, under ordinary conditions, yield excellent water. The wells situated in the dry beds of large streams, usually, yield good quality of water. In the following pages, we shall discuss about the quality and quantity of water available from wells dug into the various types of rock formations.

1. **Wells in Igneous Rocks.** In general, the mineral components and grains of igneous rocks are closely interlocked. It is thus obvious, that the prospect of getting water from wells sunk into igneous rocks is poor. Granite rocks yield a large supply of water, only when they contain joints and fissures. A decomposed granite is porous, and hence suitable for yielding a large supply of good water. Basaltic rocks, being heavily jointed, also yield a large supply of water. Coarse textured basalts and dolerites yield good quality of water. But they do not yield good quantity of water.

2. **Wells in Sedimentary Rocks.** In general, the water bearing capacity of a sedimentary rock depends upon the condition of its sediments and the cementing material. Gravel is considered to be the best formation to yield water, and sand to be the second best. Sand stones also yield a good quality and quantity of water. They can yield a large quantity of water under suitable topographical and structural conditions. The limestone formations are unreliable sources.

3. **Wells in Metamorphic Rocks.** In general, the water bearing capacity of a metamorphic rock depends upon the degree and type of metamorphism as well as foliation. The less

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metamorphosed rocks such as quartzites, slates, marbles etc. are usually jointed and thus can yield some water. But highly metamorphosed rocks such as gneisses and schists are usually massive rocks, and thus are very discouraging; unless deeply weathered.

17.11.11 Tube Wells

A tube well is adopted, where ordinary dug wells do not yield sufficient quantity of water of good quality. The tube wells have many advantage over dug wells such as cheapness, simplicity, speedy sinking, ease of working, exclusion of surface water etc. They are very successful in sand and gravel because of their high permeability.

17.11.12 Causes for the Failure of Tube Wells

Though there are many causes for the failure of tube wells, yet the following are important from the subject point of view :

1. A higher rate of pumping than the inflow of water in the storage. It effects the stability of the pipe line.
2. The screens getting corroded. It results in the pumping of sand particles alongwith the water.
3. The screens getting choaked. It results in less discharge than the calculated one.

17.11.13 Engineering Considerations of Wells

If the city (for which the project is being undertaken) is away from a river or a canal, the only source left is the undergound water. In such a case, the water supply engineer has to provide tube wells of sufficient capacity. For this purpose, he has to select the site (or sites) for tube wells after thoroughly investigating the types of rocks, quantity and quality of the water available.

17.12 Earth Movements and Volcanic Activities

17.12.1 Introduction

Sometimes, even an ordinary man is filled with curiosity, when he finds shells or sea animals fixed in the rocks at high altitudes, which are not within the reach of sea water at this stage. A farmer is also filled with curiosity when these seashells are turned up, while ploughing in his farm and his interest increases when he is told by a geologist that the scientific comparison of these shells with the living organisms of the sea, shows that his farm had been once the bottom of the sea.

The science of Geology has given answers to such curiosities, by proving that there are two types of disturbances in the earth's crust, which are (1) sudden and (2) gradual.

Sudden movements or disturbances take place only due to earthquakes, whereas gradual movements are natural and are very difficult to see. But their effects can be seen only after few years. Even now the South Eastern England is sinking very slowly into the sea. Sudden earth movements are of following two types :

1. Earthquakes. 2. Landslides.

17.12.2 Earthquakes

Sometimes, the earth's crust is subjected to sudden vibrations, which may or may not cause shaking or trembling effect. Most of these vibrations are so feeble that we, even, cannot feel them. Some of these vibrations are, however, felt by us. A few of these vibrations are severe enough to have destructive effects. A vibration, which may be feeble or severe, set up in the earth's crust is called an *earthquake*.

17.12.3 Technical Terms for Earthquakes

Before entering into the details of the subject, the following technical terms, which will be commonly used in this chapter, should be clearly understood at this stage.

1. **Epicentre.** It has been observed that an earthquake, usually, originates beneath the surface of the earth, at a point called Focus or Centre of the earthquake. The earthquake, then, moves in the form of waves which spread in all directions. These waves first reach the point

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at the surface which is immediately above the focus or the origin of the earthquake. This point is called the *epicentre* (Greek, *Epi* = Upon) as shown in Fig. 17.6.

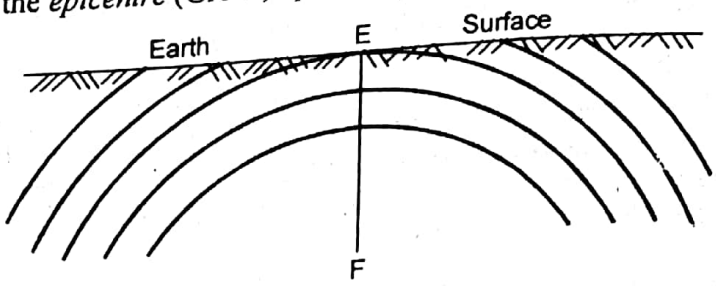

Fig. 17.6

Thus the epicentre is the point on the Earth's surface where the shock of an earthquake is experienced first. Then the waves spread in all directions on the surface, in the same way as the waves spread, if a stone is thrown into a pool.

2. **Seismograph.** As already mentioned, the waves of an earthquake spread outwards, which are recorded by an instrument known as seismograph (Greek, *Seismos* = Earthquake). Waves which spread outwards are called seismic waves, and its record is called seismogram. It may be noted that if we record seismograms of an earthquake at different stations (not less than three) the position of the epicentre can be located.
3. **Elastic rebound theory.** We have already discussed that as the interior of the earth is shrinking day by day, the earth's crust must shorten its circumference to adjust the shrunken interior. Due to this shrinkage, the rocks of the earth's crust are subjected to a number of stresses. Sometimes these rocks are deformed and strained due to the differential stresses. When the stress exceeds the elastic limit, a crack or fracture is developed. The two separated portions (or halves, as the case may be) tend to slip off along the crack. The friction along the crack, resists such a movement for a certain length of time. But when the stresses exceed the frictional resistance also, the two portions suddenly spring up and occupy a position of no strain.

   The energy stored in the system through decades is released instantaneously causing severe vibrations. This concept of earthquake is called *elastic rebound theory*.

17.12.4 Causes of Earthquakes

The earthquake may be caused due to various reasons, depending upon its intensity. Following three major causes of earthquakes are important from the subject point of view:

1. Superficial movements 2. Volcanic eruptions 3. Folding or faulting.

17.12.5 Classification of Earthquakes

The earthquakes have been, variably, classified on the basis of their:

1. Intensity 2. Cause of origin 3. Depth of the shock originated.

But the classification, based on the depth of the shock originated, is widely used. Thus the earthquakes may be classified on the basis of the depth of the shock originated into the following three categories:

1. Shallow 2. Intermediate 3. Deep.

17.12.6 Intensity of an Earthquake

In an ordinary sense, the intensity of an earthquake means the degree of damage caused by a particular earthquake. But here it means the effect produced by an earthquake on the structures and features of the earth.

17.12.7 Scale of Earthquake

There are many scales of intensities, but Rossi-Forrel's Scale is one which is widely adopted and is given below:

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S. No.	Name		Effects
1.	Imperceptible	...	Recorded by sensitive seismographs only.
2.	Feeble	...	Recorded by seismographs of different kinds. May be felt by a number of persons at rest.
3.	Very slight	...	Felt by several persons at rest. It is strong enough for the duration and direction to be recorded.
4.	Slight	...	Felt by several persons in motion. Movable object disturbed, cracking of doors, windows etc.
5.	Weak	...	Disturbances of furniture and beds. Ringing of bells.
6.	Moderate	...	General awakening of those asleep; stopping of clocks; visible disturbances of trees. People leave their houses.
7.	Strong	...	Overthrow of movable objects, fall of plaster from the walls, general panic without damage to buildings.
8.	Very strong	...	Fall of chimneys, cracks in walls of buildings.
9.	Severe	...	Partial or total destruction of some buildings.
10.	Destructive	...	Great disasters, disturbance of strata.
11.	Catastrophic	...	Wooden structures collapse, Railway tracks twisted.
12.	Absolute ruin	...	Land faults and slips, movement and collapse of buildings.

17.12.8 Earthquake Problems in India

A detailed study of the seismic activity in the geological history of our country shows that its greater part has been unstable and has experienced some of the severest earthquakes of the world. At the same time, some parts have remained perfectly calm, since ancient times.

The geological survey of India has divided our country on the basis of seismic history (since 1850) into the following three zones.

1. **Zone of severe intensity.** It comprises the Northern region of folded chains of the Himalayas. It includes Jammu and Kashmir, Himachal Pradesh, Assam and Northern strips of Punjab, U.P., Bihar, West Bengal and Gujarat.
2. **Zone of moderate intensity.** It comprises the Indo-Gangetic basin. It includes the remaining areas of Punjab, U.P., Bihar, Rajasthan and Gujarat.
3. **Zone of slight intensity.** It comprises the peninsular part of India. It includes Madhya Pradesh, Orissa, Maharashtra, Andhra Pradesh, Mysore, Kerala and Tamil Nadu.

17.12.9 Engineering Considerations of Earthquakes

Strictly speaking the position, time and intensity of an earthquake can never be predicted, thus the question of its prevention does not arise. The only remedy, that can be done at the best, is to provide additional factors in the design of a structure to minimise the losses due to shocks of an earthquake. This can be done in the following ways:

1. To collect sufficient data, regarding, the previous seismic activity in the area.
2. To assess the losses, which are likely to take place in future due to earthquake shocks.
3. To provide factors of safety, to stop or minimise the loss due to severe earth shocks.

Thus, we say that the design of a building, dam etc. in a seismic area (an area which is frequently shocked by earthquakes) is always a source of trouble and complications to an engineer. Following are the few precautions, which make the building sufficiently earthquake proof :

1. The foundations of a building should rest on a solid or firm rock bed. Grillage foundations should, preferably, be provided.

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2. The excavation of the foundation should be done up to the same level, throughout the building.
3. The concrete should be laid in rich mortar (*i.e.*, more cement ratio) and continuously. No joint should take place.
4. The masonry should be erected simultaneously in cross walls and long walls and no joint should take place in the masonry.
5. All the masonry should be done with cement mortar of not less than 1 : 4 mix.
6. Windows are always a source of weakness in a building and thus should be kept away from the outer corners. Doors and windows should be provided in the walls diagonally opposite to each other. Wide windows should be avoided.
7. Flat R.C.C. slabs should be provided.
8. All the parts of the building should be tied firmly with each other.
9. The building should be of uniform height.
10. Cantilevers, projections, parapets, domes etc. should be avoided.
11. Best materials should be used.

It has also been observed that buildings made of wood offer more resistance to seismic waves, and thus are less damaged than other types of buildings under the same set of conditions.

17.12.10 Landslides

As the word indicates, landslides mean sliding of land or in other words movement of a certain rock-mass from one place to another or from a higher level to a lower one, by the direct or indirect action of the force of gravity, on unstable material. The rate of movement of such a mass is never constant *e.g.*,

1. It may be so slow that even the most sensitive instruments may fail to record it. The effect of such a landslide can be seen after a number of years. This is a common type of movement, that occurs naturally.
2. It may be so abrupt that it may endanger the surrounding masses. This is a rare phenomenon in nature, and is generally accompanied by earthquakes.

17.12.11 Causes of Landslides

The main cause of landslides is the force of gravity. It has been observed that softer and unconsolidated rocks are more affected than the harder ones; as such rocks are generally unable to withstand the pull of gravity. Landslides may be caused due to either of the following factors :

1. Water content
2. Overloading
3. Structural features
4. Excavation of the adjoining area
5. Sudden disturbance

17.1 12 Classification of Landslides

Landslides may be classified on the basis of the type of movement into the following three types

Flowage 2. Sliding 3. Subsidence

Flowage. As the word indicates, flowage is a movement in which the top surface of a mass flows from one place to another through a small distance.

It should be noted that in flowage there is no definite line of flow on the surface. Generally, the rate of flowage is very slow and is hardly recorded even by a most sensitive instrument.

2. **Sliding.** As the word indicates, sliding is a movement in which a certain mass actually slides from one place to another under the force of gravity.

In the case of sliding, after effects of the movements can be seen, because there is always a line of failure on the earth's surface.

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3. **Subsidence.** Subsidence is a movement in which a certain mass, actually subsides (*i.e.*, sinks) or in other words settles down due to the force of gravity.

This type of movement may be caused either due to overloading of the surface or other underground geological reasons.

17.12.13 Engineering Considerations of Landslides

Strictly speaking, the damage caused by landslides or landslide activities, to a structure depends upon the following factors :

1. Type of movement 2. Intensity of movement 3. Type of structure involved.

It has been observed that structures are more damaged by subsidence than flowage or sliding under the same set of conditions. If the extent, to which the movement has taken place is large, it is obvious that it will damage the structure heavily, even if the movement may be of any type. Damage to a structure also depends upon the type of the structure itself.

It has been experienced that if the structure is light and of scattered nature like telegraphic or electric poles, the damage caused is minimum. But if the structure involved is like a tunnel, dam, sewer pipe, railway siding and multi-storeyed building, it is evident that the structure will be more damaged, under the same set of conditions.

In fact, landslides can never be predicted, thus the question of some precaution at any stage does not arise. It has been observed that proper drainage, providing retaining walls and stabilizing the slopes are only possible remedies to stop or minimise the causes and effects of landslides.

17.12.14 Creep

The angle, with the horizontal, at which loose material can stand without sliding, is called the angle of creep or angle of repose, which is different for different type of rocks as discussed below :–

Earth	30° to 45°
Gravel	30° to 40°
Dry sand	25° to 35°
Wet sand	15° to 30°

The above mentioned angles reveal that the rock materials, generally, on the hill slopes are not stable; as the angles of hill slopes are generally more than the angles of repose mentioned above. Consequently, the rock materials slide down. This sliding down of rock materials is known as *creep* and is always seen to be more effective in a wet climate.

17.12.15 Engineering Importance of Creep

The creep is a general trouble, when a road or a railway is constructed in a hilly area; as it makes the adjacent hill sides quite unstable. This happens as the loose material always tends to creep down unless it is held back by constructing retaining walls on both the sides or providing suitable slopes on the hill side in order to stop the rock materials to creep down as shown in Fig. 17.7.

It has also been experienced that if there are harder rocks like granites, gneisses or traps of slope ½ to 1 (*i.e.*, ½ horizontal to 1 vertical) can stand. In case of loose or soft rocks, proper slopes should be provided only after examining the situation carefully. It may be noted that in the case of slate the slope should preferably be cut into steps and covered with a layer of vegetation.

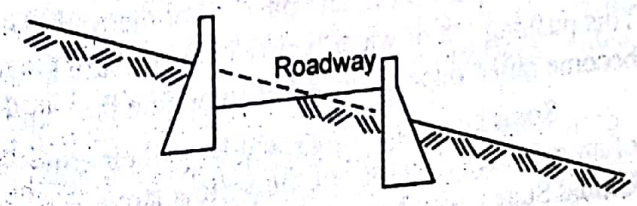

Fig. 17.7

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17.12.16 Volcanoes

Volcanoes are vents (or in other words chimney like structures) through which hot materials are discharged continuously or intermittently. These vents occur naturally and connect the surface of the earth with the molten material inside the earth.

17.12.17 Causes of Volcanoes

Volcanoes may be caused due to either of the following reasons:

1. Sometimes, the water percolating through the earth's crust, comes in contact with the molten rocks, which is already at very high temperature (more than 1000°C). Then the water suddenly changes into steam and this sudden change results in creating an enormous pressure, to force out the magma through the points of least resistance.

In support of this view, it may be noted from the histories of the volcanoes, that most of the volcanoes of the world are situated near the sea, and volcanic eruptions are generally accompanied by a good quantity of steam.

2. We know that all folded rocks are always under a considerable strain, and whenever some earth movement *e.g.*, earthquake, landslide, fault etc. of considerable intensity takes place, the pressure which is stored due to folding of the rocks is released. This release of pressure is also the cause for the eruption of the molten material.

In support of this view, it may be noted that volcanoes are in abundance in the areas where earth-movements take place very frequently.

17.12.18 Products of Eruption

Products of eruption mean the materials which are thrown out during a volcanic activity. These materials may be :

1. Gaseous 2. Liquids 3. Solids (including dust)

17.12.19 Classification of Volcanoes

The volcanoes have been classified by different scientists on different basis. But the following two classifications are important from the subject point of view :

1. Classification based on the record of activities.
   (*i*) Active volcanoes (*ii*) Dormant or slumbering volcanoes (*iii*) Extinct volcanoes
2. Classification based on the materials erupted.
   (*i*) Crater rings (*ii*) Cinder and Ash cones (*iii*) Lava volcanoes
   (*iv*) Composite volcanoes

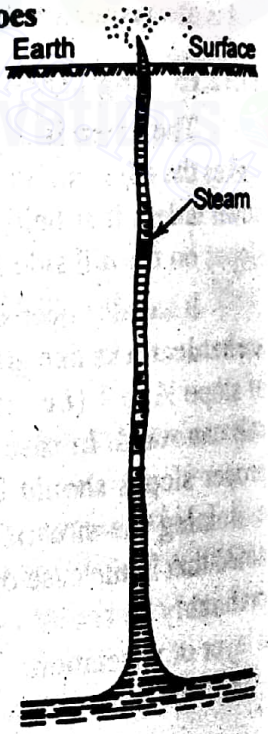

Fig. 17.8

17.12.20 Geyser

A geyser may be defined as a volcano, erupting out water, at more or less a regular interval of time. It is not dangerous to man in any way, until he is unwise enough to fall into it.

It has already been mentioned that as we descend into the earth, temperature goes on increasing. At certain depths the temperature is so high that it reaches the boiling point of water and steam is formed. Steam, in the form of bubbles, being lighter than water tends to rise upwards at the surface of the earth; and pushes out the water in the form of a spring. This pushing out of water reduces the pressure in the vent and the things become quiet, once again. After sometime the same cycle is repeated.

Some geysers are very regular in their eruption. A good example is of an old faithful geyser of the yellow stone is the National Park of the United States, which erupts water after every 66 minutes.

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17.12.21 Engineering Considerations of Volcanoes

Considerable progress, to predict a volcanic eruption, has been made, but much remains to be done, as yet. It has been experienced that volcanic eruptions not only damage the man-made structures but also cause huge loss of life. Therefore volcanic activity is, equally important to engineers, town planners and other scientists. Strictly speaking, no site for any project should be selected near the active volcanoes. But if a volcano is of a dormant or extinct type with a low intensity and at the same time the project is of scattered nature like telegraphic or electric poles, it is not so dangerous. In such cases, suitable protective measures should be taken to divert the liquid flow away from the site of work, and the work can be carried out without much of a risk.

17.13 Civil Engineering Geology

17.13.1 Introduction

In the course of time, the pure sciences like Physics, Chemistry, Mathematics and Geology assumed their due role in solving engineering problems. An engineer of today, has acquired sufficient knowledge to design and construct his structures systematically, accurately and successfully in the light of advanced geological knowledge.

17.13.2 Role of Geology in the Field of Engineering

Before a civil engineer may proceed to design his project, he must know something about the type of rocks on which the foundation of his structure has to rest, or in which his work has to be carried out. This necessitates a thorough investigation of the site, before the detailed design may be prepared. If he neglects such an investigation, he can be compared to a surgeon starting the work of an operation without diagnosis; or a lawyer pleading his client's case without prior discussion with him.

The practice, going on in the last few decades all over the world, is that geologist are called upon to give their advice regarding the foundation conditions of the major and important projects to be undertaken. The service, that is rendered by a geologist in any major civil engineering project, is being considered as the most valuable and important for the proper planning and execution of the project *e.g.*,

1. The geologist analyses the conditions of area, selected for the site, the engineer will consider as to how to improve the conditions and to adjust them, so as to make them suitable, to his plan.
2. The geologist, from his analysis, finds out the probable problems and difficulties, that are likely to be faced during the construction, the engineer will solve the problems and overcome the difficulties.
3. The geologist suggests different sites for the building materials such as stone, brick earth, stand etc. to be obtained, the engineer will obtain them economically and will put them to use.

In addition to the above mentioned few examples, engineer may have to face a variety of problems and hardships in his day-to-day work, for which fundamental knowledge of Geology is most essential. As a matter of fact, **good engineering means construction of most economical structures, which will last longer and fulfil their purposes satisfactorily. But a structure cannot work smoothly and successfully until and unless the foundations of the structure are safe. It may be noted that safety of a foundation not only depends upon its correct design and superiority of construction but also upon the underground geological features.**

It has been experienced that majority of modern failures are not due to faulty design or lack of proper supervision during construction, but only due to defective bed conditions, which are not fully detected at the time of selection of the site or during construction.

It may be noted that it is merely a geological investigation which lacks proper attention; as the engineers are seldom qualified to carry out geologic works. Moreover, geologists cannot apply their knowledge to engineering problems as they are geologists and not engineers. This gap can only be filled by an engineer who has considerable knowledge of Geology. There is also a serious defect, in

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the working of the various Indian Public Works Departments, as there is no coordination between the staff of geology and engineering departments at any level. In advanced countries the engineers and Geologists have a common platform, where they plan a neat and coordinated team work and, thus, contribute more towards the development of the country.

It has been observed that detailed geological surveys not only constitute a valuable insurance against difficulties and hardships, which otherwise the engineer has to face, during construction, but also economise the cost of construction. In the excavation of the Panama Canal igneous rocks were broken down into very small pieces when blasted. This crushed stone was utilized in the construction of canal, saving millions of rupees. Similarly by improving local land quarries lakhs of rupees were saved on the construction of Rajasthan Canal (Northern India).

There are many examples on similar lines, in which the geological knowledge has economised the cost of construction. It may be noted that even in small jobs economies are possible, if the knowledge of geology is applied by engineers at the right time and place. Thus, today the knowledge of Geology has become a major part of the studies of a civil engineer. Application of Geology to a few engineering problems is discussed here.

17.13.3 Road Metals

After finalising the route of a roadway, the engineer's next problem is the selection of suitable materials for its construction. Such a problem also arises, when an existing road is to be reconditioned.

In a broad sense, the road metal is an engineering term, which is applied for the broken stone, used in the construction of roads. As a matter of fact, the road metal constitutes a major part of the body of a road, and has to bear the stresses caused by the traffic. It is, therefore, essential that selection of a rock for the road metal should always be done, keeping in view economic considerations, amount and type of traffic the road is expected to bear, topography of the region and availability of suitable rocks for the road metal. The essential physical properties and usual tests carried out to determine the suitability of any rock, as a road metal, may be summarised as below:

The stone should be sufficiently hard *i.e.,* it should offer the maximum possible resistance to abrasion. This can be tested by putting a weighed quantity of broken pieces of the stone in a drum alongwith small cast iron balls. The drum should be revolved about 2000 times in one hour. The weight lost by the stone pieces will indicate the amount of loss by abrasion. It may be noted that a more resistant stone will show, comparatively, a little loss in its weight (*i.e.,* abrasion).

2. The stone should be quite tough. This can be tested by breaking it under a hammer.
3. The stone should have a high crushing strength, which can be determined by testing the blocks usually 10 cm. (4 inches) cube by crushing them, by a testing machine, in a laboratory.
4. The stone should have adhesive properties, *i.e.,* binding capacity of the road metal with the binding material such as coal tar etc. to ensure stability of road. This can be tested either by experiments in the laboratory or by studying the conditions of the roads, already constructed with the stone under consideration.

Sometimes, it is found that a stone, which gives good results when tested in a laboratory, may not give good service under traffic. On the other hand a stone, found to be of poor quality in the laboratory, may give good service under traffic. This difficulty may be overcome by a careful microscopic examination of the mineralogical composition of the rock under consideration.

The main geological requirements for a road metal, as suggested by Prof. P.G.H. Boswell are as follows:

1. The rock should be crystalline in nature.
2. The texture of the rock should be equiangular and interlocking.
3. The rock should be quite hard and tough.
4. All the constituent minerals should be of equal hardness.
5. The rock should be neither too fresh nor badly altered.
6. The specific gravity of the rock should be moderately high.
7. The rock should not be too porous.

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The above mentioned requirements demand supreme considerations, at the time of supplies of road metals, to be made. It has been experienced that igneous rocks generally satisfy all the above mentioned geological requirements. Following rocks are in use as road metals in India.

1. **Basalts.** Basalts are dark coloured igneous rocks and are being considered to be the best type of road metals. These rocks have a very high crushing strength and specific gravity. Basalts include dolerite andesite, prophry, diorite etc. Basalts are extensively used as road metals in India.
2. **Granites.** Granites are igneous rocks, and are considered to be the next in utility to basalts. Granites include diorite, gneiss, pegmatite, syenite, etc. These rocks possess almost all the properties of a good road metal. It has been observed that roads constructed with granites have proved to be successful under heavy traffic.
3. **Dolerites.** Dolerites are dark coloured igneous rocks. Due to interlocking of crystals, the rock is very tough and is widely used as a road metal. Dolerites have a special quality of holding a firm grip of coal tar.
4. **Quartzites.** Quartzites are hard metamorphic rocks, and are quite resistant to weathering actions. Quartzites possess almost all the requisite properties for use as a road metal, and are extensively used in India.
5. **Limestones.** Limestones are considered to be the first class road metal, when available in good quality *i.e.*, of fine grained and interlocking in structure. Soft and fossilferous limestones should never be used as road metals.
6. **Sandstones.** Sandstones are sedimentary rocks, and possess the requisite properties for use as a road metal, only when available in good quality. It may be noted that sandstones do not possess sufficient binding properties with coal tar.
7. **Slates.** Slates generally show a moderately high percentage of wear and comparatively low hardness and roughness, but have fair cementing properties. Slates split up easily into chips which is highly objectionable for a good road metal. Clayey varieties easily grind under traffic. Slates are used as a road metal only for the roads of less importance.
8. **Gneisses.** Gneisses are metamorphic rocks having the same composition as that of granites. Gneisses are sometimes, called stratified granites. Harder varieties of gneisses are extensively used as road metals in the various parts of India.
9. **Gravels.** Gravels are pebbles or rock fragments above 2 mm. in diameter rounded and smoothed during transportation by the running water. Gravels of harder rocks and of 5 cm to 10 cm in diameter are used as road metals.
10. **Kankar.** Kankar is suitable as a road metal, except for heavy traffic. Kankar varies very much in quality depending upon the admixture of clay. Inferior varieties are almost useless. Only hard and crystalline varieties may be used as road metal.

17.13.4 Building Stones

Building stone is a broad engineering term, used for the rock, that can be used safely and successfully in different shapes and sizes for all types of buildings and other various engineering projects.

From the very olden times, stones have been used for the construction of historical, monumental and all other important architectural buildings. All ancient temples of Southern India (*e.g.*, famous Stupas of Sanchi and Sarnath and the famous temple of Rameshwaram) were constructed with granites. The Taj Mahal at Agra (built in 17th century) was built with white marble obtained from Jaipur (Rajasthan). The Red Fort of Delhi (built in 17th century) was built with red sandstones obtained from Vindhyan quarries near Agra. The Parliament House, Rashtrapati Bhawan and the Central Secretariat of New Delhi (built during 1915-25) were built with grey and pink sandstones obtained from Rajasthan.

As a matter of fact, the cost of a building stone is one of the most important factors to be considered for a particular type of building, which further depends upon its availability, transhipment and workability. In recent times, the use of stone is not very common and is generally restricted only

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to particular type of structures, and in hilly areas only, where the stone is available at cheap rates. Today brick in mortar, plain and reinforced cement concrete is being used extensively, in all types of monumental and important buildings.

Strictly speaking, no one kind of stone is suitable for all types of works, or all types of purposes in the same building, *e.g.*,

1. A heavy and impervious stone is required for all types of marine engineering works.
2. A stone, unaffected by acids or fumes, is required for use in a manufacturing town or industrial area.
3. A heavy and hard stone is required for retaining walls and foundations of a building.
4. A stone of pleasing colour and impervious in nature is required for the face work of a high class building.
5. A soft and even grained stone is required for the ornamental work.
6. A soft and light stone is required for arches.
7. A very hard and resistant stone is req-uired for stair cases and floor pavings.

In addition to the above mentioned suitabilities of a stone, the essential physical properties and tests carried out to determine the suitability of any rock, as a building stone, may be summarized as below :

1. The stone must be free from cracks and cavities, and should have crystalline structure.
2. The stone should be sufficiently hard, that can be tested by scratching it with a pen knife; which should not be able to make any mark.
3. The stone should be sufficiently tough, which can be tested by breaking it under a hammer.
4. The stone should be sufficiently durable, *i.e.*, it should not be easily affected by weathering agents, which can be determined either by studying the effects of weathering on the buildings constructed by stone under consideration in the neighbouring areas, or can be tested by studying the effects of dilute hydrochloric and sulphuric acids.
5. The stone should be quite impervious, Any stone absorbing more than 5% of water should be rejected.
6. The stone for heavy engineering works should have a high specific gravity usually not less than 2.60, which can be determined by weighing a given volume of stone and comparing this weight with the weight of the same volume of water.

Following stones are in use as building materials in India :

1. **Granite.** Granite is a very hard igneous rock composed of quartz, felspar and mica. It can take an ornamental finish and fine polish. On account of its hardness, durability and variety of colours, it is considered to be the most valuable stone for all types of important structures. All the ancient temples of South India, constructed with granite, still stand in a good condition; even after hundreds of years, and appear to be good for the centuries to come.

   There is very little waste in a granite quarry. Larger blocks are used as building stones, the smaller ones as railway ballast or road metal and the chippings for concrete aggregate and artificial stone.

   Granite is found in abundance in India. Its excellent varieties are available in Gujarat, Bangalore (Mysore), Belgaum (Karnataka) Ajmer (Rajasthan), Nilgiris (Tamil Nadu), Secunderabad (Andhra Pradesh), Dalhousie and Kangra (H.P.).

2. **Sandstone.** Sandstone is a sedimentary rock, consisting of sand grains cemented together by lime, silica, magnesia, aluminium, iron oxide etc. Its durability depends upon the nature of the cementing material. It has been experienced that sandstones of Vindhyan and Gondwana formations are excellent building stones and are being used for all types of important structures.

   Sandstones are found in a variety of colours e.g., yellow, grey, brown, pink, red and black. Sandstones suitable for engineering projects are available in Mirzapur and Fatehpur Sikri (U.P.), Jabbalpur, Gwalior (M.P.), Ahmedabad (Gujarat), Nagpur (Maharashtra), Ranchi (Bihar), Cuttack (Orissa), Kangra and Dharamshala (H.P.).

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3. **Slate.** Slate is a metamorphic clayey rock, found in a variety of colours, e.g., dark blue, bluish black and green. The durability, and facility with which it can split up into thin sheets, has made it an excellent building material for use in roof covering, paving and sills of doors and windows etc.

   A good slate of even colour has a crystalline structure and gives out a sharp metallic ring, when struck.

   Slates of different qualities are found in Cuddapah (Andhra), Bijapur (Mysore), Alwar (Rajasthan), Chamba and Simla (H.P.), Baroda (Gujarat), and Gurgaon (Haryana).

4. **Marble.** Marble is a metamorphic rock, found in a variety of colours e.g., grey, red, white, blue, yellow, green and black. It is sufficiently hard and takes a fine polish. It is used extensively as a building stone especially for decorative purpose in columns, pilasters, stair cases, floors etc., where economy is not the main consideration.

   The course grained marbles are used for important monumental and architectural buildings; whereas fine grained pure white marbles are used for statues. A few white and coloured varieties of marble are imported from Great Britain, Italy, Greece and Belgium. Excellent varieties of marble are also found in India in Jodhpur, Ajmer, Jaisalmer and Jaipur (Rajasthan), Baroda (Gujarat), Chhindwara, Jabbalpur and Gwalior (M.P.).

5. **Limestone.** Limestone is a sedimentary rock, consisting mostly of carbonate of lime. There are many varieties of limestone, which differ from one another in composition, texture and hardness. Only a compact and durable limestone is suitable for building purposes. All other varieties of limestones are used in cement and lime manufacture.

   Limestones of different varieties are available in hilly regions throughout India. Porbander stone of Kathiawar is largely used in Bombay and even in Calcutta, Limestones for building purposes are also available in Hazaribagh (Bihar), Mirzapur (U.P.), Alwar (Rajasthan), Gwalior (M.P.), Hoshiarpur (Punjab) and Simla (Himachal Pradesh).

6. **Serpentine.** Serpentine is a metamorphic rock, found in green, yellowish green or dark green in colour. It is a soft rock and can be cut with a knife. It is used in superior buildings for indoor decorative purposes only.

   Serpentine is found in Rajasthan, Gujarat and Madhya Pradesh.

7.13.5 Dams and Reservoirs

All geological problems of a dam site and reservoir are, generally, common. But distinction must be made between the two. Geological investigation of a reservoir covers the entire area, over which the water is to be impounded, and relates generally to the conditions that may cause leakage. But the geological investigation of a dam site relates to a small area, with a particular stress on the strength, stability and permeability of the underlying bedrocks.

It may be noted that safe location of a dam is of greater importance than that of a reservoir. It has been observed that leakage in a reservoir does not cause any serious damage. But leakage through or beneath the dam may cause sudden failure of the dam, releasing huge volume of water, costing many lives and destroying the costly structure itself.

Geological problems of dams and reservoirs are discussed in detail here :

17.13.6 Dams

A dam may be defined as structure, erected across a stream or a river, to impound water; and to retain it above the level at which it normally stands. This impounded water is then made to pass through the dam, at the rate of certain calculated flow.

The impounded water may be used for the purposes of the generation of power, irrigation, water supplies and floor control. A dam, that serves more than one such purposes, is called a multipurpose dam.

17.13.7 Classification of Dams

Dams may be classified, on the basis of the materials of construction, into the following two categories :

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1. Earthen dams.
2. Concrete (Gravity) Dams.

The earthen dams are generally trapezoidal in section, constructed of selected soil or earth obtained from the borrow pits of the adjoining areas. Sometimes an earthen dam also contains a hard rock-fill, depending upon the height, base width and length of the dam.

It may be noted that the cost of an earthen dam depends upon its longitudinal section and is also proportional to the square of its height. Dams which are long and less in height are cheaper in construction and more safer than those short in length but more in height. Both the sides of an earthen dam should have an easy slope not less than 2 : 1 (*i.e.*, 2 horizontal to 1 vertical) in any case. The upstream side should always be stone-pitched to avoid erosion. The work of earth filling should be done layer by layer. A layer of 30 cm in height should be laid. It should then be moistened and compacted into 20 cm thick layer.

A concrete dam is preferred when its height increases 60 or 70 metres. It is generally triangular in section and is designed to withstand its own weight and thrust of the impounded water.

17.13.8 Selection of Dam Site

Since the dams are always very important and costly structures, therefore its design and construction should always be done very carefully. The record of dam failures all over the world, in the last few decades, has revealed that a majority of dam failures all over the world is not due to faulty design or lack of proper supervision during construction. But only due to the defective bed conditions, which were not fully detected at the time of selection of the site.

It is thus essential that the selection of a dam site should be carefully made on the basis of topography of the region and geological conditions of the site. An ideal dam site should have the following topography :

1. A narrow river channel, which can be blocked with a relatively small dam.
2. Availability of materials, required for the construction of the dam, in the neighbourhood of its site.
3. Level of the dam site should coincide with the designed level, with respect to water level in the reservoir.

In addition to the above mentioned topographical requirements of the dam site, it should be thoroughly investigated for underground geological details also. For this purpose, a large scale geological map should be prepared giving the following details :

1. Type of rocks.
2. Properties of the rocks, *i.e.*, chemical composition texture and hardness of the rocks.
3. Permeability of the rocks.
4. Structural features of the rocks, *i.e.*, dip, strike, outcrop etc.
5. Structural defects of the rocks, *i.e.*, folds, faults, fissures etc.
6. Crushing and shearing strengths of the rocks.
7. Spacing of joints in the rocks.
8. Extent of weathering of the rocks.
9. Thickness of the bedding planes.
10. Zones of fractures and weaknesses.
11. Water table of the area.
12. Accumulation of the stream deposits.

The ideal foundation conditions, for the successful working of a dam, are that it should be built over a uniform formation, if more than one kind of rocks is present, the different bearing strengths may lead to an unequal settlement of the structure. Moreover, the underlying rocks should be strong

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enough to bear the weight of the dam and to withstand the resultant thrust of pressure of the impounded water and the weight of the dam itself. It may be noted that a difference of water table is always set up on the two sides (upstream and downstream) of the dam. Thus all materials in the bed very close to the dam are subjected to a considerable hydraulic pressure. It is therefore essential that the bed rocks should be sufficiently hard and impervious to counteract this pressure.

For studying the undergound geological data of a dam site, boring tests should be carried out. Bore holes and core samples, should be thoroughly studied. Water pressure tests in the bore holes provide a fairly reliable data, regarding the water tightness and the structural features of the underlying rocks.

The formations, in which hard and soft layers are alternately present, provide the worst type of foundations as penetration of water may weaken the soft layers. It may be noted that if sandstones and shales are present in alternate layers, it leads to slipping. As the bearing capacity of different rocks varies widely and even two similar rocks may have different bearing strengths. It is, therefore, advisable that the rocks should be tested for their crushing strengths also.

It has been experienced that granite, when free from structural or other defects, provides an excellent type of foundations. Dolerite, gneisses, schists and quartzites, if free from open joints and fissures, also provide a good type of foundation. Limestones are generally troublesome because of their solubility.

As the dam site is always at the deepest part of a valley, therefore the impounded head is always greatest at this site. Thus the rocks of structural defects or existence of such rocks that may be easily affected by the prolonged exposure to water, are of greater danger in the vicinity of a dam. In addition to the above requirements, the site should be investigated for the structural features also.

17.13.9 Structural Features of Dam Site

It has already been mentioned that an ideal condition for a dam site is that it should be built up over a uniform formation, but the engineer is not always lucky enough, to have such a situation and he may have to face a number of difficulties, specially regarding the structural features of the underlying rocks. The following structural features of the underlying rocks should be analysed :

1. Dip and Strike 2. Folds 3. Faults 4. Joints

1. **Dip and Strike.** We know that the bedded rocks are stronger in compression, and can bear greater stresses when applied normal to the bedding planes, than the stresses applied along the bedding planes. Thus the desired conditions are that the resultant thrust (resultant of vertical force due to the weight of the dam and the horizontal force due to thrust of the impounded water), should be perpendicular to the bedding planes. Thus the beds dipping gently upstream offer best resistance to the resultant thrust and also obstruct the leakage of water than those dipping downstream.
2. **Folds.** As already mentioned, the folded rocks are always under a considerable strain, and the same is released whenever any kind of excavation is done through them or they are disturbed by some external force or stress. It is therefore desirable that a highly folded rock should always be avoided.
   If the engineer is compelled to adopt such a site, he should see that the foundations of his dam should rest on the upstream limbs of the fold, if the fold in it is anticlinal in nature. But if the fold is synclinal in nature, the foundations of the dam should rest on the downstream limbs of the fold to avoid leakage.
   In no case the foundations of a dam should rest on the axis of the fold. It has also been observed that the danger of leakage is always more beneath the strata in the case of a synclinal fold.
3. **Fault.** It is always desirable to avoid risk by rejecting a site on a fault, as the movement along the existing fault plane is much easier than along any other plane. Even a slight disturbance may damage the structure constructed on a fault.
   If the engineer is compelled by the circumstances to adopt such a situation, then he should

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see that the site has the fewest disadvantages or no serious defects. It is advisable in such cases to place the foundations of a dam upstream of the fault and not downstream of it.

The engineer should also investigate, as thoroughly as possible, the nature, extent and age of the fault. It may be noted that the different zones of a small fault can be improved effectively by grouting; whereas in the case of wider zones all the weak material should be removed and refilled with rich cement concrete. This should only be done if there is no possibility of movement along the fault plane.

4. **Joints.** A joint is always the weakest point in a structure. Similarly if the site, under consideration for a dam is jointed, the engineer is expected to face much of troubles, before the construction of dam, during the construction of dam and even after the construction of dam. The presence of joints in underlying rocks at the dam site, will cause the water to leak through them. With the passage of time, this leakage may even endanger the structure. Such a condition will change from bad to worse, if a part of the underlying rocks is of limestone formation, as the joints of such a formation are enlarged by the solution of rock.

If the joints, met with, are local in character, or the area affected is small, grouting will improve the site and may be relied upon. But if the underlying rocks are heavily jointed, the site should be straightaway rejected.

17.13.10 Geology of Reservoirs

The chief function of a reservoir is to store a predetermined quantity of water, that may be used for water supply or irrigation purposes, at a later stage.

The selection of site for a reservoir depends upon so many factors, *e.g.,* if the reservoir has to serve the purpose of storing water for water supply of a town, the site should be as near to the town as possible. An ideal site for this purpose should be free from harmful organic and inorganic materials and the capacity of the reservoir should be sufficient to ensure regular and adequate supply to the residents of the town.

If the reservoir has to serve the purposes of storing water for the generation of power or irrigation purposes, the detailed, geological survey of the site is of utmost importance.

Leakage from a reservoir is always a source of trouble, which an engineer has to face. Leakage may take place because of the defects in the structural arrangement of the underlying strata *e.g.,* faults or excessive fissures. As it is seldom possible that a reservoir can be emptied completely, or even partially, when once it has been placed under active service. Thus, it is most essential to conduct geological investigations of the reservoir site. All the sources of leakage should be discovered and suitable steps should be taken to stop the same, as discussed below :

1. Natural sealing material, such as clay or silt content of the streams, feeding the reservoir, should be employed to block-up the openings in the reservoir, through which leakage takes place. It may be noted that Kundi Tank of Bijapur (Mysore) was sealed automatically after 12 years of natural silting.
2. When the exact location of the weak area is shown, it can be improved by grouting. This is only possible if the area affected is small and local in character.
3. When the fault or fissures, met with, are large they can be improved by removing loose material and refilling the same with cement concrete; though this operation may prove costly.

17.13.11 Silting up of Reservoirs

Streams flowing into a reservoir, bring considerable amount of sediments, which are carried in suspension by the water. These sediments are deposited in the reservoir. Thus the storage capacity of the reservoir goes on decreasing gradually. It is a general trouble, which is being faced all over the world by the engineers engaged on the maintenance of reservoirs. It still requires a careful attention and a satisfactory solution. The reservoir of Austin in Texas (U.S.A.) was silted up 9% in a period of 12 years after it was built. The only possible remedies to stop or minimise the silting up of the reservoirs are :

1. Making provision for washing out the silt through passages of the dam.

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2. Constructing weirs across mouths of the feeding streams.
3. Providing a good cover of vegetation on the catchment area.

17.13.12 Tunnels

A tunnel may be defined as an underground route constructed in order :

1. To avoid the excessive cost maintenance of an open cut of more than 20 meters high, subjected to landslides etc.
2. To connect two terminals, by the shortest route, separated by a mountain.
3. To meet the requirements of rapid transportation in big.
4. To avoid expensive acquisition of valuable land or properties, on the ground.
5. To avoid holding up of traffic, for long periods, in big cities.
6. For conducting water for the generation of power. Such a tunnel is called hydropower tunnel.

Most of the tunnels are constructed to connect two terminals, separated by a mountain. It is always advisable to drive a tunnel, than to make an open cut of more than 20 metres deep.

If the tunnel is to be constructed either to meet the requirements of rapid transportation, to avoid expensive acquisition of valuable properties or to avoid holding up of traffic in big cities, there is not much of freedom for the choice of alignment for an engineer, because the geology of the area is always dominated by other factors such as location of the connecting roads, built up properties, water and sewer pipes etc. In such cases, the engineer should study the geological features of the area in details and plan his work accordingly.

If a tunnel is to be constructed for the conduction of water to generate power, no separate geological investigations are required as such a tunnel is always a part of the dam.

The ideal, geological conditions are that the rocks should be homogeneous in character, which can be easily excavated. Moreover, the rocks should not contain any kind of water bearing strata and at the same time the rocks should not be affected, in any way, when exposed to air.

The desired conditions for the construction of a tunnel are that the rocks should stand even after the tunnel is driven through, and at the same time the work should not be rendered expensive due to unforeseen problems. It is therefore absolutely essential to study the geological features of the rocks, before the excavation is undertaken. It may be noted that if an exact idea of the structural features and the nature of the rocks, through which the tunnel has to be driven, is determined beforehand, it is then possible to predict the conditions and difficulties that are likely to be faced during construction. Necessary steps should be taken to overcome such difficulties. It has been observed that carefully planned drilling, along the centre line of the proposed tunnel, gives a fairly reliable data regarding the underground geological features of the rocks. But this is not always practicable as the tunnel may be driven, sometimes, at great depths. In such cases, drills along the centre line is impracticable, if not impossible. However, in such cases accurate correlation of the strata with the surface conditions should be done or the geological features can be estimated from the indications of the adjacent land.

Rocks may be divided into the following two main groups, for the tunnelling operations :

(*i*) Unconsolidated rocks. (*ii*) Consolidated rocks.

(*i*) Unconsolidated rocks

These include loose sediments like gravel, sand, clay and highly uncomposed rocks. Such rocks do not possess cohesive power and always have low crushing strengths. Tunnels driven through such rocks always require heavy lining, depending upon the type of the rocks and importance of the tunnel. It has been experienced that the tunnelling is always difficult and complicated in unconsolidated rocks, as such rocks do not stand in their original position after excavation. It also requires heavy shuttering even before the lining is started. Moreover, water is generally present in such rocks, which worsens the situation and offers many complications during excavation and lining.

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(ii) Consolidated rocks

These include granite, basalt, gabbro, diorite, gneiss, schist, sandstone etc. Tunnels driven through such rocks require no or little lining. It has been experienced that the tunnelling in consolidated rocks is always easier as there is not possibility of the roof to fall and water to be encountered. Consolidated rocks are thus considered to be the best type of rocks for the tunnelling operations, but are expensive at the same time.

A tunnel required for the conduction of water is called a pressure tunnel or hydropower tunnel. In such a tunnel, the engineer should give a proper consideration to the following points, in detail :

1. He must ensure that the rocks, surrounding the water, are impervious.
2. He should see that some means are adopted to withstand the pressure, set up by the unbalanced head of water, passing through the tunnel.
3. He should study the abrasive effects of silt and gravel, carried in suspension or rolled along the base of the tunnel, while designing the lining of the tunnel.

17.13.13 Structural Features of Tunnel Site

It has been observed that the structural features of the rocks, through which the tunnel is driven, always play a major role in the proper planning, execution and successful working of the tunnel.

The following structural features of the rocks should be analysed :

1. Dip and strike 2. Folds 3. Faults 4. Joints.

1. **Dip and strike.** The relationship of the dip and strike, of the rock with the centre line of a tunnel, is always a most important factor for the proper planning of the project.

   In general the following two cases are studied.

   (*a*) *When the centre line of the tunnel is at right angle to the strike.* In this case there is no unsymmetrical pressure, from the sides.

   The tunnel can be driven easily and can work quite smoothly, even with a little lining, which may be required only to withstand the downward pressure of the roof.

   (*b*) *When the centre line of the tunnel is parallel to the strike.* In this case there is a considerable unsymmetrical pressure from the sides. As the block always tend to slide down into the tunnel along the bedding planes, thus the unsymmetrical pressure may result in slide, down the rocks. In such cases heavy lining has to be provided for the stability of the tunnel. In both the cases there is a likelihood of interference of water that may come into the tunnel, through the bedding planes.

2. **Folds.** As already mentioned, the folded rocks are always under a considerable strain; and the same is released, whenever any kind of excavation is done through them or the folds are disturbed by some external stress. This may result in movement of rocks or bulging out of the walls. It is therefore advisable that a highly folded site should be avoided as far as possible for the construction of a tunnel. Sometimes, if the engineer is compelled by the circumstances, to adopt such a site, then he should study the following two cases :

   (*a*) *When the tunnel is driven through an anticlinal fold.* In this case the blocks and fragments tend to fall from the roof into the tunnel as the anticlinal formations are always highly fractured. This happens during the excavation of the tunnel and necessitates heavy lining.

   (*b*) *When the tunnel is driven through a synclinal fold.* In this case there is every likelihood of interference of water, that may come through the bedding planes. It has also been observed that rocks, below the floor of the tunnel, may subside under heavy traffic, creating a number of complications.

   It is therefore advisable to avoid a synclinal fold for the construction of a tunnel.

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3. **Faults.** As already mentioned, it is always advisable to avoid risk by rejecting a site on a fault for the construction of a tunnel, because movement along the existing fault plane is much easier than any other plane. Even a slight disturbance may damage the structure constructed on a fault.

4. **Joints.** Lot of grouting is required to hold the rocks in their original position. Sometimes, when the grouting does not seem to be sufficiently safe, heavy lining has to be provided. It is therefore advisable that a rock, which is heavily jointed, should preferably be avoided for a tunnel to be driven through. It may be noted that if the tunnel is required for the conduction of water, a badly or heavily jointed rock may permit a considerable leakage of water.

13.14 Water Supply

Rainfall is the chief source of water supply, even if the supplies may be drawn from any source, e., rivers, lakes, wells and catchment areas. Thus, the estimation of the quantity of rainfall, of an ea, is the most important factor for a water supply engineer.

It has been observed that a part of the rainfall, that falls on the ground, is evaporated (termed evaporation); part will run off the surface (termed as run off); part will be absorbed by the vegetation (termed as loss); on which it falls and the rest will find its way into the subsoil (termed as percolation). It may be noted that all these four processes are dependent more or less on the geological features of the area.

It has been estimated that more than 80% of the total water supply of the world is based on the underground water and the rest on the surface water. This figure shows how important place the underground water occupies in today's life of man. The man of ancient times, used to obtain water directly from the flow of the rivers or lakes. This, perhaps, is the probable reason that all the big cities of the world are situated near the flow of the ancient rivers or lakes.

In this scientific age, a water supply engineer has to study the following two problems, while planning his water supply project :

1. Quantity of water. 2. Quality of water.

1. Quantity of water

The quantity of water, required by a town, depends upon the following two factors :

(*i*) Population of the town, and

(*ii*) Requirement of water, per head per day.

The population of a town is forecasted, by some standard method in the coming decade. This is normally done by studying the increase of population in the last 4 or 5 decades of the town.

The requirement of water per head per day is fairly estimated by studying the climate conditions, habits and customs of the people, industrial requirements and system of sanitation of the town. It includes domestic requirements (*i.e.*, drinking, cooking, washing etc.), public demands (*i.e.*, watering the parks, gardens, sprinkling on roads etc.), wastage, losses and thefts etc. Then the total quantity of water required is calculated by multiplying the population of the town with the requirement of water per head per day.

If the water supply engineer is planning his project on the underground sources, then he has to make sure that the underground rocks have the capacity to supply the required quantity of water. This is generally done by studying the porosity (*i.e.*, capacity of a rock to contain water, which is expressed numerically as the percentage of the void space contained in it) and permeability (*i.e.*, property of a rock by virtue of which it allows the water to travel through its pores and other openings) of the underground rocks. The following table shows some typical values of porosity for a few of the well known rocks.

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Type of rock	*Porosity*
Clay soil	50 to 60%
Chalk	Up to 50%
Sand and gravel	25 to 40%
Limestone	10 to 20%
Sandstone	5 to 15%
Shales	4 to 5%
Slates	Up to 4%
Granite (and other igneous rocks)	1 to 1.5%
Crystallined rocks	less than 1%

Porosities greater than 40% are rare except in soils and unconsolidated deposits. A porosity greater than 20% is regarded as high; 50 to 20% as medium and below 5% as low.

It is believed that the quantity of water, within the earth's crust, relatively close to the surface is about one third of the total volume of water in seas and oceans. It is also estimated that water exists, almost invariably, under all parts of the surface, although it may be located at such depths, so as to be of no possible use for man. It may be noted that pumping is not economical generally below the depths of 200 or 250 metres. Although water may be available below these depths, yet it cannot be regarded as commercially available.

Water table

We know that the underground water continues to percolate, downwards, through permeable rocks; so long as pores of the rocks are interconnected and are of sufficiently large size. At a certain depth, further percolation of the water stops, for want of interconnections of the pores of the rocks. The percolating water, therefore, has no other way except to accumulate there. This water, saturates the pores and other openings of the rocks. As more and more water goes on percolating up to the saturated pores of rocks, therefore it causes the level of saturated rock pores to move upwards. The upward movement of the saturation ceases at certain level. This level, below which the rocks are completely saturated with water is known as *water table* and the water, that occurs below the water table, is called *underground water*.

Extraction of the underground water

It has been observed that most of the rocks, near the ground level, consist of alternate strata of previous and impervious soils; though their thickness may vary from place to place. The water is generally obtained from the pervious strata of the rocks through the wells. Though there are many types of wells, yet the following are important from the subject point of view :–

(*i*) Shallow well (*ii*) Deep well (*iii*) Artesian well.

(*i*) **Shallow well.** An ordinary well of 2.5 metres to 5 metres in diameter, dug up to topmost water bearing strata is called a *shallow well*.

(*ii*) **Deep well.** A well of 25 cm to 50 cm in diameter, and drilled up to the second or even lower water bearing strata, is called a *deep well*. The water from a deep well is pumped out with the help of mechanically or electrically operated tube-wells.

(*iii*) **Artesian well.** A well, from which the water is obtained without pumping, is known as an *artesian well*.

This happens, when a porous strata, surrounded by impervious formations, is folded in the form of a syncline. If the pervious strata is continuously fed with water at its higher level, the same must find some way to flow out due to hydrostatic pressure. Such a well, through which the water flows out, without pumping, is called an artesian well.

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2. Quality of water

The main duty of a water supply engineer is to supply the water of good quality to the residents of the town. But he is not always lucky enough to obtain a good quality of water from the underground rocks.

Sometimes various salts are dissolved in the underground water, which affects the utility of water, depending upon the quantity of the salt present in it. The following is the chart of water containing salts in parts per million (P.P.M.) and its comparative use.

P.P.M.	*Use*
Up to 400	No taste at all
Up to 2500	Slightly brackish taste
Up to 3300	Usable domestically
Up to 4500	Almost unbearable
Up to 5000	Unfit for human use
Up to 6250	Horses live in good condition
Up to 7800	Horses can live on it
Up to 9300	Cattle can live on it
Up to 15600	Sheep can live on it
Beyond 15600	Beyond tolerance power

It is therefore essential for a water supply engineer, to know the quantity as well as quality of water available while making underground water survey. It may be noted that the content of salt, up to 3300 P.P.M., can be simply treated and supplied to the public. But if the content of the salt is more than that, it is always advisable, to reject the source of water. Following are the water bearing properties of a few rock groups.

(*i*) **Gravels and Sand.** These are considered to be the ideal water bearing rocks, as these are highly porous. In addition to the water bearing properties, gravels and sands also act as an effective filtering medium, thus yielding very clear water.

(*ii*) **Clays and Shales.** Though clays and shales are the most porous rocks, yet these are regarded as unsuitable rocks for the underground water. Clays are often wet and the water present is not readily available. Moreover, the water obtained from these rocks often contains impurities.

(*iii*) **Sandstones.** Sandstones are so variable in texture and chemical composition that they form an almost impervious rock to the most pervious one. It has been experienced that when the sandstones are found pervious in nature, they form an admirable source of underground water and also constitute an effective filtering medium. Water obtained from such sandstones is almost clear and sparkling.

(*iv*) **Limestones.** Limestones are considered to be the waterbearing rocks next to sandstones. It has been observed that water in contact with limestone dissolves a small quantity of the rock. Thus the water obtained from such rocks should be thoroughly treated before supplying to the public.

17.13.15 Excavation

Excavation for civil engineering purposes is done for either of the following two purposes :

1. To form a hole, within specified limits and up to specified levels, *e.g.*, for canals, sewer pipes and foundations etc.

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2. To utilise the excavated materials, *e.g.*, stone for building purposes; gravels and sand for concrete and earthwork for embankment etc.

Open excavation work is frequently as a simple process. But an experienced engineer knows the problems that are likely to be faced during excavation. In almost all the engineering projects little attention is paid to know the nature of materials to be handled, their relative structural arrangement, their behaviour when removed from their existing position, possibility of water to be met with during excavation and the possible effects of the excavation operation on the adjacent ground and structures.

Whenever these preliminary requirements are not fully detected before the excavation work is undertaken, it results in extra expenditure and troubles to be encountered. Preliminary investigation is sometimes neglected, as it is often considered that a few cubic metres more or less of earthwork will make little difference. But lack of preliminary investigations may cause complicated troubles; even loss of human life, during excavation. It is therefore essential that the preliminary investigations should be carried out and constant check on the excavated work be exercised for the excavation of all types of important foundations, *e.g.*, dams, bridges, multi-storeyed buildings etc.

In general excavation work, dip of the strata to be encountered is a factor of major importance. If the strata are horizontal or approximately so, excavation work will be simple. But if the bedding is appreciably inclined excavation work will be affected adversely. In such cases side slopes should be so selected as to be in accordance with the natural slopes of the bedding.

As a matter of fact, excavation work is always influenced by the nature of the material to be encountered. The materials to be excavated may be designated as below :

1. **Excavation of hard rocks.** Excavation of granite, basalts, limestones etc. which has to be carried out by blasting.
2. **Excavation of loose rocks.** Excavation of rocks, which do not require blasting; but can be carried out by means of hand shovels.
3. **Excavation of soft rocks.** Excavation of disintegrated rocks like clay and sand etc. which can be carried out economically by means of hand-shovels or similar tools.
4. **Excavation of water bearing strata.** In water bearing strata, adequate surface drainage arrangements are the first essentials to reduce the water content or to prevent its increase. This may be done by means of ditches, tile drains or pumping out by tube wells or other wells to lower down the water level.
   (During the construction of Rajasthan Canal (Northern India) as its head, centrifugal pumps were installed for lowering down the water level to facilitate the excavation.)

17.13.16 Quarrying

Quarrying is general engineering term, used for the process of taking out stones or various sizes from a stone quarry. It will be interesting to know that it is an ancient art and many ancient quarries are still preserved in many countries.

In ancient times, wedges and chisels were used for the extraction of stones. But modern methods of obtaining the stones are highly mechanised and special methods of quarrying are being used for the extraction of different varieties of stones. Explosives such as gun powder, dynamite or gelignite are extensively used in quarries.

Quarries may be open on hill tops or holes below the ground level. When a quarry is open on a hill top, dip of the strata to be encountered is a factor of major importance. The quarry faces should be kept at a safe height and inclination. If the quarry face exceeds 30 metres in height there is always a danger of rock-fall from the top of the quarry face. In such cases it is always advisable to keep the quarry face at proper sloped and suitably stepped so as to render it quite safe. It has been experienced that the possibility of rock fall is always more in a slate quarry than any other stone quarry.

A quarry, below the ground level, is a large hole in the ground. Drainage of such quarry is always a difficult problem and provision must be made for pumping out the water which may have accumulated on the quarry floor.

A quarry, below the ground level, should not be preferred unless the stones obtained from such a quarry are of superior quality than those obtained from an open hill-side quarry.

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Quarrying in jointed rocks

It has been observed that joints always facilitate the extraction of stones and cut down the quarrying expenses. If the stones are required for road metal or concrete aggregates, a jointed rock should always be preferred. But if the stones of large sizes are required, it is advisable to study the joint-systems before the quarrying is started.

Sand quarries

Sand pits, from which the sand is taken out for the construction purposes, is known as a sand quarry. A sand quarry may be small, when it is dug and loaded by manual labour which may have no, or only a rough, screening to remove pebbles. In a large mechanically operated quarry, sand may be dug by draglines and sent to washeries where the sand may be washed to remove and, clay or pebbles which may be present. In very large undertakings sand may be separated into graded sizes and then recombined, by mixing a definite proportion of graded sand, as desired.

17.13.17 Roads and Railways

Roads, railways or highways always possess a national importance in a country. As a roadway always extends over a long distance and every variety of soil is likely to be encountered, thus the engineer is supposed to carry out his work on every type of soil.

For a systematic and scientific approach, it is necessary to make sub-soil survey of the entire length of the strip of land to be acquired. Following are the few problems, which are generally faced by an engineer during the construction and maintenance of a highway.

1. Roads and Railways on embankment

The ideal earth for an embankment should be dense, free from excessive moisture and possess a high internal friction and cohesive power. It has been observed that soils having a low internal friction and cohesion always tend to flow and spread out, especially when there is excessive moisture. Theoretically, an ideal soil should contain gravel, sand, clay and silt in equal proportions with moisture slightly above the plastic limit (say 10%). However such ideal soils are rare in nature. Usually a mixture of two or three different soils gives satisfactory results, *e.g.*, sand material should be mixed with clayey soil to increase internal friction and to reduce the plasticity of clay.

The best material obtained from the borrow pits should be used in the top two or three layers of the embankment, moreover, gravelly and sandy material should be used in the topmost layer.

2. Roads and Railways in excavation

Excavation work is always influenced primarily by the nature of the materials to be encountered. Both the faces should be kept at a safe slope and stepped alongwith longitudinal drains as shown in Fig. 17.9.

If the rocks are hard like granite, basalt, gneiss etc. even a slope of ½ : 1 (½ horizontal to 1 vertical) can stand quite safe. But if the rocks are soft like clay, sand or gravel a slope of 2 : 1 or more depending upon the internal friction and cohesion of the rock particles, should be provided.

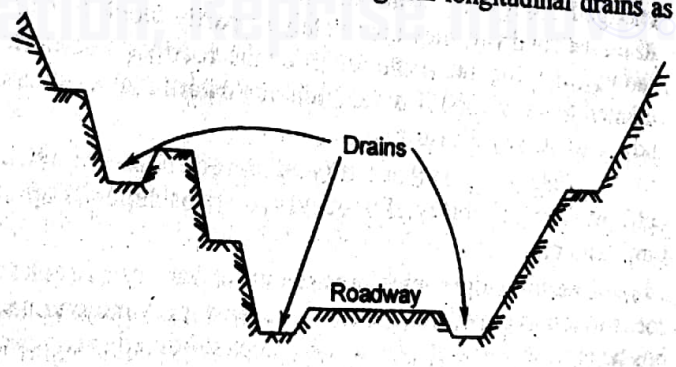

Fig. 17.9

3. Roads and Railways in marshy regions

Geological investigations of the areas are absolutely essential whenever a road happens to pass through a marshy region. It may be noted that such a region is always a treacherous one and road failure generally occurs due to subsidence (vertical settlement), which happens due to the presence of unstable material.

If the area involved is small, it can be improved by removing the weak material and refilling the same with cement concrete. But if the area involved is large, it is advisable to avoid such a region.

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4. Roads and railways in water-logged areas

We often find that roads situated in water-logged areas are always damaged. This happens when the water table in the area rises up to the ground level and moistens the subgrade to various degrees. It reduces the bearing capacity of the subgrade and road metal, which results in damaging the road.

In a water-logged area the roads should be constructed on embankments at a safe height and longitudinal drains should be provided on both sides of the road to drain off the water.

5. Roads and railways in the hilly areas

In hilly areas, the roads and railways are often led through cuttings along the slopes of the hills; to serve as means of communication between the hilly tracts and the neighbouring plains. The hill slopes, along which the roads and railway lie; walls of the cutting or filling through which they pass as shown in Fig. 17.10 should be sufficiently stable, for the safe working of the roads and railways.

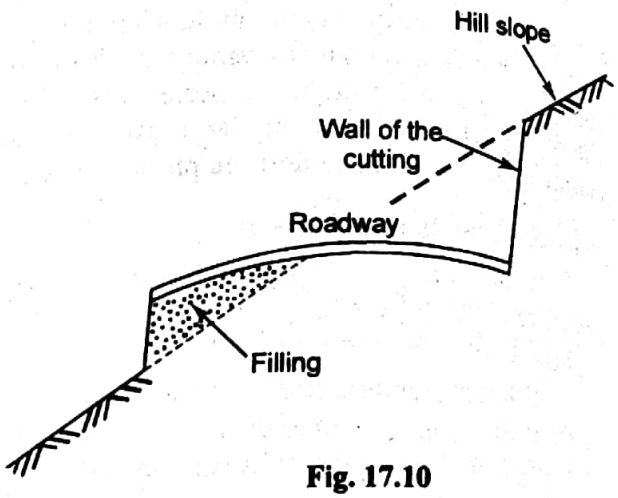

Fig. 17.10

The only problems which the engineers, employed on the maintenance of roads and railways in hilly areas face is due to landslides; which include all downward movements of rocks. Following are the two types of landslides in hilly areas :

(*i*) Soil slips (*ii*) Rock slips

(*i*) Soil Slip

Sometimes the loose soil (such as gravel, sand etc.) gently creeps down the hill slopes, and falls on the roadway. These creeping materials do not exhibit serious problems and can be held back by constructing retaining walls on both sides of the roads. Such a downward movement of the loose soil is called *soil slip*.

(*ii*) Rock Slip

Sometimes huge masses of hill rocks are dislodgedSometimes huge masses of hill rocks are dislodged, along their planes of weakness, and suddenly slide down. If such masses of massive rocks fall on the roadway, they completely or partly block it. But if such blocks, form the subgrade of the roadway, they decrease the width of the roadway; sometimes rendering it unserviceable, till it is widened towards the hill side. Such downward movements of the massive rocks are called *rock slip* and are generally disastrous.

It may be noted that the frequent rock slips are detrimental to the stability of hill-slopes and cuttings. The possibility of frequent rock slips depends upon the nature of hill rocks and their structural features.

The hill slopes may be made up of variety of rocks ranging from loose and unconsolidated rocks (such as gravel sand, etc.) to massive hard and compact rocks (such as granite, syenite etc.). It has been observed that a loose and unconsolidated rocks can not stand permanently at a slope, more than its angle of repose. It is thus obvious that walls of cutting and filling of a roadway should not have a slope more than its angle of repose. If a steep slope is unavoidable, then retaining walls should be stabilized by stone pitching or grouting.

It has been observed that the dip of the hill rocks also plays an important role in the stability of the roads or railways in hilly areas. If the beds are dipping towards the roadway at an angle, less than the angle of the wall of cutting, they are most unsafe; as the possibility of rock slips is always more in such cases. It is thus obvious that such a site should always be rejected.

It has also been observed that if the bed are dipping towards the roadway at the same angle as that of the wall of cutting, they are sufficiently safe.

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The only problem, that is likely to crop up, may be due to the subsidence of a weaker bed; whereas a harder one may remain at same level.

It has also been observed that if the beds are dipping away from the roadway they make the rocks as well as the roadway or railway very stable.

17.14 Physiography of India

17.14.1 Introduction

During a walk in a country, we find that the surface of the earth is not absolutely plain. But it exhibits an irregular topography which may be characterised by the presence of mountains, valleys, lakes etc. These features of the land may vary in size and altitude, whose development has taken place in the geological past. A detailed study of such features, alongwith the development of such land contours is called **physiography**. In the succeeding pages, we shall study the physiography of our sub-continent, the India.

17.14.2 Physio]Divisions of India

The Indian sub-continent may be divided, physiographically, into the following three zones :

1. **Peninsula.** It comprises the Southern (including South-Eastern and South-Western) regions, triangular in outline, covering Bombay, Gujarat-Bengal, Bihar and Rajasthan.
2. **Indo-Gangetic plain.** It comprises the central alluvium filled region, covering wide areas of Punjab, Uttar Pradesh, Madhya Pradesh. It forms a link between the extra-Peninsula and the Peninsula regions.
3. **Extra Peninsula.** It comprises the Northern (including North-Eastern and North-Western) region covering the Himalayan ranges and certain parts of Punjab and U.P.

17.14.3 Mountains

A mountain may be defined as a tract of land, that stands higher than the surrounding area. A mountain range consists of a number of mountains, which have been formed essentially during the same period in the geological history of the region. A mountain system consists of a number of mountain ranges of the same geological age. A mountain chain consists of a number of mountain systems of different geological ages.

17.14.4 Formation of Mountains

The formation of a mountain may take place in a variety of ways. Following is the classification of mountains, on the basis of their formation :

1. **Volcanic mountains.** The volcanic mountains are formed by the accumulation of products (solid and liquid) of volcanic eruption around a volcano in the form of heaps. Such mountains are often, small and dome-shaped.
2. **Structural mountains.** The structural mountains are formed by the disturbance of the existing rocks. The length, width and height of such mountains depends upon the structural activity of the rocks. Following are the two types of structural mountains :

   (*a*) **Fault mountains.** As already mentioned, faulting always results in displacement of the blocks along the fault plane. Fault mountains are formed whenever a horst (German, *Horst* = up throw) fault of considerable displacement takes place; in which a considerable area is thrown up.

   (*b*) **Fold mountains.** It is believed that the fold mountains are formed as a result of stresses, which cause the layers of the earth's crust to fold continuously for millions of years and ultimately to form mountains.

3. **Residual mountains.** Residual mountains are formed because of the unequal erosion of the topography of the region. This happens because of unequal erosional factors, which result in lowering down the soft parts by the chemical as well as mechanical actions of the denuding agents; whereas the harder ones remain standing. Such elevations are called residual mountains.

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17.14.5 Indian mountains

The Indian mountains can be best studied under the following two heads :

1. **Mountains of extra-Peninsula.** The most important mount in system of this zone is the Himalayas. The great Himalayan range is about 2500 kilometres long and its width is between 150 kilometres to 400 kilometres.
2. **Mountains of Peninsula.** The most important mountain ranges of this zone are the Aray "*i.e.*, the Vindhyans, the Satpuras, the Eastern Ghats and the Western Ghats."

17.14.6 Valleys

A valley may be defined as a depression surrounded by elevated tracts on two or more sides.

17.14.7 Formation of valleys

The formation of a valley may take in a variety of ways. But the following classification of the valleys, based on their formation, is important from the subject point of view :

1. **Erosional valleys.** 2. **Tectonic valleys.**

17.14.8 Indian Valleys

The valley of Kashmir is regarded as the best example of the Indian tectonic valleys, which is a synclinal depression between the Himalayan mountains. The valley of Nepal is another important example of the tectonic valleys.

The erosional valleys are numerous which are formed by many rivers *e.g.*, the Brahmputra, the Ganges, the Indus etc. Almost all the valleys of Peninsula belong to the erosional type which are very broad and shallow with very gentle gradients.

17.14.9 Indian Lakes

Almost all the lakes are Kashmir are believed to be formed as a result of abnormal deposition, probably, by glaciers. Gohana lake of Garhwal and Lonar lake of Berar are believed to be formed in the mouths of extinct volcanoes. The Sambhar lake of Rajasthan is believed to be formed as a result of abnormal erosion.

17.15 Stratigraphy of India

17.15.1 Introduction

Stratigraphy is study of stratified rocks to know the ancient events of a region.

17.15.2 The Archaean System

This system includes all the old rocks, which lie beneath the stratified rocks all over the world. These rocks are without any kind of fossil. Gneisses are the most common rocks of this system. The gneissic rocks are further sub-divided on the basis of their structure into the following series –

1. Bengal gneiss 2. Budelkhand gneiss 3. Charnockite gneiss.

17.15.3 The Dharwar System

This system includes the oldest sedimentary rocks formed from the Archaean rocks. These rocks are also without any kind of fossil. It is believed that the Dharwar rocks must have been exposed to the weathering agents and shaken by earth movements continuously for a vast interval of time creating a number of mountain ranges, like mountainous chain of the Aravallis.

Some of the minerals of the present age *e.g.*, iron, manganese, gold, copper, mica, asbestos etc. are recovered from these rocks.

17.15.4 The Cuddapah System

The Cuddapah rocks have been found to be of sedimentary origin, but some signs of metamorphism are also indicated at few places. Like the Archaean and Dharwar rocks, the Cuddapah rocks do not contain any kind of fossil.

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The Cuddapah rocks are considered to be the excellent building stones. Marble of this system has been used for the interior decoration of Taj Mahal at Agra and other important Mughal buildings.

17.15.5 The Vindhyan System

The Vindhyan rocks have been found to be of sedimentary origin and are characterised by the absence of recognisable organic remains, except at few places where some traces of animals and vegetables are found. The historically famous Panna and Golkonda diamonds are mined from the outcrops of the Vindhyan rocks.

The rocks of this system provide excellent and durable building stones. The famous stupas of Sanchi and Sarnath, Mughal palaces and mosques of Delhi, Rashtrapati Bhawan, Red Fort and India Gate have been constructed from the Vindhyan sandstones. Limestone of this system is extensively used in the manufacture of cement.

17.15.6 The Cambrian System

The rocks, onward from the Vindhyan system, contain fossils; and thus can be recognised very easily. The Cambrian rocks are of sedimentary origin which are highly folded and disturbed. These rocks contain quartzites at the bottom; black and red slates at the top. The upper rocks of this system are highly fossilferous.

17.15.7 The Gondwana System

The Gondwana rocks were formed during different periods of the geologic time; but exhibit unique formation from bottom to the top. These rocks are further sub-divided into : (1) The lower Gondwana, (2) The middle Gondwana and (3) The upper Gondwana systems on the basis of the nature of the rocks.

Almost all the coal (98%) of India is recovered from the Dharwar system. About 95% output of total Indian coal is recovered from the Damuda series alone.

17.16 Coal and Petroleum in India

17.16.1 Coal

The coal is derived from vegetable matter after decomposition and carbonization, Peat, lignite, bituminous and anthracite are the different varieties of coal and exhibit the transformation of coal from the vegetable matter. Though there are many theories regarding the accumulation of vegetable matter, yet In-situ and Drift theories are considered to be reasonable.

The coal output in India has increased steadily. In India coal occurs mainly in Gondwana system i.e., at Jharia, Giridhi, Bokaro (Bihar), Raniganj (Bengal), Telcher (Orissa), Sohagpur Umaria, Korba (M.P.), Singareni (Hyderabad) and in Tertiary, i.e., at Plana (Assam), Neyveli (Bihar), Jangalgali, Nichoama (J & K) and Bikaner (Rajasthan).

17.16.2 Petroleum

The origin of petroleum is one of the complicated problems in Geology. Theories regarding the origin of petroleum may be classified into inorganic and organic ones. Petroleum products are extracted from crude oil by vapourising the crude oil and cooling down the same at different heights in a tower.

In India oilfields are in Assam. Drilling is in progress in Assam, Gujarat and U P. Exploration work is in progress in Punjab, Rajasthan, West Bengal, Orissa, Kutch, Madras, Andhra Pradesh and Kerala.

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OBJECTIVE TYPE QUESTIONS

1. Troposphere is the:
   (*a*) lowermost atmospheric zone
   (*b*) uppermost atmospheric zone
   (*c*) atmospheric zone extending between stratosphere & ionosphere
   (*d*) none of the above
2. Stratosphere is the:
   (*a*) lowermost atmospheric zone
   (*b*) uppermost atmospheric zone
   (*c*) atmospheric zone extending between the troposphere & ionosphere
   (*d*) none of the above
3. Lithosphere is the:
   (*a*) solid part of the earth
   (*b*) lowermost atmospheric zone
   (*c*) uppermost atmospheric zone
   (*d*) none of the above
4. Ionosphere is the:
   (*a*) solid part of the earth
   (*b*) lowermost atmospheric zone
   (*c*) uppermost atmospheric zone
   (*d*) none of the above
5. Terrestrial planets include:
   (*a*) Mercury, Venus, Earth, & Mars
   (*b*) Saturn & Uranus
   (*c*) Jupiter & Neptune
   (*d*) none of the above
6. Upper boundary of the troposphere is known as:
   (*a*) tropopause
   (*b*) tropoclause
   (*c*) tropotop
   (*d*) none of the above
7. Lithosphere consists of:
   (*a*) Atmosphere & crust
   (*c*) crust, mantle, & core
   (*c*) all the above
   (*d*) none of the above
8. Core is the innermost structural shell of the earth. It starts at a depth of _____below the surface and extends right upto the centre of the earth.
   (*a*) 900 km
   (*b*) 2900 km
   (*c*) 5000 km
   (*d*) none of the above
9. Major planets include:
   (*a*) Mercury and Mars
   (*b*) Jupiter, Saturn, Uranus, Neptune, and Pluto
   (*c*) Venus & Earth
   (*d*) none of the above
10. Troposphere is the lowermost atmospheric zone whose upper boundary lies at about:
    (*a*) 115 km above the earth surface
    (*b*) 9 km and 18 km above the surface at poles and equator respectively

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(c) 700 km above the earth surface
(d) none of the above

11. Stratoscope extends from the upper boundary of the troposphere to:
(a) 115 km above the earth surface
(b) 400 km above the earth surface
(c) 700 km above the earth surface
(d) none of the above

12. The region of atmosphere beyond 700 km. above the surface is termed as:
(a) exosphere
(b) ozonosphere
(c) lithosphere
(d) none of the above

13. The softest & hardest rocks (in that order) are:
(a) marble & diamond
(b) gypsum & rthoclase
(c) talc & diamond
(d) quartz & topaz

14. The principal setback(s) of "Continental Drift Theory" lies in the fact that it is incapable of accounting for the:
(a) presence of adequate force necessary for the process of drifting
(b) exact reason for the commencement of the drift just after the Palaeozoic period
(c) all the above
(d) none of the above

15. As per Mohs's scale, the hardnesses of Talc & Gypsum (in that order) are:
(a) 1 & 2 (b) 2 & 1 (c) 2 & 3 (d) 3 & 2

16. The temples of Bhuvaneshwar, Puri, and Konark are made up of:
(a) sandstone of gondwana age
(b) vindhya limestones
(c) makrana marble
(d) none of the above

17. As per Mohs's scale, the hardness of Calcite & Fluorite (in that order) are:
(a) 1 & 2 (b) 2 & 1 (c) 3 & 4 (d) 4 & 3

18. The idea of the wandering continents was first pictured by Wagner (1912) in his:
(a) convection current hypothesis
(b) planetesimal Hypothesis
(c) continental drift theory
(d) none of the above

19. As per Mohs's scale, the hardness of Apatite & Orthoclase (in that order) are:
(a) 5 & 6 (b) 6 & 5 (c) 7 & 6 (d) 8 & 7

20. The rock used for the construction of "Gateway of India" (in Mumbai) is:
(a) light coloured variety of trap rocks
(b) granite of South India
(c) charnockite of South India
(d) none of the above

21. As per Mohs's scale, the hardnesses of Quartz & Topaz (in that order) are:
(a) 7 & 8 (b) 8 & 7 (c) 9 & 10 (d) 10 & 9

22. In India, the Archaeans and the associated Dharwarian rocks cover nearly _____ area of the peninsula.
(a) 10% (b) 30% (c) 66% (d) 95%

23. As per Mohs's scale, the hardnesses of Corundum & Diamond (in that order) are:
(a) 9 & 8 (b) 8 & 9 (c) 9 & 10 (d) 10 & 9

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24. The huge Cuddapah basin is more or less crescentic in shape. The name of this system has been derived from the Cuddapah basin of:
(a) Madhya Pradesh (b) Maharashtra
(c) Andhra Pradesh (d) none of the above

25. Which of the following theories are related to the origin of earth:
(a) the tidal hypothesis (b) the nebular hypothesis
(c) the planetesimal hypothesis (d) all the above

26. Which of the following statement is correct in the context of Gondwana system:
(a) middle Gondwana deposits are completely devoid of coal seams
(b) lower Gondwana deposits contain the most important coal bearing strata in the Indian stratigraphy.
(c) upper Gondwana deposits contain a few coal seams
(d) all the above

27. A mineral may sometimes show a definite and characteristic arrangement in its outer appearance or physical shape which is expressed by the form "structure". Gypsum, as such, has got a _____ structure.
(a) bladed (b) fibrous (c) reniform (d) granular

28. Asbestos has got a _____ structure.
(a) foliated (b) fibrous (c) granular (d) bladed

29. Hematite has got a _____ structure.
(a) fibrous (b) reniform (c) foliated (d) mammillary

30. Mica has got a _____ structure.
(a) columnar (b) bladed (c) foliated (d) acicular

31. Kyanite has got a _____ structure.
(a) columnar (b) bladed (c) mammillary (d) reniform

32. Iron Pyrite has got a _____ structure.
(a) foliated (b) acicular (c) radiating (d) reniform

33. Malacnite has got a _____ structure.
(a) mammillary (b) fibrous (c) globular (d) radiating

34. Granite, Basalt, & Trap are :
(a) stratified rocks (b) unstratified rocks
(c) foliated rocks (d) none of the above

35. Shale, Slate, Marble, Limestone, and Sandstones, etc., are:
(a) stratified rocks (b) unstratified rocks
(c) foliated rocks (d) none of the above

36. The rocks having alumina or clay as their major constituents, are known as:
(a) siliceous rocks (b) argillaceous rocks
(c) calcareous rocks (d) sedimentary rocks

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37. Maximum permissible water absorptions of Sandstone and Granite (in that order) are:
(a) 10% & 1% (b) 1% & 10%
(c) 4% & 8% (d) None of the above

38. The rocks used for the construction of harbours in Mumbai and Chennai are mostly:
(a) light coloured variety of trap rocks
(b) granite and charnockite of South India
(c) sandstones & limestones
(d) none of the above

39. Maximum permissible water absorptions of Trap & Limestone (in that order) are:
(a) 1% (b) 3% (c) 6% (d) 9%

40. Rocks for their use as road material should possess sufficient cementing value. Very coarse-grained igneous rocks such as Pegmatite possess _____ cementing property.
(a) exceptional (b) excellent (c) good (d) very poor

41. Maximum permissible water absorption values for Slate & Quartzite (in that order) are:
(a) 3% & 1% (b) 1% & 3% (c) 5% & 8% (d) 8% & 7%

42. All volcanic rocks are amply suitable for use as crushed stone because they are:
(a) hard & tough (b) having high cementing property
(c) resistant to abrasion (d) all the above

43. Maximum permissible water absorption values for Shale & Gneiss (in that order), are:
(a) 07.50% & 10.00% (b) 10.00% & 01. 00%
(c) 01.00% & 10.00% (d) none of the above

44. The most suitable road material out of the following would be:
(a) coarse-grained igneous rocks (b) volcanic rocks
(c) plutonic rocks (d) hypabyssal rocks

45. Dolomite is a Limestone containing carbonate of magnesia upto:
(a) 15% (b) 20% (c) 25% (d) 45%

46. Rocks formed from molten magma are known as:
(a) sedimentary rocks (b) igneous rocks
(c) metamorphic rocks (d) none of these

47. Rocks formed by gradual deposition, are known as:
(a) sedimentary rocks (b) igneous rocks
(c) metamorphic rocks (d) none of these

48. Rocks formed due to alteration of original structure under heat and excessive pressure, are:
(a) sedimentary rocks (b) igneous rocks
(c) metamorphic rocks (d) none of these

49. Kaolin is chemically classified as:
(a) metamorphic rock (b) argillaceous rock
(c) calcareous rock (d) silicious rock

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50. Quartzite is a:
(a) metamorphic rock (b) argtillaceous rock
(c) calcareous rock (d) silicious rock

51. Basalt is a:
(a) sedimentary rock (b) metamorphic rock
(c) extrusive igneous rock (d) intrusive igneous rock

52. Limestone is not a:
(a) sedimentary rock (b) stratified rock
(c) aqueous rock (d) metamorphic rock

53. Laterite is a:
(a) volcanic rock (b) argillaceous rock
(c) calcareous roek (d) silicious rock

54. Pegmatite is a:
(a) intrusive igneous (b) extrusive igneous rock
(c) sedimentary rock (d) metamorphic rock

55. Granite & Rhyolite (silica 70-80%) are the examples of:
(a) acidic igneous rocks (b) basic igneous rocks
(c) ultra-basic igneous rocks(d) sedimentary rocks

56. Gabbro (silica 45-60%) is an example of:
(a) acidic igneous rocks (b) basic igneous rocks
(c) ultra-basic igneous rocks(d) sedimentary rocks

57. Peridotite is an example of:
(a) acidic igneous rocks (b) metamorphic rocks
(c) basic igneous rocks (d) ultra-basic igneous rocks

58. Syenite & Andesite (silica 70-80%) are the examples of:
(a) acidic igneous rocks (b) intermediate igneous rocks
(c) basic igneous rocks (d) ultra-basic igneous rocks

59. The examples of sedimentary rocks resulting from the precipitation of salts in drying water-basin are:
(a) dolomite, gypsum, & magnesite (b) breccia, & sandstone.
(c) limestone, shale, & chalk (d) all the above

60. The examples of rocks resulting from the deteriorations of massive magmatic or sedimentary rocks are:
(a) sandstone, carbonate conglomerate, etc. (b) gypsum & magnesite
(c) limestone & shale (d) all the above

61. Sedimentary rocks resulting from the accumulation of plant & animal remains are:
(a) gypsum & magnesite (b) sand & gravel
(c) limestone, chalk, & shale (d) all the above

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Objective Type Questions

Rocks resulting from the accumulation of plant & animal remains are known as:
(a) chemical deposits (b) fragmental rocks
(c) organogenous rocks (d) none of the above

Rocks resulting from the deterioration of massive magmatic or sedimentary rocks are known as:
(a) chemical deposits (b) fragmental rocks
(c) organogenous rocks (d) none of the above

Sedimentary rocks resulting from the precipitation of salts in drying water basin are known as:
(a) chemical deposits (b) organogenous rocks
(c) fragmental rocks (d) none of the above

Gneiss is resulted from the metamorphic transformation of:
(a) dolomite (b) shale
(c) granite (d) none of the above

Schist may be resulted from the metamorphic transformation of:
(a) sandstone (b) shale
(c) conglomerate (d) none of the above

Marble is resulted from the metamorphic transformation of:
(a) dolomite & marl (b) sandstone
(c) felsite (d) none of the above

The colour of statuary marble used for Sculptor's work is
(a) red (b) blue
(c) white (d) green

Quartzite is resulted from the metamorphic transformation of:
(a) limestone (b) sandstone
(c) mudstone (d) none of the above

Slate is resulted from the metamorphic transformation of:
(a) limestone (b) sandstone
(c) mudstone (d) none of the above

Limestone & Marble – on the basis of their chemical characteristics – may be classified as:
(a) calcarious rocks (b) argillaceous rocks
(c) silicious rocks (d) none of the above

Granite, Basalt, and Trap – on the basis of their chemical characteristics – may be classified as:
(a) calcarious rocks (b) argillaceous rocks
(c) silicious rocks (d) none of the above

Slate & Laterite – on the basis of their chemical characteristics – may be classified as:
(a) calcarious rocks (b) argillaceous rocks
(c) silicious rocks (d) none of the above

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74. Hardness & specific gr. of Pyrite lies between:
(a) 6 – 6.50 & 4.90 – 5.20 respectively
(b) 6 – 6.50 & 3.90 – 4.20 respectively
(c) 6 – 6.50 & 2.90 – 3.20 respectively
(d) none of the above

75. Hardness & sp. gr. of Magnetite lies between:
(a) 5.5 – 6.5 & 4.40 – 5.20 respectively
(b) 4.5 – 5.5 & 4.40 – 5.20 respectively
(c) 3.5 – 4.5 & 4.40 – 5.20 respectively
(d) none of the above

76. Petrology confines itself to the study of the:
(a) petroleum products
(b) formation of various groups of rocks & their compositions
(c) features of the surface of the earth
(d) none of the above

77. Specific gravity of Quartz (SiO_2) lies between:
(a) 2.30 – 2.60
(b) 2.60 – 2.64
(c) 3.60 – 4.00
(d) none of the above

78. Specific gravity of Garnet lies between:
(a) 2.60 – 3.50
(b) 3.50 – 4.30
(c) 4.30 – 5.20
(d) none of the above

79. The specific gravity of Marble is:
(a) 2.50 (b) 2.60 (c) 2.66 (d) 2.72

80. Specific gravity of Dolomite is about:
(a) 1.95
(b) 2.85
(c) 3.20
(d) none of the above

81. Geomorphology confines itself to the study of:
(a) the features of the surface of the earth
(b) the origin, development, and ultimate fate of various surface features of the earth.
(c) the formation of various groups of rocks, and their composition.
(d) none of the above

82. The phenomena of pealing off of curved shells or layers from rocks under the influence of thermal effects is called:
(a) spheroidal weathering
(b) chemical weathering
(c) exfoliation
(d) none of the above

83. The branch of geology dealing with ancient life is called:
(a) palaeontology
(b) stratigraphy
(c) lithology
(d) none of the above

84. Basalt is a dark coloured igneous rock which is extensively used as road metal. Its crushing strength lies between:
(a) 1000 – 2000 kg/cm^2
(b) 2000 – 3000 kg/cm^2
(c) 3000 – 4000 kg/cm^2
(d) 4000 – 5000 kg/cm^2

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85. Sandstones are sedimentary rocks of wide distribution. Their crushing strengths from Calcareous stones to Quartzites, vary from:
(a) 2500 kg/cm^2 to 3000 kg/cm^2
(b) 600 kg/cm^2 to 2500 kg/cm^2
(c) 3500 kg/cm^2 to 2500 kg/cm^2
(d) 1600 kg/cm^2 to 800 kg/cm^2

86. Dunes are:
(a) wind-deposits made up primarily of sand grade particles
(b) aeolian deposits
(c) all the above
(d) none of the above

87. Loess may be treated as:
(a) aeolian deposits
(b) deflation created depressions
(c) slacks
(d) none of the above

88. The Quattara depression of western Egypt is 300 km long, & 140 km wide. It is the best example of a:
(a) loess
(b) dune
(c) slack
(d) none of the above

89. Small rock sediments lying in the path of abrading winds become faceted and polished in one or more directions. Such wind-carved fragments in the deserts are called:
(a) ventifacts
(b) driekenters
(c) all the above
(d) none of the above

90. A rain intervening the movement of a dust-ladden wind causes there finer sediments to settle down on the ground below. Loess is the term for the aeolian deposits which occur in many parts of the world. There known example can be found in :
(a) north India
(b) central Asia
(c) north China
(d) none of the above

91. The maximum angle of slope of a bed (or layer of rock) with the horizontal is known as:
(a) dip
(b) strike
(c) bedding
(d) none of the above

92. Geographic direction of intersection of the bedding plane with an horizontal plane is called:
(a) dip
(b) strike
(c) bedding
(d) none of the above

93. If d = apparent dip angle
B = angle of true dip
v = the angle between the strike of the bed and the direction of the apparent dip
then, the apparent & true dip values can be related to each other by the formula:
(a) tan = tan B. tan v
(b) tan = tan B. sin v
(c) tan = tan B. cas y
(d) none of the above

94. Which of the following is true in relation to apparent &, true dip·
(a) apparent dip > true dip
(b) apparent dip < true dip
(c) apparent dip > true dip
(d) apparent dip < true dip

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95. A great majority of folds are modifications of the simple types known as anticlines and synclines. An anticline is a fold in which:
(a) the strata is up arched (i.e. it becomes convex upwards)
(b) the older rocks usually occupy a position in the interior (or core of the curvature)
(c) all the above
(d) none of the above

96. A syncline is a fold in which:
(a) the strata becomes concave upwards
(b) the younger rocks usually occupy a position in the interior
(c) all the above
(d) none of the above

97. The hade of the fault plane is its inclination with the:
(a) dip (b) vertical
(c) horizontal (d) none of the above

98. Which of the following is true for Himalaya mountains :
(a) they are tectonic mountains
(b) they are complex in their character showing all sorts of structural complications in their constitution
(c) they owe their origin to orogenic forces
(d) all the above

99. Volcanic mountains are formed by the process of volcanic eruptions. The best example of such mountains is (are):
(a) Ruby mountains of Navada (b) Himalayas & Alps
(c) Mount Visuvius, Agung, and Etna (d) all the above

100. All the solid materials – thrown out by a volcano at the time of its eruption & consisting of fragments of different sizes – are known as:
(a) pyroclasts (b) lava (c) lapilli (d) volcanic bombs

101. Solidified or semi-solidified clots of lava which gets thrown out along with other materials at the time of volcanic eruptions are known as:
(a) lapilli (b) volcanic bombs (c) pyroclasts (d) magma

102. The solid materials (or pyroclasts) of different sizes are thrown out by volcanoes at the time of their eruptions. Pyroclasts consist of:
(a) volcanic blocks, lapilli, & volcanic dust (b) volcanic dust & lapilli
(c) lapilli (d) none of the above

103. Which of the following instruments may be used for the determination of the sp. gr. of minerals in geological laboratories:
(a) Walker's steel yard balance (b) The beam balance
(c) Jolly's spring balance (d) all the above

104. Calcium Carbonate is found in two mineral forms (*i.e.*, Calcite & Aragonite); the former crystallizing in hexagonal system and the later in orthorhombic one. This phenomenon is specially described as:

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(a) Isomorphism (b) Dimorphism
(c) Pseudomorphism (d) none of the above

105. Isoseismals are the lines passing through values of "same intensity" in a particular:
(a) earthquake record (b) rainfall record
(c) temperature record (d) none of the aoove

106. Which of the following statements is true in the context of "seismology" :
(a) It is an off-shoot of geophysics
(b) It deals with the study of earthquakes in all their aspects
(c) all the above
(d) none of the above

107. Pseudomorphism is a phenomenon in which the original chemical composition of a particular mineral is alteral by natural agencies in such a way that a new compound results. Examples of pseudomorphs are:
(a) gypsum (after anhydrite) (b) quartz (after fluorite)
(c) limouite (after pyrite) (d) all the above

108. Isomorphism is a character exhibited by some minerals which have analogous chemical composition and which crystallize in closely related crystal forms. Examples of isomorphous series is (are) the:
(a) calcite group (b) barite group (c) argaonite group (d) all the above

109. Many attempts have been made to classify igneous rocks on the basis of their chemical composition. The most noteworthy system is:
(a) cross, iddings, irsson, and Washington (C. I.P.W.) classification
(b) tabular classification
(c) shand classification
(d) none of the above

110. The process of incorporation of the foreign materials, generally from the country rock, into the magmatic melts is termed as:
(a) assimilation (b) immiscibility
(c) differentiation (d) none of the above

111. The process by which the magma – originally uniform and homogeneous – splits up into different types of rocks is known as:
(a) differentiation (b) assimilation
(c) all the above (d) none of the above

112. The term used for intense but essentially localized metamorphic changes brought about by high temperatures to which a given rock is subjected is:
(a) clastic metamorphism (b) contact metamorphism
(c) pyrometamorphism (d) pneumatolytic metamorphism

113. A type of thermal metamorphism – in which high temperature fluids, liquids, and gases attack the surrounding rocks and induce certain changes in them – is known as:
(a) metasomatism (b) load metamorphism
(c) clastic metamorphism (d) none of the above

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114. When the induced pressure is due to depth factor, the process of metamorphism is defined as the:
(a) Contact metamorphism
(b) Metasomatism
(c) Load metamorphism
(d) none of the above

115. The type of metamorphism – which prevails in the immediate vicinity of magmatic injections/instrusions/flows and involves changes like recrystallisation of original minerals, etc. – is referred to as:
(a) Pyrometamorphism
(b) Contact metamorphism
(c) Metasomatism
(d) none of the above

116. When pure Limestone simply recrystallises during the process of metamorphisms without any new mineral formation, the resulting rock is:
(a) Dolomite
(b) Anorthite
(c) Marble
(d) none of the above

117. Singbhum belt in Bihar is known for the presence of:
(a) Manganese
(b) Iron & Copper
(c) Coal
(d) none of the above

118. Khetri belt in Rajasthan is known for the presence of:
(a) Copper
(b) Iron
(c) Silica
(d) none of the above

119. Chalcopyrite is an ore of:
(a) Iron
(b) Copper
(c) Chalk
(d) none of the above

120. Wolfram (Wolframite) is found in Jodhpur (Rajasthan). It is an ore of:
(a) Tungsten
(b) Zinc
(c) Titanium
(d) none of the above

121. Anthracite is a coal which is formed by the metamorphism of woody materials. Anthracite contains carbon upto the extent of:
(a) 70%
(b) 70 - 90%
(c) 92 - 98%
(d) none of the above

122. Lignite - which is also known as brown coal – contains carbon upto the extent of:
(a) 30%
(b) 70%
(c) 95%
(d) none of the above

123. Bituminous coal – which is also known as common coal, cooking coal, etc. – contains carbon upto the maximum extent of:
(a) 30%
(b) 50%
(c) 60%
(d) 90%

124. Boghead coal is a variety of:
(a) Anthracite
(b) Lignite
(c) Bituminous coal
(d) none of the above

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125. About 98% of coal annually produced in India comes from:
(a) lower Gondwana formations (b) upper Gondwana formations
(c) option (a) + (b) (d) none of the above

126. Which of the following statement is true for "Fossils":
(a) They are the remains or traces of organisms that have lived on this earth in the past.
(b) Occurrence of different groups of fossils in the adjoining areas is indicative of separation of these areas by some physical or other barriers
(c) All the above
(d) None of the above

127. Black marble is generally found in the district of:
(a) Jodhpur (b) Jaipur (c) Jabalpur (d) Jaisalmer

128. Shingle is:
(a) decomposed Laterite (b) obtained by crushing Granite
(c) Water bound pebbles (d) air weathered rock

129. The rock used for roofing is:
(a) Basalt (b) Granite (c) Slate (d) Pumice

130. Laterite is found in:
(a) U.P. (b) Punjab (c) West Bengal (d) Kerala

131. Good quality stones must:
(a) be durable (b) resist action of acids
(c) all the above (d) none of the above

132. Stones used for ornamental work must be:
(a) soft (b) hard (c) light (d) heavy

133. Stones used for rubble masonry must be:
(a) soft (b) hard (c) high (d) heavy

134. Stones used for the construction of retaining walls must be:
(a) soft (b) hard (c) light (d) heavy

135. In stone masonry, stones (stratified rocks) are so placed that the direction of pressure acts:
(a) at right angles to the plane of bedding (b) at 45 to the plane of bedding
(c) at 60 to the plane of bedding (d) parallel to the plane of the bedding

136. In stone masonry, if stones are so placed that their layers are parallel to the direction of load, they:
(a) split easily (b) are affected by moisture
(c) all the above (d) none of the above

137. In arches, the stratified stones are placed so that their planes are:
(a) parallel (b) perpendicular
(c) radial (d) none of the above

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138. The tendency of a stone to split along certain parallel planes, is known as:
(*a*) texture (*b*) fracture (*c*) cleavage (*d*) structure

139. Stratigraphy is an important branch of geology. Which of the following statements is true in the context of stratigraphy:
(*a*) It is also known as Historical Geology
(*b*) It deals with the history of rocks of the earth's crust
(*c*) It gives emphatic stress on the time of formation and the changes undergone by the rocks since their formation
(*d*) all the above

ANSWERS

1.	(*a*)	2.	(*c*)	3.	(*a*)	4.	(*c*)	5.	(*a*)
6.	(*a*)	7.	(*b*)	8.	(*b*)	9.	(*b*)	10.	(*b*)
11.	(*a*)	12.	(*a*)	13.	(*c*)	14.	(*c*)	15.	(*a*)
16.	(*a*)	17.	(*c*)	18.	(*c*)	19.	(*a*)	20.	(*a*)
21.	(*a*)	22.	(*c*)	23.	(*c*)	24.	(*c*)	25.	(*d*)
26.	(*d*)	27.	(*b*)	28.	(*b*)	29.	(*b*)	30.	(*c*)
31.	(*b*)	32.	(*c*)	33.	(*a*)	34.	(*b*)	35.	(*a*)
36.	(*b*)	37.	(*a*)	38.	(*b*)	39.	(*c*)	40.	(*d*)
41.	(*b*)	42.	(*d*)	43.	(*b*)	44.	(*b*)	45.	(*b*)
46.	(*b*)	47.	(*a*)	48.	(*c*)	49.	(*c*)	50.	(*d*)
51.	(*c*)	52.	(*d*)	53.	(*b*)	54.	(*a*)	55.	(*a*)
56.	(*b*)	57.	(*d*)	58.	(*b*)	59.	(*a*)	60.	(*a*)
61.	(*c*)	62.	(*c*)	63.	(*b*)	64.	(*a*)	65.	(*c*)
66.	(*b*)	67.	(*a*)	68.	(*a*)	69.	(*b*)	70.	(*c*)
71.	(*a*)	72.	(*c*)	73.	(*b*)	74.	(*a*)	75.	(*a*)
76.	(*b*)	77.	(*b*)	78.	(*b*)	79.	(*d*)	80.	(*b*)
81.	(*a*)	82.	(*c*)	83.	(*a*)	84.	(*b*)	85.	(*b*)
86.	(*c*)	87.	(*a*)	88.	(*c*)	89.	(*c*)	90.	(*c*)
91.	(*a*)	92.	(*b*)	93.	(*c*)	94.	(*b*)	95.	(*c*)
96.	(*b*)	97.	(*b*)	98.	(*d*)	99.	(*c*)	100.	(*a*)
101.	(*b*)	102.	(*a*)	103.	(*d*)	104.	(*b*)	105.	(*a*)
106.	(*c*)	107.	(*d*)	108.	(*d*)	109.	(*a*)	110.	(*a*)
111.	(*a*)	112.	(*c*)	113.	(*a*)	114.	(*c*)	115.	(*b*)
116.	(*c*)	117.	(*b*)	118.	(*a*)	119.	(*b*)	120.	(*a*)
121.	(*c*)	122.	(*b*)	123.	(*d*)	124.	(*c*)	125.	(*c*)
126.	(*c*)	127.	(*b*)	128.	(*a*)	129.	(*a*)	130.	(*a*)
131.	(*d*)	132.	(*a*)	133.	(*b*)	134.	(*d*)	135.	(*c*)
136.	(*c*)	137.	(*c*)	138.	(*c*)	139.	(*d*)		

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14

Reinforced Cement Concrete Structures

14.1 Introduction

We know that when a structure is subjected to bending under simply supported conditions, the upper portion is subjected to compressive stresses, while the lower portion is subjected to tensile stresses. Since the permissible tensile stress in concrete is about one-tenth of the permissible compressive stress, therefore the tensile stresses in structures is taken care of by steel. Such a combination of concrete and steel is known as *reinforced cement concrete* (R.C.C.).

For the same cross-section, the tensile strength of steel may be as much as 300 times, while its compressive strength will be about 30 times that of concrete.

The steel is commonly used as a reinforcing material because of the following qualities :

1. It is cheap and easily available.
2. It possesses high tensile strength and elasticity.
3. It develops good bond with concrete.
4. Its coefficient of expansion is nearly equal to that of concrete.

In reinforced cement concrete structures, the steel reinforcement consists of

(*a*) mild steel and medium tensile steel bars; (*b*) deformed bars; and (*c*) cold twisted bars.

The deformed bars have projections which act as keys for concrete and check the slipping of bars. These bars develop a greater bond by mechanical resistance to sliding.

The bond may be increased by using twisted bars which are cold worked. The cold twisted bars increase the yield stress by about 50 percent than ordinary mild steel bar, and thus save the reinforcing material by 33 percent. The pitch of twisted bars is kept between 90 and 120 mm. The size of the bars used as reinforcement are 5, 6, 8, 10, 12, 16, 20, 22, 25, 32, 36, 40, 45 and 50 mm.

Note : According to Indian standards (IS : 456 – 1984), there are seven grades of concrete mixes, designated as M_{10}, M_{15}, M_{20}, M_{25}, M_{30}, M_{35} and M_{40}. The letter M refers to the mix and the number denotes the ultimate compressive strength of 150 mm cube at 28 days expressed in N/mm^2.

14.2 Assumptions in R.C.C. Beam Design

The analysis of R.C.C. structures subject to bending may be made by

1. Elastic theory of bending or straight line theory; and 2. Ultimate load theory.

The elastic theory of bending is applied to R.C.C. beams, on the following assumptions :

1. The tensile stresses are taken up by reinforcement alone and none by the concrete. Thus, in the tensile zone, concrete does not contribute any tensile resistance. It only helps to retain shape, keeps reinforcement in position and provides cover to steel.

2. The stresses from concrete are transferred to steel so that strains in concrete and steel are the same.

3. At any cross-section, the plain sections before bending remains plain after bending, *i.e.* unit strains above and below the neutral axis (N.A.) are proportional to their distances from N.A.

4. The modulus of elasticity of concrete is assumed constant at all stresses.

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5. The steel reinforcement is free from initial stresses when it is embedded in concrete.
6. The modular ratio (m) according to IS : 2 – 1960, is given by

$$m = \frac{280}{3\,\sigma_{cb}}$$, where σ_{cb} is the permissible stress in compression due to bending in concrete in N/mm^2.

Note : The modular ratio is defined the ratio of Young's modulus of steel to the Young's modulus of concrete. It may also be defined as the ratio of the load carried by steel to the load carried by concrete.

14.3 Direct Tension and Compression in Concrete

For members in direct tension, when full tension is taken by the reinforcement alone, the direct tensile stress (σ_t) is given by

$$\sigma_t = \frac{F_t}{A_c + m\,A_{st}}$$

where
F_t = Total tension in the member *minus* pre-tension in steel, if any, before concreting,
A_c = Cross-sectional area of concrete,
A_{st} = Cross-sectional area of reinforcing steel in tension, and
m = Modular ratio.

For members in direct compression, the direct compressive stress (σ_c) is given by

$$\sigma_c = \frac{P}{A_c + m\,A_{sc}}$$

where
P = Direct compressive force, and
A_{sc} = Cross-sectional area of compressive steel.

Note : The expression $(A_c + m\,A_{st})$ or $(A_c + m\,A_{sc})$ is called equivalent area of the section.

14.4 Design of R.C.C. Structures

The R.C.C. structures may be designed by any one of the following three methods :

1. *Working stress method.* This method is also known as *modular ratio method* or *elastic method.* It is the most popular and commonly used method for design purposes. In this method, the moment and forces acting on a structure are obtained from the actual values of service loads but the stresses in concrete and the reinforcing steel are restricted to only a fraction of their true strengths in order to provide an adequate safety factor. A factor of safety of 3 in concrete and 1.78 to 1.80 in steel, is generally adopted.

2. *Limit state method.* This method is also known as *plastic method.* In this method, the structure is designed to withstand safely all loads liable to act on it throughout its life. It should also satisfy the serviceability requirements such as prevention of excessive deflection, excessive cracking and excessive vibrations. The acceptable limit for the safety and serviceability requirements before failure occurs is called *limit state.*

3. *Ultimate strength method.* This method is also known as *load-factor method.* In this method of design, the true margin of safety is accurately known. The ultimate strength procedure is based upon the results obtained from the experimental investigations depicting the true behaviour of the structures.

14.5 Design of Singly Reinforced Beams

The first step in the design of R.C.C. beams, is the determination of neutral axis (N.A.) because it determines the position of tensile and compressive zones. The neutral axis is that axis at which the stresses are zero in the section. The areas above and below the neutral axis are subjected to compressive and tensile stresses respectively in case of simply supported beams with vertical loads acting

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downwards. In determining the neutral axis, the following two situations arise :

1. *When the stresses are known.* In this method, the stresses in steel and concrete do not exceed the given permissible values and the neutral axis obtained is called *critical neutral axis.*

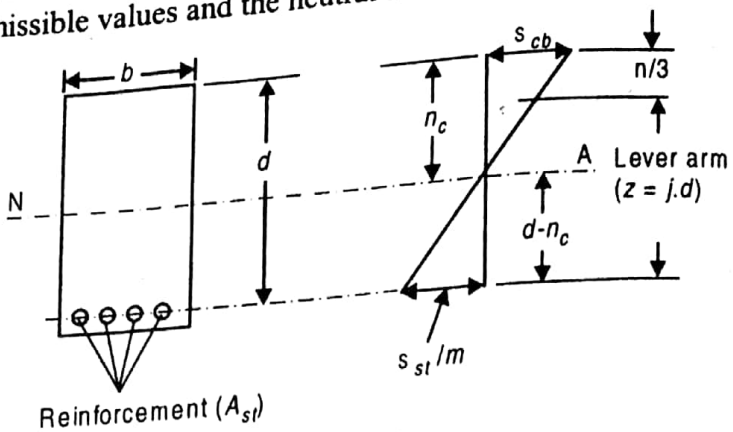

Fig. 14.1

Consider a rectangular section of beam with b as width and d as effective depth (*i.e.* the distance from top concrete edge to the centre of reinforcement) as shown in Fig. 14.1. If n_c is the depth of critical neutral axis when permissible stresses in steel (σ_{st}) and concrete (σ_{cb}) reach simultaneously, then stresses are proportional to their distances from the neutral axis.

$$\therefore \quad \frac{\sigma_{cb}}{n_c} = \frac{\sigma_{st}/m}{d-n_c} \quad \text{or} \quad n_c = \frac{m \times \sigma_{cb}}{m \times \sigma_{cb} + \sigma_{st}} \times d$$

2. *When the dimensions of beam section are known.* In this case, the maximum moments developed in a section are resisted by the compression in concrete and tension in steel. The amount of tension taken by concrete is neglected. The position of neutral axis is obtained by equating the moment of area of compression zone to the moment of area of tension zone.

We know that moment of area of compression zone

$$= b \times n \times \frac{n}{2} = \frac{bn^2}{2} \qquad ...(i)$$

and moment of area of equivalent tensile zone

$$= m \times A_{st}(d-n) \qquad ...(ii)$$

Equating equations (*i*) and (*ii*),

$$\frac{bn^2}{2} = m \times A_{st}(d-n) \qquad ...(iii)$$

where A_{st} = Cross-sectional area of steel.

The value of n obtained from equation (*iii*) gives the position of *actual neutral axis.*

Note : The lever arm is the perpendicular distance between the centre of gravity of tensile and compressive force. It is given by

$$z = d - \frac{n}{3} = \frac{3d-n}{3}$$

where d = Distance between the top of beam and the centre of steel bars, and

n = Distance of neutral axis below the top of beam.

14.6 Types of Beam Sections

The beam sections, depending upon the amount of steel reinforcement, may be classified as follows :

1. Balanced section or economical section or critical section,
2. Under-reinforced section, and
3. Over reinforced section.

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When the steel reinforcement is of such a magnitude that the permissible stresses in concrete and steel are developed simultaneously, then the section is known as *balanced section* or *economical section* or *critical section*. The neutral axis corresponding to this condition is called *critical neutral axis*. The moment of resistance (M) of a balanced section is obtained by multiplying the total compressive or tensile force and the lever arm. The lever arm (z) in a singly reinforced beam is given by

$$z = d - \frac{n}{3} = \frac{3d - n}{3}$$

where

d = Distance between the top of the beam and the centre of steel bars, and

n = Depth of neutral axis below the top of the beam.

The section in which the concrete is not fully stressed to its permissible value when stress in steel reaches its maximum value, is known as *under-reinforced section*. In this section, the amount of reinforcement provided is less than that required for a balanced section. In an under-reinforced section, the position of actual neutral axis lies above the critical neutral axis. Thus, the neutral axis depth is less than that of balanced section as shown in Fig. 14.2. The moment of resistance (M) of such a section is obtained by considering the tensile stress of steel (σ_{st}) and is given by

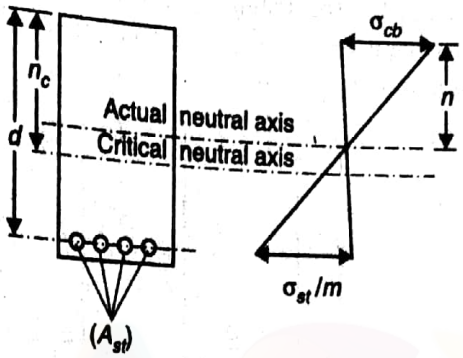

Fig. 14.2

$$M = \sigma_{st} \times A_{st}\left(d - \frac{n}{3}\right)$$

The value of moment of resistance of under-reinforced section is less than that of balanced section.

When the steel reinforcement is not fully stressed to its permissible value, then the section is known as *over-reinforced section*. The amount of steel in an over reinforced section is more than that required for a balanced section. In such a section, the stress in concrete reaches its maximum allowable value earlier than that in steel. Since the amount of steel is more, therefore the position of actual neutral axis lies below the critical neutral axis (*i.e.* towards steel). Thus, the neutral axis depth is more than that of balanced section as shown in Fig. 14.3. In over-reinforced section, the moment of resistance (M) is obtained by considering the stress in concrete (σ_{cb}) and is given by

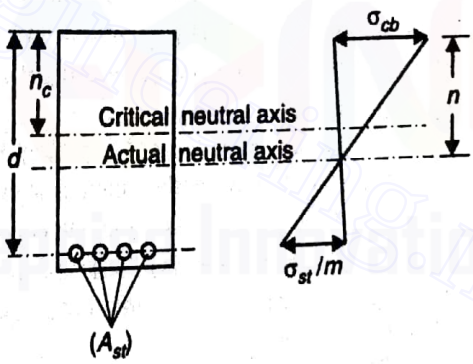

Fig. 14.3

$$M = \frac{\sigma_{cb}}{2} \times bn\left(d - \frac{n}{3}\right)$$

The value of moment of resistance of over-reinforced section is more than that of balanced section.

Note: The over-reinforced section is undesirable because failure in concrete occurs earlier due to crushing of concrete. Since concrete is brittle, therefore failure takes place suddenly and explosively without any warning.

In case of under-reinforced sections, steel tends to elongate and sagging takes place, before failure. This gives sufficient warning before the final collapse of the structure. Hence it is always desirable to design under-reinforced sections.

14.7 Shear Stress in Reinforced Beams

The shear stresses are caused by the variation of the bending moments as the bending moment

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is zero at the supports and maximum at the centre in case of simply supported beams loaded with uniformly distributed load. This variation from supports to any point on the beam will depend upon the type of loading and end supports of the beam.

The maximum shear stress in a reinforced concrete beam of width (b) and subjected to a shear force (F) is given by

$$\tau_{max} = \frac{F}{b.z} = \frac{F}{b\left(d - \frac{n}{3}\right)} = \frac{3F}{b\,(3d - n)}$$

where z = Lever arm $= d - n/3$

The maximum shear stress in a rectangular beam is 1.5 times that of average shear stress. It may be noted that the shear stress distribution, in a reinforced concrete beam, above the neutral axis is parabolic, as shown in Fig. 14.4.

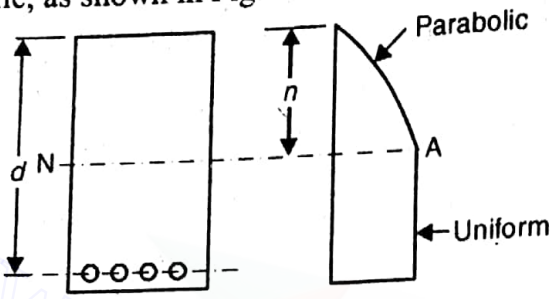

Fig. 14.4

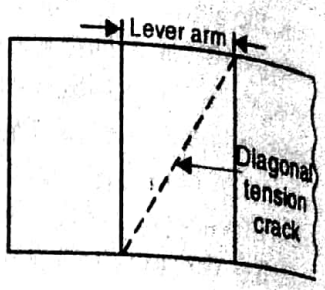

Fig. 14.5

In case the shear stress exceeds permissible shear stress of 0.5 N/mm^2, shear reinforcement (in the form of *vertical bars, inclined bars or a combination of vertical and inclined bars) is provided. If the shear reinforcement is inadequate, the beam will fail in diagonal tension. The diagonal tension is the tension that develops across the diagonal of that part of a beam which is subjected to tension. The diagonal tension cracks which extend upto a horizontal distance equal to lever arm, are inclined at 45° to the axis of the beam, as shown in Fig. 14.5.

Notes : **1.** The diagonal tension is caused by the combined action of longitudinal tension and the transverse shearing stresses.

2. According to IS : 456 – 1978, if the shear stress (τ) is less than one-tenth of the compressive stress (σ_{bc}) in concrete at extreme fibre, then no shear reinforcement is necessary.

3. If the shear stress is more than 0.4 σ_{bc} or 2 N/mm^2, then the section is to be redesigned.

4. A stirrup consists of 5 to 12 mm diameter mild steel bars bent round the tensile reinforcement.

5. According to IS : 456 – 1978, the spacing of stirrups shall not exceed a distance equal to the lever arm of the resisting moment.

6. The number of stirrups resisting shear force in a reinforced beam is given by the ratio of lever arm to the centre to centre spacing of stirrups.

7. The centre to centre spacing of vertical stirrups, in a rectangular beam, is increased towards the centre of the span of the beam.

8. The spacing of vertical stirrups in a rectangular beam is minimum near the supports.

14.8 Bond Stress

When the steel bars are embedded in concrete, the concrete after setting, adheres to the surface of the bars and thus resist any force that tends to pull or push this rod. The intensity of this adhesive force is called *bond stress*. It is the longitudinal shear stress acting on the surface between the steel and concrete. The term bond is used to describe the means by which slip between the steel and concrete is prevented. The bond is provided by anchoring the bars properly and extending the bars beyond the point of maximum shear.

* The shear reinforcement in the form of vertical bars, is called *stirrups*.

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The bond between steel and concrete is mainly due to pure adhesive resistance, frictional resistance and mechanical resistance.

The pure adhesive resistance in a reinforced concrete structure is provided by relatively weak adhesion of the chemical gum produced by concrete during setting.

The frictional resistance is provided by the shrinkage in concrete. When a reinforced concrete structure is loaded, the resistance first broken is pure adhesive resistance.

The bond stress (τ_{bd}) developed in concrete around the steel reinforcement is given by

$$\tau_{bd} = \frac{\text{Shear force at the section}}{\text{Total perimeter of bars} \times \text{Lever arm}}$$

According to Indian standard specifications (IS : 456 – 1978), the permissible value of bond stress for M_{15} grade of concrete is limited to 1 N/mm^2. In case the bond stress developed in a reinforced concrete beam is more than the permissible value, then it can be brought down by (*a*) increasing the depth of beam, (*b*) decreasing the diameter of the bars, and (*c*) increasing the number of bars.

Whenever some reinforcing bar is to be anchored or two bars have to be given an overlap, it is essential that they must get sufficient length of embedment or overlap as the case may be, so that no slippage takes place. The length of embedment (L_d) or overlap (also known as development length or anchorage) is given by

$$L_d = \frac{\phi \cdot \sigma_s}{4 \tau_{bd}}$$

where ϕ = Bar diameter,

σ_s = Actual tensile or compressive stress in bar, and

τ_{bd} = Permissible average bond stress. Its value depends upon the concrete strength, the concrete cover and the type of bar used *i.e.* whether plain or deformed.

The average bond stress for reinforcing bars in compression can be increased by 25 percent.

Notes : 1. The deformed bars may be used without end anchorages (*i.e.* hooks) provided development length required is satisfied. The hooks should normally be provided for plain bars in tension.

2. In case of deformed bars, the value of bond stress for various grades of concrete is greater by 20 percent than the plain bars.

3. When hooks are formed in deformed bars, the internal radius of the bend should be atleast three times the diameter of the bar. The length of the straight bar beyond the end of the curve should be at least four times the diameter of the bar.

4. The anchorage value of a standard U-type hook alone is equal to 16 ϕ, where ϕ is the diameter of a reinforcement bar.

5. The length of lap for reinforcement bars in tension shall not be less than L_d or 30 ϕ, whichever is greater.

6. The length of lap for reinforcement bars in compression shall not be less than L_d or 24 ϕ, whichever is greater.

7. When bars of two different diameters are to be spliced, the length of lap shall be calculated on the basis of diameter of the smaller bar.

8. The bond length used for splicing bar in tension, for M_{15} grade concrete is equal to 58 ϕ, where ϕ is the diameter of reinforcing bar.

9. The measurement of anchorage lengths of inclined bars, used to act as shear reinforcement is taken in tension zone from the end of the sloping portion of the bar and in compression zone from mid-depth of the beam.

10. The minimum spacing between horizontal parallel reinforcements of the same diameter should not be less than the diameter of bar.

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14.9 Doubly Reinforced Section

The beam section in which the steel reinforcement is provided on both sides, *i.e.* in tension as well as compression sides, is called a *doubly reinforced section*. The doubly reinforcement section is preferred in the following situations :

1. When the members are subjected to alternate external loads and the bending moment in the section reverses.
2. When the members are subjected to loading eccentric on either side of the axis.
3. When the members are subjected to shock impact or accidental lateral loads.
4. When overall size of the beam section is limited.
5. When the beam section is continuous over several supports.

The theory of doubly reinforced section is based on the same assumptions as for singly reinforced section. In the steel beam theory of doubly reinforced concrete beams, it is assumed that

(*a*) tension steel resists the tension and compression steel resists the compression,

(*b*) stress in compression steel is equal to the stress in tension steel, and

(*c*) no stress is developed in tension and compression concrete.

14.10 T-beam

The section of the beam having greater width at the top in comparison to the width below neutral axis is known as *T-beam*. It is a type of beam in which the slab is laid monolithically with the beam. The portion of the beam which projects below the slab, is called *web* or *rib* and the slab portion is called flange, as shown in Fig. 14.6. The portion of the slab which acts monolithically with the beam and which resists the compressive stresses, is called *width of flange of *T*-beam and its value is taken as minimum value of the following :

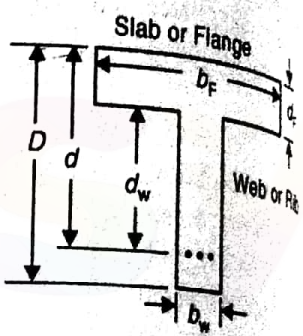

Fig. 14.6

(*a*) one-third of the effective span of the *T*-beam,

(*b*) twelve times the depth of slab (d_s) plus breadth of web or rib, and

(*c*) centre of centre distance between the adjacent beams.

The breadth of web or rib, in a *T*-beam, is equal to the width of the portion of the beam in the tensile zone. It should be sufficient to provide lateral stability and to accommodate the tensile reinforcement with proper spacing between the bases. The breadth of web or rib should atleast be equal to one-third of depth of web or rib. The vertical distance between the bottom of the flange and the centre of tensile reinforcement is called *depth of web or rib* (d_w). The vertical distance between the top of the flange and centre of the tensile reinforcement is called *effective depth* (d).

The overall depth (D) of the *T*-beam, when it is simply supported at the ends, is taken as 1/12 to 1/15 of the span of the beam and 1/10 to 1/12 of the span when the *T*-beam is continuous.

The position of neutral axis of a *T*-beam may be either in the flange or outside the flange *i.e.* in the web or rib depending upon the thickness of the flange, depth of the beam and the amount of steel. The position of neutral axis in the two cases, may be obtained as follows :

1. *When the neutral axis lies within the flange.* When the neutral axis lies within the flange (*i.e.* n is less than d_F) as shown in Fig. 14.7 (*a*) then the value of n is obtained by taking moment of areas of concrete and steel about the neutral axis, *i.e.*

$$b_F \times n \times \frac{n}{2} = m A_{st} (d - n)$$

* The width of the flange, in case of *L*-beam, is taken as the minimum value of the following :

1. one-sixth of the effective span of *L*-beam,
2. width of rib plus one-half of the clear distance between the rib, and
3. width of rib plus four times the thickness of slab or flange.

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Notes : (*a*) When the neutral axis remains within the flange or slab, then a *T*-beam behaves like a rectangular beam of width equal to its flange.

(*b*) The neutral axis may fall within the flange, when the flange or slab is comparatively thicker.

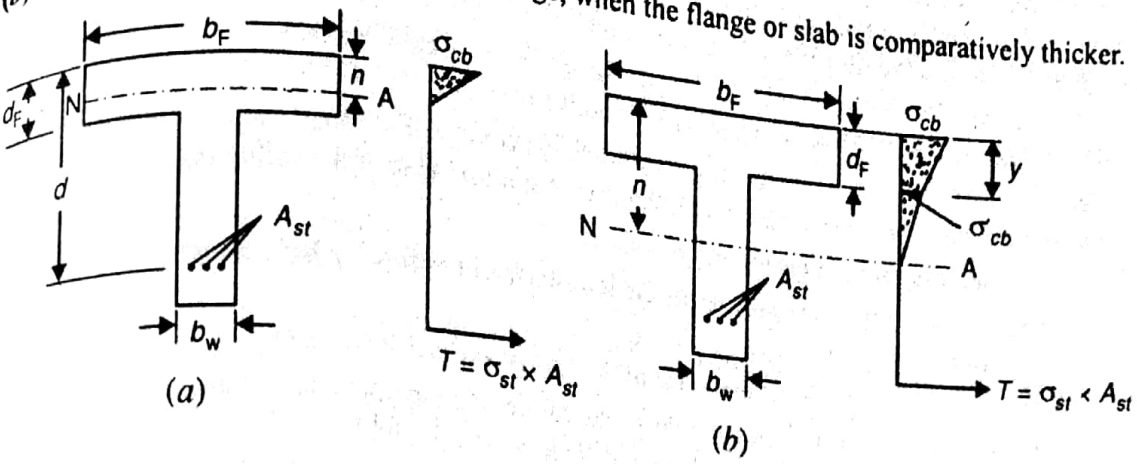

Fig. 14.7

2. *When the neutral axis lies in the web or rib.* When the neutral axis lies in the web or rib (*i.e.* below the flange), as shown in Fig. 14.7 (*b*) then the value of *n* is obtained by taking moment of effective areas of concrete and steel about the neutral axis, *i.e.*

$$b_F \times d_F (n - D_F / 2) = m \, . \, A_{st} (d - n)$$

and depth of the net compression ($\bar{y}$) below the top of the beam is given by

$$\bar{y} = \frac{3n - 2\,d_F}{2n - d_F} \times \frac{d_F}{3}$$

The moment of resistance (*M*) of a *T*-beam as balanced section, when neutral axis falls within the flange, is obtained by multiplying the total compression and the lever arm. Mathematically,

$$M = \sigma_{st} \times A_{st} \left(d - \frac{n}{3} \right)$$

When the neutral axis falls within the web, then

$$M = \sigma_{cb} \times A_c (d - \bar{y}) = \sigma_{cb} \times b_F \times d_F (d - \bar{y})$$

14.11 Columns

A structural member, carrying an axial compressive load, is called a *strut*. It may be horizontal, inclined or even vertical. But a vertical strut, used in building, is called a *column*. The shape of a column may be rectangular, square, circular or hexagonal. A column is generally a compression member having an effective length greater than three times the least lateral dimension. When the ratio of effective length of the column to its least lateral dimension does not exceed 12, then it is termed as a *short column*. When the ratio of effective length to its least lateral dimension exceeds 12, then the column is considered as a *long* or *slender column*.

According to Indian standard specifications, the permissible load (*P*) on a short column with lateral ties is given by

$$P = \sigma_{cc} \times A_c + \sigma_{sc} \times A_{sc}$$

where

σ_{cc} = Permissible stress in concrete in direct compression,

A_c = Cross-sectional area of concrete,

σ_{sc} = Permissible compressive stress in steel, and

A_{sc} = Cross-sectional area of longitudinal steel in compression.

The columns are reinforced with longitudinal, transverse or helical reinforcement. The longitudinal reinforcement is also termed as main steel. The trsansverse reinforcement is in the form of links, wound around the main steel and is termed as lateral ties, links or polygonal links.

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Notes : 1. The area of longitudinal reinforcement in a column should not be less than 0.8% of the area of concrete section required for direct load alone and it should not be more than 3% of gross cross-sectional area of column. The diameter of longitudinal bars should not be less than 12 mm. The cover should not be less than 40 mm for a longitudinal reinforcing bar in a column.

A reinforced cement concrete column having helical reinforcement, should have at least six bars of longitudinal reinforcement inside the helical reinforcement.

2. The effective lateral support to a column is provided by transverse reinforcement. The pitch of transverse reinforcement should not be more than the minimum value of the following :

(*a*) least lateral dimension of the column,

(*b*) sixteen times the diameter of the longitudinal reinforcing bar nearest to the compression face of the member, and

(*c*) forty eight times the diameter of the transverse reinforcement.

The diameter of the polygonal links or lateral ties should not be less than one-fourth of the diameter of the largest longitudinal bar. In no case, it should be less than 5 mm.

3. In a column, with helical reinforcement, the permissible load is based on the core area. The least lateral dimension of such a column should be taken as equal to the diameter of core. The pitch shall not be less than 75 mm and not more than one-sixth of the core diameter of the column or less than 25 mm or less than three times the diameter of steel bar forming helix.

14.12 Slabs

The slabs are plane structural members whose thickness is quite small as compared to its other dimensions. The slabs are most frequently used as roof coverings and floors in various shapes such as square, rectangular, circular and triangular in buildings, tanks etc. In general, slabs are divided into two categories depending upon the ratio of long span to short span. When the ratio of long span to short span is greater than or equal to 2, then the slab is known as a *slab spanning in one direction* or *one-way slab*. When the ratio of long span to short span is less than 2, then the slab is known as a *slab spanning in two directions* or *two-way slab*. In both the cases, the slab is assumed to be supported on all the four sides. However, if the slab is supported over two opposite edges only as in case of verandahs, corridors etc., such slabs are designed as one-way slabs.

The slabs spanning in one direction (*i.e.* one-way slabs) are designed in the same way as singly reinforced beams except that the width is taken as one metre. The one-way slabs may be cantilever, simply supported or continuous.

Notes : 1. The ratio of span to overall depth, for a cantilever slab spanning in one direction, should not exceed 12.

2. The ratio of span to overall depth, for a simply supported slab spanning in one direction, should not exceed 30.

3. The ratio of span to overall depth, for a continuous slab spanning in one direction, should not exceed 35.

14.13 Reinforcement in Slabs

The pitch of bars of main reinforcement in solid slab should not exceed three times the effective depth of slab or 600 mm, whichever is smaller. The transverse reinforcement (also called distribution reinforcement) is provided at right angles to the main reinforcement. The purpose of transverse reinforcement, in a slab, is as follows :

1. To keep the main reinforcement in position,
2. To distribute the effects of point load on the slab more evenly and uniformly, and
3. To distribute the shrinkage and temperature cracks more evenly.

In a simply supported slab, the pitch of transverse or distribution reinforcement should not be more than five times the effective depth of slab or 600 mm, whichever is smaller. If plain bars are used, then the area of distribution reinforcement in slabs should not be less than 0.15% of the gross cross-sectional area of concrete. If high-yield strength deformed bars are used, then the area of

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istribution reinforcement in slabs should not be less than 0.12% of the gross cross-sectional area of oncrete. The amount of transverse reinforcement, for bridge slabs, is taken as 0.3% of gross cross-ectional area of concrete. The diameter of bars used for distribution reinforcement in slabs may vary rom 6 mm to 8 mm, whereas for main reinforcement, it varies from 8 mm to 14 mm. In general, the iameter of reinforcing bar should not exceed one-eighth of the total thickness of the slab. The einforcement should have a concrete cover and the thickness of a such cover (exclusive of plaster or ther decorative finish) shall not be less than the diameter of the reinforcing bar or 15 mm, whichever s more.

4.14 Bending Moment in Slabs

In general, the bending moments have to be calculated using the effective span, considering all ead and live loads on the structure.

The one-way slab which carry uniformly distributed load should be designed to resist a sagging ending moment near mid-span.

When the slab is built into a brick or masonry wall, the slab should be designed to resist a ogging moment at the face of the support.

If the maximum bending moment of a simply supported slab is M and the moment resistance actor is R, then the effective depth of the slab (d) is given by

$$d = \sqrt{\frac{M}{1000\,R}}$$

When a slab is continuous over several spans, then hogging or negative bending moment is oduced over the intermediate supports.

When a slab is continuous over two equal spans, then the maximum bending moment near the entre of each span is taken as $+ wL^2/10$, where w is the total uniformly distributed dead and live load er unit length and L is the effective span.

4.15 Two Ways Slabs

We have already discussed that when the slab is supported on all the four edges and the ratio of ong span to short span is small, then the bending takes place along both the spans. Such a slab is nown as a slab spanning in two directions or two-way slab. A two-way slab

(*a*) may be simply supported on the four edges, with corners not held down and carrying uniformly distributed load.

(*b*) may be simply supported on the four edges, with corners held down and carrying uniformly distributed load.

(*c*) may have edges fixed or continuous and carrying uniformly distributed load.

The loads carried on each support and bending moments in the slab are not easy to calculate and ence empirical formulae and approximate theories are normally adopted.

A two-way slab simply supported on the four edges, with corners not held down and carrying niformly distributed load may be analysed by Grashof and Rankine theory.

According to this theory, the ratio of load carried by the slab in the direction of long span (W_L) to he load carried by the slab in the direction of short span (W_B) is given by

$$\frac{W_L}{W_B} = \left(\frac{B}{L}\right)^4$$

here

L = Long span of slab, and

B = Short span of slab.

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A two-way slab simply supported on the four edges, with corners held down and carrying U.D.L. may be analysed by the following methods :

(*a*) I.S. code method; (*b*) Marcus's method; and (*c*) Pigeaud's method.

Notes : 1. For a slab spanning in two directions, the ratio of span to the depth of slab should not exceed 35.

2. According to Indian standards (IS : 456 – 1978), the minimum total thickness of slab, from the stiffness point of view, should be equal to $B/35$, where B is the short span of the slab.

3. The maximum bending moment and deflection for a two way slab is much smaller than that of one-way slab.

4. If the sides of a slab simply supported on its edges and spanning in two ways are equal, then the maximum bending moment is multiplied by 0.50.

14.16 Flat Slab

A reinforced slab, built monolithically with the supporting columns and is reinforced in two or more directions, without any provision of beams, is called a *flat slab*. A flat slab may be solid slab or may have recesses formed on the soffit so that the soffit comprises of a series of ribs in two directions. The reinforcement is provided in two or more directions as per the requirements. Generally, the slab is divided into column strips and middle strips, the former acting as supports to the latter. The following definitions are important :

1. *Drop*. It is that part of a flat slab around the column, which is of greater thickness than rest of the slab.

2. *Column head*. It is the widened area at the top of the column to provide more support area to the slab. It increases rigidity of the slab and column connection.

3. *Panel*. The panel of a flat slab is the area enclosed between the centre lines connecting adjacent columns in two directions and the outline of the column heads.

4. *Column strip*. It is also called a design strip having width one-half of the width of panel, where drops are not used. However, where drops are provided, the width of column strip is taken as equal to width of the drop.

5. *Middle strip*. It is a design strip bounded on each of its opposite sides by the column strip. The width of the middle strip in the flat slab, where drops are used, is taken as the difference between the width of the panel and the drop.

Notes : (*a*) The total thickness of a flat slab, in no case, should be less than 125 mm.

(*b*) The total thickness of a flat slab should not be less than $L / 36$ for interior panels without drops, and $L / 40$ for interior panels with drops, where L is the average length of a panel.

(*c*) The angle of greatest slope of the column head from the vertical, in a flat slab, should not exceed 45°.

(*d*) The diameter of column head in a flat slab should not be more than $L / 4$, where L is the average length of panel.

(*e*) The diameter of column head should be taken as its diameter measured below the underside of the slab at a distance of 40 mm.

14.17 Circular Slab

A circular slab may be used for the roof of a room or hall circular in plan, floor of circular water tanks, roof of pump houses constructed above tube wells and roof of a traffic control post at intersection of roads. The bending of such a slab is essentially different from that of a rectangular slab. When a circular slab simply supported at edges is loaded with uniformly distributed load, it bends in the form of a saucer and the stresses are developed both in radial as well as in the circumferential directions. The reinforcement is provided at the convex side of the slab. Theoretically, reinforcement should be provided both in the radial as well as circumferential directions. However, reinforcement in the form of rectangular mesh is sometimes provided for easier working. If the edges are fixed, then radial and circumferential reinforcement near the edge becomes essential.

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If w is the uniformly distributed load per unit area, on a circular slab of radius R, is freely supported edges, then

Maximum radial moment at the centre $= \frac{3wR^2}{16}$

Maximum circumferential moment at the centre $= \frac{3wR^2}{16}$

Maximum circumferential moment at the support $= \frac{2wR^2}{16}$

The radial moment at the edges of the slab will be zero.

For a circular slab, fixed at the supports,

Maximum positive radial moment at the centre $= \frac{wR^2}{16}$

Maximum negative radial moment at the support $= \frac{2wR^2}{16}$

Maximum circumferential moment at the centre $= \frac{wR^2}{16}$

.18 Ribbed, Hollow Block or Voided Slab

A ribbed slab is provided where plain ceiling, thermal insulation and acoustic insulation is quired. The following types of floors fall under this category :

(*a*) The slabs containing a series of ribs with topping of concrete over forms, which is removed after concrete has set.

(*b*) A series of ribs with topping of concrete, having the same strength as that of the rib.

The main advantage of the ribbed floor is the reduction of the quantity of concrete and hence the nsiderable saving in the cost. It may be considered as a *T*-beam in which the space between the tees the ribs is kept hollow and the bottom contains light concrete. The weight of the structure is duced considerably and at the same time heat and sound insulation is provided.

otes : 1. The thickness of the topping of a ribbed slab is kept from 50 mm to 80 mm.

2. The width of the ribs should not be less than 65 mm.

3. The spacing between the ribs should not be greater than 1.5 metres centre to centre. The actual ear spacing depends upon the size of the hollow blocks available, but it should not normally exceed 12 times e thickness of the slab.

4. The overall depth of the ribbed slab shall not exceed four times the width of rib.

5. The diameter of bar used in ribbed slab should not be more than 22 mm.

4.19 Foundations

The foundation is that part of a structure whose function is to distribute the load of *super-ructure over a large bearing area. The foundation increases the stability of the structure and prevent e lateral movement of the supporting material. The lower most portion of a foundation which is in irect contact with the sub-soil (*i.e.* which deliver the load to the soil) is called *footing*.

The foundations may be broadly classified as shallow foundation and deep foundation. According o Terzaghi, a foundation is said to be shallow if its depth is equal to or less than its width. In case of deep foundations, the depth is equal to or greater than the width.

The shallow foundations are suitable when soil with adequate bearing pressure is available at reasonable depth below the ground level. The deep foundations are usually adopted for supporting structure like multi-storey buildings.

* The portion of a structure which is above the ground level is called *superstructure*.

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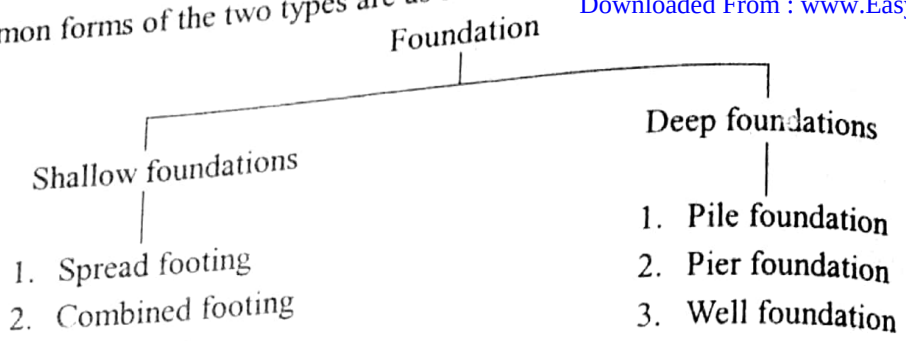
The common forms of the two types are as follows :



The *spread footing* distributes the load over a larger area because the base of the structure transmitting load to the soil is made wider. The *wall footings* and *isolated footings* fall under the category of spread footing. The wall footing may be either simple or stepped. The simple footing is provided for walls which carry light loads and stepped footing is provided for walls which carry heavy loads. The isolated footing is provided under isolated columns to transfer the load of the structure to the soil bed. The isolated footing may be square, rectangular or circular.

The *combined footing* is provided to support two or more columns and the end column is near the property line. It is also provided when the bearing capacity of the soil is less and the columns are very near to each other so that their footings overlap. The combined footing may be square, rectangular or trapezoidal in shape. In order to get uniform pressure distribution under the combined footing, the centre of gravity of the footing area should coincide with the centre of gravity of the combined loads of the two columns.

In a *strap footing* for two or more columns, the load from the outer column is balanced by the load from the inner column through a cantilever beam acting about a fulcrum. The strap footing does not transfer any pressure to the soil.

A *raft footing* is a combined footing that covers the entire area beneath a structure.

A *pile foundation* is a deep foundation and it is used where the top soil is relatively weak, particularly in multi-storey buildings. The load is transmitted to the soil by driving long vertical member of concrete called pile. The hammer used in driving piles may be drop hammer, diesel hammer, single and double acting hammer, and vibratory hammer. The piles may be classified as end bearing piles, friction piles, pre-cast concrete piles and cast-in-situ concrete piles. The *end bearing piles* are used to transfer loads through water or soft soil to a suitable bearing stratum. The *friction piles* are used to transfer loads to a depth by means of skin friction along the length of the piles.

The *precast concrete piles* are generally used for a maximum design load of 80 tonnes except for large prestressed piles. They must be reinforced to withstand handling stresses.

The *cast-in-situ piles* are suitable in practically all ground conditions.

The *pier foundation* is specially suitable for heavy structure such as flyovers in sandy soil or soft soil overlying hard bed at reasonable depth.

The *well foundation* is suitable for bridges.

14.20 Design of Shallow Foundations

The footings shall be designed to sustain the applied loads, moments and forces. The following points are worth nothing in the design of shallow foundations :

1. In the design of reinforced concrete footings, the pressure distribution is assumed to be linear.

2. According to IS : 456 – 1978, the thickness at the edge, in reinforced and plain concrete footings on soils shall not be less than 150 mm and not less than 300 mm above the top of piles for footings on piles.

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3. The minimum depth of footing (D), according to Rankine's formula is given by

$$D = \frac{P}{w}\left[\frac{1-\sin\phi}{1+\sin\phi}\right]^2$$

where
P = Safe bearing capacity of the soil in kN/m^2,
w = Unit weight of the soil in kN/m^3, and
ϕ = Angle of repose of the soil.

4. The weight of footing is assumed as 10% of the weight transmitted to the column.

5. If W is the weight or load transferred to the footing from the column, W_1 is the self weight of footing (which is generally taken as 10% of W), and A is the area of footing, then the bearing capacity of soil.

$$q_0 = \frac{W+W_1}{A} \quad \text{or} \quad A = \frac{W+W_1}{q_0} \qquad ...(i)$$

The maximum upward pressure on the footing (p_0) is given by

$$p_0 = \frac{W}{A} = \frac{W \times q_0}{W+W_1} \qquad ...[\text{From equation } (i)]$$

6. The depth of square footing should not be less than 150 mm.

7. If the net upward pressure on a square footing is p_0, width of footing is B, width of column or wall is b, then the maximum bending moment (M) near the column is given by

$$M = \frac{p_0 \times B}{8}(B-b)^2$$

8. Normally, footings fail by punching shear or diagonal tension. The area over which punching shear is calculated is the perimeter of the column multiplied by the effective depth of the footing i.e. $4b \times D$) where b is width of square column and D is depth of footing. The punching shear intensity (τ_p) is given by

$$\tau_p = \frac{p_0 (B^2 - b^2)}{4b \times D}$$

For a circular footing,

$$\tau_p = \frac{p_0 (R^2 - r^2)}{2r \times D}$$

where
R = Radius of circular footing, and
r = Radius of column.

9. The combined footing (rectangular) is shown in Fig. 4.8. Let W_1 and W_2 be the loads from the columns C_1 and C_2 and l be the centre to centre distance between the columns. The length of the combined footing for the two columns is L and the distance of centre of gravity (G) from the centre of left hand column (C_1) is $\bar{x}$. We know that net upward pressure on footing,

$$p_0 = \frac{W_1 + W_2}{L \times B}$$

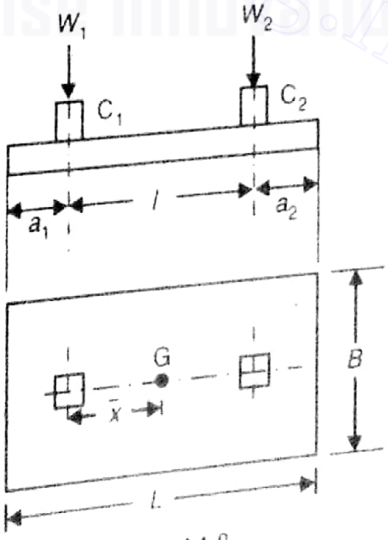

Fig. 14.8

In order to have uniformly distributed load on the footing, the projection (a_2) on the right hand side of the column is given by

$$a_2 = \frac{L}{2} - (l - \bar{x})$$

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10. The combined footing, in the transverse direction, will have sagging bending moment. In the longitudinal direction, it will have sagging bending moment in the two cantilever portions and hogging bending moment in some length of middle portion.

11. In a combined footing for two columns carrying unequal loads, the shear force is zero at a certain section. The hogging bending moment will be maximum at this section.

12. A combined footing for two columns should be designed for the maximum hogging bending moment and sagging bending moment at the outer face of each column. The reinforcement should be provided on the bottom face for sagging bending moment and on the top face for hogging bending moment.

14.21 Design of Deep Foundations

The following points are worth nothing in the design of deep foundations :

1. A reinforced concrete pile is usually designed as a column, considering it fixed at one end and hinged at the other end.

2. The effective length of reinforced concrete pile is taken as two-third of the length embedded in firm stratum (soil), the design load being taken as 50% to 100% higher to take care of impact.

3. The longitudinal reinforcement for reinforced piles having length upto 30 times its least width, should not be less than 1.25% of the gross cross-sectional area of the pile. It is increased to 2% for a length above 40 times the least width of pile.

4. The volume of lateral reinforcement (with at least 5 mm diameter bars) provided in the form of links, should not be less than 0.2% of the gross volume of the pile.

5. The centre to centre spacing of lateral reinforcement should not exceed half the least width of the pile. At ends of the pile for a distance of three times the least lateral dimension, the lateral reinforcement should not be less than 0.60% of the gross volume of the pile.

6. When the pile has to penetrate hard stratum (soil), the lateral reinforcement at the top of the pile for a distance of three times the width, should be in the form of helix. In addition, the longitudinal bars should be held apart by provision of spreaders of 12 mm to 16 mm bar provided at interval of not exceeding 1.5 metres. In order to prevent the outward displacement of the bars, 6 mm diameter links should also be provided with the spreaders. The piles should be provided with cast iron shoes at its lower end.

7. When a pile is lifted by means of a derrick, it is subjected to bending moment due to its own weight. A pile of length less than 12 metres is usually suspended from its middle point. The longer piles are usually suspended at two or three points suitably spaced at its length, so that bending moment is as small as possible.

8. When a pile of length L carrying uniformly distributed load w per unit length is suspended at one point, then maximum bending moment (M_{max}) at the point of suspension is given by

$$M_{max} = \frac{wL^2}{8}$$

9. When the pile is suspended at two points, then the maximum bending moment at the points of suspension is

$$M_{max} = \frac{wL^2}{47}$$

In such a case, the hogging bending moment at the point of suspension will be equal to sagging bending moment at the middle of the pile, if the point of suspension from either end of the pile is equal to 0.207 L.

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10. When the pile is suspended at three points, then maximum bending moment,

$$M_{max} = \frac{wL^2}{90}$$

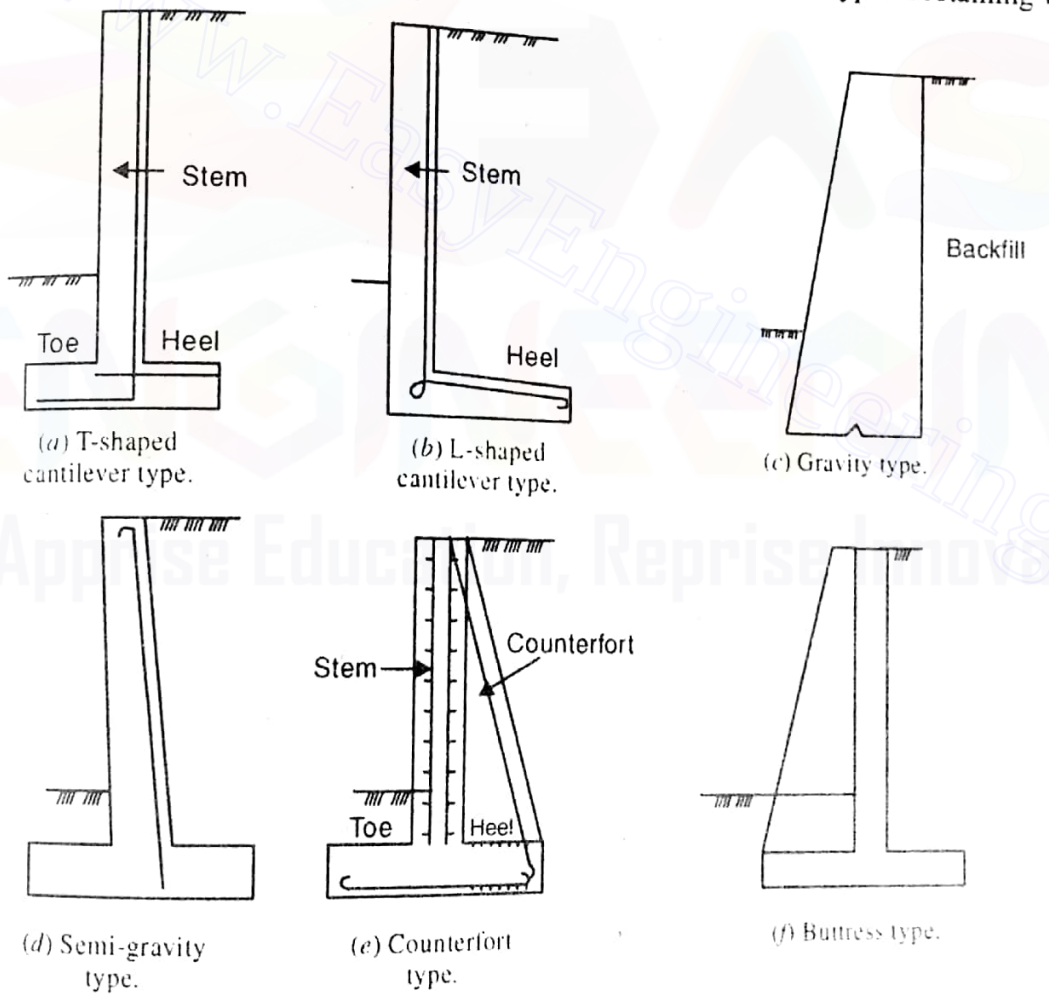
In such a case, the bending moment will be least when the end points are located at a distance of 0.15 L from the corresponding ends.

11. For cast-in-situ piles, the minimum reinforcement should be 0.40% of the sectional area calculated on the basis of outside area of the casing or shaft. The reinforcement can be curtailed along the depth of pile depending upon the nature of soil. In soft clay or loose sands, the reinforcement is to be provided upto the full pile depth. The minimum clear distance between two main reinforcements shall be 100 mm. The minimum diameter of the links or spirals shall be 6 mm and the spacing not less than 150 mm.

14.22 Retaining Walls

The retaining walls are used to retain earth fill or any other material so that the ground surfaces at different elevations are maintained on either side of the retaining wall. These are mostly used for roads in hilly areas, swimming pools, at the end of bridges in the form of abutments, and under ground water tanks. The various types of retaining walls are as follows :

1. *Cantilever retaining wall.* It is a reinforced concrete wall utilising the weight of the soil itself to provide the desired weight. The *T*-shaped and *L*-shaped cantilever type of retaining wall are shown in Fig. 14.9 (*a*) and (*b*) respectively.



(*a*) T-shaped cantilever type. (*b*) L-shaped cantilever type. (*c*) Gravity type.

(*d*) Semi-gravity type. (*e*) Counterfort type. (*f*) Buttress type.

Fig. 14.9

2. *Gravity retaining wall.* It depends entirely on their own weight to provide the necessary stability. The gravity retaining wall is shown in Fig. 14.9 (*c*).

3. *Semi-gravity retaining wall.* It is lighter than gravity retaining wall and is intermediate between the cantilever and gravity types. The semi-gravity retaining wall is shown in Fig. 14.9 (*d*).

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4. *Counterfort retaining wall.* It looks like a *T* or *L* shaped cantilever wall and likewise uses the weight of the soil for stability. The counterforts supports the stem and heel slab of a retaining wall, as shown in Fig. 14.9 (*e*).

5. *Buttress retaining wall.* It is like a covered counterfort type with ribs or walls. The toe and stem are a continuous slab, as shown in Fig. 14.9 (*f*).

In order to calculate earth pressure on retaining walls, the following two theories are used :

(*a*) Rankine's theory; and (*b*) Coulumb's theory.

According to Rankine's theory, as applied to retaining walls, the following assumptions are taken :

1. The soil mass is semi-infinite, homogeneous, dry and cohesionless,
2. The back of the retaining wall is vertical and smooth, and
3. The retaining wall yields about the same.

Fig. 14.10 (*a*) shows a retaining wall of height *H*, having dry or moist back fill, with no surcharge. According to Rankine's theory, the intensity of active earth pressure (p_a) trying to move the retaining wall of height *H*, away from the back fill is given by

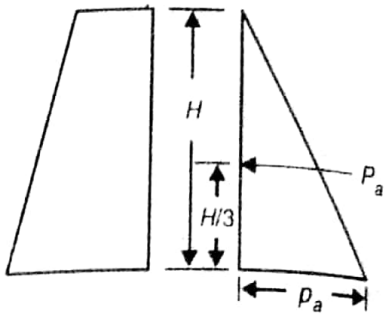

Fig. 14.10

$$p_a = wH\left[\frac{1-\sin\phi}{1+\sin\phi}\right]$$

where w = Unit weight of soil, and

ϕ = Angle of internal friction (or repose) for the back fill.

Fig. 14.10 (*b*) shows the distribution of active pressure over the retaining wall.

The total active earth pressure (P_a) or resultant pressure per unit length of the retaining wall is given by

$$P_a = \frac{wH^2}{2}\left[\frac{1-\sin\phi}{1+\sin\phi}\right]$$, acting at *H*/3 above the base of the retaining wall. If the soil is dry, then *w* is the dry weight of the soil or if most, *w* is the moist weight of the soil.

When the earth is surcharged and the surcharge is horizontal, then the intensity of lateral earth pressure (p_s) due to surcharge of w_1 per unit length is given by

$$p_s = w_1\left[\frac{1-\sin\phi}{1+\sin\phi}\right]$$

and the pressure intensity (p_a) at the base of the retaining wall of height *H*, is given by

$$p_a = wH\left[\frac{1-\sin\phi}{1+\sin\phi}\right] + w_1\left[\frac{1-\sin\phi}{1+\sin\phi}\right]$$

When the retaining wall has a sloping backfill with surcharge angle α, then the intensity of lateral earth pressure (p_a) at the base of the retaining wall of height *H*, is given by

$$p_a = wH\cos\alpha\left[\frac{\cos\alpha - \sqrt{\cos^2\alpha - \cos^2\phi}}{\cos\alpha + \sqrt{\cos^2\alpha - \cos^2\phi}}\right]$$

The overturning moment (*M*) due to active earth pressure, at toe of the retaining wall is given by

$$M = \frac{wH^3}{6}\left[\frac{1-\sin\phi}{1+\sin\phi}\right]$$

Notes : **1.** The factor of safety due to overturning and sliding of the retaining wall is generally taken as 2 and 1.5 respectively.

2. The passive earth pressure is exerted on the retaining wall, when it has a tendency to move towards the back fill.

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3. The retaining walls with heights exceeding 6 metres are usually provided with counterforts.

4. The spacing of the counterforts is $\frac{1}{3}$ to $\frac{1}{2}$ of the height of the retaining wall. It is kept between 3 to 3.5 metres.

14.23 Staircase

The staircase provides means of movement from one level to another in a building. It consists of number of steps arranged in series with landing at appropriate locations for the purpose of giving access to different floors of a building. The width of a staircase depends upon the purpose for which it is provided. It generally varies between one metre for residential building to two metres for public buildings. The length of the staircase situated between two landings is called *flight*. The number of steps in a flight may vary from three to twelve. The rise of a step and the tread, as shown in Fig. 14.11, should be such as to give the maximum comfort to the users. Generally, the sum of tread plus twice the rise of a stair is kept about 600 mm and the product of tread and rise (in mm) is kept between 40000 to 45000. In residential buildings, the rise of a stair may vary between 150 mm to 200 mm and the tread between 200 mm to 300 mm. The waist is the thickness of an inclined slab. When the stair slab is spanning horizontally, a waist slab of about 80 mm is provided.

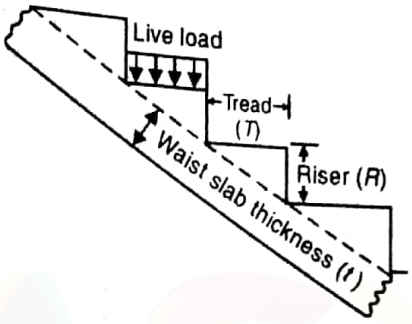

Fig. 14.11

The dead weight or load on stairs consists of dead weight of waist slab and dead weight of the steps. The dead weight (w_d) per unit area is first calculated at right angles to the slope of the waist slab. The corresponding load per unit horizontal area is then obtained by multiplying the dead weight (w_d) by the ratio $\frac{\sqrt{R^2 + T^2}}{T}$, where R is the rise and T is the tread of the stair. Hence the dead weight of slab (w_{d1}) per unit horizontal area is given by

$$w_{d1} = \frac{w_d \sqrt{R^2 + T^2}}{T}$$

The dead weight of the steps is determined by treating the step to an equivalent horizontal slab of thickness equal to half the rise ($R/2$).

In designing stairs spanning horizontally, each step is designed by considering it equivalent to a horizontal beam of width $\sqrt{R^2 + T^2}$, measured parallel to the slope of the stair, and an effective depth equal to the average depth. The main reinforcement is provided in the direction of the span. The distribution reinforcement is provided in the form of 6 mm diameter rods at 300 mm centre to centre.

14.24 Prestressed Concrete

The basic concept of prestressing the concrete consists in introducing the artificially the compressive stresses in a structure before it is loaded. The tensile stress in the prestressed concrete structure may be reduced to a great extent or even entirely eliminated depending upon the magnitude of prestressing. In a prestressed concrete structure, the cost of supporting structure and foundation is reduced, dead load of structure is reduced and cracking of concrete is avoided. The high strength concrete and high tensile steel should be used in a prestressed concrete member. According to Indian standards, the cube strength of the concrete used should not be less than 35 N/mm^2. The ultimate strength of high tensile steel wires used in prestressing varies from 1500 N/mm^2 for 8 mm diameter bars to 2350 N/mm^2 for 1.5 mm diameter bars. The various methods adopted in prestressing are as follows :

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1. *Pre-tensioning.* The method of providing desired amount of compressive stress in the concrete member before setting the concrete to the desired strength, is known as pre-tensioning of concrete. In this method, the tendons (wires of high tensile strength) are stretched to the desired amount. One end of the tendon is secured to an abutment, while the other end is stretched out with the help of a prestressing jack. The form work is then erected around the tensioned tendons and other reinforcing bars (distribution bars, stirrups etc.) are placed suitably and fresh concrete poured, compacted and properly cured. At the end of the curing period, concrete is hard enough to sustain the compression passed through the bond. The projecting steel wires are then cut. This method is particularly adopted in precast beams, posts and simply supported slabs.

2. *Post-tensioning.* The method of prestressing in which the prestressing force is applied to the tendons after the concrete has set or hardened and has acquired necessary strength, is known as post-tensioing method of prestressing the concrete member. This method consists of pouring the concrete into the mould in which steel tendons are placed and then stretched after the concrete has hardened. The tendons are not bonded to the concrete before tensioning. The reinforcing steel may be in the form of single tendon, cables made of separate wires of alloy bars. The hydraulic jacks acting against the ends of precast member are used for pulling or stretching the tendons or cables. The tendons are pulled through holes, ducts or grooves left for them in the precast concrete member. When the required stretch has been given, the jack end of the tendon is anchored and the duct is grouted with cement. It will save the steel from rusting as the cement grout forms a bond between tendons and concrete. Such type of beams are known as bonded post-tensioned beams.

The post-tensioning method of prestressing the concrete is used for either cast-in-situ or pre-cast construction.

The post-tensioning can be achieved by the following methods :

(*a*) Freyssinet system; (*b*) Magnet Balton system; (*c*) Gifford Udall system; (*d*) Lee-Mc Call system; and (*e*) Bauer-Leon hardt system.

3. *Linear prestressing.* The linear prestressing is done in straight members like beams, slabs, piles etc. These members are normally precast, using pretensioning technique.

4. *Circular prestressing.* The circular prestressing is adopted for circular structures like water or oil tanks, pipes, silos, in which the tendons are in the form of a ring and special device such as Merry-go-round equipment.

14.25 Losses in Prestressing

The various losses due to prestressing are as follows :

1. *Loss of prestress due to creep of concrete.* The creep of concrete causes loss of stress in tensioned steel. The creep coefficient of concrete for loss of prestress is defined as the ratio of creep strain to the elastic strain. The value of creep coefficient depends upon the humidity, concrete quality, duration of loading and age of concrete when load is applied. It varies from 1.5 for watery condition to 4.0 for dry condition.

2. *Loss of prestress due to relaxation of steel.* The loss of prestress due to relaxation of steel depends upon the quality of steel, initial prestress, age after pestressing and temperature. This loss should be taken 2 to 8% of the average initial stress.

3. *Loss of prestress due to shrinkage of concrete.* The loss of prestress due to shrinkage of concrete is taken as the product of modulus of elasticity of steel (E_s) and the shrinkage strain of concrete. According to Indian standards, the shrinage strain for a pretensioned member is taken as 3×10^{-4}.

4. *Loss of prestress due to slip in anchorage.* The loss of prestress due to slip in anchorage is of special importance with short members and is taken care of by providing additional stretch at the time of stretching the tendons. An average of about 2.5 mm is estimated as anchorage slip in wedge type of grips and for heavy strands, the slip may be 5 mm.

5. *Loss of prestress due to shortening of concrete.* The loss of prestress due to shortening of concrete depends upon the strength of concrete (modular ratio) and the initial prestress. In case of

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pre-tensioning tendon, the loss is calculated on the least modular ratio and the stress in the adjoining concrete. For post-tensioned tendon, the loss is calculated on the basis of half the product of stress in the adjoining concrete, averaged along their lengths and modular ratio. It is assumed that the tendons are located at the centroid of concrete.

6. *Loss of prestress due to friction*. There will be considerable movement of sliding of tendon relative to the surrounding duct during tensioning operation. Since the tendon is in direct contact with the duct or with spacers provided, therefore the friction will cause a reduction in prestressing force as the distance from the jack increases.

Notes : 1. At the time of tensioning, the maximum tensile stress behind the anchorages shall not exceed

(*a*) 80% of ultimate tensile strength of the wire or bar steel without a definite yield point, and

(*b*) The yield stress for steel with a guaranteed yield point.

2. After accounting for losses due to creep and shrinkage of the concrete, friction effects and relaxation of steel, the maximum tensile strees (σ_t) at the point of maximum bending shall not exceed

(*a*) 60% of the ultimate strength of wire or bar for steel without a definite yield point, and

(*b*) 80% of the yield stress for steel with guaranteed yield point.

14.26 Analysis of Prestress

When the tendon is placed concentric in the concrete member, then the stress due prestressing force is a direct stress and when the tendon is placed eccentrically, then combined direct and bending stresses are induced.

Consider a tendon of a rectangular prestressed beam of cross-sectional area A is subjected to eccentric prestressing force of magnitude P located at eccentricity e, as shown in Fig. 14.12. The stresses developed at bottom and top fibres are as follows :

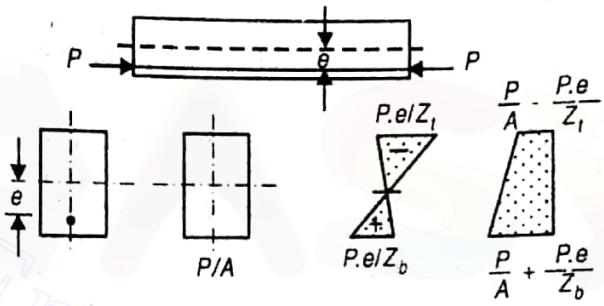

Fig. 14.12

$$\sigma_b = \frac{P}{A} + \frac{P.e}{Z_b} = \frac{P}{A} + \frac{M}{Z_b}$$

and

$$\sigma_t = \frac{P}{A} - \frac{P.e}{Z_t} = \frac{P}{A} - \frac{M}{Z_t}$$

14.27 Concept of Load Balancing

Consider a prestressed beam loaded as shown in Fig. 14.13. In order to completely balance a bent tendon of span L carrying a point load W at the centre, the minimum central dip (h) should be equal to

$$h = \frac{WL}{4P}$$

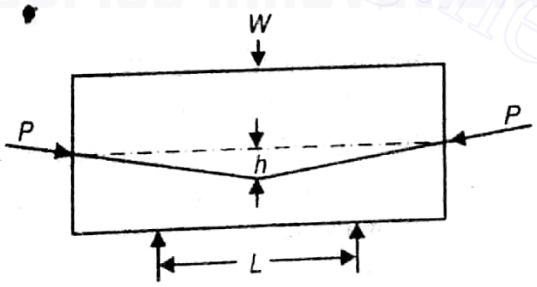

Fig. 14.13

When prestressing force P is such that completely balances the load, then stress at any section = P/A.

14.28 Ultimate Load Theory or Load Factor Method of R.C.C. Design

The ultimate load theory depends upon the ultimate load taken by a R.C.C. member at failure. This method is also known as load factor method as the load factor is used for calculating the ultimate load from the safe load. The *load factor* is defined as the ratio of ultimate load to the safe load. In this method of R.C.C. design, the optimum use of inherent strength of both steel and concrete, is made. The ultimate load theory is based on the fact that a beam fails by yielding of steel and subsequently crushing of concrete rather than crushing of concrete alone as in the case of elastic theory or working stress method of design. In elasic theory or working stress method, the designer ensures that stresses

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in concrete and steel do not exceed their safe permissible limits, when the member is subjected to maximum probable load (dead load + live load).

All the tensile stresses developed are taken by steel reinforcement in tensile zone and the concrete is considered in-effective as only top most fibre of the concrete is under compression and is fully stressed to their permissible value and the concrete below the top most fibres is not accounted for maximum compressive stress which occur at top concrete which is quite strong in compression.

The main advantage in the adoption of ultimate load design method is that the full utilisation of actual compressive strength offered by the concrete in compression is made use of. Since the section obtained by ultimate load theory is smaller than that obtained by working load method, therefore this method gives economical design.

The ultimate load method is limited to beams and eccentrically loaded columns only.

The following assumptions are made in ultimate load design method :

1. The plane sections of the beam normal to the axis remains plane after bending.
2. The tensile strength of concrete is neglected.
3. At the ultimate strength, the stresses and strains are proportional and the distribution of compressive stresses in a section subjected to bending is non-linear. The diagram of compressive concrete stress distribution may be assumed rectangular, parabolic, trapezoidal or any other shape to suit the tests.
4. The maximum fibre stress in concrete does not exceed 0.68 σ_{cu}, where σ_{cu} is the ultimate strength of concrete cube at 28 days.

The following table gives the comparison of ultimate load method and elastic theory method :

S.No.	*Ultimate Load Method*	*Elastic Theory Method*
1.	It takes into account the elasto-plastic properties of the materials to decide upon the strength of a member. It is much close to actual load tests at failure.	It considers only the elastic properties of the materials and does not allow to exceed the safe stresses on any fibre.
2.	The materials are stressed to its maximum value	The materials are understressed to a great extent.
3.	The sections are designed for ultimate loads for which suitable factors are assumed to get a critical combination of various loads anticipated.	Only the maximum probable loads anticipated to be born by the members are considered.
4.	The design procedure is based on actual experimental observations. The procedure stands quite close to actual tests. However some sutiable assumptions are made to simplify the computation.	The design procedure is based on the laws of mechanics.
5.	The actual test strength of the two materials are made use of in the design of members.	The modular ratio (m) is used in the design of members.
6.	The design made by this method is economical.	The design made by this method is uneconomical as compared to ultimate load method.
7.	The under-reinforced sections are designed to obtain the full strength of the materials used in R.C.C. construction.	Mostly the designed R.C.C. sections are balanced or over-reinforced.
8.	The full compressive strength of concrete is utilised for design purpose.	The concrete which is quite strong in compression remains under stressed.
9.	In this method, both concrete and steel are stressed full.	In this method, steel is more stressed than concrete.

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OBJECTIVE TYPE QUESTIONS

1. In reinforced cement concrete structures, the steel reinforcement consists of
   (*a*) deformed bars (*b*) cold twisted bars
   (*c*) mild steel and medium tensile steel bars (*d*) all of these
2. A twisted bar has about ..... more yield stress than ordinary mild steel bar.
   (*a*) 10% (*b*) 20% (*c*) 35% (*d*) 50%
3. The compressive strength of concrete is about 10 to 15% of its tensile strength.
   (*a*) True (*b*) False
4. In singly reinforced beams, steel reinforcement is provided in
   (*a*) tensile zone (*b*) compressive zone
   (*c*) both tensile and compressive zones (*d*) neutral zone
5. In a simply supported reinforced concrete beam, the reinforcement is placed
   (*a*) below the neutral axis (*b*) above the neutral axis
   (*c*) at the neutral axis (*d*) any one of these
6. The joint action of steel and concrete, in a reinforced concrete section, depends upon the
   (*a*) bond between concrete and steel bars
   (*b*) absence of corrosion of steel bars embedded in the concrete
   (*c*) practically equal thermal expansion of both concrete and steel
   (*d*) all of the above
7. In a singly reinforced beam, the effective depth is measured from the compression edge to the
   (*a*) tensile edge (*b*) centre of tensile reinforcement
   (*c*) neutral axis of the beam (*d*) none of these
8. Analysis of reinforced concrete can be done by
   (*a*) straight line theory (*b*) elastic theory (*c*) ultimate load theory (*d*) all of these
9. The application of elastic theory to the beams is based on the assumption that
   (*a*) at any cross-section, plane sections before bending remain plane after bending
   (*b*) all tensile stresses are taken up by reinforcement alone and none by the concrete
   (*c*) steel reinforcement is free from initial stresses when it is embedded in concrete
   (*d*) all of the above
10. In case of a cantilever beam, the tensile zone is above the neutral axis.
    (*a*) Agree (*b*) Disagree
11. If σ_{cb} is the permissible stress in compression due to bending in concrete in N/mm^2, the modular ratio (m) is of the order of
    (*a*) $\frac{280}{3\sigma_{cb}}$ (*b*) $\frac{280}{4\sigma_{cb}}$ (*c*) 19 (*d*) 23
12. When load on the reinforced concrete beam is small so that the tensile stress set up in the concrete below the neutral axis is smaller than the permissible, then the concrete area ..... the neutral axis will not crack.
    (*a*) above (*b*) below
13. In a singly reinforced concrete beam, if the load is very small
    (*a*) only concrete will resist tension (*b*) only steel bars will resist tension
    (*c*) both concrete and steel will resist tension
    (*d*) both concrete and steel will resist compression

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14. The modular ratio is the ratio of
(*a*) Young's modulus of steel to the Young's modulus of concrete
(*b*) Young's modulus of concrete to the Young's modulus of steel
(*c*) load carried by steel to the load carried by concrete
(*d*) load carried by concrete to the load carried by steel

15. In a reinforced concrete column, the cross-sectional area of steel bar is A_s and that of concrete is A_c. The equivalent area of the section in terms of concrete is equal to
(*a*) $A_s + mA_c$ (*b*) $A_c + mA_s$ (*c*) $A_s - mA_c$ (*d*) $A_c - mA_s$

16. In a singly reinforced concrete beam, as the load increases
(*a*) only concrete will resist tension (*b*) only steel bars will resist tension
(*c*) both concrete and steel will resist tension
(*d*) both concrete and steel will resist compression

17. The stress in concrete increases in direct proportion to increase in strain.
(*a*) Right (*b*) Wrong

18. Normally, the tensile strength of concrete is about ..... of its compressive strength.
(*a*) 10 to 15% (*b*) 15 to 20% (*c*) 20 to 25% (*d*) 25 to 30%

19. If the load on beam is increased, the tensile stress in the concrete below the neutral axis will
(*a*) decrease (*b*) increase (*c*) remain unchanged

20. Under normal loading conditions, the tensile stresses set up in the concrete will be ..... the permissible stress.
(*a*) more than (*b*) less than (*c*) equal to

21. A reinforced concrete beam will crack if tensile stress set up in the concrete below the neutral axis is
(*a*) less than the permissible stress (*b*) more than the permissible stress
(*c*) equal to the permissible stress (*d*) any one of these

22. In a singly reinforced beam, the depth of neutral axis below the top of the beam (n_c) is given by

(*a*) $n_c = \dfrac{m \times \sigma_{cb}}{m \times \sigma_{cb} + \sigma_{st}} \times d$ (*b*) $n_c = \dfrac{m \times \sigma_{cb}}{m \times \sigma_{cb} - \sigma_{st}} \times d$

(*c*) $n_c = \dfrac{m \times \sigma_{cb} + \sigma_{st}}{m \times \sigma_{cb}} \times d$ (*d*) $n_c = \dfrac{m \times \sigma_{cb} - \sigma_{st}}{m \times \sigma_{cb}} \times d$

where m = Modular ratio,
σ_{cb} = Compressive stress in extreme fiber of concrete,
σ_{st} = Tensile stress in steel reinforcement, and
d = Distance between the top of the beam and the centre of steel bars (also known as effective depth).

23. If the breadth of a singly reinforced beam is b, effective depth is d, depth of neutral axis below the top of beam is n and the compressive stress in the extreme fibre of concrete is σ_{cb}, then the moment of resistance of the beam is equal to

(*a*) $\dfrac{\sigma_{cb}}{2} \times bn\left(\dfrac{d-n}{3}\right)$ (*b*) $\dfrac{\sigma_{cb}}{2} \times bn\left(\dfrac{2d-n}{3}\right)$

(*c*) $\dfrac{\sigma_{cb}}{2} \times bn\left(\dfrac{3d-n}{3}\right)$ (*d*) $\dfrac{\sigma_{cb}}{2} \times bn\left(\dfrac{4d-n}{3}\right)$

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24. The lever arm in a singly reinforced beam is equal to
(a) $\frac{d-n}{3}$ (b) $\frac{2d-n}{3}$ (c) $\frac{3d-n}{3}$ (d) $\frac{4d-n}{3}$

where d = Distance between the top of beam and the centre of steel bars, and
n = Depth of neutral axis below the top of beam.

25. In a beam section, if the steel reinforcement is of such a magnitude that the permissible stresses in concrete and steel are developed simultaneously, the section is known as
(a) balanced section (b) critical section (c) economical section (d) any one of these

26. The section in which concrete is not fully stressed to its permissible value when stress in steel reaches its maximum value, is called
(a) under-reinforced section (b) over-reinforced section
(c) critical section (d) balanced section

27. The actual neutral axis of an under-reinforced section is above the critical neutral axis of a balanced section.
(a) Correct (b) Incorrect

28. The neutral axis of a balanced section is called
(a) balanced neutral axis (b) critical neutral axis
(c) equivalent neutral axis (d) all of these

29. The moment of resistance of an under-reinforced section is computed on the basis of
(a) compressive force developed in concrete (b) tensile force developed in steel
(c) both (a) and (b) (d) none of these

30. In a singly reinforced beam, if the stress in concrete reaches its allowable limit later than the steel reaches its permissible value, the beam section is said to be under-reinforced.
(a) True (b) False

31. If the tensile stress in steel reinforcement is σ_{st}, area of tensile reinforcement is A_{st}, depth of neutral axis is n and the effective depth is d, then the moment of resistance of an under-reinforced section is equal to
(a) $\sigma_{st} \times A_{st}\left[\frac{d-n}{3}\right]$ (b) $\sigma_{st} \times A_{st}\left[\frac{2d-n}{3}\right]$
(c) $\sigma_{st} \times A_{st}\left[\frac{3d-n}{3}\right]$ (d) $\sigma_{st} \times A_{st}\left[\frac{4d-n}{3}\right]$

32. In an over-reinforced section
(a) steel reinforcement is not fully stressed to its permissible value
(b) concrete is not fully stressed to its premissible value
(c) either (a) and (b) (d) both (a) and (b)

33. For an over reinforced (singly reinforced) rectangular reinforced concrete section
(a) the lever arm will be less than that for a balanced section
(b) the maximum stress developed by steel will be equal to the allowable stress in steel
(c) the maximum stress developed by concrete will be equal to allowable stress in concrete
(d) none of the above

34. The moment of resistance of an over-reinforced section is determined on the basis of
(a) tenisle force developed in steel (b) compressive force developed in concrete
(c) both (a) and (b) (d) none of these

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35. The neutral axis of an over-reinforced section falls
(*a*) on the critical neutral axis of balanced section
(*b*) below the critical neutral axis of balanced section
(*c*) above the critical neutral axis of balanced section
(*d*) none of the above

36. For a balanced section, the moment of resistance obtained from compressive force will be ..... the moment of resistance obtained from the tensile force.
(*a*) greater than (*b*) less than (*c*) equal to

37. As the percentage of steel in a beam increases, the depth of neutral axis also increases.
(*a*) Yes (*b*) No

38. For a balanced reinforced section, the depth of critical neutral axis from the top of the beam (n_c) is given by the relation

(*a*) $\frac{m\,\sigma_{cb}}{\sigma_{st}} = \frac{n_c}{d - n_c}$ (*b*) $\frac{m\,\sigma_{cb}}{\sigma_{st}} = \frac{d - n_c}{n_c}$ (*c*) $\frac{m\,\sigma_{cb}}{\sigma_{st}} = \frac{n_c}{d + n_c}$ (*d*) $\frac{m\,\sigma_{cb}}{\sigma_{st}} = \frac{d + n_c}{n_c}$

39. The effective depth of a singly reinforced rectangular beam is 300 mm. The section is over-reinforced and the neutral axis is 120 mm below the top. If the maximum stress attained by concrete is 5 N/mm^2 and the modular ratio is 18, then the stress developed in the steel will be
(*a*) 130 N/mm^2 (*b*) 135 N/mm^2 (*c*) 160 N/mm^2 (*d*) 180 N/mm^2

40. When a beam is loaded with transverse loads, the bending moment
(*a*) remains constant at every section (*b*) varies from section to section
(*c*) develops shear stresses in the beam (*d*) none of these

41. The maximum shear stress (τ_{max}) in a reinforced concrete beam of width (b) and subjected to a shear force (F) is equal to

(*a*) $\frac{F}{b(3d - n)}$ (*b*) $\frac{2F}{b(3d - n)}$ (*c*) $\frac{3F}{b(3d - n)}$ (*d*) $\frac{4F}{b(3d - n)}$

42. Which one of the following statements about the percentage of tensile steel required to produce a balanced reinforced concrete section is correct ?
(*a*) reduces as the yield strength of steel increases.
(*b*) remains unchanged irrespective of the yield strength of steel.
(*c*) is the same for a given quality of steel irrespective of whether working stress method is followed or ultimate load method is used.
(*d*) only a function of modulus of elasticity of steel.

43. Which of the following statement is correct regarding the working stress design of under-reinforced concrete section ?
(*a*) The neutral axis depth will be greater than that of a balanced section.
(*b*) The stress in steel in tension will reach its maximum permissible value first.
(*c*) The moment of resistance will be less than that of the balanced section.
(*d*) The concrete on the tension side is also to be considered for calculating the moment of resistance of the section.

44. If modular ratio is m, effective depth is d and stress ratio is $r = \sigma_{st} / \sigma_{cb}$, then the depth of neutral axis (n_c) of a balacned section is

(*a*) $\frac{m}{m - r} \times d$ (*b*) $\frac{m}{m + r} \times d$ (*c*) $\frac{m + r}{m} \times d$ (*d*) $\frac{m}{r} \times d$

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15. The deep beams are designed for
(a) shear force only (b) bending moment only
(c) both shear force and bending moment (d) bearing

46. The maximum permissible shear stress given in IS : 456 – 1978 is based on
(a) diagonal tension failure (b) diagonal compression failure
(c) flexural tension failure (d) uniaxial compression

47. When the lever arm of a reinforced concrete bream is z and width of beam is b, then the maximum shear stress in a beam subjected to shear force F will be equal to
(a) $\frac{Fb}{z}$ (b) $\frac{F}{bz}$ (c) $\frac{Fz}{b}$ (d) Fzb

48. Shearing stresses in the beam are not caused by the variation of bending moment along the span.
(a) True (b) False

49. In a reinforced concrete beam, the shear stress distribution above the neutral axis follows a
(a) straight line (b) circular curve (c) parabolic curve (d) none of these

50. The maximum shear stress in a rectangular beam is ..... times of average shear stress.
(a) 1.15 (b) 1.25 (c) 1.50 (d) 1.75

51. Which one of the following sections of equal cross-sectional area can resist the torsional moment of a R.C.C. beam section more efficiently when working stress design is adopted ?
(a) An unsymmetrical section (b) A box section
(c) A solid rectangular section (d) A symmetrical I-section

52. For a reinforced concrete beam section, the shape of the shear stress diagram is
(a) parabolic over the whole section with maximum value at the neutral axis
(b) parabolic above the neutral axis and rectangular below the neutral axis
(c) linearly varying as the distance from the neutral axis
(d) dependent on the magnitude of shear reinforcement provided

53. The chances of diagonal tension cracks in R.C.C. member reduce when
(a) only shear force act (b) flexural and shear force act
(c) axial tension and shear force act simultaneously
(d) axial compression and shear force act simultaneously

54. The diagonal tension in concrete can be resisted by providing
(a) diagonal tension reinforcement (b) shear reinforcement
(c) inclined tension reinforcement (d) all of these

55. Shear reinforcement is provided in the form of
(a) vertical bars (b) inclined bars
(c) combination of vertical and inclined bars (d) any one of these

56. For M 15 grade concrete, shear reinforcement is necessary, if shear stress is more than
(a) 0.5 N/mm^2 (b) 1 N/mm^2 (c) 1.5 N/mm^2 (d) 2 N/mm^2

57. For M 15 grade concrete, the section is to be redesigned if shear stress is more than
(a) 0.5 N/mm^2 (b) 1 N/mm^2 (c) 1.5 N/mm^2 (d) 2 N/mm^2

58. The section is to be redesigned, if the shear stress is more than 0.4 σ_{bc}, where σ_{bc} is the compressive stress in concrete.
(a) Yes (b) No

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59. Which of the following statement is correct ?
(*a*) Diagonal tension is caused by the combined action of longitudinal tension and the transverse shearing stresses.
(*b*) Shear reinforcement in the form of vertical bars is known as stirrups.
(*c*) According to IS : 456 – 1978, if the shear stress is less than one-tenth of compressive stress (σ_{cb}) in concrete at extreme fibre, no shear reinforcement is necessary.
(*d*) all of the above

60. At the centre of beam, the shearing stresses are practically negligible.
(*a*) Agree (*b*) Disagree

61. The centre to centre spacing of vertical stirrups, in a rectangular beam, is
(*a*) increased towards the centre of the span of the beam
(*b*) decreased towards the centre of the span of the beam
(*c*) increased at the ends (*d*) none of these

62. The spacing of vertical stirrups in a rectangular beam is
(*a*) maximum near the supports (*b*) minimum near the supports
(*c*) maximum near the centre (*d*) minimum near the centre

63. The number of stirrups resisting shear force, in a reinforced beam, is given by
(*a*) $\frac{\text{Shear force}}{\text{Spacing of stirrups}}$ (*b*) $\frac{\text{Lever arm}}{\text{Spacing of stirrups}}$
(*c*) $\frac{\text{Spacing of stirrups}}{\text{Lever arm}}$ (*d*) $\frac{\text{Spacing of stirrups}}{\text{Shear force}}$

64. A stirrups consists of ..... diameter mild steel bars bent round the tensile reinforcement.
(*a*) 1 to 5 mm (*b*) 5 to 12 mm (*c*) 12 to 18 mm

65. According to IS : 456 – 1978, the spacing of stirrups shall not exceed a distance ..... the lever arm of the resisting moment.
(*a*) equal to (*b*) double (*c*) three times

66. The torsion resisting capacity of a given reinforced concrete section
(*a*) decreases with decrease in stirrup spacing (*b*) decreases with increase in longitudinal bars
(*c*) does not depend upon stirrup and longitudinal steels
(*d*) increases with increase in stirrup and longitudinal steels

67. When the steel bars are embedded in concrete, the concrete after setting, adheres to the surface of the bars and thus resist any force that tends to pull or push this rod. The intensity of this adhesive force is called
(*a*) bond stress (*b*) shear stress (*c*) compressive stress (*d*) none of these

68. The longitudinal shearing stresses acting on the surface between the steel and concrete are called
(*a*) bond stresses (*b*) tensile stresses
(*c*) compressive stresses (*d*) none of these

69. The bond between steel and concrete is mainly due to
(*a*) pure adhesive resistance (*b*) frictional resistance
(*c*) mechanical resistance (*d*) all of these

70. Pure adhesive resistance in a reinforced concrete structure is provided by
(*a*) shrinkage of the concrete (*b*) deformed bars
(*c*) relatively weak adhesion of the chemical gum produced by concrete during setting
(*d*) all of the above

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71. Frictional resistance in a reinforced concrete structure is provided by the shrinkage of concrete.
(a) Correct (b) Incorrect

72. When a reinforced concrete structure is loaded, the resistance first broken is
(a) pure adhesive resistance (b) frictional resistance
(c) mechanical resistance (d) none of these

73. The hooks and other means of anchoring steel bar do not prevent the initial slipping of reinforced concrete structure.
(a) Right (b) Wrong

74. The term 'bond' is used to describe the means by which ..... between steel and concrete is prevented.
(a) resistance (b) crack (c) slip

75. Which of the following statement is wrong ?
(a) The hooks and other means of anchoring do not delay the collapse of structure.
(b) The frictional resistance is high for smooth bar surface.
(c) In the case of deformed bars, adhesion and friction become major elements.
(d) all of the above

76. If L is the lever arm in a reinforced concrete beam, S is the total perimeter of the steel bars and F is the shear force, then the bond stress developed in concrete around the steel reinforcement is equal to
(a) $\frac{F.S}{L}$ (b) $\frac{F.L}{S}$ (c) $\frac{F}{S.L}$ (d) $F.S.L$

77. As per IS : 456 – 1978, the permissible value of bond stress for M15 grade of concrete is limited to
(a) 0.5 N/mm^2 (b) 1 N/mm^2 (c) 1.5 N/mm^2 (d) 2 N/mm^2

78. If the bond stress developed in a reinforced concrete beam is more than permissible value, it can be brought down by
(a) increasing the depth of beam (b) increasing the number of bars
(c) decreasing the diameter of the bars (d) all of these

79. If ϕ is the diameter of reinforceing bar, then for M15 grade concrete, the bond length used for splicing bar in tension is approximately equal to
(a) 28 ϕ (b) 38 ϕ (c) 58 ϕ (d) 68 ϕ

80. For reinforcing bars in compression, the average bond stress can be increased by
(a) 10% (b) 25% (c) 50% (d) 75%

81. When hooks are formed in deformed bars, the internal radius of the bend should be at least ..... times the diameter of the bar.
(a) two (b) three (c) four (d) six

82. In the above question, the length of straight bar beyond the end of the curve should be at least
(a) two times the diameter of bar (b) three times the diameter of bar
(c) four times the diameter of bar (d) five times the diameter of bar

83. In the case of deformed bars, the value of bond stress for various grades of concrete is greater by ..... than the plain bars.
(a) 10% (b) 20% (c) 30% (d) 40%

84. The deformed bars may be used without hooks, provided anchorage requirements are adequately met with.
(b) No

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85. Bars of tensile reinforcement of a rectangular beam

(*a*) are curtailed when not required to resist the bending moment

(*b*) are bent up at suitable places to serve as shear reinforcement

(*c*) are maintained in the bottom to provide at least the local bond stress

(*d*) all of the above

86. When the diameter of a reinforcement bar is ϕ, the anchorage value of the hook alone is equal to

(*a*) $2\,\phi$ (*b*) $8\,\phi$ (*c*) $16\,\phi$ (*d*) $32\,\phi$

87. The length of lap for reinforcement bars in tension shall not be less than

(*a*) $\dfrac{\phi\,\sigma_s}{2\,\tau_{bd}}$ or $24\,\phi$ whichever is smaller (*b*) $\dfrac{\phi\,\sigma_s}{4\,\tau_{bd}}$ or $24\,\phi$ whichever is greater

(*c*) $\dfrac{\phi\,\sigma_s}{2\,\tau_{bd}}$, or $30\,\phi$ whichever is smaller (*d*) $\dfrac{\phi\,\sigma_s}{4\,\tau_{bd}}$ or $30\,\phi$ whichever is greater

where ϕ = Bar diameter, σ_s = Actual tensile stress in bar, and

τ_{bd} = Permissible average bond stress.

88. The length of lap for reinforcement bars in compression shall not be less than

(*a*) $\dfrac{\phi\,\sigma_s}{2\,\tau_{bd}}$ or $24\,\phi$ whichever is smaller (*b*) $\dfrac{\phi\,\sigma_s}{4\,\tau_{bd}}$ or $24\,\phi$ whichever is greater

(*c*) $\dfrac{\phi\,\sigma_s}{2\,\tau_{bd}}$ or $30\,\phi$ whichever is smaller (*d*) $\dfrac{\phi\,\sigma_s}{4\,\tau_{bd}}$ or $30\,\phi$ whichever is greater

where σ_s = Actual compressive stress in bar.

89. The maximum spacing of vertical reinforcement in R.C.C. wall should not exceed ..... the thickness of wall.

(*a*) equal to (*b*) 1.5 times (*c*) 2 times (*d*) 3 times

90. The measurement of anchorage lengths of inclined bars, used to act as shear reinforcement is taken in

(*a*) tension zone from the end of the sloping portion of the bar

(*b*) compression zone from mid-depth of the beam

(*c*) tension zone from the mid-depth of the beam

(*d*) compression zone from the end of the sloping portion of the bar

91. The minimum spacing between horizontal parallel reinforcements of the same diameter should not be less than the diameter of bar.

(*a*) Agree (*b*) Disagree

92. Generally, the lapped splices in tensile reinforcement, are not used for bars of more than 50 mm diameter.

(*a*) True (*b*) Flase

93. Which of the following statement is correct ?

(*a*) The anchorage value of a hook is assumed sixteen times the diameter of the round bar if the angle of the bend is 45°.

(*b*) Steel bars are generally connected together to get greater length than the standard lengths by providing hooked splice.

(*c*) For plain mild steel reinforcing bars, when hooks are used, they should be of U-type.

(*d*) all of the above

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94. In a doubly reinforced beam, steel reinforcement is provided in a
(a) tensile zone (b) compression zone (c) either (a) and (b) (d) both (a) and (b)

95. A doubly reinforced section is used
(a) when the members are subjected to alternate external loads and the bending moment in the sections reverses
(b) when the members are subjected to loading eccentric on either side of the axis
(c) when the members are subjected to accidental lateral loads
(d) all of the above

96. The theory of doubly reinforced section is based on the same assumptions as for singly reinforced section.
(a) Correct (b) Incorrect

97. In doubly reinforced rectangular beam, the allowable stress in compression steel is ..... the permissible stress in tension in steel.
(a) equal to (b) less than (c) greater than

98. A doubly reinforced beam is considered less economical than a singly reinforced beam because
(a) shear reinforcement is more (b) compressive steel is under-stressed
(c) tensile steel required is more than that for balanced section
(d) concrete is not stressed to its full value

99. If the effective depth of a doubly reinforced concrete beam is d, and maximum stress in steel and concrete is σ_{st} and σ_{cb} respectively, then the neutral axis depth factor (k) is given by

(a) $k = \dfrac{m\,\sigma_{cb} + \sigma_{st}}{m\,\sigma_{cb}}$ (b) $k = \dfrac{m\,\sigma_{cb}}{m\,\sigma_{cb} + \sigma_{st}}$

(c) $k = \dfrac{m\,\sigma_{cb} - \sigma_{st}}{m\,\sigma_{cb}}$ (d) $k = \dfrac{m\,\sigma_{cb}}{m\,\sigma_{cb} - \sigma_{st}}$

100. In a doubly reinforced concrete section, the presence of steel bars in compression zone ..... the depth of the neutral axis.
(a) effects (b) does not effect

101. If the area of tensile steel reinforcement is doubled, the moment of resistance of the beam increases only by about
(a) 12% (b) 22% (c) 32% (d) 42%

102. In the steel beam theory of doubly reinforced concrete beams, it is assumed that
(a) compression steel resists the compression
(b) stress in compression steel is equal to stress in tension steel
(c) in tension and compression concrete, no stress in developed
(d) all of the above

103. The concrete below the neutral axis
(a) resists the bending moment (b) embeds the tensile steel
(c) both (a) and (b) (d) none of these

104. The section of the beam having greater width at the top in comparison to the width below neutral axis is known as
(a) critical section (b) T-section (b) L-section (d) none of these

105. The portion of the slab which acts monolithically with the beam and which resists the compressive stresses, is called ..... of flange of the T-beam.
(a) breadth (b) thickness (c) depth

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106. The breadth of the flange of a T-beam is taken as
(*a*) one-third of the effective span of the T-beam
(*b*) twelve times the depth of slab plus breadth of rib
(*c*) centre to centre distance between the adjacent beams
(*d*) minimum value of (*a*), (*b*) or (*c*)

107. In a T-beam, the breadth of the rib is equal to the
(*a*) total thickness of the slab, including cover
(*b*) width of the portion of the beam in the compression zone
(*c*) width of the portion of the beam in the tensile zone
(*d*) none of the above

108. The breadth of rib in a T-beam should be sufficient to
(*a*) provide lateral stability (*b*) carry heavy loads
(*c*) accommodate the tensile reinforcement with proper spacing between the bases
(*d*) all of the above

109. The thickness of flange in a T-beam is taken equal to the total thickness of the slab, including cover.
(*a*) Right (*b*) Wrong

110. The intensity of compressive stress just, above the neutral axis, is of very ..... magnitude.
(*a*) small (*b*) large

111. The slab forms the compression flange of the T-beam.
(*a*) Yes (*b*) No

112. The breadth of rib in a T-beam should atleast be equal to ..... the depth of rib.
(*a*) one-half (*b*) one-third (*c*) one-fourth (*d*) one-sixth

113. In a T-beam, the vertical distance between the bottom of the flange and the centre of the tensile reinforcement is known as the
(*a*) breadth of flange (*b*) thickness of flange
(*c*) breadth of slab (*d*) depth of rib

114. The side face reinforcement, if required, in a T-beam will be
(*a*) 0.1 % of the web area (*b*) 0.15 % of the web area
(*c*) 0.2 % to 0.3 % of the web area depending upon the breadth of the slab
(*d*) half the longitudinal reinforcement

115. The effective depth of a T-beam is the distance between the
(*a*) centre of the flange and the top of the tensile reinforcement
(*b*) top of the flange and the centre of the tensile reinforcement
(*c*) bottom of the flange and the centre of the tensile reinforcement
(*d*) centre of the flange and the bottom of the tensile reinforcement

116. The assumed overall depth of the T-beam is taken as ..... of the span when it is simply supported at ends.
(*a*) $\frac{1}{10}$ to $\frac{1}{12}$ (*b*) $\frac{1}{12}$ to $\frac{1}{15}$ (*c*) $\frac{1}{15}$ to $\frac{1}{20}$ (*d*) $\frac{1}{20}$ to $\frac{1}{25}$

117. When the T-beam is continuous, the assumed overall depth of the beam of heavy loads is taken as
(*a*) $\frac{1}{10}$ to $\frac{1}{12}$ of span (*b*) $\frac{1}{12}$ to $\frac{1}{15}$ of span
(*c*) $\frac{1}{15}$ to $\frac{1}{20}$ of span (*d*) $\frac{1}{20}$ to $\frac{1}{25}$ of span

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118. The neutral axis in a T-beam section falls
(a) within the flange (b) outside the flange
(c) either (a) or (b) (d) none of these

119. A T-beam behaves like a rectangular beam of width equal to its flange, if neutral axis
(a) remains outside the flange (b) remains within the flange
(c) remains below the slab (d) both (a) and (b)

120. The neutral axis in a T-beam section may fall within the flange when the slab is comparatively thicker.
(a) Agree (b) Disagree

121. In a reinforced concrete T-beam (in which the flange is in compression), the position of neutral axis will
(a) be within the flange (b) be within the web
(c) depend on the thickness of flange in relation to total depth and percentage of reinforcement
(d) at the junction of flange and web

122. When the neutral axis of a T-beam falls outside the flange (below the slab), then
(a) $b_F \times d_F (n + 0.5\, d_F) = m\, A_{st} (d + n)$ (b) $b_F \times d_F (n - 0.5\, d_F) = m\, A_{st} (d - n)$
(c) $b_F \times d_F (n + d_F) = m\, A_{st} (d + n)$ (d) $b_F \times d_F (n - d_F) = m\, A_{st} (d - n)$

where
b_F = Width of flange,
d_F = Depth of flange or slab,
d = Effective depth or vertical distance between the top of the flange and the centre of tensile reinforcement,
n = Depth of neutral axis below the top of the beam,
A_{st} = Gross area of tensile steel, and
m = Modular ratio.

123. In the previous question, the depth of the net compression ($\bar{y}$) below the top of a beam is given by

(a) $\bar{y} = \dfrac{2n - d_F}{n - d_F} \times \dfrac{d_F}{3}$ (b) $\bar{y} = \dfrac{3n - 2d_F}{2n - d_F} \times \dfrac{d_F}{3}$

(c) $\bar{y} = \dfrac{n - d_F}{2n - d_F} \times \dfrac{d_F}{3}$ (d) $\bar{y} = \dfrac{2n - d_F}{3n - 2d_F} \times \dfrac{d_F}{3}$

124. The moment of resistance of a T-beam when the neutral axis falls in the web is equal to
(a) $\sigma_{cb} \times b_F \times d_F (d - \bar{y})$ (b) $\sigma_{cb} \times b_F \times d_F (d + \bar{y})$
(c) $\sigma_{cb} \times b_F \times d_F (0.5\, d - \bar{y})$ (d) $\sigma_{cb} \times b_F \times d_F (0.5\, d + \bar{y})$

125. The moment of resistance of the T-beam is found by multiplying the total ..... and the lever arm.
(a) tension (b) compression

126. When a vertical member is carrying mainly axial loads, it is termed as a
(a) strut (b) column (c) tie (d) all of these

127. The width of the flange of the L-beam is taken as
(a) one-sixth of the effective span of L-beam
(b) breadth of rib *plus* one-half of the clear distance between the rib
(c) breadth of rib *plus* four times the thickness of the slab
(d) minimum value of (a), (b) or (c)

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128. When an inclined or horizontal member is carrying mainly axial loads, it is termed as a
(*a*) strut (*b*) column (*c*) tie (*d*) all of these

129. The shape of a column should be
(*a*) circular (*b*) rectangular (*c*) square (*d*) any one of these

130. In reinforced columns, higher percentage of steel may cause difficulty in placing and compacting the concrete.
(*a*) True (*b*) False

131. When the ratio of effective length of the column to its least lateral dimension does not exceed 15, it is termed as a
(*a*) long column (*b*) short column (*c*) plain column (*d*) none of these

132. While designing a reinforced concrete pole as a column, it is considered as
(*a*) fixed at both ends (*b*) hinged at both ends
(*c*) fixed at one end and hinged at the other end
(*d*) none of the above

133. The purpose of lateral ties in short reinforced concrete columns is to
(*a*) facilitate construction (*b*) facilitate compaction of concrete
(*c*) avoid buckling of longitudinal bars
(*d*) increase the load carrying capacity of the column

134. A long column is one whose ratio of effective length to its least lateral dimension exceeds
(*a*) 5 (*b*) 10 (*c*) 12 (*d*) 20

135. In a column, with helical reinforcement, the permissible load is based on the core area. The least lateral dimension of such a column should be taken as
(*a*) equal to the diameter of core (*b*) one-half the diameter of core
(*b*) one-third the diameter of core (*d*) one-fourth the diameter of core

136. If the unsupported lengths of columns do not exceed four times the least lateral dimension they may be made of plain concrete.
(*a*) Right (*b*) Wrong

137. The area of longitudinal steel reinforcement in a column should not be
(*a*) less than 0.8 % of the area of concrete section required for direct load alone
(*b*) more than 6 % of the gross sectional area of column
(*c*) either (*a*) and (*b*)
(*d*) both (*a*) and (*b*)

138. The reinforced cement concrete column, having helical reinforcement, should have atleast ..... bars of longitudinal reinforcement within this helical reinforcement.
(*a*) two (*b*) four (*c*) six (*d*) eight

139. The diameter of longitudinal bars in a column should not be less than
(*a*) 4 mm (*b*) 8 mm (*c*) 12 mm (*d*) 16 mm

140. The effective lateral support to a column is given by transverse reinforcement.
(*a*) Yes (*b*) No

141. The pitch of transverse reinforcement should not be more than the
(*a*) least lateral dimension of the column
(*b*) sixteen times the diameter of the longitudinal reinforcing bar nearest to the compression face of the member
(*c*) forty-eight times the diameter of the transverse reinforcement
(*d*) minimum value of (*a*), (*b*) and (*c*)

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142. The diameter of the polygonal links or lateral ties should not be less than ..... of the diameter of the largest longitudinal bar.
(a) one-half (b) one-third (c) one-fourth

143. The diameter of lateral ties, in no case, shall be less than
(a) 5 mm (b) 10 mm (c) 15 mm (d) 20 mm

144. For a longitudinal reinforcing bar in a column, the cover should not be less than
(a) 10 mm (b) 20 mm (c) 30 mm (d) 40 mm

145. According to the load factor method, the permissible load (W) on a short column reinforced with longitudinal bars and lateral stirrups, is equal to
(a) $\sigma_{cb} \cdot A_c$ (b) $\sigma_{st} \cdot A_t$ (c) $\sigma_{cb} \cdot A_c + \sigma_{st} \cdot A_t$ (d) $\sigma_{st} \cdot A_c + \sigma_{cb} \cdot A_t$

where σ_{cb} and σ_{st} = Stress in concrete and steel respectively, and
A_c and A_t = Area of concrete and steel respectively.

146. Which of the following statement is correct ?
(a) The maximum longitudinal reinforcement in an axially loaded short column is 6 % of gross cross-sectional area.
(b) The columns with circular cross-section are provided with transverse reinforcement of helical type only.
(c) The spacing of lateral ties cannot be more than 16 times the diameter of tie bar.
(d) The longitudinal reinforcement bar need not be in contact with lateral ties.

147. The analysis of slab spanning in one direction is done by assuming it to be a beam of
(a) 1 m length (b) 1m width (c) 1 m^2 area (d) none of these

148. The purpose of transverse reinforcement, in a slab, is to
(a) distribute the effects of point load on the slab more evenly and uniformly
(b) distribute the shrinkage and temperature cracks more evenly
(c) keep the main reinforcement in position
(d) all of the above

149. In a slab, the transverse reinforcement is provided at ..... to the span of the slab.
(a) 45° (b) 60° (c) 75° (d) 90°

150. For bridge slabs, the amount of transverse reinforcement is taken as
(a) 0.15 % of gross concrete area (b) 0.3 % of gross concrete area
(c) 0.45 % of gross concrete area (d) 0.6 % of gross concrete area

151. For simply supported slabs spanning in one direction, the ratio of span to overall depth should not exceed
(a) 15 (b) 20 (c) 30 (d) 50

152. The ratio of span to the overall depth for a continuous slab spanning in one direction should not exceed 35.
(a) Agree (b) Disagree

153. Which of the following statement is correct ?
(a) For bridge slabs, the amount of reinforcement is taken as 0.6 % of gross concrete area.
(b) In a circular slab, the reinforcement is provided at the concave side of the slab.
(c) The transverse reinforcement in a simply supported slab distributes the temperature stress.
(d) all of the above

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154. According to IS : 456 - 1978, the deflection of reinforced concrete slab or beam, for the purpose of design, is limited to ..... of span.

(*a*) 0.2 % (*b*) 0.25 % (*b*) 0.4 % (*d*) 0.45 %

155. The distribution reinforcement is also called ..... reinforcement.

(*a*) longitudinal (*b*) transverse

156. Which of the following statement is correct ?

(*a*) The amount of transverse reinforcement for ordinary slab is taken as 0.15 % of gross concrete area.

(*b*) The transverse reinforcement in a simply supported slab distributes the temperature stress,

(*c*) The transverse reinforcement is placed in contact with the main reinforcement.

(*d*) none of the above

157. A reinforced concrete slab is 75 mm thick. The maxium size of reinforcement bar that can be used is

(*a*) 6 mm dia. (*b*) 8 mm dia. (*c*) 10 mm dia. (*d*) 12 mm dia.

158. The shrinkage in a concrete slab

(*a*) causes shear cracks (*b*) causes tension cracks

(*c*) causes compression cracks (*d*) does not cause any cracking

159. The diameter of bars for main reinforcement in slabs, may vary from

(*a*) 2 to 4 mm (*b*) 4 to 8 mm (*c*) 8 to 14 mm (*d*) 14 to 18 mm

160. The pitch of bars of main reinforcement in solid slab should not exceed ..... the effective depth of slab or 60 cm whichever is smaller.

(*a*) double (*b*) three times (*c*) five times (*d*) six times

161. If plain bars are used, the area of distribution reinforcement in slabs should not be less than

(*a*) 0.12 % of the gross area of concrete (*b*) 0.15 % of the gross area of concrete

(*c*) 0.18 % of the gross area of concrete (*d*) 0.21 % of the gross area of concrete

162. If high yield strength deformed bars are used, the area of distribution reinforcement in slabs should not be less than 0.12 % of the gross area of concrete.

(*a*) True (*b*) False

163. The diameter of bars used for distribution reinforcement in slabs, may vary from

(*a*) 2 to 4 mm (*b*) 4 to 6 mm (*c*) 6 to 8 mm (*d*) 8 to 12 mm

164. If the maximum bending moment of a simply supported slab is M and the moment resistance factor is R, then the effective depth of slab (d) is given by

(*a*) $d = \frac{M}{\sqrt{100R}}$ (*b*) $d = \frac{\sqrt{M}}{100\ R}$ (*c*) $d = \sqrt{\frac{M}{100\ R}}$ (*d*) $d = \frac{M}{100R}$

165. In a simply supported slab, the pitch of distribution reinforcement should not be more than ..... the effective depth of slab or 60 cm whichever is smaller.

(*a*) double (*b*) three times (*c*) five times (*d*) six times

166. The clear cover in a simply supported slab should not be less than the diameter of the reinforcing bar.

(*a*) Correct (*b*) Incorrect

167. In a simply supported slab, alternate bars are curtailed at

(*a*) one-fifth of the span (*b*) one-sixth of the span

(*b*) one-seventh of the span (*d*) one-eighth of the span

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168. When a slab is continuous over several spans, negative (*i.e.* hogging) bending moment is produced over the
(*a*) end supports (*b*) intermediate supports
(*c*) both (*a*) and (*b*) (*d*) none of these

169. The reinforcement in a continuous slab is provided at the top of the slab portion over the intermediate supports.
(*a*) Right (*b*) Wrong

170. For a slab continuous over two equal spans, the maximum bending moment near the centre of each span is taken as
(*a*) $-\frac{wL^2}{8}$ (*b*) $+\frac{wL^2}{8}$ (*c*) $-\frac{wL^2}{10}$ (*d*) $+\frac{wL^2}{10}$
where w = Total uniformly distributed dead and live load per unit length, and
L = Effective span.

171. Which of the following statement is correct ?
(*a*) For a cantilever slab, the ratio of span to overall depth should not exceed 12.
(*b*) One-way slab which carry uniformly distributed load should be designed to resist a sagging bending moment near mid-span.
(*c*) When the slab is built into a brick or masonry wall, the slab should be designed to resist a hogging moment at the face of the support.
(*d*) all of the above

172. When the slab is supported on all the four edges and the ratio of long span to short span is small, bending takes place along both the spans. Such a slab is known as a
(*a*) slab spanning in one direction (*b*) one-way slab
(*c*) slab spanning in two directions (*d*) two-way slab

173. A two way slab
(*a*) may be simply supported on the four edges, with corners not held down and carrying uniformly distributed load
(*b*) may be simply supported on the four edges, with corners held down and carrying uniformly distributed load
(*c*) may have edges fixed or continuous and carrying uniformly distributed load
(*d*) all of the above

174. A slab simply supported on the four edges, with corners not held down and carrying uniformly distributed load, is used in multistroyed buildings.
(*a*) Yes (*b*) No

175. A slab simply supported on the four edges, with corners held down and carrying uniformly distributed load may be analysed by
(*a*) Pigeaud's method (*b*) Marcus's method
(*c*) I.S. code method (*d*) all of these

176. As per IS : 456 - 1978, from stiffness point of view, minimum total thickness of slab should be equal to
(*a*) $B/15$ (*b*) $B/25$ (*c*) $B/35$ (*d*) $B/45$
where B = Short span of slab.

177. The reinforcement in the short span is placed ..... the reinforcement in the long span.
(*a*) below (*b*) above

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178. The maximum bending moment and deflection for a two way slab is much smaller than that of a one-way slab.

(*a*) True (*b*) False

179. According to Grashoff-Rankine theory for a two-way slab

(*a*) $\frac{W_L}{W_B} = \frac{B}{L}$ (*b*) $\frac{W_L}{W_B} = \left(\frac{B}{L}\right)^2$ (*c*) $\frac{W_L}{W_B} = \left(\frac{B}{L}\right)^3$ (*d*) $\frac{W_L}{W_B} = \left(\frac{B}{L}\right)^4$

where L = Long span of a slab,

B = Short span of a slab,

W_L = Load carried by the slab in the direction of long span, and

W_B = Load carried by the slab in the direction of short span.

180. For a slab spanning in two directions, the ratio of span to the depth of slab should not exceed

(*a*) 10 (*b*) 20 (*c*) 35 (*d*) 50

181. In the design of a two-way slab restrained at all edges, torsional reinforcement required is

(*a*) 0.375 times the area of steel provided in the shorter span

(*b*) 0.375 times the area of steel provided at mid-span in the same direction

(*c*) 0.75 times the area of steel provided at mid-span in the same direction

(*d*) none of the above

182. In case of two-way slab, the limiting deflection of the slab is

(*a*) primarily a function of the long span

(*b*) primarily a function of the short span

(*c*) independent of long or short spans

(*d*) dependent on both long and short spans

183. If the sides of a slab simply supported on its edges and spanning in two ways are equal, then the maximum bending moment is multiplied by

(*a*) 0.25 (*b*) 0.50 (*c*) 0.75 (*d*) 0.85

184. A reinforced slab, built monolithically with the supporting columns and is reinforced in two or more directions, without any provision of beams, is called a

(*a*) two way slab (*b*) flat slab (*c*) continuous slab (*d*) circular slab

185. The part of a flat slab around the column, which is of greater thickness than the rest of the slab, is known as

(*a*) column head (*b*) panel (*c*) capital (*d*) drop

186. The column head of a flat slab

(*a*) increases rigidity of the slab and column connection

(*b*) decreases resistance of the slab to shear (*c*) increases the effective span of the slab

(*d*) all of the above

187. A panel of a flat slab is

(*a*) that part of a slab around the column which is of greater thickness than the rest of the slab

(*b*) that part of column which has increased diameter

(*c*) the area enclosed between the centre lines connecting adjacent columns in two directions and the outline of the column heads

(*d*) none of the above

188. In flat slabs, the width of column strip, where drops are not used, is taken as

(*a*) one-half of the width of panel (*b*) one-third of the width of panel

(*c*) one-fourth of the width of panel (*d*) none of these

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...The drops are provided in flat slabs to resist
(a) torsion (b) bending moment (c) thrust (d) shear

...The flat slab transfers the load directly to the supporting columns suitably spaced below the
(a) Agree (b) Disagree

...The width of the middle strip in flat slab, where drops are used, is taken as
(a) one-half of the width of panel (b) equal to the width of the drop
(c) the difference between the width of the panel and the drop
(d) any one of the above

...The total thickness of flat slab, is no case, should be less than
(a) 125 mm (b) 200 mm (c) 275 mm (d) 350 mm

...If L is the average length of a panel, then the total thickness of a flat slab of interior panels ...out drops, should not be less than
(a) $L/32$ (b) $L/36$ (c) $L/40$ (d) $L/48$

...In a flat slab, the angle of greatest slope of the column head from the vertical should not exceed
(a) 30° (b) 45° (c) 60° (d) 75°

...The diameter of the column head should be taken as its diameter measured below the underside ...slab at a distance of
(a) 20 mm (b) 40 mm (c) 60 mm (d) 80 mm

...The diameter of column head in a flat slab, should not be more than
(a) 0.10 L (b) 0.25 L (c) 0.40 L (d) 0.50 L
where L = Average length of a panel.

...In four-way system of arranging the reinforcement, the reinforcement is provided in
(a) column strips (b) diagonal strips (c) either (a) or (b) (d) both (a) and (b)

...Which of the following statement is wrong as regard to reinforcement in four-way system ?
(a) The reinforcement in the direct band should resist the entire positive moment on the column strip.
(b) The reinforcement in the diagonal bands should resist the entire positive moment on the middle strip.
(c) The reinforcement in the direct band *plus* the reinforcement in the diagonal bands should resist the negative moment on the column strip.
(d) none of the above

...While arranging the reinforcement in four-way system, the additional reinforcement should be ...ided to resist the negative moment on the middle strip.
(a) Correct (b) Incorrect

...In a flab slab, the shear force value used for the calculation of bond stress should be taken ...to ..... times the total load on one panel, for exterior panels.
(a) 0.2 (b) 0.4 (c) 0.6 (d) 0.8

...Circular slab is used for
(a) roof of pump houses constructed above tube wells
(b) roof of a traffic control post at the intersection of roads
(c) floor of circular water tanks (d) all of these

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202. When a circular slab simply supported at the edge is loaded with uniformly distributed load, the stresses are developed in

(*a*) radial direction only (*b*) circumferential direction only

(*c*) both radial and circumferential direction (*d*) none of these

203. If '*w*' is the uniformly distributed load on a circular slab of radius '*R*' is freely supported at edges, then the radial moment at the middle of the slab will be

(*a*) $\frac{wR^2}{16}$ (*b*) $\frac{3wR^2}{16}$ (*c*) $\frac{5wR^2}{16}$ (*d*) $\frac{7wR^2}{16}$

204. If '*w*' is the uniformly distributed load on a circular slab of radius '*R*' is freely supported at edges, then the radial moment at the edges of the slab will be zero.

(*a*) Right (*b*) Wrong

205. For a circular slab carrying a uniformly distributed load, the ratio of maximum negative radial moment and the maximum positive radial moment is equal to

(*a*) 2 (*b*) 4 (*c*) 6 (*d*) 8

206. In a circular slab, the reinforcement is provided at the ..... side of the slab.

(*a*) convex (*b*) concave

207. When a circular slab simply supported at the edge is loaded with uniformly distributed load, it bends in the form of a saucer.

(*a*) Yes (*b*) No

208. A ribbed slab is provided where

(*a*) plain ceiling is required (*b*) thermal insulation is required

(*c*) acoustic insulation is required (*d*) all of these

209. The thickness of the topping of a ribbed slab is kept from

(*a*) 10 to 30 mm (*b*) 30 to 50 mm (*c*) 50 to 80 mm (*d*) 80 to 110 mm

210. In a ribbed slab, the clear spacing between the ribs should not be more than

(*a*) 300 mm (*b*) 450 mm (*c*) 600 mm (*d*) 800 mm

211. For a ribbed slab, the overall depth of the slab shall not exceed ..... the width of slab

(*a*) two times (*b*) three times (*c*) four times (*d*) five times

212. The width of rib, for a ribbed slab, should not be less than 75 mm.

(*a*) Agree (*b*) Disagree

213. The diameter of a bar used in ribbed slab should not be more than

(*a*) 12 mm (*b*) 18 mm (*c*) 22 mm (*d*) 30 mm

214. Footing is that portion of a foundation which do not deliver the load to the soil.

(*a*) True (*b*) False

215. According to Terzaghi, a foundation is said to be shallow if its depth is

(*a*) equal to its width (*b*) less than its width

(*c*) greater than its width (*c*) either (*a*) and (*b*)

216. The object of providing foundation to a structure is to

(*a*) distribute the load of superstructure over a large bearing area

(*b*) prevent the lateral movement of the supporting material

(*c*) increase the stability of structure

(*d*) all of the above

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17. A footing which supports two or more columns is termed as
(a) combined footings (b) raft footing (c) strap footing (d) none of these

18. Which of the following statement is correct ?
(a) The strap footing does not transfer any pressure to the soil.
(b) A raft footing is a combined footing that covers the entire area beneath a structure.
(c) A pile foundation is used where the top soil is relatively weak.
(d) all of the above

19. In a footing, it is used to assume that the maximum value of transverse bending will occur at a distance, equal to (measured from the face of the column)
(a) half of effective depth (b) effective depth
(c) twice the effective depth (d) breadth of column on each side

20. When the footing is symmetrically loaded, the pressure beneath the footing will
(a) be uniform (b) not be uniform
(c) be zero in the centre (d) be more at the edges

21. For the purposes of the design of reinforced concrete footings, pressure distribution is assumed to be
(a) linear (b) parabolic (c) hyperbolic (d) none of these

22. According to IS : 456 - 1978, the thickness at the edge, in reinforced concrete footings shall not be less than ..... for footings on soils.
(a) 100 mm (b) 150 mm (c) 250 mm (d) 350 mm

23. According to IS : 456 - 1978, the thickness at the edge, in reinforced concrete footings on piles, shall not be less than 300 mm above the tops of the piles.
(a) Correct (b) Incorrect

24. The weight of footings is assumed as ..... of the weight transferred to the column.
(a) 5 % (b) 10 % (c) 15 % (d) 20 %

25. The net upward pressure on footing (p_o) is given by

(a) $p_o = \dfrac{W + W'}{W \times q_o}$ (b) $p_o = \dfrac{W \times q_o}{W + W'}$ (c) $p_o = \dfrac{W - W'}{W \times q_o}$ (d) $p_o = \dfrac{W \times q_o}{W - W'}$

where W = Weight transferred from the column,
W' = Weight of footing, and
q_o = Safe bearing capacity of soil.

26. If the net upward pressure on a square footing is p_o, width of footing is B and width of column or wall is b, then maximum bending moment (M) near the column is given by

(a) $M = \dfrac{p_o B}{2}(B - b)^2$ (b) $M = \dfrac{p_o B}{4}(B - b)^2$

(c) $M = \dfrac{p_o B}{8}(B - b)^2$ (d) $M = \dfrac{p_o B}{16}(B - b)^2$

27. For M 15 concrete, the unit punching shear strength of concrete is taken as
(a) 1 N/mm^2 (b) 2 N/mm^2 (c) 3 N/mm^2 (d) 4 N/mm^2

28. The depth of a square footing should not be less than 150 mm.
(a) Right (b) Wrong

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229. For a square footing of width B, the depth of footing (D) considering punching shear, is calculated by the relation

(a) $D = \frac{p_o (B^2 - b^2)}{2\, b . \tau_p}$ (b) $D = \frac{p_o (B^2 - b^2)}{4\, b . \tau_p}$

(c) $D = \frac{p_o (B^2 - b^2)}{8\, b . \tau_p}$ (c) $D = \frac{p_o (B^2 - b^2)}{16\, b . \tau_p}$

where p_o = Net upward pressure on the footing,
b = Width of column, and
τ_p = Unit punching shear strength of concrete.

230. When there are some restrictions on the maximum value of the footing, a ..... footing should be provided even for a square column.

(a) triangular (b) trapezoidal (c) rectangular (d) circular

231. The footing at the base for a circular column may be

(a) trapezoidal (b) square (c) circle (d) either (b) or (c)

232. The depth of a circular footing (D) from punching shear consideration is given by

(a) $D = \frac{p_o (R^2 - r^2)}{2\, r\, \tau_p}$ (b) $D = \frac{p_o (R^2 - r^2)}{4\, r\, \tau_p}$

(c) $D = \frac{p_o (R^2 - r^2)}{8\, r\, \tau_p}$ (d) $D = \frac{p_o (R^2 - r^2)}{16\, r\, \tau_p}$

where R = Radius of circular footing,
r = Radius of column,
p_o = Net upward pressure intensity of footing, and
τ_p = Unit punching shear strength of concrete.

233. A combined footing is provided when the

(a) bearing capacity of soil is less (b) end column is near a property line
(c) columns are very near to each other so that their footings overlap
(d) all of the above

234. A combined footing may be

(a) trapezoidal (b) square (c) circle (d) either (a) or (b)

235. In order to get uniform pressure distribution under the combined footing, the centre of gravity of the footing area should not coincide the centre of gravity of the combined loads of the two columns.

(a) Yes (b) No

236. The length of a combined footing for two columns is L, the centre to centre distance between the columns is l, and the distance of centre of gravity of the column loads from the centre of left hand column is $\bar{x}$. In order to have uniformly distributed load on the footing, the projection (a_2) on the right hand side of the column is

(a) $a_2 = \frac{L}{2} + (l - \bar{x})$ (b) $a_2 = \frac{L}{2} - (l - \bar{x})$

(c) $a_2 = L + (l - \bar{x})$ (d) $a_2 = L - (l - \bar{x})$

237. The combined footing, in the longitudinal direction, will have

(a) sagging bending moment in the two cantilever portions
(b) hogging bending moment in some length of middle portion
(c) either (a) or (b) (d) both (a) and (b)

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The combined footing, in the transverse direction., will have ..... bending moment.
(a) sagging (b) hogging

The footing have a tendency to bend in the form of a saucer, near the columns.
(a) Agree (b) Disagree

In a combined footing, the sections near and around the column will be subjected to ..... ding stresses.
(a) minimum (b) maximum

At a certain section, in a combined footing for two columns carrying unequal loads, the shear is zero. At this section
(a) sagging moment is zero (b) sagging moment is maximum
(c) hogging moment is zero (d) hogging moment is maximum

A combined footing for two columns should be designed for the
(a) maximum hogging bending moment
(b) sagging bending moment at the outer face of each column
(c) sagging bending moment at the inner face of each column
(d) none of the above

In a combined footing, the reinforcement should be placed
(a) on the bottom face for sagging bending moment
(b) on the top face for hogging bending moment
(c) on the bottom face for hogging bending moment
(d) on the top face for sagging bending moment

A combined trapezoidal footing for two columns becomes essential when
(a) there is some restriction on the total length of the footing
(b) heavily loaded column is near the property line
(c) minimum loaded column is near the property line
(d) none of the above

When the shear stress in a combined footing does not exceed 0.5 N/mm^2, then eight legged mups should be provided.
(a) True (b) False

End bearing piles are used
(a) to transfer load through water or soft soil to a suitable bearing stratum
(b) to resist large horizontal or inclined forces (c) to compact loose granular soils
(d) all of the above

The precast concrete piles are generally used for a maximum design load of about ..... cept for large prestressed piles.
(a) 40 tonnes (b) 60 tonnes (c) 80 tonnes (d) 100 tonnes

The hammer used in driving piles should be
(a) drop hammer (b) diesel hammer
(c) vibratory hammer (d) all of these

In designing reinforced concrete piles as a column, it is considered as
(a) fixed at both ends (b) hinged at both ends
(c) fixed at one end and hinged at the other end
(d) any one of the above

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250. The length of a reinforced concrete pile is taken as ..... the length embedded in firm stratum.

(*a*) one-half (*b*) one-third (*c*) two-third (*d*) three-fourth

251. For reinforced piles having length upto 30 times its width, the main longitudinal reinforcement should not be less than ..... of the gross cross-sectional area of the pile.

(*a*) 1.25 % (*b*) 1.5 % (*c*) 2 % (*d*) 2.5 %

252. Which of the following statement is wrong ?

(*a*) The volume of lateral reinforcement provided in reinforced piles should not be less than 0.2 % of the gross volume of the pile.

(*b*) The centre to centre spacing of lateral reinforcement in reinforced piles should not exceed half the width of the pile.

(*c*) When the pile has to penetrate hard stratum, the lateral reinforcement at the top of the pile for a distance of three times the width, should be in the form of helix.

(*d*) none of the above

253. When a pile of length L carrying uniformly distributed load w per unit length is suspended at one point, then the maximum bending moment at the point of suspension will be

(*a*) $\frac{w L^2}{2}$ (*b*) $\frac{wL^2}{4}$ (*c*) $\frac{wL^2}{8}$ (*d*) $\frac{wL^2}{16}$

254. When a pile of length L carrying uniformly distributed load w per unit length is suspended at two points, then the maximum bending moment at the points of suspension will be

(*a*) $\frac{wL^2}{16}$ (*b*) $\frac{wL^2}{47}$ (*c*) $\frac{wL^2}{90}$ (*d*) $\frac{wL^2}{118}$

255. If the maximum bending moment of a pile of length L carrying uniformly distributed load w per unit length is $wL^2/90$, then the pile is suspended at

(*a*) one point (*b*) two points (*c*) three points (*d*) four points

256. A pile of length L carrying uniformly distributed load, is suspended at two points. The hogging bending moment at the points of suspension will be equal to sagging bending moment at the middle of pile, if the point of suspension from either end of a pile is equal to

(*a*) 0.15 L (*b*) 0.207 L (*c*) 0.312 L (*d*) 0.41 L

257. A pile of length L carrying uniformly distributed load is suspended at three points. The bending moment will be least, if the end points are located at a distance 0.15 L from the corresponding ends.

(*a*) Correct (*b*) Incorrect

258. According to Rankine's theory as applied to retaining walls,

(*a*) the soil mass is semi-infinite, homogeneous, dry and cohesionless

(*b*) the back of the retaining wall is vertical and smooth

(*c*) the retaining wall yields about the base

(*d*) all of the above

259. According to Rankine's theory, the intensity of active earth pressure (p_a) trying to move the retaining wall of height H away from the back fill is given by

(*a*) $p_a = wH\left(\frac{1+\cos\phi}{1-\sin\phi}\right)$ (*b*) $p_a = wH\left(\frac{1-\sin\phi}{1+\cos\phi}\right)$

(*c*) $p_a = wH\left(\frac{1-\sin\phi}{1+\sin\phi}\right)$ (*d*) $p_a = wH\left(\frac{1+\cos\phi}{1-\cos\phi}\right)$

where w = Unit weight of soil, and ϕ = Angle of internal friction for the back fill.

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2. The total active earth pressure (P_a) or the resultant pressure per unit length of the retaining is given by

(a) $P_a = \frac{wH^2}{2}\left(\frac{1+\cos\phi}{1-\sin\phi}\right)$ (b) $P_a = \frac{wH^2}{2}\left(\frac{1-\sin\phi}{1+\cos\phi}\right)$

(c) $P_a = \frac{wH^2}{2}\left(\frac{1-\sin\phi}{1+\sin\phi}\right)$ (d) $P_a = \frac{wH^2}{2}\left(\frac{1+\cos\phi}{1-\cos\phi}\right)$

1. The total active earth pressure acts at ..... above the base of the retaining wall.

(a) $H/2$ (b) $H/3$ (c) $H/4$ (d) $H/6$

2. In submerged backfill, the sand fill behind the retaining wall

(a) is dry (b) is saturated with water

(c) has uniform surcharge (d) has sloping surface

3. If the surcharge is horizontal and carries a surcharge of intensity w_1 per unit area, then the ssure intensity (p_a) at the base of the retaining wall of height H is given by

(a) $p_a = wH\left(\frac{1+\cos\phi}{1-\sin\phi}\right) + w_1\left(\frac{1+\cos\phi}{1-\sin\phi}\right)$ (b) $p_a = wH\left(\frac{1-\sin\phi}{1+\sin\phi}\right) + w_1\left(\frac{1-\sin\phi}{1+\sin\phi}\right)$

(c) $p_a = wH\left(\frac{1-\sin\phi}{1+\cos\phi}\right) + w_1\left(\frac{1-\sin\phi}{1+\cos\phi}\right)$ (d) $p_a = wH\left(\frac{1+\cos\phi}{1-\cos\phi}\right) + w_1\left(\frac{1+\cos\phi}{1-\cos\phi}\right)$

4. The overturning moment, due to active earth pressure, at toe of the retaining wall is

(a) $\frac{wH^3}{2}\left(\frac{1-\sin\phi}{1+\sin\phi}\right)$ (b) $\frac{wH^3}{4}\left(\frac{1-\sin\phi}{1+\sin\phi}\right)$

(c) $\frac{wH^3}{6}\left(\frac{1-\sin\phi}{1+\sin\phi}\right)$ (d) $\frac{wH^3}{8}\left(\frac{1-\sin\phi}{1+\sin\phi}\right)$

5. When the retaining wall has a sloping backfill with surcharge angle β, then the intensity of al earth pressure (p_a) at the base of the retaining wall of height H, is given by

(a) $p_a = wH\sin\beta \times \frac{\sin\beta - \sqrt{\sin^2\beta - \sin^2\phi}}{\sin\beta + \sqrt{\sin^2\beta - \sin^2\phi}}$

(b) $p_a = wH\cos\beta \times \frac{\cos\beta - \sqrt{\cos^2\beta - \cos^2\phi}}{\cos\beta + \sqrt{\cos^2\beta - \cos^2\phi}}$

(c) $p_a = wH\tan\beta \times \frac{\tan\beta - \sqrt{\tan^2\beta - \tan^2\phi}}{\tan\beta + \sqrt{\tan^2\beta - \tan^2\phi}}$

(d) none of the above

6. In the above question, the total active pressure will act at $H/3$ from the base of the retaining ll, in a direction perpendicular to the surcharge.

(a) Right (b) Wrong

7. The passive earth pressure is exerted on the retaining wall when it has a tendency to move ..... the backfill.

(a) away from (b) towards

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268. A buttress in a wall is intended to provide
(*a*) lateral support to roof slab only
(*b*) lateral support to wall
(*c*) to resist vertical loads only
(*d*) lateral support to roof beams only

269. In the design of a masonry retaining wall, the
(*a*) vertical load should fall within the middle-third of base width
(*b*) horizontal thrust should act at $h/3$ from base
(*c*) resultant load should fall within a distance of one-sixth of base width on either side of its mid point
(*d*) resultant load should fall within a distance of one-eight of base width on either side of its mid point

270. In a reinforced concrete retaining wall, a shear key is provided, if the
(*a*) shear stress in the vertical stream is excessive
(*b*) shear force in the toe slab is more than that in the heel slab
(*c*) retaining wall is not safe against sliding
(*d*) retaining wall is not safe against over turning.

271. The factor of safety due to overturning of the retaining wall is generally taken as
(*a*) 2 (*b*) 4 (*c*) 6 (*d*) 8

272. The factor of safety due to sliding of the retaining wall is generally taken as
(*a*) 1 (*b*) 1.5 (*c*) 2 (*d*) 4

273. A reinforced concrete T-shaped cantilever retaining wall is shown in Fig. 14.14. The portion *AB* is known as
(*a*) toe slab (*b*) heel slab
(*c*) stem (*d*) base



Fig. 14.14

274. In Fig. 14.14, the toe slab is
(*a*) portion *AB* (*b*) portion *BC*
(*c*) portion *BE* (*d*) portion *DE*

275. The toe slab of a retaining wall is reinforced at bottom face of the slab.
(*a*) Yes (*b*) No

276. The stem of a retaining wall is reinforced near the earth side.
(*a*) True (*b*) False

277. The heel slab of a retaining wall is reinforced at the ..... of the slab.
(*a*) bottom face (*b*) top face (*c*) middle

278. In a cantilever retaining wall, the bending moment in the vertical stem varies as
(*a*) h (*b*) h^2 (*c*) h^3 (*d*) h^4
where h = Height of the stem.

279. A cantilever retaining wall should not be used for heights more than
(*a*) 4 m (*b*) 6 m (*c*) 8 m (*d*) 10 m

280. The counterforts in a retaining wall supports the
(*a*) stem (*b*) toe slab (*c*) heel slab (*d*) none of these

281. The spacing of the counterforts usually varies from ..... of the height of wall.
(*a*) $\frac{1}{8}$ to $\frac{1}{6}$ (*b*) $\frac{1}{6}$ to $\frac{1}{3}$ (*c*) $\frac{1}{3}$ to $\frac{1}{2}$ (*d*) $\frac{1}{2}$ to $\frac{1}{4}$

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282. The length of the staircase situated between two landings is called
(a) rise (b) flight (c) tread (d) waist slab

283. The sum of tread *plus* twice the rise of a stair is kept as
(a) 300 mm (b) 400 mm (c) 500 mm (d) 600 mm

284. The product of tread and rise (in mm) of a stair is kept as
(a) 30 000 (b) 40 000 (c) 50 000 (d) 60 000

285. In residential buildings, the rise of a stair may vary between
(a) 100 mm to 150 mm (b) 150 mm to 200 mm
(c) 200 mm to 250 mm (d) 250 mm to 300 mm

286. The tread of a stair is kept as 250 mm to 300 mm for public buildings.
(a) Agree (b) Disagree

287. When the stair slab is spanning horizontally, a waist-slab of about ..... is provided.
(a) 50 mm (b) 80 mm (c) 100 mm (d) 120 mm

288. The dead weight of a stair consists of
(a) dead weight of waist slab (b) dead weight of steps
(c) dead weight of stringer beam (d) all of these

289. If R is the rise and T is the tread of a stair spanning horizontally, then each step is designed by considering it equivalent to a horizontal beam of width $\sqrt{R^2 + T^2}$, measured parallel to the slope of stair.
(a) Correct (b) Incorrect

290. In stairs spanning horizontally, the distribution reinforcement provided in the form of ..... meter rods at 30 cm centre to centre is normally adequate.
(a) 4 mm (b) 6 mm (c) 10 mm (d) 12 mm

291. If R is the rise, T is the tread and W is the weight of waist slab on the slope, then the equivalent weight on the horizontal plane will be equal to

(a) $\frac{W(R+T)}{T}$ (b) $\frac{W.T}{R+T}$ (c) $\frac{W\sqrt{R^2+T^2}}{T}$ (d) $\frac{W\sqrt{R^2+T^2}}{R}$

292. The pre-stressed concrete induces artificially ..... stresses in a structure before it is loaded.
(a) tensile (b) compressive (c) shear

293. A pre-stressed concrete member is made of reinforced concrete.
(a) Right (b) Wrong

294. In a pre-stressed concrete structure
(a) dead load of structure is reduced (b) cracking of concrete is avoided
(c) the cost of supporting structure and foundation is reduced
(d) all of the above

295. In a pre-stressed concrete member
(a) high strength concrete should be used (b) low strength concrete should be used
(c) high strength concrete and low tensile steel should be used
(d) high strength concrete and high tensile steel should be used

296. In pre-stressed concrete structures, no tensile stresses are induced.
(a) Yes (b) No

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297. The ultimate moment resisting capacity of a simple supported pre-stressed concreted beam is obtained by using

(*a*) force and moment equilibrium equations

(*b*) stress-strain relationship of concrete and steel

(*c*) moment equilibrium and compatibility condition

(*d*) force equilibrium equation alone

298. The ultimate strength of the steel used for pre-stressing is nearly

(*a*) 250 N/mm^2 (*b*) 415 N/mm^2 (*c*) 500 N/mm^2 (*d*) 1500 N/mm^2

299. The cube strength of the concrete used for pre-stressed member should not be less than

(*a*) 10 N/mm^2 (*b*) 25 N/mm^2 (*c*) 35 N/mm^2 (*d*) 50 N/mm^2

300. The assumption made in the design of pre-stressed concrete sections under working load is that

(*a*) a plane cross-section before loading remain plane after loading

(*b*) any change in loading produces change of stress in concrete

(*c*) pre-stressing in steel remains constant

(*d*) all of the above

301. The cable for a pre-stressed concrete simply supported beam subjected to uniformly distributed load over the entire span should ideally be

(*a*) placed at the centre of cross-section over the entire span

(*b*) placed at some eccentricity over the entire span

(*c*) varying linearly from the centre of cross-section at the ends to maximum eccentricity at the middle section

(*d*) parabolic with zero eccentricity at the ends and maximum eccentricity at the centre of the span

302. In post-tensioned pre-stressed concrete beam, the end block zone is the zone between the end of the beam and the section where

(*a*) no lateral stresses exist (*b*) only longitudinal stresses exist

(*c*) only shear stresses exist (*d*) shear stresses are maximum

303. The propagation of a shear crack in a pre-stressed concrete member depends upon

(*a*) tensile reinforcement (*b*) compression reinforcement

(*c*) shear reinforcement (*d*) shape of the cross-section of beam

304. The major loss of pre-stress is caused due to

(*a*) creep of concrete (*b*) relaxation of steel

(*c*) shrinkage of concrete (*d*) all of these

305. The loss of stress with time at constant strain is called

(*a*) relaxation (*b*) creep (*c*) shrinkage (*d*) ductility

306. The losses in pre-stress in pre-tensioning system are due to

(*a*) friction (*b*) shrinkage and creep of concrete

(*c*) elastic deformation of concrete when wires are tensioned successively

(*d*) none of the above

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307. If the loading on a simply supported pre-stressed concrete beam is uniformly distributed, the centroid of tendons should be preferably
(a) a straight profile along the centroidal axis (b) a straight profile along with the lower kern
(c) a parabolic profile with convexity downward
(d) a circular profile with convexity upward

308. In pre-tensioning scheme, pre-stress load is transferred in
(a) a single stage process (b) a multi stage process
(c) either single stage or multi stage process depending upon the magnitude of load transfer
(d) the same manner as in post-tensioning scheme

309. In the conventional pre-stressing, the diagonal tension in concrete
(a) increases (b) decreases
(c) does not change (d) may increase or decrease

310. The magnitude of loss of pre-stress due to relaxation of steel should be taken to vary from ..... of the average initial stress.
(a) 0.5 to 2% (b) 2 to 8% (c) 8 to 10% (d) 10 to 12%

311. According to Indan standard, the total amount of shrinkage for a pre-tensioned beam is taken as
(a) 3×10^{-4} (b) 3×10^{-5} (c) 3×10^{-6} (d) 3×10^{-7}

312. At the time of tensioning, the maximum tensile stress behind the anchorages should not exceed
(a) 60% of the ultimate tensile strength of the bar for steels without a definite yield point
(b) 80% of the yield stress for steels with guaranteed yield point
(c) 80% of the ultimate strength of the bar for steel without a definite yield point
(d) the yield stress for steel with guaranteed yield point

313. For prestressed structural elements, high strength concrete is used primarily because
(a) both shrinkage and creep are more (b) shrinkage is less but creep is more
(c) modulus of elasticity and creep values are higher
(d) high modulus of elasticity and low creep

314. When the tendon of a rectangular pre-stressed beam of cross-sectional area A is subjected to a load W through the centroidal longitudinal axis of beam, then the maximum stress in the beam section will be

(a) $\frac{W}{A} + \frac{M}{Z}$ (b) $\frac{W}{A} - \frac{M}{Z}$ (c) $\frac{A}{W} + \frac{Z}{M}$ (d) $\frac{A}{W} - \frac{Z}{M}$

where M = Maximum bending moment, and
Z = Section modulus.

315. In the previous question, the minimum stress in the beam section will be

(a) $\frac{W}{A} + \frac{M}{Z}$ (b) $\frac{W}{A} - \frac{M}{Z}$ (c) $\frac{A}{W} + \frac{Z}{M}$ (d) $\frac{A}{W} - \frac{Z}{M}$

316. The diagonal tension in a pre-stressed concrete member will be ..... shear stress.
(a) equal to (b) less than (c) more than

317. When a pre-stressed rectangular beam is loaded with uniformly distributed load, the tendon provided should be parabolic with convexity downward.
(a) True (b) False

318. In Lee-Mc Call system, low alloy steel bars are used as the pre-stressing tendons.
(a) Agree (b) Disagree

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319. It is required to completely balance a bent tendon of span L carrying a point load W at the centre. The minimum central dip should be equal to

(*a*) $\frac{WL}{P}$ (*b*) $\frac{WL}{2P}$ (*c*) $\frac{WL}{3P}$ (*d*) $\frac{WL}{4P}$

where P = Tension in the bent tendon.

320. A simply supported concrete beam, prestressed with a force of 2500 kN is designed by load balancing concept for an effective span of 10 m and to carry a total load of 40 kN/m. The central dip of the cable profile should be

(*a*) 100 mm (*b*) 200 mm (*c*) 300 mm (*d*) 400 mm

ANSWERS

1. (*d*)	2. (*d*)	3. (*b*)	4. (*a*)	5. (*a*)	6. (*d*)
7. (*b*)	8. (*d*)	9. (*d*)	10. (*a*)	11. (*a*)	12. (*b*)
13. (*c*)	14. (*a*), (*c*)	15. (*b*)	16. (*b*)	17. (*b*)	18. (*a*)
19. (*b*)	20. (*a*)	21. (*b*)	22. (*a*)	23. (*c*)	24. (*c*)
25. (*d*)	26. (*a*)	27. (*a*)	28. (*b*)	29. (*b*)	30. (*a*)
31. (*c*)	32. (*a*)	33. (*c*)	34. (*b*)	35. (*b*)	36. (*c*)
37. (*a*)	38. (*a*)	39. (*b*)	40. (*b*), (*c*)	41. (*c*)	42. (*a*)
43. (*b*), (*c*)	44. (*b*)	45. (*b*)	46. (*a*)	47. (*b*)	48. (*b*)
49. (*c*)	50. (*c*)	51. (*c*)	52. (*b*)	53. (*b*)	54. (*a*)
55. (*d*)	56. (*a*)	57. (*d*)	58. (*a*)	59. (*d*)	60. (*a*)
61. (*a*)	62. (*b*)	63. (*b*)	64. (*b*)	65. (*a*)	66. (*d*)
67. (*a*)	68. (*a*)	69. (*d*)	70. (*c*)	71. (*a*)	72. (*a*)
73. (*a*)	74. (*c*)	75. (*d*)	76. (*c*)	77. (*b*)	78. (*d*)
79. (*c*)	80. (*b*)	81. (*b*)	82. (*c*)	83. (*b*)	84. (*a*)
85. (*d*)	86. (*c*)	87. (*d*)	88. (*b*)	89. (*d*)	90. (*a*), (*b*)
91. (*a*)	92. (*b*)	93. (*d*)	94. (*d*)	95. (*d*)	96. (*a*)
97. (*b*)	98. (*a*)	99. (*b*)	100. (*b*)	101. (*b*)	102. (*d*)
103. (*b*)	104. (*b*)	105. (*a*)	106. (*d*)	107. (*c*)	108. (*a*), (*c*)
109. (*a*)	110. (*a*)	111. (*a*)	112. (*b*)	113. (*d*)	114. (*a*)
115. (*b*)	116. (*b*)	117. (*a*)	118. (*c*)	119. (*b*)	120. (*a*)
121. (*c*)	122. (*b*)	123. (*b*)	124. (*a*)	125. (*b*)	126. (*b*)
127. (*d*)	128. (*a*)	129. (*d*)	130. (*a*)	131. (*b*)	132. (*c*)
133. (*c*)	134. (*c*)	135. (*a*)	136. (*a*)	137. (*d*)	138. (*c*)
139. (*c*)	140. (*a*)	141. (*d*)	142. (*c*)	143. (*a*)	144. (*d*)
145. (*c*)	146. (*a*)	147. (*b*)	148. (*d*)	149. (*d*)	150. (*b*)
151. (*c*)	152. (*a*)	153. (*c*)	154. (*c*)	155. (*b*)	156. (*d*)
157. (*b*)	158. (*b*)	159. (*c*)	160. (*b*)	161. (*b*)	162. (*a*)
163. (*c*)	164. (*c*)	165. (*c*)	166. (*a*)	167. (*c*)	168. (*b*)
169. (*a*)	170. (*d*)	171. (*d*)	172. (*c*)	173. (*d*)	174. (*b*)

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175. (d) 176. (c) 177. (a) 178. (a) 179. (d) 180. (c)
181. (d) 182. (b) 183. (b) 184. (b) 185. (d) 186. (a)
187. (c) 188. (a) 189. (d) 190. (a) 191. (c) 192. (a)
193. (b) 194. (b) 195. (b) 196. (b) 197. (d) 198. (d)
199. (a) 200. (b) 201. (d) 202. (c) 203. (b) 204. (a)
205. (a) 206. (a) 207. (a) 208. (d) 209. (c) 210. (b)
211. (c) 212. (a) 213. (c) 214. (b) 215. (d) 216. (d)
217. (a) 218. (d) 219. (b) 220. (b) 221. (a) 222. (b)
223. (a) 224. (b) 225. (b) 226. (c) 227. (a) 228. (a)
229. (b) 230. (c) 231. (d) 232. (a) 233. (d) 234. (d)
235. (b) 236. (b) 237. (d) 238. (a) 239. (a) 240. (b)
241. (d) 242. (a), (b) 243. (a), (b) 244. (a), (b) 245. (a) 246. (a)
247. (c) 248. (d) 249. (c) 250. (c) 251. (a) 252. (d)
253. (c) 254. (b) 255. (c) 256. (b) 257. (a) 258. (d)
259. (c) 260. (c) 261. (b) 262. (b) 263. (b) 264. (c)
265. (b) 266. (b) 267. (b) 268. (b) 269. (c) 270. (c)
271. (a) 272. (b) 273. (c) 274. (d) 275. (a) 276. (a)
277. (b) 278. (c) 279. (b) 280. (c) 281. (c) 282. (b)
283. (d) 284. (b) 285. (b) 286. (a) 287. (b) 288. (a)
289. (a) 290. (b) 291. (c) 292. (b) 293. (b) 294. (d)
295. (d) 296. (a) 297. (a) 298. (c) 299. (c) 300. (d)
301. (d) 302. (b) 303. (d) 304. (d) 305. (a) 306. (b)
307. (c) 308. (b) 309. (b) 310. (b) 311. (a) 312. (c), (d)
313. (d) 314. (a) 315. (b) 316. (b) 317. (a) 318. (b)
319. (d) 320. (b)

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15

Steel Structures Design

15.1 Introduction

When a body is subjected to a system of loads and as a result of this some deformation takes place. If the resistance is set up against this deformation, then the body is known as a *structure*. The structural analysis deals with the determination of loads and other forces to which the various parts of the structure are subjected. The structural design deals with the selection of proper material and selection of proper size and shape of each member.

A steel structure has the following advantages :

1. It possesses high strength.
2. It has long service life.
3. It is gas and water tight.
4. It can be readily disassembled or replaced.
5. It can be readily transported from the place of manufacture to the work site.
6. It can resist high loads with comparatively light weight and smaller dimensions.

Notes : 1. A structure may be one dimensional, two dimensional and three dimensional. If the width and thickness of a structure is small in comparison to its length, it is known as *one dimensional structure*. A *two dimensional structure* is also called a *surface structure*. A *three dimensional structure* is also called a *space structure* and may have any shape.

2. A structure in which the member is represented by a line, is called a *skeleton structure*.

3. A structure large in two dimensions and small in third dimension, is called a *surface structure*.

15.2 Structural Steel Sections

The structural steel sections are generally hot rolled steel sections.

The following *rolled steel sections are mainly used as structural member :

1. *I-sections or beams*. The following five series are standardised I-sections for structural steel used as beams :

(*a*) Indian Standard Junior Beams (ISJB);

(*b*) Indian Standard Light Beams (ISLB);

(*c*) Indian Standard Medium Weight Beams (ISMB);

(*d*) Indian Standard Wide Flange Beams (ISWB); and

(*e*) Indian Standard Column Section (ISCS).

The rolled steel beams are designated by the series to which beam sections belong, followed by the depth of the section and weight per metre length of the beam. These beams are mainly used to resist axial forces (compressive or tensile), to resist-bending and in the built up sections of columns.

2. *Channel sections*. The rolled steel channel sections, according to Indian standards, are classified with the following five series :

(*a*) Indian Standard Gate Channel (ISGC);

*For further details, Indian standard (IS : 808-1978 and its parts) may be referred.

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(*b*) Indian Standard Junior Channel (ISJC);

(*c*) Indian Standard Light Channel (ISLC);

(*d*) Indian Standard Medium Weight Channel with Sloping Flange (ISMC); and

(*e*) Indian Standard Medium Weight Channel with Parallel Flange (ISMCP).

A channel section consists of one web and two flanges. The channels are subjected to torsion ecause of the absence of symmetry of the section with regards to the axis parallel to the web. These e used where transverse loads are to be carried and a combination of two channels are used in olumns.

3. *Angle sections.* The angle sections may be of the following two types

(*a*) Indian standard equal angles; and

(*b*) Indian standard unequal angles.

The rolled steel equal and unequal sections are designated as ISA followed by the lengths and ickness of legs. For example, ISA 100 × 100 × 10 mm, is an equal angle section 10 mm thick with oth begs 100 mm long. ISA 100 × 75 × 8 mm, is an unequal angle section 8 mm thick with one leg 00 mm long and the other leg 75 mm long. The supplementary angle sections are designated by the ize of legs and their thicknesses without the prefix ISA. These angle sections are used as tension and ompression members in the trusses.

4. *T-sections.* The various types of T-sections are as follows :

(*a*) Indian Standard Rolled Normal Tee Bars (ISNT);

(*b*) Indian Standard Rolled Deep Legged Tee Bars (ISDT);

(*c*) Indian Standard Slit Light Weight Tee Bars (ISLT);

(*d*) Indian Standard Slit Medium Weight Tee Bars (ISMT); and

(*e*) Indian Standard Slit Tee Bars from *H-sections (ISHT).

The T-sections are designated by the respective abbreviations followed by their depth. For xample, a normal tee bar of depth 100 mm is designated as ISNT 100.

The rolled steel T-sections are used to transmit bracket loads to the columns. These are also sed with flat strips to connect plates in the steel rectangular tanks.

5. *Rolled steel flats.* The rolled steel flats are used as tension members. These are designated by ISF along with the width and thickness. For example 50ISF8 means that the flat is of 50 mm width and 8 mm thickness.

15.3 Important Terms

The following terms are important in the design of structures :

1. *Dead load.* The self weight of the structure alongwith all the super-imposed loads permanently attached to the structure, is called dead load. The dead loads do not change their position or magnitude with time.

2. *Live load.* The load on a structure other than the dead load is called live load. The live loads change their position and magnitude with time, such as weight of the furniture. It is expressed as uniformly distributed static load.

3. *Working stress or permissible stress.* The allowable stress to which a structural member can be subjected, is called working stress or permissible stress. It may be developed in the member without causing structural damage to it.

4. *Bearing stress.* When a load is exerted or transferred from one surface to another in contact, the stress is known as bearing stress. It is calculated on the net projected area of contact.

5. *Factor of safety.* The ratio of yield stress of the material to the working stress, is called

*H-sections have been deleted as per IS : 808 (Part II)–1978.

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factor of safety. The value of factor of safety is decided keeping in view the average strength of the material, value of design loads, value of internal forces and variation in temperature and settlement of supports. It may be noted that for a greater value of factor of safety, a large cross-section of member has to be adopted.

6. *Modulus of elasticity.* The ratio of longitudinal stress to the longitudinal strain within the elastic region, is known as modulus of elasticity.

7. *Shear modulus of elasticity or modulus of rigidity.* The ratio of shear stress to shear strain, within the elastic region, is known as shear modulus of elasticity or modulus of rigidity.

8. *Bulk modulus of elasticity.* The ratio of hydrostatic stress (or volumetric stress) to the volumetric strain within the elastic region, is called bulk modulus of elasticity.

9. *Poisson's ratio.* The ratio of transverse strain (or lateral strain) to the longitudinal strain under an axial load, is known as Poisson's ratio. Its value for steel, within the elastic region, varies from 0.25 to 0.33.

10. *Fatigue strength.* The strength at which steel fails under repeated applications of load, is known as fatigue strength.

11. *Impact strength.* The impact strength of steel is the measure of its ability to absorb energy at high rates of loading.

15.4 Riveted Joints

A rivet is a round bar of steel or wrought iron provided with a head on one side and tail on the other side. The portion between the head and tail is called as body or shank of the rivet. The size of the rivet is expressed by the diameter of shank. When two or more parts are riveted, the tail end of the rivet is also formed as head by the process of forging. The process consists of joining two or more than two members by means of rivet by giving the final shape of rivets on both sides to act as a permanent fastener. The rivets may be driven into the members either *cold or hot. When a cold rivet is used, then the process of joining the members is called *cold riveting* and when a hot rivet is used, the process is known as *hot riveting.* The cold riveting process is used for structural joints while hot riveting is used to make leak proof joints. The cold driven rivets need large pressure to form the head and complete the driving. The strength of the rivet increases in the cold driving. The diameter of cold driven rivets ranges from 12 to 22 mm and for structural steel works, the diameter of hot driven rivets is 16 to 30 mm. The hot driven rivets are classified as power driven shop rivets, power driven field rivets and hand driven rivets.

The holes are drilled or punched in the structural members which are to be riveted. The size of the rivet hole is kept 1.5 mm larger than the size of the rivets upto 24 mm and 2 mm larger than the diameter of rivet more than 24 mm.

Though these are many types of rivet heads, yet the snap head and counter sunk heads are usually employed for structural work. The snap head is also termed as button head.

The following are the two types of riveted joints depending upon the manner in which the structural members are connected :

1. *Lap joint.* A lap joint is that in which one member is placed above the other and they are connected by means of rivets.

2. *Butt joint.* A butt joint is that in which the two members are kept in alignment butting (*i.e.* touching) each other and a cover (*i.e.* strap) plate is placed either on one side or on both sides of the main members. The cover plate is then riveted together with the main members.

The butt joints may be single cover butt joint or double cover butt joints. Depending upon the number of rows of rivets, the butt joints may be single riveted or double riveted. It may also be triple riveted or quadruple riveted.

*The rivets which are driven at atmospheric temperature, are known as cold driven rivets.

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When the rivets in the various rows are arranged opposite to each other, then the joint is said to be *chain riveted*. On the other hand, when the rivets in the adjacent rows are staggered in such a way that every rivet is in the middle of two rivets of the opposite row, then the joint is said to be *zig-zag riveted*. When the number of rivets (in zig-zag riveting) increases successively from the outermost row to the inner most row, then it is called a *diamond riveting*.

The following are some important terms used in riveted joints :

1. *Nominal diameter.* It is the diameter of the shank of a rivet before riveting.
2. *Effective diameter or gross diameter.* It is the diameter of the hole it fills after riveting.
3. *Pitch.* It is the centre to centre distance of two adjacent rivets measured parallel to the direction of force.
4. *Diagonal pitch.* It is the diagonal distance between the centres of two rivets in the adjacent row.
5. *Staggered pitch or alternate pitch or reeled pitch.* It is the distance measured along one rivet line from the centre of a rivet on it to the centre of the adjoining rivet on the adjacent parallel rivet line. In other words, it is the distance between the centres of two consecutive rivets in a zig-zag riveting, measured parallel to the direction of stress in the member.
6. *Gauge line or rivet line.* It is the line along which the rivets are placed. The perpendicular distance between the adjacent gauge lines is known as gauge.
7. *Margin.* It is the distance between the centre of rivet hole to the nearest edge of the plate.
8. *Tacking rivets.* The tacking rivets are those rivets which are used to connect long lengths of members as in the members of roof trusses. These are provided at suitable distances so that the members may act as one unit.

15.5 Assumption in the Theory of Riveted Joints

The various assumptions in the theory of riveted joints are as follows :

1. The friction between the plates is neglected.
2. The load is uniformly distributed among all the rivets.
3. The rivet hole is completely filled by the rivet.
4. The bending stress in the rivets is neglected.
5. The shear stress is uniform on the cross-section of the rivet.
6. The tensile stress is uniformly distributed on the portions of the plate between the rivets.
7. The bearing stress distribution is uniform.

15.6 Failures of a Riveted Joint

A riveted joint may fail in the following ways :

1. *Tearing of the plate between the rivet hole and an edge of the plate.* The failure can be avoided by providing the margin (m) = 1.5 d, where d is the diameter of rivet hole.

2. *Tearing of the plate across a row of rivets.* A plate may tear off or fail due to the applied load being more than the maximum safe tensile strength of the plate. The strength of the plate is reduced by rivet holes and the plate may tear off along the line of rivet holes. The strength of the plate in tearing (P_t) per pitch length is given by

$$P_t = (p - d)\, t\, \sigma_t$$

where

p = Pitch of the rivets,

d = Diameter of the rivet hole,

t = Thickness of the plate, and

σ_t = Maximum permissible stress in tearing for the plate.

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3. *Shearing of rivets.* The plates which are connected by rivets exert tensile stress on the rivets and if the rivets are unable to resist the stress, then they are sheared off. It may be noted that the rivets are always in *single shear in case of lap joints and in single cover butt joints, but the rivets are in double shear in a double cover butt joint. The strength of rivet in shearing (P_s) per pitch length is given by

$$P_s = n \times \frac{\pi}{4} \times d^2 \times \tau \quad \text{...(In single shear)}$$

$$= n \times 2 \times \frac{\pi}{4} \times d^2 \times \tau \quad \text{...(In double shear)}$$

where n = Number of rivets per pitch length, and

τ = Safe permissible shear stress for the rivet material.

4. *Crushing or bearing of rivets.* Sometimes, the rivets do not actually shear off under the tensile stresses, but are crushed. Due to this, the rivet hole becomes of an oval shape and hence the joint becomes loose. The strength of the rivet in bearing (P_b) per pitch length is given by

$$P_b = n \times d \times t \times \sigma_b$$

where σ_b = Safe permissible bearing stress for the rivet material.

Notes : (*a*) The nominal diameter of the rivet (d), according to Unwin's formula is given by

$$d = 6\sqrt{t}$$

where t = Thickness of plate in mm.

(*b*) The minimum pitch should not be less than 2.5 times the gross diameter of the rivet. The maximum pitch should not exceed $32t$ or 300 mm whichever is less, where t is the thickness of the thinner outside plate.

(*c*) The smaller of the shearing strength and bearing strength is known as *rivet value.*

(*d*) The number of rivets (n) required for the joint is given by

$$n = \frac{\text{Force}}{\text{Rivet value}}$$

(*e*) The number of rivets in shear shall be equal to the number of rivets in crushing or bearing.

(*f*) The minimum value of P_t, P_s and P_c is known as *strength of the riveted joint.*

(*g*) The strength of the un-riveted or solid plate (P) per pitch length is given by

$$P = p \,.\, t \,.\, \sigma_t$$

(*h*) The ratio of the strength of the riveted joint to the strength of the un-riveted or solid plate per pitch length, is called *efficiency of the riveted joint.*

(*i*) The maximum efficiency (η_{max}) can be achieved when the number of holes are minimum. Mathematically,

$$\eta_{max} = \frac{\text{Strength of the plate in tearing per pitch length}}{\text{Strength of the unriveted or solid plate per pitch length}}$$

$$= \frac{(p-d)\,t\,\sigma_t}{p.t\,\sigma_t} = \frac{p-d}{p}$$

(*j*) The permissible stresses for power driven shop rivets are as follows :

(*i*) Shear stress on gross area of rivets = 102.5 N/mm^2

(*ii*) Bearing stress on gross area of rivets = 236.0 N/mm^2

(*k*) The permissible stresses for power driven field rivets are as follows :

(*i*) Shear stress on gross area of rivets = 94.5 N/mm^2

(*ii*) Bearing stress on gross area of rivets = 212.5 N/mm^2

---

*When the shearing of rivet takes place at one cross-section, then rivets are said to be in *single shear.* When the shearing of rivet takes place at two cross-sections, then the rivets are said to be in *double shear.*

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15.7 Eccentric Riveted Connections

When the line of action of the load does not pass through the centroid of the rivet system and thus all the rivets are not equally loaded, then the joint is said to be eccentric loaded riveted joint, as shown in Fig. 15.1. The perpendicular distance between the line of action of the load (P) and the centroid (G) of the rivet system, is called eccentricity (e).

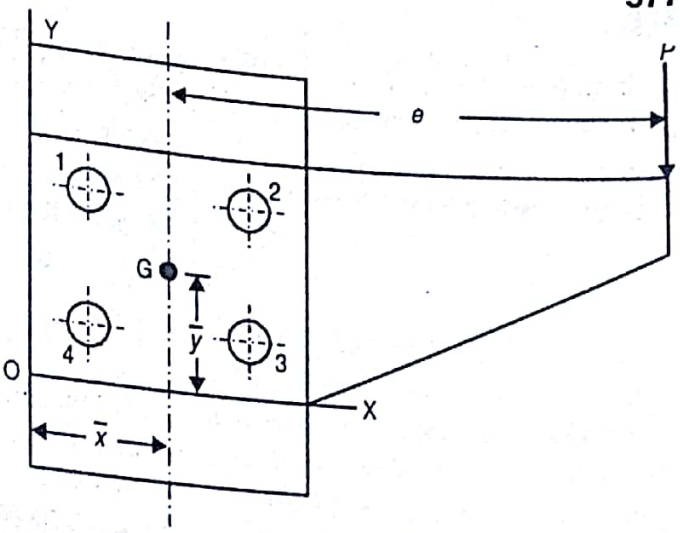

Fig. 15.1

In eccentric loaded riveted joint, the load or force resisting the moment in any rivet is inversely proportional to the distance of the centre of rivet from the centre of gravity of the group of the rivets.

In designing an eccentric loaded riveted joint, the approximate number of rivets (n) essential for resisting the external moment (M) is given by

$$n = \sqrt{\frac{6M}{R.p}}$$

where

$$M = \frac{P.e}{\text{Number of vertical rows}},$$

R = Rivet value, and

p = Pitch of rivets.

15.8 Welded Joints

The welding is a process of connecting metal parts by fusion. An electric arc welding and oxy-acetylene gas welding are the two methods commonly used in joining structural parts. The *electric arc welding* is a *fusion welding process in which the heat is obtained from an electric arc struck between the parts to be welded and an electrode held by a welder or automatic machines. During welding, the electrode melts and fills the gap at the joint of the two parts. The oxy-acetylene gas welding is also a type of fusion welding, in which the heat for welding is obtained by the combustion of a fuel gas. The most widely used gas combination for producing a hot flame for welding metals is oxygen and acetylene. The edges or surfaces to be joined are melted by the heat of a gas flame. The additional metal is filled by melting a welding rod in the flame and a solid continuous joint is obtained as the molten metal solidifies.

The following two types of welded joints are commonly used :

1. *Fillet joint or lap joint.* The fillet joint or lap joint is obtained by overlapping the parts to be connected and then welding the edges of the parts. The section of the fillet weld for design purposes is taken as an isosceles right angled triangle as shown in Fig. 15.2. The length of each side is known as *leg* or *size of weld* (s) and the perpendicular distance of the hypotenuse from the intersection of the legs (*i.e.* BD) is known as *throat thickness* (t).

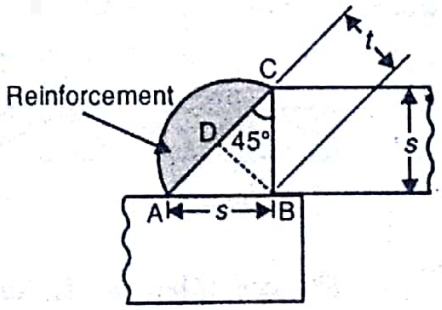

Fig. 15.2

The minimum area of the weld is obtained at the throat BD, which is given by the product of

* The welding is broadly divided into the following two groups :
(*a*) Forge or pressure welding (under pressure without additional filler metal), and
(*b*) Fusion or non-pressure welding (with additional filler metal).

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the throat thickness and the length of weld. The fillet welds are designed for the shear stress at the minimum section *i.e.* throat of weld. From Fig. 15.2, we find that throat thickness,

$$t = s \times \sin 45^\circ = 0.707\, s$$

and *minimum area of the weld or throat area,

$$A = \text{Throat thickness} \times \text{Length of weld}$$
$$= t \times l = 0.707\, s \times l$$

If τ is the permissible shear stress for the weld metal, then the shear strength of the fillet weld,

$$P = A \times \tau = 0.707\, s \times l \times \tau$$

The permissible shear stress is usually taken as 110 N/mm^2. Since the weld is weaker than the part material, due to slag and blow holes, therefore the weld is given a reinforcement which may be taken as 10% of the plate thickness.

The following points may be noted in the design of fillet weld :

(*a*) The effective length of the fillet welds is taken equal to its actual length *minus* twice the size of weld. The deduction is made to allow for craters to be formed at the ends of welded length.

(*b*) The effective length of a fillet weld should not be less than four times the size of weld. If the effective length is smaller than this, the effective size of the weld is assumed to be equal to one-fourth of the effective length.

(*c*) When the minimum size of the fillet weld is greater than the thickness of thinner part, the minimum size of the weld should be equal to the thickness of the thinner part.

(*d*) The fillet weld is not used for joining parts, if the angle between fusion faces is greater than 120° or less than 60°.

(*e*) The size of deep penetration fillet weld is specified as minimum leg *plus* 2.4 mm.

(*f*) A fillet weld whose axis is at right angles to the direction of the applied load is known as *end fillet weld*. The overlap of the plates in such a joint should not be less than five times of thickness of thinner plate.

(*g*) An end fillet weld is subjected to transverse shear.

(*h*) A fillet weld stressed in longitudinal shear is known as *side fillet weld*. They carry shear stresses only.

2. *Butt joint.* The butt joint is obtained by placing the structural members edge to edge. The butt joints may be square butt joint, single *V*-butt joint, double *V*-butt joint, single *U*-butt joint and double *U*-butt joint. These joints are shown in Fig. 15.3.



(*a*) Square. (*b*) Single V. (*c*) Double V. (*d*) Single U. (*e*) Double U.

Fig. 15.3

The size of butt welds, for full penetration of weld metal, is specified by its throat thickness which is taken equal to the thickness of the thinner part joined. The strength of a butt weld is taken equal to the strength of the parts joined if full penetration of the weld metal is ensured. A full penetration of the weld metal can be ensured in case of double *V*, double *U* and double bevel joint.

The penetration of the weld metal is incomplete in case of single *V*, single *U*, single *J* and single bevel joints. The effective throat thickness in case of incomplete penetration butt weld is taken as 7/8 of the thickness of the thinner part connected.

*The minimum area of the weld is taken because the stress is maximum at the minimum area.

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The effective length of a butt weld is the length for which the throat thickness of the weld exists. The effective area is taken as the product of effective throat thickness and the effective length of butt weld.

The effective length of intermittent butt weld is taken not less than four times the thickness of the thinner part joined. The longitudinal space between the effective length of intermittent butt welds is taken not more than sixteen times the thickness of the thinner part joined. The intermediate butt welds are used to resist shear stresses.

Notes : *(a)* When two plates of unequal thicknesses are butt welded, a smooth transition is provided by reducing the thickness of the thicker plate gradually such that the taper does not exceed 1 in 5. The tapering is only required when the difference in thickness of parts exceeds 25% of the thickness of the thinner plate or 3 mm, whichever is greater.

(b) The thickness of the weld is kept atleast 1 mm more than the thickness of the plate. This additional thickness called reinforcement, should be kept less than 3 mm and it should not be considered as part of the throat thickness.

15.9 Compression Members

In general, a structural member subjected to an axial compressive force is called a *column*. The vertical compression members in buildings are called *columns*, *posts* or *stanchions*. The compression members in roof trusses are called *struts*. The main compression members of a roof truss are called *rafters*. The jib of a crane, which is a compression member, is called a *boom*.

All compression members have a tendency to bend even when loaded axially. This bending of columns is called *buckling*. The buckling of the column is affected to a very large extent by its own curvature or crookedness, by the type of end conditions (*i.e.* free, hinged or fixed) and the slenderness ratio (*i.e.* the ratio of effective length of column and its least radius of gyration). The axial load which is sufficient to keep the column in a slight deflected shape is called *buckling load*, *crippling load* or *critical load*.

The effective length corresponding to a given column is the length of an equivalent column of the same material and cross-section with hinged ends and having the same value of the buckling load as that of the given column.

The effective lengths for various end conditions as recommended by IS : 800-1984, are given in Table 15.1. The actual length (L) of the compression member shall be taken as the length from the centre to centre of effective lateral supports.

Table 15.1. Effective length of compression members according to IS : 800-1984

S.No.	*End conditions*	*Recommended value of effective length (l)*
1.	Effectively held in position and restrained in direction at both ends.	0.65 L
2.	Effectively held in position at both ends and restrained in direction at one end.	0.80 L
3.	Effectively held in position at both ends but not restrained in direction.	L
4.	Effectively held in position and restrained in direction at one end and the other end effectively restrained in direction but not held in position.	1.2 L
5.	Effectively held in position and restrained in direction at one end and the other end partially restrained in direction but not held in position.	1.5 L
6.	Effectively held in position and restrained in direction at one end and not held in position or restrained in direction at the other end.	2 L

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The slenderness ratio (*i.e.* the ratio of effective length of the column to its least radius of gyration) should not exceed the values given in the following table.

Table 15.2. Maximum slenderness ratio.

S.No.	Types of member	Maximum slenderness ratio (l/r)
1.	For compression members which carry dead loads and superimposed loads	180
2.	For compression members which carry compressive load due to wind or seismic forces only	250
3.	For members carrying mainly tension in a roof truss or a bracing system	350
4.	Tension members (other than pre-tensioned members)	400

15.10 Euler's Formula

The Euler's formula for columns is valid for large slenderness ratio. According to Euler's formula, the critical stress in a column (σ_{cr}) for elastic buckling is given by

$$\sigma_{cr} = \frac{\pi^2 E}{(l/r)^2}$$

where E = Young's modulus,
l = Effective length of column, and
r = Radius of gyration.

Notes : **1.** When the slenderness ratio for the column is less than or equal to the minimum slenderness ratio, then the failure of column occurs by inelastic buckling.

2. Rankine-Gordon formula for buckling load is adopted for columns having slenderness ratio more than 120 and less than 200.

3. The tangent modulus formula for the buckling load (W_{cr}) of an axially loaded column is given by

$$W_{cr} = \frac{\pi^2 E_t I}{l^2}$$

where E_t = Tangent modulus of elasticity.

4. In order to determine the allowable stress in axial compression, Bureau of Indian Standards (B.I.S.) has adopted secant formula. This formula takes into account any initial curvature or crookedness of the column and imperfections of axial loading.

15.11 Angle Iron Struts

In roof trusses, the angle iron members are connected at joints by means of gusset plates. The angles may be discontinuous (*i.e.* in small lengths from one joint to the next) or continuous (*i.e.* going over many successive joints like the principal rafters in roof trusses).

Depending upon the loading, a single angle or double angle section may be necessary. When double angles are used, they may be connected both on the same side of the gusset plate or on both sides of it. In all cases, the connection of the angle to the gusset is made through only one leg of the angle. This causes eccentricity of the load on the section of the angle strut which would naturally give rise to bending stresses in the member. For this reason, the allowable stress in angle struts must be reduced. Then, if the angle is connected at its ends by one rivet or bolt only, it will behave as a strut with hinged ends, because the members can turn around the single rivets. But if there are two or more rivets at each end, the rotation of the member will be checked to a large extent and the ends would behave as restrained against rotation. This will reduce the effective length of the member making it

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stronger in compression. The allowable stresses and effective lengths of angle struts, taking all the above factors into account, as per IS : 800-1984, are as follows :

1. When a single angle strut is connected to a gusset plate with one rivet, then allowable working stress corresponding to the slenderness ratio of the member, is reduced to 80%.

2. When a single angle strut is connected with two or more number of rivets, its effective length is adopted as 0.85 times the length of the strut between node point (*i.e.* centre to centre intersection of each end) and the allowable working stress corresponding to the slenderness ratio is not reduced.

Note : The single angle sections are used for small trusses and bracing, single plane trusses and trusses having gusset plates in one plane.

15.12 Compression Member Composed of Two Components Back-to-Back

When a double angle section is used as a strut, the two angles must act together as one piece, otherwise each of them may buckle separately and fail. Therefore, the two angles, channels or tees are connected together back-to-back or at suitable intervals throughout their length. Such a connection is called *stitching* or *tacking* and the connecting rivets (or bolts) are called *tacking rivets*.

According to Indian standards (IS : 800-1984), the spacing of tacking rivets should be such that the slenderness ratio for each angle between the connections is less than or equal to 40 or 0.6 times the slenderness ratio for the whole column, whichever is less. In no case, the spacing of tacking rivets should exceed 600 mm. For other types of built-up compression members, say where cover plates are used, the maximum distance between centres of two adjacent rivets (*i.e.* pitch) should not exceed $32t$ or 300 mm, whichever is less, where t is the thickness of the thinner outside plate. When the plates are exposed to weather, the pitch should not exceed $16t$ or 200 mm whichever is less.

The ends of the struts comprising of two components back-to-back should be connected together with not less than two rivets or bolts or substantial welding and there should be ateast two additional connections at equal distance apart in the length of the strut.

If the two parts are separated by a distance, solid packing or washers must be used between them through which at least one rivet or bolt should pass. However, if the angle leg is 125 mm wide or wider or the channel is 150 mm or wider, there should be at least two rivets or bolts on the gauge lines.

The diameter of tacking rivets should be 16 mm for angles 10 mm thick or less, 20 mm for members from 10 mm to 16 mm thick and 22 mm for angles thicker than 16 mm.

Notes : (*a*) The two angle sections placed back-to-back are frequently used in roof trusses.

(*b*) The built-up sections are used because they provide large cross-sectional area, sufficient large radius of gyration and special shape and depth.

15.13 Lacing and Battening for Built-up Columns

The lateral systems used in built-up columns, to carry the transverse shear force, are lacing, batten plates or perforated plates. The lacing is also known as *latticing*. The different components of the built-up section should be placed uniformly at a maximum possible distance from the axis of the column for greater strength of the column. The different components of the built-up section are connected together so that they act as a single column. The lacing is generally preferred in case of eccentric loads. The battening is normally used for axially loaded columns where the components are not far apart. The flat bars are generally used for lacing. The angles, channels and tubular sections are also used for lacing of very heavy columns. The plates are used for battens. The lacing may be single lacing and double lacing. Following are the general requirements for the design of lacing as per IS : 800-1984 :

1. The compression member comprising two main component laced and tied should, where practicable, have a radius of gyration about the axis perpendicular to the plane of the lacing not less than the radius of gyration at right angles to that axis.

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2. The lacing system should not be varied throughout the length of the strut as far as practicable.

3. The cross members (except tie plates) should not be provided along the length of the column with lacing system, unless all forces resulting from deformation of column members are calculated and provided for in the lacing and its fastening.

4. The single laced systems on opposite sides of the main components should preferably be in the same direction so that one be the shadow of the other.

5. The laced compression members should be provided with tie plates at the ends of the lacing system and at points where the lacing systems are interupted. The tie plates should be designed by the same method as battens.

The lacing system should be designed as discussed below :

(*a*) The angle of inclination of lacing bars with the longitudinal axis of the compression member (column) should not be less than 40° and greater than 70°

(*b*) The slenderness ratio (L/r) of the lacing bar should not exceed 145. The effective length (L) of the lacing bars should be taken as follows :

(*i*) For single lacing, riveted at ends, the effective length of lacing bars is adopted as the length between inner end rivets (l).

(*ii*) For double lacing, riveted at ends and at intersection, the effective length of lacing bars is adopted as 0.7 times the length beween inner end rivets (*i.e.* $0.7l$),

(*c*) The minimum thickness of flat lacing should not be more than $l/40$ for single lacing and $l/60$ for double lacing, where l is the length between inner end rivets.

(*d*) The minimum width of lacing bars in riveted construction should be as follows :

Nominal rivet diameter (mm)	16	18	20	22
Width of lacing bars (mm)	50	55	60	65

(*e*) The lacing bars of compression members should be designed to resist a transverse shear equal to 2.5% of axial load in the member.

15.14 Batten Plates

The batten plates serve the same purpose as lacing bars. These are placed along the whole length of compression members at particular intervals and connect the different parts of the built-up column. The batten plates are also used in laced columns at places where the lacing is interrupted by the introduction of gusset plates and at the end of lacing system. The following are the general requirements for the design of batten plates :

1. The compression members composed of two main components battened should preferably have their two main components of the same cross-section and symmetrically disposed about their x-x axis. Where practicable, the compression member should have a radius of gyration about the axis perpendicular to the plane of battens not less than the radius of gyration at right angles to that axis.

2. The battens should be placed opposite to each other at each end of the member and at points where the member is stayed in its length and should as far as practicable, be spaced and proportioned uniformly throughout.

3. The number of battens should be such that the member is divided into not less than three parts longitudinally.

4. The effective length of battened columns should be increased by 10%.

5. The width of intermediate battens is kept equal to or more than three-quarters of the distance between the end connections joining the batten with the main member. In the case of end battens, the width is equal to or greater than the distance between its end connections.

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6. The thickness of batten plate should be greater than 1/50th of the distance between the innermost connecting lines or welds.

The batten plates used to connect the components of built-up column are designed to resist longitudinal shear and moment arising from transverse shear.

15.15 Perforated Plates

The perforated cover plates are particularly suitable for a built up box section consisting of four angle sections. The centre to centre distance between the perforations should not be less than 1.5 times the length of perforation.

The shape of the perforations should be elliptical or circular. The clear distance between perforations should not be less than the unsupported distance between the nearest lines of connecting rivets. At the point of perforation, each flange should be designed to resist half the total transverse shear force.

15.16 Eccentrically Loaded Column

An eccentrically loaded column is subjected to direct stress as well as bending stress. When the column is subjected to an eccentric load (W_E) having eccentricity e_X with respect to X-axis and eccentricity e_Y with respect to Y-axis, then the equivalent axial load (W_{EQ}) is given by

$$W_{EQ} = W_E + M_X B_X + M_Y B_Y$$

where M_X and M_Y = Bending moment with respect to X-axis and Y-axis respectively,

B_X and B_Y = Bending factor with respect to X-axis and Y-axis respectively.

The *equivalent axial load* is the load of sufficient magnitude to produce a stress equal to the maximum stress produced by the eccentric load.

The *bending factor* is defined as the ratio of cross-sectional area (A) of an eccentrically loaded column to the section modulus (Z).

The design of an eccentrically loaded column is safe, if

$$\frac{\sigma_{c'}}{\sigma_c} + \frac{\sigma_{b'}}{\sigma_b} < 1$$

where σ_c = Allowable working stress in compression on the member subjected to axial load only,

$\sigma_{c'}$ = Calculated average axial compressive stress = $\frac{\text{Total load}}{\text{Area}}$,

σ_b = Maximum allowable bending compressive stress on the extreme fibre, and

$\sigma_{b'}$ = Calculated bending stress in the extreme fibre.

15.17 Column Splice

The splicing of columns becomes necessary when the required length of the column is not available or when the section is to be changed. The splicing of a long column is usually done above the floor level. There are two types of compression splices, one having the ends of the column cut by ordinary methods and the other having the ends milled to provide plane surfaces.

When the ends of the column are cut by ordinary method, the load is transferred to the lower column through rivets and the column splice is designed for full axial load and other forces to which the joint is subjected.

When the ends of the column are faced for bearing over the whole area, the rivets essential to hold the connected members are designed for 50% axial load and other forces acting on the column.

When the upper column does not provide full bearing area over lower column, the bearing plate provided is designed by assuming that

(a) The axial load of the column is taken up by flanges,

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(*b*) The bearing plate act as short beam to transmit the axial load to the lower column section,

(*c*) The load transmitted from flanges of upper column and reaction from flanges of lower column are equal and form a couple, and

(*d*) The width of the bearing plate is equal to the width of the flange of column.

Notes : 1. The column splice plate may be assumed to act as short column of zero slenderness ratio.

2. The allowable working stress in column splice plates may be taken as 125 N/mm^2.

3. If M is the moment due to couple in a bearing plate of width b, and the allowable bending stress in slab or bearing plates is σ_b, then the thickness of bearing plate (t) is given by

$$t = \sqrt{\frac{6M}{b.\sigma_b}}$$

15.18 Column Bases

The purpose of a column base is to support and distribute the load of a column on a greater area so that the bearing pressure on concrete or masonry, on which the steel column stands, does not exceed the permissible value. Following three types of column bases are used for axially loaded columns :

1. *Slab base.* The slab bases are very convenient to use because the fabrication required is minimum. The column end is machined to transfer the load to slab base by direct bearing. The sufficient fastenings are provided to retain the column securely on the base plate and resist all moments and forces (other than direct compression) arising due to transit, unloading and erection.

The minimum thickness of a rectangular slab base (t), according to IS : 800–1984, is given by

$$t = \sqrt{\frac{3w}{\sigma_b}\left(a^2 - \frac{b^2}{4}\right)} \quad \text{(in mm)}$$

where w = Pressure or loading on the under side of the base in N/mm^2,

a = Greater projection of the plate beyond column in mm,

b = Lower projection of the plate beyond column in mm, and

σ_b = Permissible bending stress in slab bases in N/mm^2 = 185 N/mm^2 for all steels.

When a solid round steel column is supported on a square slab base, the minimum thickness of the square slab base (t), according to IS : 800–1984, is given by

$$t = \frac{3}{4}\sqrt{\frac{W}{\sigma_b}\left(\frac{B}{B-d}\right)} \quad \text{(in mm)}$$

where W = Total axial load in newtons,

σ_b = Permissible bending stress in slab bases in N/mm^2 = 185 N/mm^2 for all steels,

d = Diameter of the reduced end of the column in mm, and

B = Length of the side base in mm. It should not be less than 1.5 (d + 75) mm.

2. *Gusseted base.* A gusseted base consists of a base plate connected to the column through gusset plates. The thickness of the base plate will be less than the thickness of the slab base for the same axial load as the bearing area of the column on base plate increases by the gusset plates.

According to Indian standards (IS : 800–1984) for columns with gusseted base including fastenings such as gusset plates, angle cleats, stiffeners etc. in combination with the bearing area of shaft should be sufficient to take the loads, bending moment and reactions to the base plate without exceeding the specified stresses. All bearing surfaces are machined to ensure perfect contact. However, if the ends of the column shaft and the gusset plates are not faced for complete bearing, the fastening connectings to the base plate will be designed to transmit all forces to which the base is subjected.

3. *Grillage footing.* When the column load is to be distributed on a relatively larger area, the Jab base or gusseted base may be economical. In such cases, grillage footing is used. The grillage

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footing is also used as column footing when the bearing capacity of the soil is poor. It consists of two or more layers or tiers of steel beams completely encased in well compacted concrete. The beams in the lower tier are perpendicular to those in the upper tier. According to Indian standards (IS : 800–1984), the following points regarding the design of grillage footing may be kept in mind :

(a) The permissible stress in grillage beams encased in concrete may be taken $33\frac{1}{3}$ % higher than ordinary beams. When the effect of wind, seismic or erection load is also taken into account, then the permissible increase in stresses becomes 50%.

(b) The beams are unpainted and solidly encased in ordinary dense concrete with 10 mm aggregate and for working cube strength not less than 16 N/mm^2 at 28 days.

(c) The pipe separators or their equivalent are provided to keep the grillage beams properly spaced apart so that the distance between the edges of adjacent flanges is not less than 75 mm.

(d) The thickness of concrete cover on the top of the upper flange at the ends, and at the outer edges of the sides of the outermost beams is not less than 100 mm.

Consider a tier of grillage beams of length L and carrying a column load W over a central column base of length a, as shown in Fig. 15.4. The grillage beams of the tier are designed to withstand the maximum bending moment at the middle of the beams and then checked for maximum shear and web crippling.

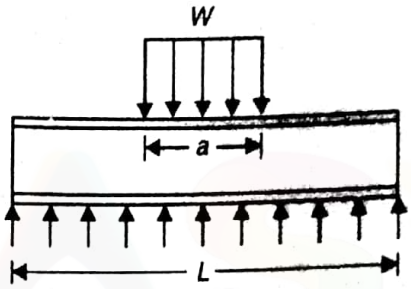

Fig. 15.4

The maximum bending moment (M) at the middle of the beam is given by

$$M = \frac{W}{8}(L - a)$$

Maximum shear force on the beam at the edge of load,

$$F = \frac{W}{2L}(L - a)$$

The bearing pressure on the web at the root of the fillet

$$= \frac{W / n}{(a + 2\sqrt{3}\, h_2)\, t_w}$$

where n = Number of beams in the tier under consideration,

h_2 = Distance from the extreme fibre to the bottom of the fillet between the web and flange, and

t_w = Thickness of web.

The bearing pressure should be less than or equal to the safe bearing stress of 250 N/mm^2.

15.19 Tension Members

A structural member subjected to a tensile force in the direction parallel to its longitudinal axis is called a *tension member*. It is also called a *tie member* or simply a *tie*. When the tension member is subjected to an axial tensile force, then the distribution of stress over the cross-section is uniform. A tension member subjected to axial tension is said to be efficient and economical member. The wire ropes, circular, square and flat bars are the simplest forms of tension members used for light bridges and roof trusses. The steel sections such as angle section, *I*-section, channel section and *T*-section, provide more rigidity towards buckling in compression when reversal of load takes place under wind-load. The *single angle sections*, as shown in Fig. 15.5(*a*), have high rigidity in the direction of web and low rigidity in the direction of flange. These are extensively used in light roof trusses. These are also used as bracing members in buildings, plate girder bridges, and light latticed girder bridges. The single angles are not the best type of member because these are subjected to bending stresses and therefore, the whole of the area is not fully stressed. The *double angles*, as shown in Fig. 15.5(*b*), if

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connected on both sides of the gusset plate, avoid the bending stresses. These are widely used in all kinds of roof trusses. The two channels, as shown in Fig. 15.5 (*c*), are similar to two angles. These can be connected by one gusset plate. The arrangements of built-up sections as shown in Fig. 15.5 (*d*), (*e*) and (*f*), are made with angle or channel sections and cover plates (firm lines) or lacing (dotted lines) to provide sufficient cross-sectional area and to suit the joints with adjoining members. The built up section are used for heavy loads.

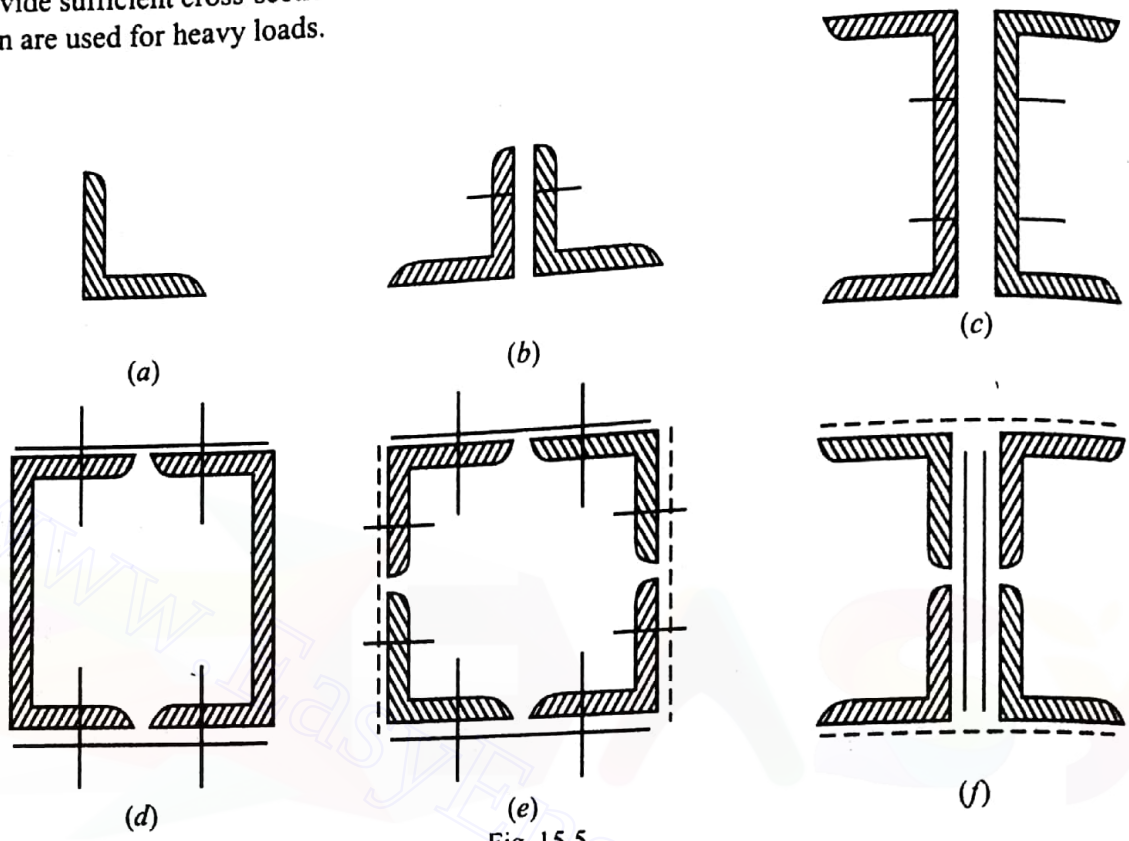

Fig. 15.5

15.20 Net Sectional Area

The net sectional area of a tension member is equal to the gross sectional area *minus* the maximum deduction for rivet holes. The deduction for a hole is the product of the hole diameter and the thickness of the material.

When the tension members are spliced or joined to gusset plate by rivets or bolts, the gross sectional area is reduced by the rivet holes. According to Indian standards (IS : 800–1984), the net sectional area for various members is calculated as follows :

1. When the plates are connected by chain riveting, the net sectional area at any section is given by

$$A_N = b \times t - n \times d \times t = t\,(b - nd)$$

where A_N = Net sectional area along rivet chain,

b = Width of plate,

t = Thickness of plate,

d = Gross diameter of rivet holes, and

n = Number of rivets at the section.

In case of zig-zag riveting or diagonal chain of holes, the net cross-sectional area along a chain of rivets is increased by an amount equal to $\frac{p_s^2 \times t}{4g}$,

where p_s = Staggered pitch, *i.e.* the distance between any two consecutive rivets measured parallel to the direction of stress in the member, and

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stress through a packing greater than 6 mm thick should be increased above the number required by normal calculations by 2.5% for each 2 mm thickness of packing.

4. For double shear connections packed on both sides, the number of additional rivets or bolts should be determined from the thickness of the thicker packing. The additional rivets or bolts may preferably be placed in an extension of the packing.

15.24 Lug Angle

A lug angle is a short length of an angle section used at a joint to connect the outstanding leg of a member. It reduces the length of the joint. Fig. 15.11 shows the use of lug angles with single angle or a channel type tension member. According to Indian standards (IS : 800–1984), the following specifications for the design of lug angles, may be followed :

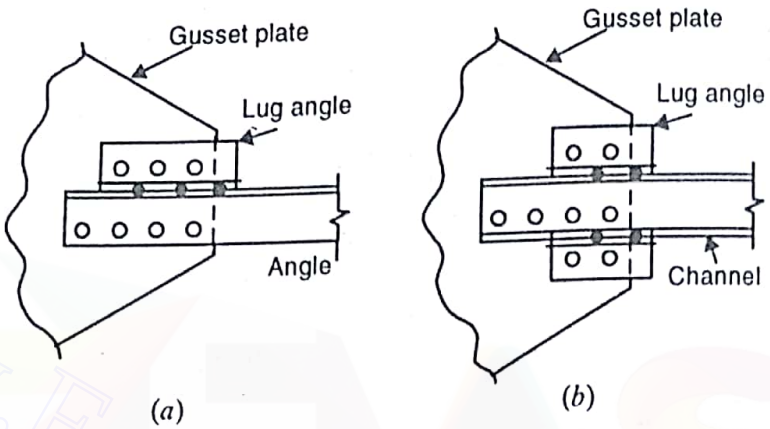

Fig. 15.11

1. The lug angles connecting a channel shaped member should, as far as possible, be connected symmetrically with respect to the section of the member.
2. In case of angle members, the lug angles and their connections to the gusset or other supporting member should be designed to develop a strength not less than 20% in excess of the force in the outstanding leg of the main angle and the attachment of the lug angle to the angle member should be designed to develop 40% in excess of that force.
3. In case of channel sections, the lug angles and their connections to the gusset plate or other supporting member should be designed to develop a strength of not less than 10% in excess of the force not accounted for by the direct connection of the member and the attachment of the lug angles to the member should be designed to develop 20% in excess of that force.
4. In any case, atleast two rivets or bolts should be used to connect the lug angle to the gusset or the other supporting member.
5. The effective connection of the lug angle should, as far as possible, terminate at the end of the member connected and the fastening of the lug angle to the member should preferably start in advance of the direct connection of the member to the gusset or supporting member.
6. Where lug angles are used to connect an angle member, the net effective area of the member shall be equal to the gross area *minus* the deduction for holes.

15.25 Beams

A beam is a structural member subjected to bending moments and shearing forces due to transverse loads. The rolled I-sections with or without cover plates are usually used for floor beams. The angle, tee and channel sections are usually used for beams in roof trusses in the form of purlins and common rafters. A beam is subjected to both compressive and tensile stresses at any section. A beam may be of the following types :

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(*a*) Cantilever beam; (*b*) Simply supported beam; (*c*) Restrained beam; (*d*) Unrestrained beam; (*e*) Built-in or fixed beam; and (*f*) Continuous beam.

The various important terms used in beams are as follows :

1. *Joist.* A beam supporting flooring but no other beams, is called a joist.
2. *Floor beam.* A major beam supporting other beams or joists in a building, is called a floor beam.
3. *Girder.* Any major beam in a structure, also used for floor beam in building, is known as a girder.
4. *Lintel.* A beam supporting wall directly over door, window or verandah openings, is called lintel.
5. *Spandrel beam.* A beam on the outside wall of a building, supporting its share of the floor and also the wall upto the floor above it, is called a spandrel beam.
6. *Header.* A beam usually at stair well openings, is called a header.
7. *Trimmer.* One of the beams supporting a header, is called a trimmer.
8. *Stringer.* A beam supporting the stair steps, is called a stringer.
9. *Girt.* A beam supported by external wall columns and supporting wall covering, is called a grit.
10. *Purlin.* A horizontal beam spanning between two adjacent roof trusses, is called a purlin.
11. *Rafter.* A roof beam resting on purlins is called a rafter.

15.26 Design Considerations of a Beam

The following points should be considered in the design of a beam :

1. *Bending moment and shear force.* The section of the beam must be able to resist the maximum bending moment and shear force to which it is subjected.
2. *Deflection.* The maximum deflection of a loaded beam should be within a certain limit so that the strength and efficiency of the beam should not be affected. According to Indian standards, maximum deflection should not exceed 1/325 of the span.
3. *Bearing stress.* The beam should have enough bearing area at the supports to avoid excessive bearing stress which may lead to crushing of the beam or the support itself.
4. *Buckling.* The compression flange should be prevented from buckling. Similarly, the web of the beam should also be prevented from crippling.

15.27 Design of Beams

A beam section is usually chosen which can resist maximum bending moment occurring over its span. The shear stress and deflection for the chosen beam are then checked to be within the permissible limits. The check for web crippling and web buckling are the secondary design requirements to be checked in some cases of beams with heavy concentrated loads or reaction at supports. The following procedure in the design of beams is followed :

1. *Design for bending.* The bending stress in tension or compression (σ_{bt} or σ_{bc}) at any point on a cross-section of a beam due to bending moment (M) is given by

$$\sigma_{bt} \text{ or } \sigma_{bc} = \frac{M}{I} \times y = \frac{M}{I/y} = \frac{M}{Z}$$

where

I = Moment of inertia of the cross-section of the beam,

σ_{bt} or σ_{bc} = Bending stress in tension or in compression calculated at a point at a distance y from the neutral axis, and

Z = Section modulus = I/y

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When the load is acting downward in a simply supported beam, the bending stress is *compressive* above the neutral axis and *tensile* below the neutral axis. At neutral axis, the bending stress is zero and it is maximum (tensile or compressive) at the exteme fibre. Hence, for the beam section to be safe in bending stress, the stress at any extreme fibre should be less than the corresponding permissible bending stress in tension or compression (σ_{bt} or σ_{bc}). Thus

$$\frac{M}{Z} \leq \sigma_{bt} \text{ or } \sigma_{bc}$$

or

$$Z \geq \frac{M}{\sigma_{bt}} \text{ and } Z \geq \frac{M}{\sigma_{bc}}$$

The above expressions give the value of Z for respective extreme fibre distances in tension or compression. A suitable beam section is chosen which have the section modulus slightly more than Z calculated from the above expressions.

The *moment of resistance* is the bending moment which a beam can resist. We know that the moment of resistance

$$= Z \times \sigma_{bt} \quad \text{or} \quad Z \times \sigma_{bc}$$

The external loads should not cause a bending moment more than the moment of resistance of the beam.

The permissible bending stress in tension (σ_{bt}), according to IS : 800–1984, is given by

$$\sigma_{bt} = 0.66\, \sigma_y, \text{ where } \sigma_y \text{ is the yield stress of steel.}$$

For $\sigma_y = 250$ N/mm^2, $\sigma_{bt} = 0.66 \times 250 = 165$ N/mm^2

The bending tension stresses should be taken on the net area of tension flange obtained after deducting filled or unfilled rivet or bolt holes.

The permissible bending stress in compression (σ_{bc}) in case of beams whose compression flange is laterally restrained throughout the length is equal to σ_{bt} as given above (*i.e.* $\sigma_{bc} = 0.66\, \sigma_y$).

Fig. 15.12 shows a case of slab-beam construction with the compression flange restrained against lateral buckling. A beam is deemed to be effectively restrained laterally if the friction or positive connection of the slab to the beam is capable of resisting a lateral force of 2.5% of the maximum force in the compression flange of the beam, considered to be distributed uniformly along the flange.

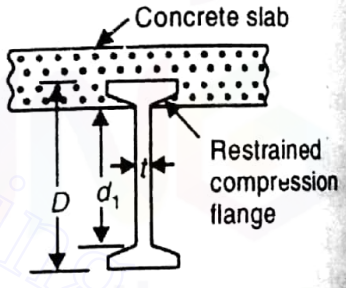

Fig. 15.12

When the compression flange is not restrained against lateral buckling, the permissible bending stresses σ_{bt} and σ_{bc} may be taken from tables given in IS : 800–1984 (second revision).

The safe compressive stress for a given grade of steel depends upon a number of parameters as given below :

(*i*) Overall depth of beam (D), (*ii*) Clear distance between the flanges (d_1), (*iii*) Effective length of the compression flange (l) as given in Table 15.3, (*iv*) Radius of gyration of the section (r_y) about its axis of minimum strength (Y-Y axis), (*v*) Mean thickness of compression flange (T), and (*vi*) Web thickness (t).

Table 15.3. Effective length of compression flange.

End condition	*Effective length (l)*
Simply supported beams, each end restrained against torsion, compression flange unrestrained laterally	L = Span of beam
(*a*) Ends of compression flange unrestrained for lateral bending	$l = L$
(*b*) Ends of compression flange partially restrained for lateral bending	$l = 0.85\, L$
(*c*) Ends of compression flange fully restrained for lateral bending	$l = 0.7\, L$

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The restraint against torsion can be provided by providing

(*a*) web or flange cleats in the end connection,

(*b*) bearing stiffeners acting in conjunction with the bearing of the beam,

(*c*) lateral end frames or other external supports to the end of the compression flange.

When the ends of the beams are not restrained against torsion or where load is applied to the compression flange and both the load and flange are free to move laterally, the above values of the effective length given in Table 15.3, shall be increased by 20%.

For cantilever beams of projecting length (L), the effective length (l) to be used shall be taken as follows :

(*a*) Built-in at the support, free at the end — $l = 0.85\,L$

(*b*) Built-in at the support, restrained against torsion at the end by cross members — $l = 0.75\,L$

(*c*) Built-in at the support, restrained against lateral deflection and torsion at the free end — $l = 0.5\,L$

(*d*) Continuous at the support, unrestrained against torsion at the support and free at the end — $l = 3L$

(*e*) Continuous at the support with partial restrained against torsion at the support and free at the end — $l = 2L$

(*f*) Continuous at the support, restrained against torsion at the support and free at the end — $l = L$

2. *Check for shear.* The shear stress (τ) at any point on the cross-section of a beam is given by

$$\tau = \frac{F.A.\bar{y}}{Ib}$$

where

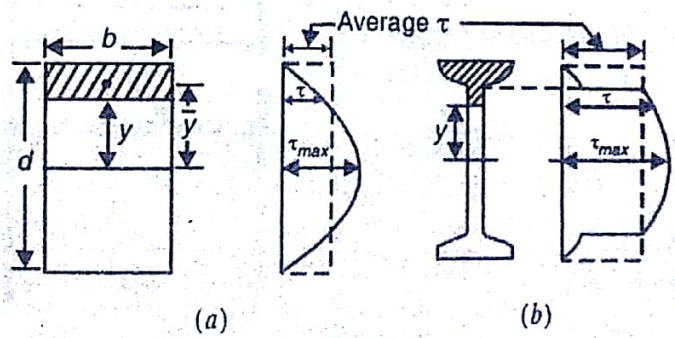
F = Shear force on the section,

I = Moment of inertia of the section,

b = Width of the section at the point where the shear stress is required, and

$A.\bar{y}$ = Moment of the area about the neutral axis of the part of the section situated beyond the fibre whose shear stress is required.

The maximum value of the shear stress occurs at the neutral axis. Its magnitude should be less than the maximum permissible shear stress.



(*a*) (*b*)

Fig. 15.13

The distribution of shear stress in case of rectangular beams is parabolic, as shown in Fig. 15.13 (*a*) and the maximum shear stress is 1.5 times the average shear stress. The distribution of shear stress in case of I-sections is shown in Fig. 15.13 (*b*). For design purposes, it is assumed that whole of the shear is resisted by the web of the I-section. The average shear stress is worked out on the gross area of the web which is taken equal to the product of web thickness and the overall depth of beam. The shear stress determined on this basis is found to be less than the maximum value at the neutral axis. Therefore, the permissible stress is also lowered in about the same ratio of the average to the

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maximum shear stress. Thus for *I*-section, the shear stress is given by

$$\tau = \frac{F}{d \times t_w}$$

where d = Overall depth of beam, and

t_w = Web thickness.

For the beam to be safe in shear, the value of shear stress obtained from the above equation should be less than or equal to the permissible average shear stress in the web.

The maximum permissible shear stress should not excced 0.45 σ_y, where σ_y is the yield stress of steel. The permissible average shear stress in a member calculated on the cross-section of unstiffened web shall not excced 0.4 σ_y.

The permissible shear stresses may be increased by $33\frac{1}{3}$ % when the effects of wind or seismic forces are taken into account.

3. *Check for deflection.* The maximum deflection in a beam (δ) in general, is given by

$$\delta = K \times \frac{Wl^3}{EI}$$

where W = Total load on the beam,

l = Effective span length,

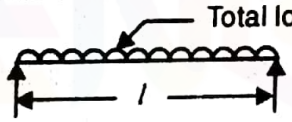
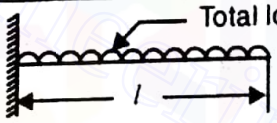
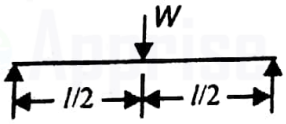
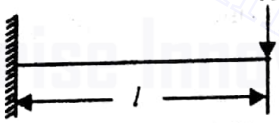
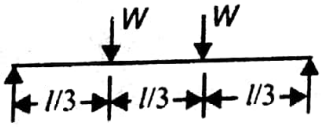
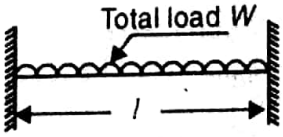
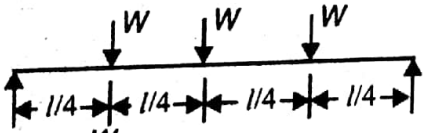
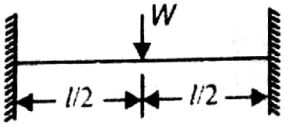
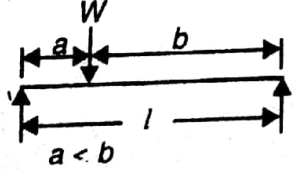
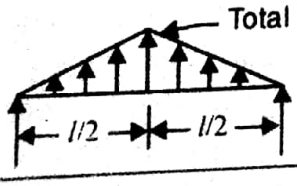
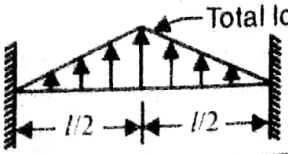
E = Young's modulus of elasticity. It is generally taken as 200 kN/mm^2,

I = Moment of inertia of the cross-section of the beam,

K = A coeffcient depending upon the distribution of loading and conditions of the beam.

The values of coefficient (K) for certain cases of loading for simply supported, cantilever and fixed beams are as given in Table 15.4.

Table 15.4. Values of coefficient (K)

Beam with loading	*Coefficient K*	*Beam with loading*	*Coefficient K*
1. 	$\frac{5}{384}$	7. 	$\frac{1}{8}$
2. 	$\frac{1}{48}$	8. 	$\frac{1}{3}$
3. 	$\frac{23}{648}$	9. 	$\frac{1}{384}$
4. 	$\frac{19}{384}$	10. 	$\frac{1}{192}$
5. 	$\frac{a}{9\sqrt{3}l}\left(1-\frac{a^2}{l^2}\right)^{3/2}$		
6. 	$\frac{1}{60}$	11. 	$\frac{7}{1920}$

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Generally, the maximum deflection for simply supported beams, should not exceed 1/325 of span and 2/325 of span for cantilever beams. This limit may be exceeded in cases where greater deflection will not affect the strength and will not crack the finishing.

It may be noted that large deflections in a beam may result in cracking of ceiling plaster. It indicates the lack of rigidity and may cause distortions in the connections. The deflection of beam may be decreased by increasing the depth of beam.

4. *Check for web crippling and web buckling.* The web crippling is a failure of web in direct crushing under concentrated load. It means the stress concentration due to bottle-neck condition at the web toe of the fillet under or over heavy load concentrations. It is a localised bearing stress caused by the transmission of compression from the comparatively wide flange to the narrow web.

The bearing stress (σ_b) in the web at the root of the fillet is given by

$$\sigma_b = \frac{W}{t_w(a + 2h_2\sqrt{3})} \text{ for intermediate loads}$$

$$= \frac{R}{t_w(a + h_2\sqrt{3})} \text{ for end supports}$$

where W = Concentrated load on the beam in newtons,

R = End reaction at supports in newtons,

t_w = Web thickness in mm,

a = Length of bearing plate in mm, and

h_2 = Depth of the root of the fillet from the top of the flange in mm.

The expression $(a + 2h_2\sqrt{3})$ is called the bearing length of web (B).

The bearing stresses calculated as above shall not exceed the maximum permissible bearing stress (σ_p) which is taken as 0.75 σ_y or 187.5 N/mm^2.

The *web buckling* (also known as vertical web buckling or column buckling) states the failure of a web in which the web, vertically above the bearing plate at the reaction or below a concentrated load is subjected to column action and tend to buckle under it.

According to IS : 800–1984, web buckling states that load bearing stiffeners at all point of concentrated loads (including points of support) should be provided where

$$W \text{ or } R > \sigma_{ap} \times t_w \times B$$

where W or R = Concentrated load or reaction at support respectively,

σ_{ap} = Maximum permissible axial stress for column for *slenderness ratio $\frac{\sqrt{3}h}{t_w}$,

t_w = Web thickness,

h = Clear depth of web between root fillets, and

B = Length of the stiff portion of the bearing *plus* the additional length given by the dispersion of 45° to the level of the neutral axis, *plus* thickness of seating angle, if any. The length of the stiff portion of a bearing shall not be taken more than half the depth of beam for simply supported beams and the full depth of the beam continuous over a bearing.

---

*The slenderness ratio for the portion of the web acting as a column, when the two flanges are restrained against lateral displacement and rotation, is equal to $\sqrt{3}h/t_w$.

The slenderness ratio for the portion of the web acting as a column, when the top flange is held in position only while the bottom flange is restrained against lateral displacement and rotation, is equal to $\sqrt{6}h/t_w$.

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Since the flanges and web are so proportioned to prevent such failure, therefore, there is no need to check for web crippling and web buckling. A beam that is safe in web crippling is also safe in web buckling. The web crippling and web buckling may be prevented by increasing the thickness of web and length of bearing plates.

15.28 Built-up Beams

The beams which are made by providing extra steel sections to form a built-up section, is known as *built-up beam*. The built-up beams are required when the available rolled steel joists are found to be insufficient. In such cases, girders built-up of simpler shapes *i.e. I*-joists, plates and angles etc. are used. Two *I*-joists with cover plates and placed side by side, are used where spans are small but loads are very heavy like column loads in buildings. Two *I*-joists placed one on top of the other may be used where span is large but loads are light and deflection is a consideration. There are other situations in which a built-up section is provided because it is structurally better and more economical.

The design of built-up beams is done approximately to simplify the calculations. For a symmetrical built-up beam, the moment of inertia (I) is given by

$$I = I_1 + 2A_P\left(\frac{d}{2}\right)^2 \qquad ...(i)$$

where I_1 = Moment of inertia of rolled I-section available,

A_P = Area of each flange plate, and

d = Distance between the centroids of the top and bottom flange plates.

Since the thickness of flange plates is generally small as compared with the depth of I beam, therefore, d may be taken equal to the depth of I section itself. Assuming this and dividing equation (i) by $d/2$, we have

$$Z = Z_1 + A_P \times d \text{ or } A_P = \frac{Z - Z_1}{d} \qquad ...(ii)$$

The equation (ii) gives the net area of flange plate when there are no holes. When there are rivet or bolt holes, the gross cross-sectional area of flange plate is taken 20% more than the net cross-sectional area to allow for rivet holes.

15.29 Lintels

A lintel is a structural member provided over door and window openings to support the load of masonry constructed over them. The width of the lintel is kept equal to the thickness of wall and depth is adjusted as a multiple of the thickness of courses of masonry. The load on the lintel is considered as uniformly distributed load, if the masonry above the lintel is upto a height of 1.25 times the effective span. The length of wall on either side of the opening should be at least one-half the effective span of the lintel.

15.30 Jack Arch Roofs

The jack arches consist of brick arches supported on the lower flanges of I-sections which in turn are supported on walls. The I-sections are provided at a spacing of 1 metre to 1.20 metre. The thickness of the arch shall not be less than 100 mm. The rise of the jack arch is kept about 1/8 to 1/12 of the span of arch. The cement concrete is filled in the lower portion of the spandrill of the arches. The remaining portion is filled with either mud or lime concrete. A suitable water proofing material is used with lime concrete. Over the concrete layer, flat tiles in one or two courses may be laid.

The I-section beams are designed for vertical loads only. However, for the end beam of the jack arch, the horizontal thrust is resisted by providing tie rods of atleast 12 mm diameter. These rods are properly secured to the webs of the beams, at a height of atleast 75 mm above the bottom of the beams. These tie rods are provided at a spacing not exceeding 20 times the width of the beams. The

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...ge rods are designed for a tension equal to horizontal thrust (T) which may be obtained by using the following relation :

$$T = WL/8R$$

where
W = Total load (live and dead load) per metre length of the arch,
L = Span of the arch, and
R = Rise of the arch.

15.31 Beam and Column Connections

The steel beams are connected with other beams or columns by the following types of joints :

1. Framed connection, and 2. Seated connection which may be unstiffened seated connection or stiffened seated connection.

When the beam is connected to a stanchion by means of two angles riveted to them, then the connection is known as *framed connection*. The size of the angle section should be sufficient to resist the maximum shear stress,

$$\tau_v = \frac{1.5R}{2t.d}$$

where
R = End reaction in newtons,
t = Thickness of angle legs in mm, and
d = Depth of angle in mm.

The maximum shear stress as calculated from the above relation should not exceed the permissible maximum shear stress of $0.45\ \sigma_y$ or $112.5\ N/mm^2$.

When the connection is made by using a seat angle to support the beam end, it is then known as *unstiffened seated connection*. The seat angle provides bearing length to satisfy the web crippling requirement of the beam. The unstiffened seated connections are used to transmit end reaction of beam upto 150 kN. In designing, the length of seating angle is assumed to be equal to the width of flange of the beam.

When the end reaction is more than about 150 kN, then stiffened seat connection are provided. A pair of stiffening angles are used with their outstanding legs tack riveted and providing the bearing length required by the web crippling consideration of the beam. In designing stiffened seated connections, the outstanding leg of the stiffening angles should not exceed 16 times its thickness to avoid local buckling of the angles. The length of the stiffening angle will depend upon the space required for rivets on column. These rivets are designed for direct shear and bending stress. The horizontal seat angle is provided with legs slightly longer than the legs of stiffening angle.

15.32 Plate Girder

A plate girder is a deep built-up beam subjected to transverse loads. It consists of plates or plates and angles riveted together. The plates and angles, in a plate girder, form an I-section, as shown in Fig. 15.14. The plate girders are economically used for spans upto 100 metres in building construction and when the loads are very heavy *e.g.* column loads. A plate girder in its general form consists of the following components :

1. *Web plate.* It is a vertical plate 8 mm to 15 mm in thickness. The depth may vary from 1/10 to 1/12 of the span. It may vary from 1 metre for small spans and 3 metres for large spans. The web plate may be unstiffened or stiffened. The web plate is unstiffened when the ratio of clear depth to the thickness of web

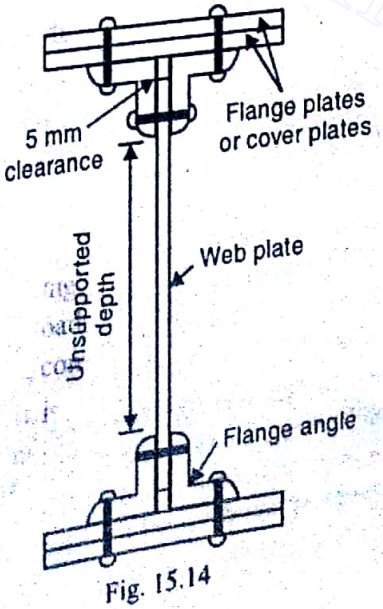

Fig. 15.14

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does not exceed 85. If this ratio exceeds 85, then the diagonal buckling of web occurs and the web is stiffened by providing stiffeners.

The *clear depth* is the distance between the vertical legs of flange angles at the top and at the bottom, in case horizontal stiffeners are not used. The distance between the centre of gravity of compression flange and centre of gravity of tension flange of a plate girder is called *effective depth*.

2. *Flange angles.* Usually, two flange angles at the top and two flange angles at the bottom are provided. The thickness of the angles may be from 10 mm to 25 mm.

3. *Flange plates or cover plates.* Generally horizontal flange plates are provided and connected to the outstanding legs of the flange angles. These plates contribute considerable moment of inertia for the section of the girder. The width of the flange may be 1/30 to 1/40 of span.

4. *Stiffeners.* These are members provided to protect the web against buckling. The web may be stiffened with vertical as well as longitudinal stiffeners.

15.33 Design of a Plate Girder

The plate girder is designed on the following two assumptions :

(*a*) The shear force for the girder is resisted entirely by the web and the shear stress intensity is uniform in the web.

(*b*) The bending moment for the girder is mainly resisted by the flange and the intensity of bending stress is uniform in the flange.

The various components of a plate girder are designed as discussed below :

1. *Design for economical depth and self weight.* The depth of a plate girder and self weight have to be assumed before its design. The depth of plate girder can be adjusted to get the minimum self weight of the girder which includes the weight of two flanges plus the weight of web and stiffeners etc. The depth which gives the minimum weight of the plate girder, is known as *economical depth*. If M is the maximum bending moment, σ_b is the bending stress and t_w is the thickness of web plate, then the economical depth (d_e) of the plate girder is given by

$$d_e = 1.1\sqrt{\frac{M}{t_w \cdot \sigma_b}}$$

The economical depth is usually taken 15 to 20% less than the depth calculated by the above expression.

The self-weight of a plate girder, for all practical purposes, is taken as $W.l/300$, where W is the total superimposed load and l is span of the plate girder in metres.

The weight of the plate girder varies 1 percent for 10% variation in depth of the girder.

2. *Design of web.* The web of a plate girder is designed for shear force. It is assumed that the shear force is uniformly distributed over the entire depth of web. We know that average shear stress in the web,

$$\tau_{av} = \frac{F}{d_w \cdot t_w}$$

where

F = Maximum shear force,

d_w = Width of web plate, and

t_w = Thickness of web.

The average shear stress in the web as calculated by the above expression should be less than the permissible shear stess. The depth of web is fixed from many other considerations like the headroom restrictions, economy etc. The total depth of the girder lies usually between 1/10 and 1/12 of the span. When depth of the plate girder is less than 750 mm, then such girders are known as *shallow plate girders*.

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3. *Design for web stiffeners.* According to Indian standards (IS : 800 - 1984), when the ratio of clear depth (d) to the thickness of web (t_w) is less than 85, then no stiffener is required. When the ratio of d/t_w exceeds 85 and less than 200, then intermediate vertical stiffeners are provided. The vertical stiffeners are also known as intermediate transverse stiffeners. These are used to avoid diagonal buckling of the web. An intermediate transverse stiffener may consist a pair of angles connected on each side of web. When single angle is used for the vertical stiffeners, then they are placed alternately on opposite sides of the web. When two angles are used for the vertical stiffeners, then they are provided on either side of web. The vertical stiffeners are provided at spacing not greater than $1.5d$ and not less than $0.33d$, where d is the distance between flange angles. In no case, the larger clear dimension of any web should not exceed $270\ t_w$ nor the lesser clear dimension of the same panel exceed $180\ t_w$.

When the ratio d/t_w is larger than 200, then the horizontal stiffener is used on the web at a distance of $d/5$ from the compression flange. The horizontal stiffeners are used to safeguard the web against buckling due to longitudinal bending compression. If the ratio d/t_w of the web exceeds 250, another horizontal stiffener should be used. This should be placed at the neutral axis of the web.

The bearing stiffeners are required at points of application of concentrated loads and end reactions. These are used in a plate girder to avoid local bending failure of the flange and to avoid local crippling and crushing of the web. A bearing stiffener consists of one or more pairs of angles connected on both sides of the web. The bearing stiffener will be designed as a column to transmit the concentrated load applied to it. The effective length of the stiffener will be assumed as 0.7 times the actual length of the stiffener.

The bearing stiffeners at the support points should project as nearly as possible to the outer edges of the flanges. When these stiffeners are meant to provide restraint against torsion of the plate girder at the ends, the moment of inertia of the stiffener about the centre line of the web plate should not be less than

$$\frac{d^3 . t}{250} \times \frac{R}{W}$$

where
d = Overall depth of the girder,
t = Maximum thickness of compression flange,
R = Reaction on bearing, and
W = Total load on the grider.

The rivets connecting the stiffener angles with the web will be designed to transmit the whole of concentrated load. The rivet values will be computed in double shear or in bearing on the web of the girder.

4. *Design of flanges.* The flanges are designed for resisting the maximum bending moment over the beam. The area of the flanges should be so proportioned that the maximum bending stress in tension or compression flange is less than the permissible limit. The maximum stresses are computed on the basis of gross moment of inertia and the neutral axis is assumed at the centre of gravity of the gross area. However, the stresses so computed are increased by multiplying with the ratio of gross area of flange to net area of flange. On the tension side, the net area of the flange is equal to the gross area *minus* the deductions for holes. On compression flange, the deduction for those holes will be made in full which are not filled by rivets or bolts and 25% of those holes which are filled by black bolts, otherwise no reduction is made. We know that the maximum bending stress,

$$\sigma_b = \frac{M . y}{I} \quad ...(i)$$

where
M = Maximum bending moment, and
y = Distance of remote fibre from the centre of gravity of the section.

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For a typical plate girder section, as shown in Fig. 15.15, moment of inertia,

$$I = 2I_f + 2A_f\left(\frac{d_f}{2}\right)^2 + t_w \times \frac{d_w^3}{12} \qquad ...(ii)$$

where
I_f = Moment of inertia of flange about its own centre of gravity,
A_f = Gross area of one flange,
d_f = Distance between the centre of gravity of the flanges,
d_w = Depth of web plate,
d = Total depth of the girder, and
t_w = Thickness of web.

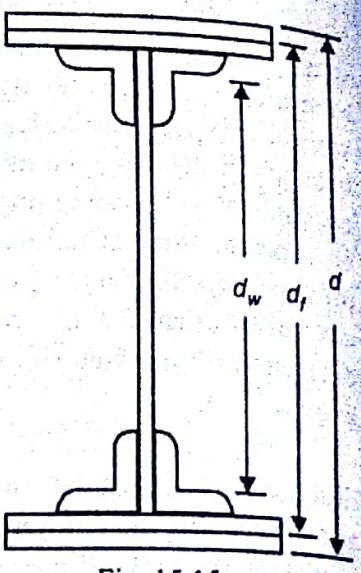

Fig. 15.15

In most of the plate girders, $d_w = d_f = d$ and neglecting I_f as it is very small, therefore equation (*ii*) is written as

$$I = A_f \times \frac{d^2}{2} + A_w \times \frac{d^2}{12} = \frac{d^2}{2}\left(A_f + \frac{A_w}{6}\right)$$

where A_w = Gross area of web = $t_w \times d_w$.

From equation (*i*), moment of resistance (M) is given by

$$M = \sigma_{bt} \text{ or } \sigma_{bc} \times \frac{I}{y}$$

$$= \sigma_{bt} \text{ or } \sigma_{bc} \times \frac{\frac{d^2}{2}\left(A_f + \frac{A_w}{6}\right)}{d/2}$$

$$= \sigma_{bt} \text{ or } \sigma_{bc} \times d\left(A_f + \frac{A_w}{6}\right) \qquad ...(iii)$$

The term $\left(A_f + \frac{A_w}{6}\right)$ is called the effective flange area.

Let us now consider the tension flange and compression flange as follows :

(*i*) *Tension flange.* We have already discussed that the net area of the flange (A_f') will be considered in calculating the fibre stresses. The rivet holes are also necessary in the web to connect the transverse stiffeners or splice plates. Assuming that 25 mm diameter holes are provided in the web at 100 mm spacing, the net area of web will be 75% of the gross area.

$$\therefore \quad \text{Net area} = A_f' + 0.75 \times \frac{A_w}{6} = A_f' + \frac{A_w}{8}$$

and maximum tensile stress,

$$\sigma_{bt} = \frac{M}{d\left(A_f' + \frac{A_w}{8}\right)} \qquad ...(iv)$$

or

$$A_f' = \frac{M}{\sigma_{bt} \times d} - \frac{A_w}{8} \qquad ...(v)$$

(*ii*) *Compression flange.* The gross compression flange area is effective in resisting the compressive bending stress. Hence the compression flange may be adopted similar to the tension

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flange which will be on the safer side if σ_{bc} is equal to σ_{bt}. However, if the compression flange is not laterally restrained, σ_{bc} will be less than σ_{bt} and equation (*iii*) may be used to choose a greater compression flange area.

OBJECTIVE TYPE QUESTIONS

1. The structural design deals with the
   (*a*) determination of loads and other forces to which the various parts of the structure are subjected
   (*b*) selection of proper material
   (*c*) selection of proper size and shape of each member
   (*d*) all of the above
2. The structural analysis deals with the
   (*a*) determination of loads and other forces to which the various parts of the structure are subjected
   (*b*) selection of proper material
   (*c*) selection of proper size and shape of each member
   (*d*) none of the above
3. When a body is subjected to a system of loads and as a result of this, some deformation takes ace. If the resistance is set up against this deformation, the body is known as a
   (*a*) compressed member (*b*) tensile member
   (*c*) structure (*d*) all of these
4. In order to analyse the statically indeterminate structures, the equations of statical equilibrium enough to determine all the forces on the structure.
   (*a*) True (*b*) False
5. If the width and thickness of a structure is small in comparison to its length, it is known as
   (*a*) one dimensional structure (*b*) two dimensional structure
   (*c*) three dimensional structure (*d*) none of these
6. A skeleton structure is one in which the member is represented by a
   (*a*) circular curve (*b*) straight curve (*c*) line (*d*) all of these
7. A three dimensional structure may have any shape.
   (*a*) Agree (*b*) Disagree
8. A two dimensional structure is also called ..... structure.
   (*a*) line supporting (*b*) surface (*c*) space
9. A space structure is also called ..... dimensional structure.
   (*a*) one (*b*) two (*c*) three
10. The structure large in two dimensions and small in third dimension, is called a
    (*a*) supporting structure (*b*) surface structure
    (*c*) space structure (*d*) none of these
11. Aluminium is being increasingly used for structural purposes because
    (*a*) its modulus of elasticity is double that of steel
    (*b*) its coefficient of thermal expansion is half that of steel
    (*c*) the strength to unit weight ratio of aluminium is high
    (*d*) it requires less maintenance
12. The main advantage of a steel member is that it
    (*a*) has high strength (*b*) is gas and water tight
    (*c*) has long service life (*d*) all of these

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13. The type of rolled steel section mainly used as structural member is
(a) rolled steel I-section
(b) rolled steel channel section
(c) rolled steel T-section
(d) all of these

14. As per Indian standards, rolled steel I-sections are classified into
(a) four series (b) five series (c) six series (d) seven series

15. The outer and inner faces of a rolled steel beam section are inclined to each other and they intersect at a certain angle. This angle of intersection for Indian standard medium weight beams is
(a) 4° (b) 8° (c) 16° (d) 20°

16. Rolled steel beams are designated by the series to which beam sections belong, followed by
(a) depth of the section and weight per metre length of the beam
(b) depth of flange and weight per metre length of the beam
(c) width of flange and weight per metre length of the beam
(d) width of web and weight per metre length of the beam

17. The rolled steel beams are mainly used
(a) in the built up sections of columns
(b) to resist bending
(c) to resist axial forces (compressive or tensile)
(d) all of the above

18. Rolled steed channel sections, according to Indian standards, are classified into five series.
(a) Correct
(b) Incorrect

19. The channels are subjected to torsion because of the absence of symmetry of the section with regards to the axis ..... to the web.
(a) parallel
(b) perpendicular

20. Junction between the flange and web of a beam is known as
(a) lap joint (b) butt joint (c) fillet (d) shear joint

21. A channel section consists of
(a) two webs
(b) two flanges
(c) two webs and two flanges
(d) one web and two flanges

22. Rolled steel T-sections are used
(a) to transmit bracket loads to the columns
(b) with flat strips to connect plates in the steel rectangular tanks
(c) in both (a) and (b)
(d) none of these

23. Rolled steel angle sections are classified as
(a) two series (b) three series (c) four series (d) five series

24. Rolled steel angle sections are classified as Indian standard equal and unequal angles.
(a) Yes
(b) No

25. Rolled steel equal and unequal sections are designated as ISA followed by
(a) lengths and thickness of legs
(b) width of flange and depth of web
(c) depth of section and weight per metre length
(d) any one of the above

26. Which of the following statement is correct ?
(a) The rolled steel tubes are efficient structural sections to be used as compression members.
(b) The rolled steel flats are used for lacing of elements in built-up members.
(c) The rolled steel bars threaded or looped at the ends are used as tension members.
(d) all of the above

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17. Rolled steel flats designated by 50 ISF 8 means that the flat is of
(a) 50 mm length and 8 mm thick (b) 50 mm width and 8 mm thick
(c) 50 mm thick and 8 mm length (d) 50 mm thick and 8 mm width

18. The rolled steel flats are used as ..... members.
(a) tension (b) compression

19. The brittleness of steel ..... with the increase of percentage of carbon.
(a) increases (b) decreases

20. The ductility of steel increases with the increase of percentage of carbon.
(a) Yes (b) No

21. The strength of steel increases with the increase of percentage of carbon.
(a) True (b) False

22. The dead load includes
(a) self-weight of the structure (b) all superimposed loads
(c) weight of stationary equipments (d) weight of furniture

23. The dead loads
(a) change their position (b) do not change their position
(c) vary in magnitude (d) do not vary in magnitude

24. The live loads
(a) change their position (b) do not change their position
(c) vary in magnitude (d) do not vary in magnitude

25. Which of the following statement is wrong ?
(a) The dead loads are known in the beginning of the design.
(b) The live load is expressed as uniformly distributed static load.
(c) The weight of furniture comes under live load.
(d) all of the above

26. If V is the velocity of wind in km/h, the intensity of wind pressure is directly proportional to
(a) V (b) V^2 (c) V^3 (d) V^4

27. The external wind pressure exerted on the structure will be less, if the height of structure is more.
(a) Agree (b) Diagree

28. The internal air pressure in building is ..... if the degree of permeability of the structure is large.
(a) less (b) more

29. When a load is exerted or transferred from one surface to another in contact, the stress is known as
(a) direct stress (b) bending stress (c) bearing stress (d) shear stress

30. The bearing stress is calculated on the
(a) cross-sectional area of contact (b) net projected area of contact
(c) mean of cross-sectional area and net projected area of contact
(d) none of the above

31. The allowable stress to which a structural member can be subjected is called
(a) working stress (b) permissible stress
(c) tensile stress (d) bearing stress

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42. The working stress is the stress which may be developed in the member
(*a*) causing structural damage to it (*b*) causing residual strain
(*c*) without causing structural damage to it (*d*) none of these

43. Factor of safety is the number by which the yield stress of material is divided to give the
(*a*) bearing stress (*b*) bending stress (*c*) shear stress (*d*) working stress

44. If the actual stress in a structural member as obtained from design loads exceeds the working stress, then the member will be safe.
(*a*) Right (*b*) Wrong

45. The value of factor of safety is decided keeping in view
(*a*) average strength of material (*b*) value of design loads
(*c*) value of internal forces (*d*) all of these

46. For a greater value of factor of safety, a ..... cross-section of the member has to be adopted.
(*a*) small (*b*) large

47. If δP is the maximum probable deviation of actual value from the computed value of strength P and δF is the maximum probable deviation of actual value from the computed value of internal load F, then the minimum factor of safety is equal to

(*a*) $\frac{1+\delta P/P}{1-\delta F/F}$ (*b*) $\frac{1-\delta F/F}{1+\delta P/P}$ (*c*) $\frac{1+\delta F/F}{1-\delta P/P}$ (*d*) $\frac{1-\delta P/P}{1+\delta F/F}$

48. Within the elastic range, the bulk modulus of elasticity is defined as the ratio of
(*a*) longitudinal stress to the longitudinal strain
(*b*) shearing stress to the shearing strain
(*c*) hydrostatic stress to the volumetric strain
(*d*) none of the above

49. Shear modulus of elasticity is also known as
(*a*) modulus of elasticity (*b*) bulk modulus of elasticity
(*c*) modulus of rigidity (*d*) tangent modulus of elasticity

50. The ratio of longitudinal stress to the longitudinal strain within the elastic region, is known as modulus of elasticity.
(*a*) Correct (*b*) Incorrect

51. The ratio of transverse strain to the longitudinal strain under an axial load is known as
(*a*) tangent modulus of elasticity (*b*) bulk modulus of elasticity
(*c*) modulus of rigidity (*d*) Poisson's ratio

52. The value of Poisson's ratio for steel within the elastic region ranges from
(*a*) 0.17 to 0.25 (*b*) 0.25 to 0.33 (*c*) 0.33 to 0.41 (*d*) 0.41 to 0.49

53. The strength at which steel fails under repeated applications of load, is known as
(*a*) impact strength (*b*) tensile strength (*c*) yield strength (*d*) fatigue strength

54. The impact strength of steel is the measure of its ability to absorb energy at high rates of loading.
(*a*) Yes (*b*) No

55. The stability of a structure is ensured if the restoring moment is ..... the maximum overturning moment.
(*a*) equal to (*b*) smaller than (*c*) greater than

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56. A piece of round steel forged in place to connect two or more steel members is known as a
(a) bolt (b) rivet (c) screw (d) stud

57. The size of rivet is expressed by the
(a) length of shank (b) diameter of shank (c) type of head (d) all of these

58. The hot driven rivets are
(a) power driven shop rivets (b) hand driven rivets
(c) power driven field rivets (d) all of these

59. The rivets which are driven at atmospheric temperature, are known as
(a) power driven shop rivets (b) hand driven rivets
(c) power driven field rivets (d) cold driven rivets

60. The power driven shop rivets are ..... as compared to power driven field rivets.
(a) weaker (b) stronger

61. For structural steel works, the diameter of hot driven rivets is 16 mm, 18 mm, 20 mm and 22 mm.
(a) True (b) False

62. The diameter of cold driven rivets ranges from
(a) 6 to 12 mm (b) 12 to 22 mm (c) 22 to 32 mm (d) 32 to 42 mm

63. The cold driven rivets need large pressure to form the head and complete the driving.
(a) Agree (b) Disagree

64. Which of the following statement is correct ?
(a) Snap heads are used for rivets connecting structural members.
(b) Snap head is also termed as button head.
(c) Counter sunk heads are used to provide a flush surface.
(d) all of the above

65. The strength of rivet ..... in the cold driving.
(a) increases (b) decreases

66. For rivet diameters upto 24 mm, the diameter of rivet hole is larger than the diameter of rivet by
(a) 1 mm (b) 1.5 mm (c) 2 mm (d) 2.5 mm

67. The diameter of a rivet hole is made larger than the diameter of the rivet by 2 mm for rivet diameters
(a) upto 12 mm (b) upto 15 mm (c) upto 24 mm (d) exceeding 24 mm

68. The diameter of the cold rivet measured before driving is known as ..... diameter of rivet.
(a) nominal (b) gross

69. A steel plate is 300 mm wide and 10 mm thick. A rivet of nominal diameter 18 mm is driven. The net sectional area of the plate is
(a) 1800 mm^2 (b) 2805 mm^2 (c) 2820 mm^2 (d) 3242 mm^2

70. The distance between two consecutive rivets of adjacent chains and measured at right angles to the direction of the force in the strutural member, is known as
(a) pitch of rivet (b) staggered pitch of rivet
(c) gauge distance of rivet (d) any one of these

71. The rivet line is also known as
(a) scrieve line (b) back line (c) gauge line (d) all of these

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72. The rivet line is an imaginary line along which the rivets are placed.
(*a*) True (*b*) False

73. The distance measured along one rivet line from the centre of a rivet on it to the centre of the adjoining rivet on the adjacent parallel rivet line, is known as
(*a*) staggered pitch (*b*) alternate pitch (*c*) reeled pitch (*d*) any one of these

74. The working shear stress on gross area of power-driven field rivets, as per IS : 800-1984, is
(*a*) 78.5 N/mm^2 (*b*) 94.5 N/mm^2 (*c*) 102.5 N/mm^2 (*d*) 157.5 N/mm^2

75. When one member is placed above the other and they are connected by means of rivets, the joint is known as
(*a*) lap joint (*b*) single cover butt joint
(*c*) double cover butt joint (*d*) none of these

76. Bending stress may develop in the case of
(*a*) lap joints (*b*) single cover butt joints
(*c*) double cover butt joints (*d*) all of these

77. The failure of a riveted joint may take place due to
(*a*) shear failure of rivets (*b*) bearing failure of rivets
(*c*) tearing failure of plates (*d*) all of these

78. Bearing failure of rivet occurs when the rivet is crushed by the plate
(*a*) Correct (*b*) Incorrect

79. The strength of a riveted joint is equal to the
(*a*) strength of joint against shearing of the rivets
(*b*) strength of joint against bearing of the rivets
(*c*) strength of plate in tearing
(*d*) least of the value obtained in (*a*), (*b*) and (*c*)

80. The efficiency of a riveted joint is equal to
(*a*) $\dfrac{\text{Least strength of riveted joint}}{\text{Strength of solid plate}}$ (*b*) $\dfrac{\text{Greatest strength of riveted joint}}{\text{Strength of solid plate}}$
(*c*) $\dfrac{\text{Least strength of solid plate}}{\text{Least strength of riveted joint}}$ (*d*) $\dfrac{\text{Least strength of solid plate}}{\text{Greatest strength of riveted joint}}$

81. If the same number of rivets are used in the joints, then which of the following pattern will yield highest efficiency ?
(*a*) Chain riveting (*b*) Zig-zag riveting (*c*) Diamond riveting (*d*) all of these

82. The strength of a riveted joint against shearing of rivets is equal to the strength against bearing of rivets.
(*a*) Right (*b*) Wrong

83. If the thickness of thinnest plate is t, gross diameter of rivet is d, and the maximum permissible stress in bearing for the rivet is σ_b, then the strength of a riveted joint against bearing of rivets per pitch length is equal to
(*a*) $n \times \dfrac{\pi d^2}{4} \times t \times \sigma_b$ (*b*) $n \times \dfrac{\pi d^2}{2} \times t \times \sigma_b$
(*c*) $n \times d \times t \times \sigma_b$ (*d*) $2n \times d \times t \times \sigma_b$
where n = Number of rivets per pitch length.

84. The strength of plate in tearing per pitch length is equal to

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84. The strength of plate in tearing per pitch length is equal to
(a) $p.t.\sigma_t$ (b) $p.d.\sigma_t$ (c) $(p-d)\,t.\sigma_t$ (d) $(p+d)\,t.\sigma_t$
where p = Pitch of the rivets, and
σ_t = Maximum permissible stress in tearing for the plate.

85. Rivet value is equal to
(a) strength of a rivet in shearing (b) strength of a rivet in bearing
(c) minimum of the value obtained in (a) and (b)
(d) maximum of the value obtained in (a) and (b)

86. In designing a riveted joint, it is assumed that
(a) load is uniformly distributed among all the rivets
(b) rivet hole is completely filled by the rivet
(c) friction between plates is neglected
(d) all of the above

87. In the design of a riveted joint, the bearing stress is assumed to be uniform between the contact surfaces of plate and rivet.
(a) Yes (b) No

88. Minimum pitch in a riveted joint should not be
(a) less than 200 mm (b) more than 200 mm
(c) greater than 2.5 times the gross diameter of the rivet
(d) less than 2.5 times the gross diameter of the rivet

89. When the line of rivets does not lie in the direction of stress, the maximum pitch in a riveted joint should not exceed
(a) 12 t or 200 mm whichever is less (b) 16 t or 200 mm whichever is less
(c) 24 t or 300 mm whichever is less (d) 32 t or 300 mm whichever is less
where t = Thickness of the thinner outside plate.

90. Which of the following statement is wrong ?
(a) A minimum edge distance equal to 1.5 times gross diameter of rivet measured from the rivet hole is provided in the riveted joint.
(b) When the grip of rivets carrying calculated loads exceed 6 times the diameter of the holes, then the rivets are subjected to bending in addition to shear and bearing.
(c) For compression members composed of two components back to back, the tacking rivets shall be at a pitch in a line not exceeding 600 mm.
(d) none of the above

91. If the thickness of plate is t mm and the nominal diameter of rivet is d mm, then according to Unwin's formula
(a) $d = t\sqrt{6}$ (b) $d = 6\sqrt{t}$ (c) $d = \sqrt{6\,t}$ (d) $d = 6\,t$

92. Number of rivets required in a riveted joint is equal to
(a) $\dfrac{\text{Force}}{\text{Rivet value}}$ (b) $\dfrac{\text{Force}}{\text{Strength of rivet in shearing}}$
(c) $\dfrac{\text{Force}}{\text{Strength of rivet in bearing}}$ (d) $\dfrac{\text{Force}}{\text{Strength of plate in tearing}}$

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93. A structural member carrying a pull of 700 kN is connected to a gusset plate using rivets. If the pulls required to shear the rivets, to crush the rivet and to tear the plate per pitch length are respectively 60 kN, 35 kN and 70 kN, then the number of rivets required will be

(*a*) 12 (*b*) 18 (*c*) 20 (*d*) 22

94. When the load line coincides with the centre of gravity of the rivet group, then the rivets are subjected to

(*a*) shear only (*b*) tension only

(*c*) bending only (*d*) both shear and tension

95. If p is the pitch of rivets and d is the gross diameter of rivets, the tearing efficiency of joint is equal to

(*a*) $\frac{p}{p-d}$ (*b*) $\frac{p}{p+d}$ (*c*) $\frac{p-d}{p}$ (*d*) $\frac{p+d}{p}$

96. In eccentric loaded riveted connections, the force resisting the moment in any rivet is inversely proportional to the distance of the centre of the rivet from the centre of gravity of the group of the rivets.

(*a*) True (*b*) False

97. In a bracket riveted connection, the number of rivets (n) essential for resisting the external moment (M) is given by

(*a*) $n = \sqrt{\frac{R.p}{6M}}$ (*b*) $n = \sqrt{\frac{6M}{R.p}}$ (*c*) $n = \frac{R.p}{6M}$ (*d*) $n = \frac{6M}{R.p}$

where R = Rivet value, and p = Pitch of rivets.

98. The load on connection is not eccentric for

(*a*) lap joint (*b*) single cover butt joint

(*c*) double cover butt joint (*d*) all of these

99. In a riveted connection as shown in Fig. 15.16, the rivets subjected to maximum stress would include

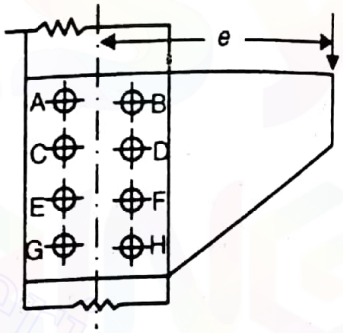

Fig. 15.16

(*a*) A, B, C and D (*b*) C, D, E and F

(*c*) E, F, G and H (*d*) A, B, G and H

100. Which one of the following is the most important consideration in the design of a riveted joint between structural members when the centroid of the rivets does not coincide with the axis of the load ?

(*a*) The direct shear force in each rivet is proportional to its radial distance from its centroid and the resultant force in each rivet should not exceed its rivet value.

(*b*) The shear force caused in each rivet due to eccentricity of the load is proportional to its radial distance from its centroid and the direct shear force in each rivet should be limited to half the rivet value.

(*c*) The shear force caused in each rivet due to eccentricity of the load is proportional to the radial distance of the rivet from the centroid of the rivet group and the maximum resultant force in any rivet should not exceed the rivet value.

(*d*) The shear force caused in the rivet due to eccentricity of load as well as direct shear force caused in the rivet should not exceed the rivet value individually.

101. The common assumption that 'all rivets share equally a non-eccentric load' is valid at a load

(*a*) below the working load (*b*) equal to the working load

(*c*) above the working load (*d*) equal to the failure load

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102. Which of the following statement is correct ?
(a) The welded structures are lighter than riveted structures.
(b) The welding allows the arrangement of structural components in such a manner that the joint provides maximum efficiency.
(c) During welding, the member do not get distorted.
(d) all of the above

103. Arc welding is a
(a) fusion welding (b) pressure welding (c) thermit welding (d) all of these

104. The effective throat thickness in case of incomplete penetration butt weld is taken as
(a) 7/8th of the thickness of the thicker part joined
(b) 7/8th of the thickness of the thinner part joined
(c) 5/7th of the thickness of the thicker part joined
(d) 5/7th of the thickness of the thinner part joined

105. The effective area of a butt weld is taken as the ..... of the effective throat thickness and the effective length of butt weld.
(a) sum (b) difference (c) product (d) ratio

106. The effective length of a butt weld is the length for which the throat thickness of the weld exists.
(a) Right (b) Wrong

107. A butt weld is specified by
(a) leg length
(b) plate thickness
(c) effective throat thickness
(d) penetration thickness

108. The effective length of intermittent butt weld is taken not less than
(a) four times the thickness of the thicker part joined
(b) four times the thickness of the thinner part joined
(c) sixteen times the thickness of the thicker part joined
(d) sixteen times the thickness of the thinner part joined

109. Intermediate butt welds are used to resist
(a) shear stresses (b) dynamic stresses (c) alternate stresses (d) all of these

110. The longitudinal space between the effective length of intermittent butt welds is taken not more than
(a) four times the thickness of the thicker part joined
(b) four times the thickness of the thinner part joined
(c) sixteen times the thickness of the thicker part joined
(d) sixteen times the thickness of the thinner part joined

111. A fillet weld is known as a standard fillet weld when its cross-section is
(a) square
(b) circular
(c) 45° isosceles triangle
(d) 30° and 60° triangle

112. A fillet weld is known as a special fillet weld when its cross-section is 45° isosceles triangle.
(a) Yes (b) No

113. In a fillet weld, throat is the
(a) minimum dimension
(b) maximum dimension
(c) average dimension
(d) leg of weld

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114. The reinforcement of butt weld
(*a*) is ignored in calculating stresses
(*b*) increases efficiency of joint
(*c*) should not exceed 3 mm
(*d*) all of these

115. The weakest plane in a fillet weld is
(*a*) a side parallel to the force
(*b*) a side normal to the force
(*c*) along the throat
(*d*) normal to the throat

116. A fillet weld whose axis is at right angles to the direction of the applied load is known as
(*a*) side fillet weld
(*b*) end fillet weld
(*c*) diagonal fillet weld
(*d*) all of these

117. A fillet weld stressed in transverse shear is known as
(*a*) side fillet weld
(*b*) end fillet weld
(*c*) diagonal fillet weld
(*d*) all of these

118. A fillet weld stressed in longitudinal shear is known as side fillet weld.
(*a*) True
(*b*) False

119. According to Indian standards, if the angle between fusion faces of a fillet weld is 60° – 90°, the effective throat thickness is equal to
(*a*) $\frac{1}{\sqrt{2}} \times$ size of weld
(*b*) $\frac{1}{\sqrt{3}} \times$ size of weld
(*c*) $\sqrt{2} \times$ size of weld
(*d*) $\sqrt{3} \times$ size of weld

120. The size of deep penetration fillet weld is specified as minimum leg length *plus*
(*a*) 1.2 mm (*b*) 2.4 mm (*c*) 3.6 mm (*d*) 4.8 mm

121. When the minimum size of the fillet weld is greater than the thickness of the thinner part, the minimum size of the weld should be ..... the thickness of thinner part.
(*a*) equal to (*b*) less than (*c*) more than

122. The effective length of a fillet weld is taken as
(*a*) the actual length *plus* twice the size of weld
(*b*) the actual length *minus* twice the size of weld
(*c*) the actual length *plus* thrice the size of weld
(*d*) the actual length *minus* thrice the size of weld

123. Fillet weld is not used for joining parts, if the angle between fusion faces is greater than 120° or less than 60°.
(*a*) Agree
(*b*) Disagree

124. The effective length of fillet weld should not be less than
(*a*) the size of weld
(*b*) two times the size of weld
(*c*) three times the size of weld
(*d*) four times the size of weld

125. A welded joint fails earlier than riveted joint, if the structure is under fatigue stresses.
(*a*) Right
(*b*) Wrong

126. For two plates of equal thickness, full strength of fillet can be ensured if its maximum size, for square edge, is limited to
(*a*) 1.5 mm less than the thickness
(*b*) 75% of the thickness
(*c*) 80% of the thickness
(*d*) thickness of the plate

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127. Match the correct type of weld given in Group B for the statements given in Group A.

Group A	Group B
(a) Structural members subject to direct tension or compression	(A) Slot weld
(b) Joining two surfaces approximately at right angles to each other	(B) Seam weld
(c) A hole is made in one of the components and welding is done around the periphery of the hole	(C) Fillet weld
(d) Pressure is applied continuously	(D) Butt weld

128. A structural member subjected to compressive force in a direction parallel to its longitudinal axis, is called
(a) column (b) post (c) stanchion (d) any one of these

129. Which of the following is not a compression member ?
(a) Strut (b) Tie (c) Rafter (d) Boom

130. A strut is a structural member subjected to
(a) tension in a direction parallel to its longitudinal axis
(b) tension in a direction perpendicular to its longitudinal axis
(c) compression in a direction parallel to its longitudinal axis
(d) compression in a direction perpendicular to its longitudinal axis

131. When compression members are overloaded, then their failure takes place because of
(a) direct compression (b) excessive bending
(c) bending combined with twisting (d) any one of these

132. The axial load which is sufficient to keep the column in a slight deflected shape is called
(a) critical load (b) crippling load (c) buckling load (d) any one of these

133. The failure of a column depends upon
(a) weight on column (b) length of column
(c) cross-sectional area of column (d) slenderness ratio of column

134. When the cross-sectional area of the column is kept constant, the load required to cause failure due to direct compression ..... as the length of column increases.
(a) increases (b) decreases

135. Buckling is defined as the sudden bending of the elements or members under compressive stresses.
(a) Agree (b) Disagree

136. The term strut is commonly used for ..... members in roof trusses.
(a) compression (b) tension

137. A strut is a compression member which is
(a) small in length (b) loaded lightly (c) vertical or inclined (d) all of these

138. If l is the length of column hinged at both ends and EI is its flexural rigidity, then critical load is equal to

(a) $\frac{\pi^2 EI}{l^2}$ (b) $\frac{\pi^2 EI}{2l^2}$ (c) $\frac{\pi^2 EI}{3l^2}$ (d) $\frac{\pi^2 EI}{4l^2}$

139. In position restraint condition of column
(a) end of the column is free to change its position
(b) rotation about the end of column cannot take place
(c) end of column is not free to change its position
(d) rotation about the end of column can take place

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140. In direction restraint condition of column
(*a*) end of the column is free to change its position
(*b*) rotation about the end of column cannot take place
(*c*) end of column is not free to change its position
(*d*) rotation about the end of column can take place

141. Effective length of a column is the length between the points of
(*a*) maximum moments (*b*) zero shear (*c*) zero moments (*d*) none of these

142. The effective length is the supported length of a column.
(*a*) Right (*b*) Wrong

143. The effective length of a column (*l*), held in position at both ends but not restained in direction, is equal to
(*a*) 0.67 *L* (*b*) 0.85 *L* (*c*) *L* (*d*) 1.2 *L*
where *L* = Length of column.

144. The effective length of a column (*l*), held in position and restrained in direction at one end and the other end effectively restrained in direction but not held in position, is equal to
(*a*) 0.67 *L* (*b*) 0.85 *L* (*c*) *L* (*d*) 1.2 *L*

145. If *I* is the moment of inertia of a section about the axis and *A* is its effective sectional area, then the radius of gyration (*r*) of the section about the axis, is equal to
(*a*) $\sqrt{\frac{I}{A}}$ (*b*) $\sqrt{\frac{I}{2A}}$ (*c*) $\sqrt{\frac{I}{3A}}$ (*d*) $\sqrt{\frac{I}{4A}}$

146. Slenderness ratio of a compression member is the ratio of effective length of the compression member to the
(*a*) area of cross-section (*b*) moment of inertia
(*c*) radius of gyration (*d*) critical load

147. A column of length *l* is hinged at both the ends restrained from lateral displacement at mid-height. The critical load of the column is given by
(*a*) $\frac{\pi^2 EI}{l^2}$ (*b*) $\frac{2\pi^2 EI}{l^2}$ (*c*) $\frac{4\pi^2 EI}{l^2}$ (*d*) $\frac{\pi^2 EI}{4l^2}$

148. Four vertical columns of the same material, height and weight have the same end conditions. The buckling load will be the largest for a column having the cross-section of
(*a*) a solid square (*b*) a thin hollow circle
(*c*) a solid circle (*d*) an I-section

149. The slenderness ratio of a single angle single strut should be less than
(*a*) 180 (*b*) 250 (*c*) 300 (*d*) 350

150. Maximum slenderness ratio of a compression member which carry loads resulting from wind or seismic forces only, is
(*a*) 180 (*b*) 250 (*c*) 300 (*d*) 350

151. In computing the maximum slenderness ratio, the minimum value of the radius of gyration is used.
(*a*) Correct (*b*) Incorrect

152. The maximum slenderness ratio of a compression member which carry loads resulting from ..... is 180.
(*a*) dead loads and superimposed load (*b*) wind loads

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153. Which of the following statement is wrong ?
(a) When the unsupported lengths of the columns are reduced by providing intermediate supports, then the smaller sections may be used at a higher average stress.
(b) In a rolled steel I-section, the radius of gyration about Y-axis is much more than the radius of gyration about X-axis.
(c) When a column is subjected to different bending moments in two directions, the greater value of the radius of gyration should be kept in the direction of greater moment.
(d) all of the above

154. The average axial stress in the column at the time of its failure is ..... the yield strength of the material.
(a) equal to (b) less than (c) more than

155. The Euler's formula for columns is valid for
(a) zero slenderness ratio (b) small slenderness ratio
(c) large slenderness ratio (d) all of these

156. The columns having very large slenderness ratios fail in elastic buckling.
(a) Yes (b) No

157. The effective length of a structural steel compression member of length L effectively held in position and restained against rotation at one end but neither held in position not restrained against rotation at the other end, is
(a) L (b) $1.2\,L$ (c) $1.5\,L$ (d) $2\,L$

158. The effective length of a column with one end effectively held in position and restrained against rotation and partially restrained against rotation but not held in position at the other end is
(a) $0.65\,L$ (b) $0.8\,L$ (c) $1.5\,L$ (d) $2\,L$

159. According to Euler's formula, the critical stress (σ_{cr}) in a column for elastic buckling is given by

(a) $\sigma_{cr} = \dfrac{\pi^2 E}{l/r}$ (b) $\sigma_{cr} = \dfrac{\pi^2 E}{(l/r)^2}$ (c) $\sigma_{cr} = \dfrac{\pi^2 E}{(l/r)^3}$ (d) $\sigma_{cr} = \dfrac{\pi^2 E}{(l/r)^4}$

where E = Young's modulus,
l = Effective length of column, and
r = Radius of gyration.

160. When the slenderness ratio for the column is less than or equal to the minimum slenderness ratio, then the failure of column occurs by ..... buckling.
(a) elastic (b) inelastic

161. The tangent modulus formula for the buckling load (W_{cr}) of an axially loaded column is

(a) $W_{cr} = \dfrac{\pi^2 E_t I}{l^2}$ (b) $W_{cr} = \dfrac{\pi^2 E_t I}{2 l^2}$ (c) $W_{cr} = \dfrac{\pi^2 E_t I}{3 l^2}$ (d) $W_{cr} = \dfrac{\pi^2 E_t I}{4 l^2}$

where E_t = Tangent modulus of elasticity.

162. Rankine - Gordon formula for buckling load is adopted for columns having slenderness ratio
(a) more than 120 (b) less than 120
(c) more than 120 and less than 200 (d) none of these

163. In order to determine the allowable stress in axial compression, Burean of Indian Standards (BIS) has adopted
(a) Perry-Robertson formula (b) Euler's formula
(c) Secant formula (d) Rankine's formula

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164. The formula which takes into account any initial crookedness of the column and imperfectness of axial loading is

(*a*) Perry-Robertson formula (*b*) Euler's formula

(*c*) Secant formula (*d*) Rankine's formula

165. Which of the following statement is correct ?

(*a*) A tubular section is most economical for the column free to buckle in any direction.

(*b*) The radius of gyration for the tubular section in all directions remains same.

(*c*) The solid round bar is less economical than the tubular section.

(*d*) all of the above

166. The tubular section of a column has ..... local buckling strength.

(*a*) low (*b*) high

167. Which of the following is a best compression member section ?

(*a*) Single angle section (*b*) Double angle section

(*c*) I-section (*d*) Tubular section

168. The single rolled steel I-section and single rolled steel channel section are widely used as column.

(*a*) Agree (*b*) Disagree

169. A short column of external diameter D and internal diameter d, is subjected to a load W, with an eccentricity e, causing zero stress at an extreme fibre. The value of e must be

(*a*) $\frac{D^2 + d^2}{8\pi D}$ (*b*) $\frac{D^2 + d^2}{8D}$ (*c*) $\frac{D^2 - d^2}{8D}$ (*d*) $\frac{D^3 + d^3}{8D}$

170. The effective length of continuous compression members is adopted between ..... times the distance between centres of intersection.

(*a*) 0.7 and 1 (*b*) 1 and 1.3 (*c*) 1.3 and 1.6 (*d*) 1.6 and 2

171. When a single angle strut is connected to a gusset plate with one rivet, then the allowable working stress corresponding to the slenderness ratio of the member, is reduced to

(*a*) 60 % (*b*) 70 % (*c*) 80 % (*d*) 90 %

172. When a single angle strut is connected with two or more number of rivets, its effective length is adopted as ..... times the length of the strut centre to centre of intersection of each end.

(*a*) 0.65 (*b*) 0.75 (*c*) 0.85 (*d*) 0.95

173. When a single angle strut is connected with two or more number of rivets, then the allowable working stress corresponding to the slenderness ratio of the member, is

(*a*) reduced to 60 % (*b*) reduced to 80 % (*c*) reduced to 90 % (*d*) not reduced

174. A discontinuous compression member extends between two adjacent joints only.

(*a*) True (*b*) False

175. Tacking rivets in compression members are used, if the maximum distances between centres of two adjacent rivets exceeds

(*a*) 12 t or 200 mm whichever is less (*b*) 16 t or 200 mm whichever is less

(*c*) 24 t or 300 mm whichever is less (*d*) 32 t or 300 mm whichever is less

where t = Thickness of outside plate.

176. In case where cover plates are used, tacking rivets are provided at a pitch in line not exceeding ..... times the thickness of outside plate or 300 mm whichever is less.

(*a*) 8 (*b*) 16 (*c*) 32 (*d*) 64

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177. When the plates are exposed to weather, the pitch in line should not exceed 16 times the thickness of outside plate or 200 mm whichever is less.
(a) Correct (b) Incorrect

178. The minimum radius of gyration of the single angle section is much ..... other sections of same cross-sectional area.
(a) less than (b) more than

179. The single angle sections are used for
(a) small trusses and bracing (b) single plane trusses
(c) trusses having gusset plates in one plane (d) all of these

180. The built-up sections are used because they provide
(a) large cross-sectional area (b) special shape and depth
(c) sufficient large radius of gyration (d) all of these

181. In roof trusses, the most frequently used section is
(a) two-angle sections placed back to back (b) two-channel sections placed back to back with flanges outward
(c) two-channel sections placed at a distance apart
(d) four angle section

182. When large radius of gyration is required, a two channel sections placed at a distance apart should be used.
(a) Right (b) Wrong

183. Match the correct answer from *Group B* for the statements given in *Group A*.

Group A	*Group B*
(a) A column is said to be short if its slenderness ratio is	(A) 60 to 180
(b) A column is said to be long if its slenderness ratio is	(B) 110 to 130
(c) For a strut, the slenderness ratio is	(C) 70 to 90
(d) For rolled beam section compression members, the slenderness ratio is	(D) less than 60

184. Allowable working stress for rolled steel beam section compression members may be assumed as
(a) 60 N/mm^2 (b) 80 N/mm^2 (c) 100 N/mm^2 (d) 120 N/mm^2

185. Allowable working stress for struts may be assumed as
(a) 60 N/mm^2 (b) 80 N/mm^2 (c) 100 N/mm^2 (d) 120 N/mm^2

186. The buckling load in a steel column is
(a) related to the length
(b) directly proportional to slenderness ratio
(c) inversely proportional to slenderness ratio
(d) non-linearly to the slenderness ratio

187. The lateral system used in built-up columns, to carry the transverse shear force, is
(a) lacing (b) batten plates (c) perforated plates (d) any one of these

188. The common section used in lacing, is
(a) rolled steel flat (b) rolled channel (c) rolled angle (d) all of these

189. A single triangular system is formed in the case of
(a) single lacing (b) double lacing (c) both (a) and (b) (d) none of these

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190. When the components of built-up column are connected by a lateral system, the reduction in buckling strength due to shear deflection is ..... that of solid built-up columns.
(*a*) equal to (*b*) less than (*c*) more than

191. The angle of inclination of lacing bars with the longitudinal axis of the component member should not be
(*a*) less than 40° (*b*) more than 70° (*c*) both (*a*) and (*b*) (*d*) none of these

192. According to IS : 800 - 1984, lacing bars should resist a transverse shear equal to ..... of the axial load in the member.
(*a*) 2.5 % (*b*) 5 % (*c*) 7.5 % (*d*) 10 %

193. Which of the following statement is wrong ?
(*a*) In single lacing, the thickness of flat lacing should not be more than 1/40th length between inner end rivets.
(*b*) In double lacing, the thickness of flat lacing should not be more than 1/60th length between inner end rivets.
(*c*) In riveted construction, effective length of lacing bars in single lacing is adopted as the length between inner end rivets
(*d*) none of the above

194. Slenderness ratio of the lacing bar for compression member should not exceed
(*a*) 125 (*b*) 135 (*c*) 145 (*d*) 155

195. In a double lacing, the lacing flats are placed to form a single triangular system.
(*a*) Yes (*b*) No

196. In riveted construction, effective length of lacing bars in double lacing is adopted as ..... times the length between inner end rivets.
(*a*) 0.4 (*b*) 0.7 (*c*) 1.2 (*d*) 1.8

197. The battening is preferred when the
(*a*) column is axially loaded
(*b*) space between the two main components is not very large
(*c*) both (*a*) and (*b*) (*d*) none of these

198. The batten plates used to connect the components of built-up column are designed to resist
(*a*) longitudinal shear (*b*) transverse shear
(*c*) moment arising from transverse shear (*d*) none of these

199. The number of batten plates should be such that it divides the column longitudinally in atleast ..... parts.
(*a*) two (*b*) three (*c*) four (*d*) five

200. The effective length of a battened columns should be increased by
(*a*) 5% (*b*) 10% (*c*) 15% (*d*) 20%

201. The thickness of batten plate should be greater than 1/50th of the distance between the innermost connecting lines or welds.
(*a*) True (*b*) False

202. The perforated cover plates are particularly suitable for a built up box section consisting of
(*a*) two angle sections (*b*) two channel sections
(*c*) four angle sections (*d*) four channel sections

203. In perforated cover plates, the centre to centre distance between the perforations should not be
(*a*) less than 1.5 times the length of perforation
(*b*) more than 1.5 times the length of perforation
(*c*) less than 2.5 times the length of perforation
(*d*) less than 3.5 times the length of perforation

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204. An eccentrically loaded column is subjected to
(a) bending stress (b) direct stress (c) shear stress (d) both (a) and (b)

205. The design of an eccentrically loaded column should be revised, if
(a) $\frac{\sigma_c'}{\sigma_c} + \frac{\sigma_b'}{\sigma_b} < 1$ (b) $\frac{\sigma_c'}{\sigma_c} - \frac{\sigma_b'}{\sigma_b} < 1$ (c) $\frac{\sigma_c'}{\sigma_c} + \frac{\sigma_b'}{\sigma_b} > 1$ (d) $\frac{\sigma_c'}{\sigma_c} - \frac{\sigma_b'}{\sigma_b} > 1$

where σ_c = Allowable working stress in compression in the member subjected to axial load only,
σ_c' = Calculated average axial compression stress,
σ_b = Maximum allowable bending compressive stress on the extreme fibre, and
σ_b' = Calculated bending stress in the extreme fibre.

206. The equivalent axial load is the load of sufficient magnitude to produce a stress equal to the ..... stress produced by the eccentric load.
(a) maximum (b) minimum

207. Which of the following statement is correct in designing a laced column ?
(a) A single lacing system on opposite planes shall preferably be in the same direction so that one is shadow of the other.
(b) The laced compression members are to be provided with tie plates at ends.
(c) The lacing bar should only be flat angle channels generally.
(d) The slenderness ratio of the lacing bars for compression shall not exceed 180.

208. If A is the cross-sectional area of an eccentrically loaded column and Z is the section modulus, then bending factor is equal to
(a) Z/A (b) A/Z (c) $2A/Z$ (d) $A/2Z$

209. When the column is subjected to an eccentric load (W_E) having eccentricity e_X with respect of X-axis and eccentricity e_Y with respect to Y-axis, then the equivalent axial load (W_{EQ}) is given by
(a) $W_{EQ} = W_E + M_X B_X + M_Y B_Y$ (b) $W_{EQ} = W_E - M_X B_X + M_Y B_Y$
(c) $W_{EQ} = W_E + M_X B_X - M_Y B_Y$ (d) $W_{EQ} = W_E - M_X B_X - M_Y B_Y$

where M_X and M_Y = Bending moment with respect to X-axis and Y-axis respectively, and
B_X and B_Y = Bending factor with respect to X-axis and Y-axis respectively.

210. A joint in the length of a column is known as
(a) shear joint (b) load bearing joint
(c) column splice (d) compression joint

211. A column splice is used to increase the strength of a column.
(a) True (b) False

212. When the ends of a column are cut by ordinary method
(a) the load is transferred to the lower column through rivets
(b) the column has complete bearing over the whole area
(c) the column splice is designed for full axial load and other forces to which the joint is subjected.
(d) both (a) and (c)

213. When the ends of the column are faced for bearing over the whole area, the rivets essential to hold the connected members are designed for ..... axial load and other forces acting on the column.
(a) 50% (b) 75% (c) 85% (d) 100%

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214. Allowable working stress in compression in the column splice plates may be taken as
(*a*) 60 N/mm^2 (*b*) 80 N/mm^2 (*c*) 100 N/mm^2 (*d*) 125 N/mm^2

215. Column splice plates may be assumed to act as short column of zero slenderness ratio.
(*a*) Agree (*b*) Disagree

216. A column base is subjected to moment. If the intensity of bearing pressure due to axial load is equal to stress due to the moment, then the bearing pressure between the base and the concrete is
(*a*) uniform compression throughout (*b*) uniform tension throughout
(*c*) zero at one end and compression at the other end
(*d*) tension at one end and compression at the other end

217. When upper column does not provide full bearing area over lower column, the bearing plate provided is designed by assuming that
(*a*) the bearing plate act as short beam to transmit the axial load to the lower column section
(*b*) the axial load of the column is taken up by flanges
(*c*) the load transmitted from flanges of upper column and reaction from flanges of lower column are equal and form a couple
(*d*) all of the above

218. The width of bearing plate is ..... the width of the flange of column.
(*a*) equal to (*b*) less than (*c*) greater than

219. If the moment due to couple in a bearing plate (of width b) is M and the allowable bending stress in slab or bearing plates is σ_b, then the thickness of bearing plate (t) is given by

(*a*) $t = \sqrt{\frac{M}{b \cdot \sigma_b}}$ (*b*) $t = \sqrt{\frac{2M}{b \cdot \sigma_b}}$ (*c*) $t = \sqrt{\frac{4M}{b \cdot \sigma_b}}$ (*d*) $t = \sqrt{\frac{6M}{b \cdot \sigma_b}}$

220. Which of the following statement is wrong ?
(*a*) Columns are supported on column bases.
(*b*) Column bases transmit the column load to the concrete or masonry foundation blocks.
(*c*) Column load is spread over large area on concrete or masonry foundation blocks.
(*d*) none of the above

221. For solid round steel column, where the load is distributed over the whole area, the minimum thickness of square base (t), as per IS : 800 – 1984, is given by

(*a*) $t = \frac{1}{4}\sqrt{\frac{W}{\sigma_b}\left(\frac{B}{B-d}\right)}$ (*b*) $t = \frac{1}{2}\sqrt{\frac{W}{\sigma_b}\left(\frac{B}{B-d}\right)}$

(*c*) $t = \frac{3}{4}\sqrt{\frac{W}{\sigma_b}\left(\frac{B}{B-d}\right)}$ (*d*) $t = \sqrt{\frac{W}{\sigma_b}\left(\frac{B}{B-d}\right)}$

where W = Total axial load,
B = Length of the side base,
d = Diameter of reduced end of the column, and
σ_b = Allowable bending stress in steel.

222. The rivets connecting gusset plate and column section are in double shear.
(*a*) Correct (*b*) Incorrect

223. The intensity of pressure between column base (of width B and length L) and concrete will be compressive throughout the length of column bar and will vary from zero to $2P/BL$, if the ratio of the moment (M) and axial load (P) is
(*a*) greater than $L/6$ (*b*) equal to $L/6$ (*c*) less than $L/6$ (*d*) none of these

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224. When the ratio of the moment (M) and the axial load (P) is less than one-sixth the length of column base, then the intensity of bearing pressure between column base and concrete is throughout the length of column base.

(a) tensile (b) compressive

225. When the bearing capacity of the soil is poor, then ..... footing should be used as column footing.

(a) independent (b) grillage

226. In a grillage footing, the maximum bending moment occurs at the

(a) edge of beam (b) edge of base plate

(c) centre of beam (d) none of these

227. In a grillage column footing, if a column load (W) is distributed through a column base of length (a) to the grillage beam of length (L), the maximum bending moment (M) is given by

(a) $M = \frac{W}{2}(L - a)$ (b) $M = \frac{W}{4}(L - a)$

(c) $M = \frac{W}{6}(L - a)$ (d) $M = \frac{W}{8}(L - a)$

228. In the above question, maximum shear force is equal to

(a) $\frac{W}{2L}(L - a)$ (b) $\frac{W}{4L}(L - a)$ (c) $\frac{W}{6L}(L - a)$ (d) $\frac{W}{8L}(L - a)$

229. In a grillage footing, the maximum shear force occurs at the edge of base plate.

(a) Right (b) Wrong

230. After 28 days, the cube strength of a grillage beam should not be less than

(a) 10 N/mm^2 (b) 12 N/mm^2 (c) 14 N/mm^2 (d) 16 N/mm^2

231. If the overall length of a combined footing is L, area of base of footing is A and the distance between the centre of base and the centre of gravity of the base is d, then the smaller width (c) for the trapezoidal base of the footing is equal to

(a) $\frac{A}{L} + \frac{6Ad}{L^2}$ (b) $\frac{A}{L} - \frac{6Ad}{L^2}$ (c) $\frac{L}{A} + \frac{L^2}{6Ad}$ (d) $\frac{L}{A} - \frac{L^2}{6Ad}$

232. In combined footing, the shape for the base of footing should be ..... to support two equal column loads.

(a) rectangular (b) trapezoidal (c) triangular (d) circular

233. For an economical design of a combined footing supporting two equal column loads, the projections of beams in lower tier are kept such that the bending moments under the columns and at the centre of beam are approximately equal.

(a) Yes (b) No

234. A structural member subjected to tensile force in the direction parallel to its longitudinal axis, is called

(a) a tension member (b) a tie member (c) a tie (d) any one of these

235. Which of the following statement is correct ?

(a) The term tie is commonly used for tension members in the roof trusses.

(b) When a tension member is subjected to axial tensile force, then the distribution of stress over the cross-section is uniform.

(c) A tension member subjected to axial tension is said to be efficient and economical member.

(d) all of the above

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236. The tension members are used as hangers for floors.
(*a*) Correct (*b*) Incorrect

237. The wire ropes
(*a*) have the advantages of flexibility and strength
(*b*) require special fittings for proper end connections
(*c*) are used as guy wires with the steel towers
(*d*) all of the above

238. A steel wire when used as a tie requires
(*a*) no prestressing (*b*) nominally prestressing
(*c*) pretensioning to its full capacity (*d*) prestressing to half it capacity

239. A steel rope when used as a tie requires no prestressing.
(*a*) True (*b*) False

240. Which of the following is not a tension member ?
(*a*) Cable (*b*) Bar (*c*) Tie (*d*) Boom

241. The single channel sections, used as tension member, have
(*a*) low rigidity in the direction of web and high rigidity in the direction of flange
(*b*) high rigidity in the direction of web and low rigidity in the direction of flange
(*c*) equal rigidity in the direction of web and flange
(*d*) none of the above

242. The net area of a round bar which resists the tension is the area of cross-section at the
(*a*) root of the thread (*b*) crest of the thread
(*c*) mid-section of the thread (*d*) none of these

243. The net sectional area of a tension member is equal to
(*a*) gross-sectional area
(*b*) gross-sectional area *minus* the maximum deduction for rivet holes
(*c*) gross-sectional area *plus* the maximum deduction for rivet holes
(*d*) two times the gross-sectional area

244. In a tension member, when one or more than one rivet hole is off the line, then the failure of plate depends upon
(*a*) diameter of rivet hole (*b*) pitch of rivets
(*c*) gauge of rivets (*d*) all of these

245. When the gauge distance is large as compared to the pitch, the failure of section occurs in a straight right angle section passing through rivet holes.
(*a*) Agree (*b*) Disagree

246. The net area of the flat, as shown in the Fig. 15.17, to be considered in the design, will be along
(*a*) 1 – 2 – 3 – 4 (*b*) 5 – 6 – 7
(*c*) 1 – 2 – 6 – 3 – 4 (*d*) 1 – 2 – 6 –7

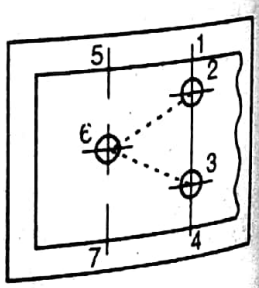

Fig. 15.17

247. In a tension member, the failure will occur in zig-zag line if the gauge distance is ..... pitch of rivets.
(*a*) equal to (*b*) less than (*c*) more than

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248. In case, the staggered rivets are used in the two legs of an angle section, then the gross width of angle is equal to
(a) sum of lengths of two legs
(b) sum of lengths of two legs *minus* the thickness of angle
(c) sum of lengths of two legs *plus* the thickness of angle
(d) sum of gauge distance for rivets in each leg *minus* the thickness of angle

249. When a single angle in tension is connected by one leg, the net effective area of the angle (A_N) is taken as
(a) $A_N = a + \frac{b}{1 - 0.2\, b/a}$
(b) $A_N = a + \frac{b}{1 + 0.2\, b/a}$
(c) $A_N = a + \frac{b}{1 - 0.33\, b/a}$
(d) $A_N = a + \frac{b}{1 + 0.33\, b/a}$

where a and b = Area of connecting and outstanding legs respectively.

250. When a pair of angles back to back in tension are connected by one leg of each angle, the net effective area of the section (A_N) is taken as
(a) $A_N = a + \frac{b}{1 - 0.2\, b/a}$
(b) $A_N = a + \frac{b}{1 + 0.2\, b/a}$
(c) $A_N = a + \frac{b}{1 - 0.33\, b/a}$
(d) $A_N = a + \frac{b}{1 + 0.33\, b/a}$

251. A tension member subjected to axial tension is designed on the basis of its
(a) load carrying capacity
(b) net sectional area
(c) gross-sectional area
(d) all of these

252. Net sectional area of a tension member is equal to
(a) axial pull × allowable stress in axial tension
(b) axial pull – allowable stress in axial tension
(c) axial pull + allowable stress in axial tension
(d) none of the above

253. If the tension member is normally acting as a tie in roof truss but subjected to possible reversal of stress resulting from the action of wind, the member should have slenderness ratio not greater than
(a) 150 (b) 280 (c) 350 (d) 450

254. In order to determine the gross-sectional area of a tension member consisting of two angle sections, the allowance for holes is made as
(a) one hole for each angle
(b) two holes for each angle
(c) three holes for each angle
(d) four holes for each angle

255. In order to determine the gross-sectional area of a tension member consisting of two laced channels, the allowance for holes is made as
(a) two holes from each flange
(b) two holes from each web
(c) two holes from each channel web or one hole from each flange, whichever is more
(d) none of the above

256. A single angle steel tie is connected to gusset plates at both ends using rivets. For determining the load carrying capacity of the tie, the allowable tensile stress should be multiplied by the
(a) gross area of the angle
(b) net area of the angle
(c) net area of the connected leg *plus* the effective area of the outsanding leg
(d) effective area of the connected leg *plus* the gross area of the outstanding leg

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257. In double angle section tension member with the angles on the opposite side of gusset plate, the effective area is the gross area *minus* the area of rivet holes, provided tacking rivets have been provided.

(*a*) Correct (*b*) Incorrect

258. When a built-up tension member is made of four angles with or without plates, then the gross-sectional area is determined by making the allowance as two rivet holes for each angle and one rivet hole for every 150 mm width of the plate.

(*a*) True (*b*) False

259. When the radius of gyration of a tension member is r, the maximum allowable bending stress in tension is σ_b, the distance to the extreme fibre from the neutral axis is y and the bending moment is M when the member is subjected to pure bending, then the cross-sectional area (A) is given by

(*a*) $A = \dfrac{My}{\sigma_b \cdot r^2}$ (*b*) $A = \dfrac{Mr^2}{\sigma_b \cdot y}$ (*c*) $A = \dfrac{\sigma_b \cdot r^2}{My}$ (*d*) $A = \dfrac{\sigma_b \cdot y}{Mr^2}$

260. When the tension member is subjected to both axial tension and bending, then it should be proportioned in such a manner that

(*a*) $\dfrac{\sigma_t'}{\sigma_t} + \dfrac{\sigma_b'}{\sigma_b} > 1$ (*b*) $\dfrac{\sigma_t'}{\sigma_t} + \dfrac{\sigma_b'}{\sigma_b} < 1$ (*c*) $\dfrac{\sigma_t}{\sigma_t'} + \dfrac{\sigma_b'}{\sigma_b} > 1$ (*d*) $\dfrac{\sigma_t'}{\sigma_t} + \dfrac{\sigma_b}{\sigma_b'} < 1$

261. When a tension member is subjected to pure axial tensile load (P), then the net area required for the member is equal to P/σ_t, where σ_t is the maximum allowable stress in axial tension.

(*a*) Correct (*b*) Incorrect

262. The load, which produces the average axial tensile stress in the section equivalent to the maximum combined stress at the extreme fibre of the section, is known as

(*a*) equivalent axial tensile load (*b*) buckling load

(*c*) crippling load (*d*) critical load

263. Indian standards recommend that for a splice plate, rivets or bolts carrying calculated shear stress through a packing greater than 6 mm thick should be increased above the number required by normal calculations by

(*a*) 1.5% for each 1 mm thickness of packing (*b*) 2.5% for each 1 mm thickness of packing

(*c*) 1.5% for each 2 mm thickness of packing (*d*) 2.5% for each 2 mm thickness of packing

264. A beam is a structural member subjected to ..... loads.

(*a*) axial (*b*) transverse (*c*) axial and transverse

265. Which of the following statement is correct ?

(*a*) The length of end connections of angle or channel section to a gusset plate is reduced by using lug angles.

(*b*) When lug angles are used to connect an angle member, the gross area of the member shall be taken as effective.

(*c*) The rivets connecting lug angle and gusset plates are provided less than the number of rivets required by computation.

(*d*) all of the above

266. The main beam is a beam, which supports

(*a*) floor construction (*b*) joists (*c*) secondary beam (*d*) none of these

267. Any major beam in a structure is known as a

(*a*) subsidiary beam (*b*) joist (*c*) girder (*d*) secondary beam

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268. Joists support floor construction only.
(a) Right (b) Wrong

269. In the roof trusses, the horizontal beams spanning between the two adjacent trusses are known as
(a) spandrel beams (b) rafters (c) purlins (d) all of these

270. The beams resting on purlins are known as
(a) spandrel beams (b) rafters (c) trimmers (d) stringers

271. The beams at the outside wall of a building, supporting its share of the floor and also the wall to the floor above it are known as rafters.
(a) Yes (b) No

272. The beams supporting the stair steps are called as
(a) spandrel beams (b) rafters (c) trimmers (d) stringers

273. A rolled I-section provides
(a) large moment of inertia about X-axis with less cross-sectional area
(b) large moment of resistance as compared to the other sections
(c) greater lateral stability
(d) all of the above

274. The rolled steel channel sections are used as purlins.
(a) True (b) False

275. Which of the following statement is wrong ?
(a) The rolled steel channel sections are unsymmetrical sections about Y-axis
(b) The rolled steel angle sections are unsymmetrical sections about both X-axis and Y-axis.
(c) The rolled steel T-sections are used as beams in the rectangular water tanks.
(d) none of the above

276. For a beam in equilibrium, the moment of resistance is
(a) one-half the bending moment at the section
(b) equal to the bending moment at the section
(c) twice the bending moment at the section
(d) none of the above

277. In case of bending of beams about one axis, the load is considered to be applied through the shear centre (*i.e.* centre of area) of the beams sections.
(a) Agree (b) Disagree

278. In angle and channel sections, the load ..... through the shear centre.
(a) passes (b) does not pass

279. When the load does not pass through the shear centre of the beam, it produces
(a) torsional moment only (b) bending moment only
(c) torsional moment along with the bending moment
(d) none of the above

280. The bending stress in a beam at neutral axis is
(a) zero (b) minimum (c) maximum

281. When the load is acting downward in a simply supported beam, the bending stress is
(a) maximum at the extreme fibre (b) compressive above the neutral axis
(c) tensile above the neutral axis (d) both (a) and (b)

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282. When the load on a simply supported beam is acting downward, the bending stress is ..... below the neutral axis.

(*a*) tensile (*b*) compressive

283. The shear stress in a beam at neutral axis is

(*a*) zero (*b*) minimum (*c*) maximum

284. For simply supported beams, shear force is maximum at the supports.

(*a*) Correct (*b*) Incorrect

285. The average shear stress for rolled beams is calculated by dividing the shear force at the cross-section by the

(*a*) depth of beam (*b*) web thickness

(*c*) gross-section of web (*d*) width of flange

286. The gross-section of the web of a beam is equal to

(*a*) $\frac{\text{Depth of beam}}{\text{Web thickness}}$ (*b*) $\frac{2 \times \text{Depth of beam}}{\text{Web thickness}}$

(*c*) Depth of beam × Web thickness (*d*) none of these

287. The average shear stress on the gross-section of web (when web buckling is not a factor) should not exceed

(*a*) 74.5 MPa (*b*) 84.5 MPa (*c*) 94.5 MPa (*d*) 104.5 MPa

288. When a beam is subjected to co-existent bending stress (σ_b) and shear stress (τ), then the equivalent stress is equal to

(*a*) $\sqrt{\sigma_b^2 + \tau^2}$ (*b*) $\sqrt{\sigma_b^2 + 2\tau^2}$ (*c*) $\sqrt{\sigma_b^2 + 3\tau^2}$ (*d*) $\sqrt{\sigma_b^2 + 4\tau^2}$

289. The equivalent stress should be ..... the maximum allowable equivalent stress.

(*a*) less than (*b*) more than

290. The maximum allowable stress for rolled steel beams and channels is

(*a*) 128.5 MPa (*b*) 156.5 MPa (*c*) 181.5 MPa (*d*) 228.5 MPa

291. The maximum deflection, for a simply supported beam, should not exceed

(*a*) 1/125 of span (*b*) 1/225 of span (*c*) 1/325 of span (*d*) 1/425 of span

292. A rectangular beam of width 200 mm and depth 300 mm is subjected to a shear force of 200 kN. The maximum shear stress produced in the beam is

(*a*) 3.33 MPa (*b*) 5.0 MPa (*c*) 7.5 MPa (*d*) 10.0 MPa

293. A symmetrical channel section is made of a material which is equally strong in tension and compression. It is used as a simply supported beam with its web horizontal to carry vertical loads. It will be

(*a*) strongest if the web is used as a top face

(*b*) strongest if the web is used as a bottom face

(*c*) equally strong in (*a*) and (*b*)

(*d*) not possible to state which of the above statements is correct

294. The large deflections in beam

(*a*) may result in cracking of ceiling plaster

(*b*) indicate the lack of rigidity

(*c*) may cause the distortions in the connections

(*d*) all of the above

295. The deflection of beam may be decreased by ..... the depth of beam.

(*a*) increasing (*b*) decreasing

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296. The beams having lateral support from other members may buckle between points of lateral support.
(a) Right (b) Wrong

297. The torsional restraint can be provided by providing
(a) web or flange cleats in the end connections
(b) bearing stiffeners acting in conjunction with the bearing of the beam
(c) external support to the end of the compression flange
(d) all of the above

298. The effective length (l) of a simply supported beam with ends restrained against torsion and the end of compression flange fully restrained against lateral bending, is equal to
(a) $0.7\,L$ (b) $0.85\,L$ (c) L (d) $2\,L$
where L = Span of beam.

299. The effective length (l) for cantilever beams built-in at the support with projecting length L and free at the end is equal to
(a) $0.5\,L$ (b) $0.75\,L$ (c) $0.85\,L$ (d) L

300. The effective length (l) for cantilever beams continuous at the support with projecting length L, partially restrained against torsion at the support and free at the end, is equal to
(a) $0.5\,L$ (b) L (c) $2\,L$ (d) $3\,L$

301. In rolled steel beams, the failure of web occurs
(a) at the concentrated loads (b) at the supports
(c) at a point where deflection is maximum (d) both (a) and (b)

302. In web crippling, local buckling of the web occurs immediately adjacent to a concentration of stress.
(a) Yes (b) No

303. The allowable bearing stress for rolled steel beams is
(a) 128 N/mm^2 (b) 156 N/mm^2 (c) 189 N/mm^2 (d) 228 N/mm^2

304. The web crippling
(a) is a failure of web in direct crushing under concentrated load
(b) means the stress concentration due to bottle-neck condition at the web toe of the fillet under or over heavy load concentrations
(c) is a localised bearing stress caused by the transmission of compression from the comparatively wide flange to the narrow web
(d) all of the above

305. The bearing length of web (B) under concentrated load is given by
(a) $B = b + h\sqrt{3}$ (b) $B = b - h\sqrt{3}$ (c) $B = b + 2h\sqrt{3}$ (d) $B = b - 2h\sqrt{3}$
where b = Length of bearing plate, and
h = Depth of root of fillet from the outer surface of flange.

306. An out-of-plane web distortion is known as
(a) web buckling (b) vertical web buckling
(c) column buckling (d) all of these

307. The failure of a web in which the web, vertically above bearing plate at the reaction or below concentrated load is subjected to column action and tend to buckle under it, is known as
(a) web buckling (b) vertical web buckling
(c) column buckling (d) all of these

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308. The slenderness ratio for the portion of web acting as a column, when the two flanges are restrained against lateral displacement and rotation, is equal to

(a) $\frac{h}{t_w}$ (b) $\frac{\sqrt{3}h}{t_w}$ (c) $\frac{\sqrt{5}h}{t_w}$ (d) $\frac{\sqrt{6}h}{t_w}$

where h = Clear depth of web between root fillets, and

t_w = Thickness of web.

309. The slenderness ratio for the portion of web acting as a column, when the top flange is held in position only while the bottom flange is restrained against lateral displacement and rotation, is equal to

(a) $\frac{h}{t_w}$ (b) $\frac{\sqrt{3}h}{t_w}$ (c) $\frac{\sqrt{5}h}{t_w}$ (d) $\frac{\sqrt{6}h}{t_w}$

310. A beam that is safe in web crippling will not be safe in web buckling.

(a) Agree (b) Disagree

311. Web crippling occurs due to

(a) column action of web (b) failure of web under concentrated load

(c) excessive bending moment (d) secondary bending moment

312. The web crippling and web buckling may be prevented by

(a) increasing the thickness of web (b) increasing the length of bearing plates

(c) decreasing the thickness of web (d) decreasing the length of bearing plates

313. In the riveted built-up beams, an allowance of about ..... of the area of cover plates is added to the calculated area.

(a) 10% (b) 15% (c) 20% (d) 25%

314. The area of cover plates in one flange (A_P) of a built-up beam is given by

(a) $A_P = \frac{Z + Z_I}{d}$ (b) $A_P = \frac{Z - Z_I}{d}$ (c) $A_P = \frac{Z \times Z_I}{d}$ (d) $A_P = \frac{Z \times d}{Z_I}$

where Z = Required section modulus of the rolled beam section,

Z_I = Section modulus of the rolled beam section, and

d = Distance between the centroids of the top and bottom flange plates.

315. The load on a lintel is considered as uniformly distributed load, if the masonry above the lintel is upto a height of

(a) 0.5 times the effective span (b) 0.75 times the effective span

(c) 1.25 times the effective span (d) 1.50 times the effective span

316. The rise of the jack arch is kept about ..... of the span.

(a) $\frac{1}{8}$ to $\frac{1}{12}$ (b) $\frac{1}{12}$ to $\frac{1}{16}$ (c) $\frac{1}{16}$ to $\frac{1}{20}$ (d) $\frac{1}{20}$ to $\frac{1}{30}$

317. Which of the following statement is correct in connection with the designing of jack arch roof?

(a) The deflection of beams should not exceed 1/480 of the span.

(b) The thickness of arch shall not be less than 10 cm.

(c) The spacing of the tie rods should not exceed 20 times the width of rolled steel beams.

(d) all of the above

318. The horizontal thrust (T) on the tie rods provided at the end beams of jack arch is given by

(a) $T = \frac{WL}{2R}$ (b) $T = \frac{WL}{4R}$ (c) $T = \frac{WL}{6R}$ (d) $T = \frac{WL}{8R}$

where W = Live and dead load per metre length of the arch,

L = Span of the arch, and

R = Rise of the arch.

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319. When a beam is connected to a stanchion by means of two angles riveted to them, the connection is known as
(a) unstiffened seated connection
(b) stiffened seated connection
(c) framed connection
(d) none of these

320. Match the correct answer from *Group B* (Type of connection) for the statements given in *Group A* (Type of beam).

Group A (Type of beam)	*Group B (Type of connection)*
(a) To permit large angles of rotation and to transmit negligible moment	(A) Semi-rigid connection
(b) To allow small end rotation and transmit appreciable moment	(B) Framed connection
(c) When a beam is connected to a beam or stanchion by means of an angle at the bottom of the beam which is shop-riveted to the beam and an angle at the top of which is field riveted	(C) Flexible connection
(d) When a beam is connected to a beam or stanchion by means of two angles riveted to them	(D) Seated connection

321. The unstiffened seated connections are used to transmit end reaction of beam upto
(a) 100 kN (b) 150 kN (c) 200 kN (d) 300 kN

322. In designing unstiffened seated connections, the length of seating angle is assumed to be ..... the width of flange of the beam.
(a) equal to (b) less than (c) more than

323. The stiffened seated connections are used when the end reaction of beam is less than 200 kN.
(a) True (b) False

324. In designing stiffened seated connections, the outstanding of the stiffener angles should not exceed ..... its thickness to avoid local buckling of the angles.
(a) 4 times (b) 8 times (c) 12 times (d) 16 times

325. In small moment resistant connections, if the pull on rivets is P, the gauge distance for connected leg of angle is g and the thickness of angle is t, then the bending moment (M) to be resisted by the angle for a single cantilever flexure, is equal to
(a) $P(g + t)$ (b) $P(g - t)$ (c) $2P(g + t)$ (d) $2P(g - t)$

326. In the above question, the bending moment to be resisted by the angle for double cantilever flexure is half of the bending moment for single cantilever flexure.
(a) Correct (b) Incorrect

327. The steel beam of light sections placed in plain cement concrete are called
(a) joists (b) simple joists (c) filler joists (d) concrete joists

328. Which of the following statement is wrong ?
(a) When filler joists are continuous over more than two supports, then these are called discontinuous fillers.
(b) When filler joist spans between two main steel beams only, then these are called continuous fillers.
(c) The continuous fillers are connected to main beams by means of cleat angles.
(d) all of the above

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329. Spans of continuous fillers are considered approximately equal when the longest span does not exceed the shortest span by more than
(*a*) 5% (*b*) 10% (*c*) 15% (*d*) 20%

330. The bending moment for filler joists near the middle of end span is
(*a*) $+\frac{wl^2}{10}$ (*b*) $-\frac{wl^2}{10}$ (*c*) $+\frac{wl^2}{12}$ (*d*) $-\frac{wl^2}{12}$

where w = Dead load plus live load per unit length of span, and
L = Span, centre to centre of supports.

331. The spacing of filler joist centre to centre should not exceed ..... the minimum thickness of the structural concete slab having imposed load up to 2500 N/m^3.
(*a*) 6 times (*b*) 7 times (*c*) 8 times (*d*) 9 times

332. When the underside of the concrete is arched between the filler joists, the thickness at the crown should not be less than
(*a*) 50 mm (*b*) 70 mm (*c*) 85 mm (*d*) 100 mm

333. The span of filler joists centre to centre of supports, should not exceed ..... the depth from the underside of the joist to the top of the structural concrete.
(*a*) 15 times (*b*) 25 times (*c*) 35 times (*d*) 45 times

334. In case of cantilever fillers, the span of filler joists centre to centre of supports should not exceed 12 times the depth from the underside of the joist to the top of the structural concrete.
(*a*) Right (*b*) Wrong

335. The rolled steel section used in cased beam has width B mm and diameter D mm. The minimum width of the finished cased beam is given by
(*a*) (B + 50 mm) (*b*) (B + 100) mm (*c*) ($B + D$ + 100) mm (*d*) 2 ($B + D$) mm

336. Which of the following statement is correct ?
(*a*) Plate girders are deep structural members subjected to transverse loads.
(*b*) Plate girders consist of plates and angles riveted together.
(*c*) Plate girders are economically used for spans upto 100 mm in building construction.
(*d*) all of the above

337. The vertical plate of a plate girder is termed as
(*a*) web plate (*b*) flange plate (*c*) cover plate (*d*) none of these

338. A web plate is called stiffened, when the ratio of clear depth to thickness of web is greater than
(*a*) 55 (*b*) 65 (*c*) 75 (*d*) 85

339. The distance between C.G. of compression flange and C.G. of tension flange of a plate girder, is known as
(*a*) overall depth (*b*) effective depth (*c*) clear depth (*d*) economical depth

340. In general, the depth of plate girder is kept as ..... of span.
(*a*) $\frac{1}{5}$ to $\frac{1}{8}$ (*b*) $\frac{1}{8}$ to $\frac{1}{10}$ (*c*) $\frac{1}{10}$ to $\frac{1}{12}$ (*d*) $\frac{1}{12}$ to $\frac{1}{16}$

341. The clear depth of a plate girder is the
(*a*) depth between outer surface of flanges
(*b*) distance between C.G. of compression flange and C.G. of tension flange
(*c*) distance between vertical legs of flange angles at the top and at the bottom, in case horizontal stiffeners are not used
(*d*) depth which gives minimum weight of plate girder

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342. When the depth of plate girder is less than 75 cm, then such girders are known as
(a) deep plate girders (b) shallow plate girders
(c) economical plate girders (d) none of these

343. A steel welded plate girder is subjected to a maximum bending moment of 1500 kN-m. If the maximum permissible bending stress is 165 N/mm^2, then the most economical depth of the girder will be
(a) 600 mm (b) 800 mm (c) 1000 mm (d) 1200 mm

344. The economical depth of the plate girder is defined as the
(a) depth between outer surfaces of flanges
(b) distance between vertical legs of flange angles at the top and at the bottom
(c) depth which gives minimum weight of plate girder
(d) depth which gives maximum weight of plate girder

345. When the depth of a girder is atleast eight times the depth of vertical leg of the flange angles, such girders are known as shallow plate girders.
(a) Yes (b) No

346. In a plate girder, if M is maximum bending moment, σ_b is allowable bending stress, and t is the thickness of web plate, then the economical depth of plate girder (d_e) is equal to
(a) $0.1\sqrt{\frac{M}{t.\sigma_b}}$ (b) $1.1\sqrt{\frac{M}{t.\sigma_b}}$ (c) $2.1\sqrt{\frac{M}{t.\sigma_b}}$ (d) $3.1\sqrt{\frac{M}{t.\sigma_b}}$

347. The weight of a plate girder varies 1 percent for ..... variation in the depth of the girder.
(a) 5% (b) 10 % (c) 15% (d) 20%

348. The economical depth of a plate girder is assumed 15 to 20 percent less than the calculated value.
(a) Agree (b) Disagree

349. For all practical purposes, self weight of girder is taken as
(a) $\frac{Wl}{100}$ (b) $\frac{Wl}{200}$ (c) $\frac{Wl}{300}$ (d) $\frac{Wl}{400}$
where W = Total superimposed load, and
l = Span of plate girder in metres.

350. According to Vawter and Clark formula, the economical depth of web plate of a plate girder is approximately equal to
(a) $(M/\sigma_b)^{1/3}$ (b) $2.5\,(M/\sigma_b)^{1/3}$ (c) $3.5\,(M/\sigma_b)^{1/3}$ (d) $4.5\,(M/\sigma_b)^{1/3}$
where M = Maximum bending moment, and
σ_b = Allowable bending stress.

351. As per IS : 800 – 1984, the maximum thickness of a plate girder web plate should not be less than ..... for vertically stiffened webs.
(a) $d/85$ (b) $d/200$ (c) $d/250$ (d) $d/400$
where d = Clear depth of plate girder.

352. The diagonal buckling of web, in a plate girder, occurs when the ratio of clear depth to the thickness of web exceeds 85.
(a) True (b) False

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353. Bearing stiffeners are used in a plate girder
(*a*) to avoid local bending failure of the flange
(*b*) to avoid local crippling and crushing of web
(*c*) under concentrated loads and at the points of supports
(*d*) all of the above

354. In a plate girder bridge, the thickness of web is less than $d/200$, where d is the unsupported depth of web. The web plate should be provided with
(*a*) vertical stiffeners
(*b*) horizontal stiffeners
(*c*) end stiffeners
(*d*) both vertical and horizontal stiffeners

355. When torsional restraint at the ends of plate girder is provided only by stiffeners, then moment of inertia of the stiffener about the centre line of the web shall not be less than

(*a*) $\frac{d.t}{250} \times \frac{R}{W}$ (*b*) $\frac{d^2.t}{250} \times \frac{R}{W}$ (*c*) $\frac{d^3.t}{250} \times \frac{R}{W}$ (*d*) $\frac{d^4.t}{250} \times \frac{R}{W}$

where d = Overall depth of the girder,
t = Maximum thickness of compression flange,
R = Reaction on bearing, and
W = Total load on the girder.

356. In a plate girder, the vertical stiffeners are provided when the ratio of clear depth to the thickness of web exceeds
(*a*) 50 (*b*) 65 (*c*) 75 (*d*) 85

357. Which of the following statement is wrong ?
(*a*) Vertical stiffeners are also termed as transverse stiffeners.
(*b*) When two angles are used for the vertical stiffeners, then they are provided on either side of web.
(*c*) When single angle is used for the vertical stiffeners, then they are placed alternately on opposite sides of the web.
(*d*) none of the above

358. The allowable shear stress in stiffened webs of mild steel beams decreases with
(*a*) decrease in the spacing of the stiffeners
(*b*) increase in the spacing of the stiffeners
(*c*) decrease in the effective depth
(*d*) increase in the effective depth

359. In a plate girder, the vertical stiffeners are provided at spacing not greater than ..... and not less than 0.33 d.
(*a*) 0.5 d (*b*) 0.75 d (*c*) 1.25 d (*d*) 1.5 d

where d = Distance between flange angles.

360. The length of outstanding leg of vertical stiffener may be taken equal to 1 / 20th of clear depth of girder *plus* 50 mm.
(*a*) Correct
(*b*) Incorrect

361. A welded steel plate girder consisting of two flange plates of 350 mm × 16 mm and a web plate of 1000 mm × 6 mm requires
(*a*) no stiffeners
(*b*) vertical stiffeners
(*c*) intermediate vertical stiffeners
(*d*) vertical and horizontal stiffeners

362. Horizontal stiffeners, in addition to vertical stiffeners, are provided on the web of a plate girder, when the ratio of clear depth to the thickness of web exceeds
(*a*) 50 (*b*) 100 (*c*) 150 (*d*) 200

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363. Intermediate vertical stiffeners are provided in plate girders to
(a) eliminate web buckling
(b) eliminate local buckling
(c) transfer concentrated loads
(d) prevent excessive deflection

364. A typical section of a crane girder is shown in Fig. 15.18. The function of the top channel is to
(a) increase torsional stiffness
(b) increase lateral buckling strength
(c) increase moment of inertia about vertical axis
(d) all of the above



Fig. 15.18

365. At a section along the span of a welded plate girder, where web is spliced, the bending moment is M. If the girder has top flange, web and bottom flange plates of equal area, then share of the bending moment which would be taken by the splice plates would be
(a) M (b) $M/3$ (c) $M/7$ (d) $M/13$

366. Horizontal stiffeners in plate girders are used to
(a) increase the bending strength of web
(b) increase the shear capacity of the web
(c) prevent local buckling of the web
(d) prevent local buckling of the flange

367. At least one horizontal stiffener should be placed in the plate girder in which the thickness of the web is less than
(a) $d/200$ (b) $d/100$ (c) $d/60$ (d) $d/4$
where d = Depth of the web.

368. Intermediate vertical stiffeners in plate girders need to be provided if the depth of the web exceeds
(a) $50\,t_w$ (b) $85\,t_w$ (c) $125\,t_w$ (d) $175\,t_w$
where t_w = Thickness of the web.

369. Gantry girders are designed to resist
(a) lateral load
(b) longitudinal loads
(c) lateral and longitudinal loads
(d) lateral, longitudinal and vertical loads

370. Vertical stiffeners in plate girders are provided
(a) to increase bearing strength of web
(b) to prevent local buckling of the flange
(c) to prevent local buckling of the web
(d) none of these

ANSWERS

1. (b), (c)	2. (a)	3. (c)	4. (b)	5. (a)	6. (c)
7. (a)	8. (b)	9. (c)	10. (b)	11. (c), (d)	12. (d)
13. (d)	14. (b)	15. (b)	16. (a)	17. (d)	18. (a)
19. (a)	20. (c)	21. (d)	22. (c)	23. (a)	24. (a)
25. (a)	26. (d)	27. (b)	28. (a)	29. (a)	30. (b)
31. (a)	32. (a)	33. (b), (d)	34. (a), (c)	35. (a)	36. (b)
37. (b)	38. (b)	39. (c)	40. (b)	41. (a), (b)	42. (c)
43. (d)	44. (b)	45. (d)	46. (b)	47. (c)	48. (c)
49. (c)	50. (a)	51. (d)	52. (b)	53. (d)	54. (a)
55. (c)	56. (b)	57. (b)	58. (d)	59. (d)	60. (a)
61. (a)	62. (b)	63. (a)	64. (d)	65. (a)	66. (b)
67. (d)	68. (a)	69. (b)	70. (c)	71. (d)	72. (a)

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73. (d) 74. (b) 75. (a) 76. (a) 77. (d) 78. (a)
79. (d) 80. (a) 81. (c) 82. (b) 83. (c) 84. (c)
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299. (c) 300. (c) 301. (d) 302. (a) 303. (c) 304. (d)
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370. (c)

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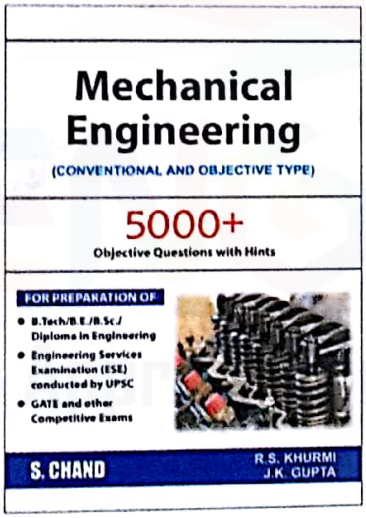

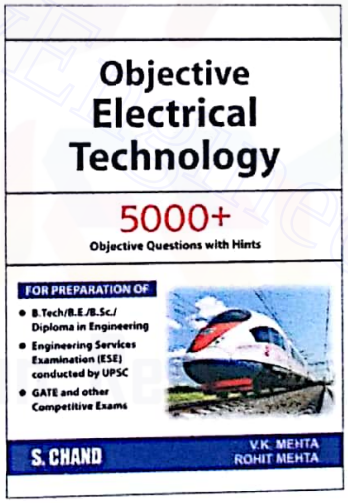

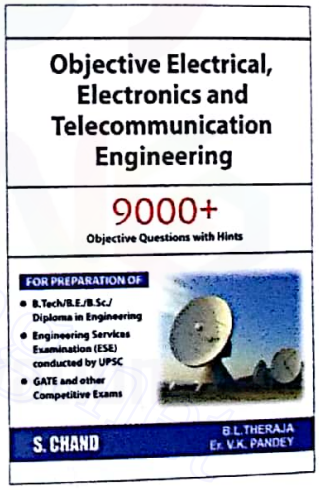

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