Surveying

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Surveying: Surveying is the technique of determining the relative position of different features on, above or beneath the surface of the earth by means of direct or indirect measurements and finally representing them on a sheet of paper known as plan or map.

Objectives of Surveying

- To determine the relative position of any objects or points of the earth.
- To determine the distance and angle between different objects.
- To prepare a map or plan to represent an area on a horizontal plan.
- To develop methods through the knowledge of modern science and the technology and use them in the field.
- To solve measurement problems in an optimal way.

Uses of Surveying

Some of the numerous functions of surveying are given below.

- Topographical maps showing hills, rivers, towns, forests etc. are prepared by surveying.
- For planning and estimating new engineering projects like water supply and irrigation schemes, mines, railroads, bridges, transmission lines, buildings etc. surveying is required.
- Cadastral Map showing the boundaries a field houses are prepared by surveying.
- Engineering map showing the position of engineering works like roads, railways, buildings, dams, canals etc. are prepared through surveying.
- To set out a work and transfer details from map to ground knowledge of surveying is used.
- For planning navigation routes and harbors, marine and hydro-graphic surveying are used.
- To help military strategic planning, military maps are prepared by surveying.
- For exploring mineral wealth, mine survey is necessary
- To determining different strata in the earth crust, geological surveys are required
- Archaeological surveys are used to unearth relics of antiquity.

Surveying is primarily classified as under:

Plane surveying: The curvature of the earth is not taken into consideration. Plane surveying is carried out over a small area.

Geodetic surveying: The curvature of the earth is taken into consideration. Geodetic surveying is carried out over large area.

Metric chain: Widely used 5m, 10m, 20m, and 30m.

Engineer's chain: 100' long, 100 links, each links 1'

Gunter's chain: 66' long, 100 links, each links 0.66'

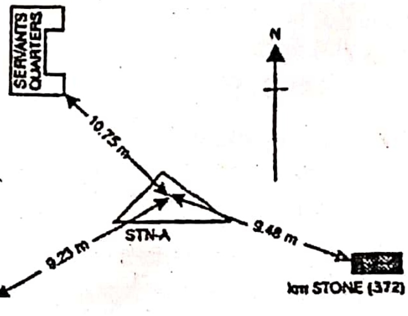
Question: Chain Survey বলতে কি বুঝায়? এটি পরিচালনার পদ্ধতি বর্ণনা করুন। (HED – 2017)

Solution:

It is the method of surveying in which the area is divided into network of triangles and the sides of the various triangles are measured directly in the field with chain or tape. It is the type of surveying in which only linear measurements are made, no angular measurements are taken. It is the simplest kind of surveying and is most suitable when the area to be surveyed is small in extent.

The principle of chain surveying is to divide the area to be surveyed into a network of connected triangles as a triangle is the only simple figure that can be plotted from the lengths of its sides measured in the field.

Chain survey steps:



Reference Sketch for Station A

1. Reconnaissance: The preliminary inspection of the area to be chain surveyed is called reconnaissance. The surveyor inspects the area to be surveyed, survey or prepares index sketch or key plan. Walk the whole area and thoroughly examine the ground, note the position of boundaries, road, and river etc., various difficulties to chain lines, select stations, and prepare neat sketches called index sketches or key plan.

2. Marking stations: Stations are marked with ranging rod, or wooden peg, driving a nail or spikes if hard surface, or embedding stone with a cross mark.

3. Reference sketches: After marking the station should be referenced i.e. located by measurement called ties taken from 3 permanent points which are easily identified such as corner of building.

4. Running survey line: After the preliminary work, chaining is started from base line and carried throughout all the line of the framework continuously. So chain is laid and kept lying, offset are taken to locate the nearby details. Make ranging wherever necessary. Measure the change and offset and enter in the field book.

Errors and mistakes in chaining

Errors in chaining may be caused due to variation in temperature and pull, defects in instruments etc. They may be either compensating or cumulative.

Compensating errors: Errors which may occur in both directions (both positive and negative) and which finally tend to compensate are known as compensating errors. These errors do not affect survey work seriously. They are proportional to $\sqrt{L}$, where L is the length of the line. Such errors may be caused by:

1. Incorrect holding of the chain
2. Fractional parts of the chain or tape not being uniform throughout its length.
3. Inaccurate measurement of right angles with chain tape.
4. Horizontal and verticality of steps not being properly maintained during the stepping operation.

Cumulative errors: Errors which may occur in the same direction and which finally tend to accumulate are said to be cumulative. They seriously affect the accuracy of the work and are proportional to the length of the line. The errors may be positive or negative.

Positive errors: When the measured length is more than the actual length (which the chain is too short), the error is said to be positive. Such errors due to:

1. The length of chain or tape being shorter than the standard length.
2. Slope correction not being applied.
3. Correction for sag not being made.
4. Measurement being taken with faulty alignment.
5. Measurement being taken in high winds with the tape in suspension.

Negative errors: When the measured length of the line is less than the actual length (when the chain is too long), the error is said to be negative. These errors occur when the length of the chain or tape is greater than the standard length due to the following reasons:

1. The opening of ring joints.
2. The applied pull being much greater than the standard pull.
3. The temperature during measurement being much higher than the standard.
4. Elongation of the links due to heavy pull.

Mistakes: Errors due to the carelessness of the chainman are called mistakes. The following are a few common mistakes.

1. Displacement of arrows.
2. A reading may be taken from the wrong end of the chain.
3. The numbers may be read from the wrong directions.
4. A full chain length may be omitted or added. This happens when arrows are lost or wrongly counted.

Question: Define surveying and mention different type of surveying for a bridge work? (EED-2019)

Solution:

Surveying: Surveying is the branch of civil engineering which deals with measurement of relative positions of an object on earth's surface by measuring the horizontal distances, elevations, directions, and angles.

Bridge surveying is necessary to locate a site, obtain information for design, and furnish lines and grades for construction.

1. Reconnaissance: Tentative bridge sites are selected by reconnaissance and the more promising are determined in detail. Selection of a bridge site is governed by both tactical and technical considerations.

2. Bridge Length: The surveyor determines the length of the bridge crossing to estimate the materials required for construction. Depending on the distance and equipment available, the surveyor measures this distance with a tape, an electronic measuring device.

3. Banks: The surveyor reports on the character and shape of the riverbanks. This includes the amount and type of vegetation; the slope, height, and composition of the banks; and pertinent dimensions of any natural dikes.

4. Character of the Flow: The surveyor determines stream velocity by timing a floating object over a measured course .Surveyor observes the character of the river bottom for each site and reports information on the design of intermediate supports.

5. Profile: The surveyor profiles the streambed or gap to facilitate the design of intermediate supports. Profile interval is measured by a tape or cable stretched horizontally across the stream or gap or by the electronic instrument.

6. The surveyor estimates and records quantities of local materials such as standing timber, sand and gravel beds, and available cement, water, and lumber.

Question: Write down the correction of chain survey? (ISTT – 2015)

Solution:

The following five corrections may be found for the measured lengths of tape:

1. Corrections for absolute length
2. Corrections for pull
3. Corrections for temperature
4. Corrections for slope and
5. Corrections for sag.

Question: Name five modern surveying equipment's. (WASA – 214)

Solution:

Following are the modern surveying instruments which are used for surveying:

- Electronic Distance Measurement (EDM) Instruments
- Total Station
- Global Positioning System (GPS)
- Automatic Level
- Digital Level
- Tachymeter
- Dioptra
- Theodolite
- Dumpy level

Chain and tape corrections

A. Tape correction

1. Temperature correction (C_t): This correction is necessary because the length of the tape or chain may be increased or decreased due to rise or fall of temperature during measurement.

$$C_t = \alpha \, (T_m - T_0) \, L$$

C_t = Correction for temperature in meters
α = Coefficient of thermal expansion
T_m = Temperature during measurement in degree centigrade or Celsius
T_0 = Temperature at which the tape was standardised in degree centigrade or Celsius
L = Length in tape in meters
When α for the steel tape is not given it may be assumed to be 11×10^{-6} per degree centigrade or Celsius

2. Pull correction (C_p): During measurement the applied pull may be either more or less than the pull at which the chain or tape was standardised. Due to elastic property of materials, the strain will vary according to the variation of applied pull and hence necessary correction should be applied.

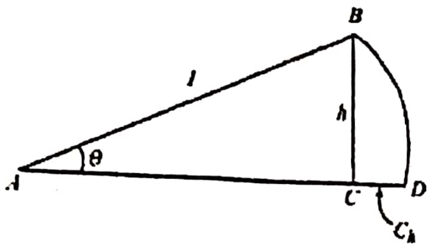
$$C_p = \frac{(P_m - P_0) \, L}{A \times E}$$

C_p = Pull correction in meters
P_m = Pull applied during measurement in kilograms
P_0 = = pull at which the tape was standardised in kilograms
L = Length in tape in meter
A = Cross-sectional area of tape in square centimetres
E = Modulus of elasticity (Young's modulus)

3. Slope correction (C_h)

$$C_h = l - \sqrt{l^2 - h^2} \quad \text{(exact)}$$
$$= l\,(1 - \cos\theta) \quad \text{(exact)}$$
$$= \frac{h^2}{2\,l} \quad \text{(approx.)}$$

This correction is always negative.



4. Sag correction (C_s): This correction is taken with the tape in suspension.

$$C_s = \frac{L\,(\omega\,L)^2}{24\,n^2\,P_m^2}$$

When unit weight is given

$$C_s = \frac{L\,W^2}{24\,n^2\,P_m^2}$$

When total weight is given

$C_s =$ Sag correction in meters
$L =$ Length in tape or chain in metres
$\omega =$ Weight of tape per unit length in kilograms per metre
$W =$ Total weight of tape in kilograms
$n =$ Number of spans
$P_m =$ Pull applied during measurement in kilograms

This sign of correction is always negative.

B. Chain correction:

1. Correction applied to incorrect length

True length of line $(TL) = \frac{L'}{L}$ x measured lenmgth (ML)

$L =$ Standard or true length of chain
$L' =$ True length $\pm$ error $= L \pm e$

2. Correction of incorrect area

True area $(TA) = \left(\frac{L'}{L}\right)^2$ x Measured area (MA)

Question: The distance between two points, measured with a 20 m chain was recorded as 327 m. It was afterwards found that the chain was 3 cm too long. What was the true distance between the points?

Solution:

$L = 20$ m, $L' = 20 + 0.03 = 20.03$

True length of line $(TL) = \dfrac{L'}{L} \times ML = \dfrac{20.03}{20} \times 327 = 327.49$ m

Question: A distance of 1000 m was measured with a 25 m chain which was actually found to be 24.90. Calculate the chained distance. (WRGCL – 2014, WARPO – 2017)

Solution:

Here, $ML = 1000$ m, $L = 25$ m, $L' = 24.90$ m

$$TL = \frac{L'}{L} \times ML = \frac{24.90}{25} \times 1000 = 996 \text{ m}$$

Question: The length of the line measured with 20 m chain found to be 250 m. It was subsequently found that the chain was 10 cm to long. What is the length of line? (BB AD – 2018)

Solution:

Here, $ML = 500$ m, $L = 20$ m, $L' = 20 + 0.1 = 20.1$ m

True length of line $(TL) = \dfrac{L'}{L} \times ML = \dfrac{20.1}{20} \times 250 = 251.25$ m

Question: A road is measured by a 20 m chain is found to be 500 m. It was found later that the chain is 4 cm too long. What is the actual length? (AB – 2017)

Solution:

Here, $ML = 500$ m, $L = 20$ m, $L' = 20 + 0.04 = 20.04$ m

True length of line $(TL) = \dfrac{L'}{L} \times ML = \dfrac{20.04}{20} \times 500 = 501$ m

Question: The length and breadth of a plot of land were measured by an engineer's chain exactly 20' in length at beginning. But it was found to be 20.03' at the end. Calculated area is 50.4 cm², find the correct area. (BREB – 2018)

Solution:

Here, $MA = 50.4$ cm^2, $L = 20'$ m, $L' = 20.03'$

$$\text{True area} = \left(\frac{\text{Wrong scale}}{\text{Correct scale}}\right)^2 \times \text{Measured area}$$

$$TA = \left(\frac{L'}{L}\right)^2 \times MA = \left(\frac{20.03}{20}\right)^2 \times 20.4 = 50.55 \text{ cm}^2$$

Question: A road is actually 25320 ft long, this distance is measure by a defective engineers chain and it was found 25270. How much increase or decrease needed of the length for the chain. (MPL – 2017, JOCL – 2018)

Solution:

$$TL = \frac{L'}{L} \times ML$$

$$25320 = 25270 \times \frac{L'}{100}$$

$L' = 100.1978'$

Amount of error, $e = L' - L = 100.1978' - 100' = +0.1978'$

The chain needs to shorten by 0.1978'

Question: The distance between two points measured 1000 m with a 25 m chain, but it was found that the chain is 25.15 m. calculate the actual length. (TGTDCL – 2021)

Solution:

Here, $ML = 1000$ m, $L = 25$ m, $L' = 25.15$ m

$$TL = \frac{L'}{L} \times ML = \frac{25.15}{25} \times 1000 = 1006 \text{ m}$$

Question: The distance between two stations was 1200 m when measured with a 20 m chain. The same distance when measure with 30 m chain was found to be 1195 m. If the 20 m chain was 0.05 m too long, what was the error in the 30 m chain?

Solution:

Let us consider the 20 m chain.

$L = 20$ m

$L' = 20 + 0.05 = 20.05$ m

Measured length $= 1200$ m

True length of line $= 1200 \times \frac{20.05}{20} = 1203$ m

Let us consider the 30 m chain.

$L = 30$ m, $L' = ?$

True length of line 1203 m (as obtained from 20 m chain)

Measured length $= 1195$ m

$$TL = \frac{L'}{L} \times ML$$

$$L' = \frac{1203 \times 30}{1195} = 30.20 \text{ m}$$

Now, L' is greater than L. So, the chain is to long.

Amount of error, $e = 30.20 - 30 = 0.20$ m

Question: A steel tape was exactly 30 m long at 20° C when supported throughout its length under a pull of 10 kg. A line was measured with this tape under a pull of 15 kg and at a mean temperature of 32° C and found to be 780 m long. The cross section area of the tape = 0.03 cm² and its total weight = 0.693 kg. α for steel = 11 x 10^{-6} per degree centigrade and E for steel = 2.1 x 10^6 kg/cm². Compute the true length of the line if the tape was supported during measurement at every 30 m and at every 15 m.

Solution:

When supported at every 30 m:
Total correction per tape length is to be found out first. Here, n = 1

Temperature correction, $C_t = \alpha\,(T_m - T_0)\,L = 11 \times 10^{-6}\,(32 - 20) \times 30 = 0.00396$ m (+ ve)

Pull correction, $C_p = \dfrac{(P_m - P_0)\,L}{A \times E} = \dfrac{(15 - 10)\,30}{0.03 \times 2.1 \times 10^6} = 0.00238$ (+ ve)

Sag correction, $C_s = \dfrac{L\,W^2}{24\,n^2\,P_m^2} = \dfrac{30 \times 0.693^2}{24 \times 15^2} = 0.00267$ m (− ve)

Total correction = + 0.00396 + 0.00238 − 0.00267 = + 0.00367 m (too long)

$L' = L + e = 30 + 0.00367 = 30.00367$ m

True length, $TL = \dfrac{L'}{L} \times ML = \dfrac{30.00367}{30} \times 780 = 780.094$ m

When supported at every 15 m:
Here, span n = 2
Temperature correction, $C_t = 0.00396$ m (+ ve) as before

Pull correction, $C_p = 0.00238$ m (+ ve) as before

Sag correction, $C_s = \dfrac{L\,W^2}{24\,n^2\,P_m^2} = \dfrac{30 \times 0.693^2}{24 \times 2^2 \times 15^2} = 0.00067$ m (− ve)

Total correction = + 0.00396 + 0.00238 − 0.00067 = + 0.00567 m (too long)

$L' = L + e = 30 + 0.00567 = 30.00567$ m

True length, $TL = \dfrac{L'}{L} \times ML = \dfrac{30.00567}{30} \times 780 = 780.147$ m

Question: Chainage of a survey line is actual 36990 ft, but it found in practical field is 36995 ft .Find the % of error. (BUET M. Sc. −2014)

Solution:

$$\%\text{ of error} = \frac{\Delta L}{L} \times 100 = \frac{36995 - 36990}{36990} \times 100 = 0.0135\%$$

Compass Traversing

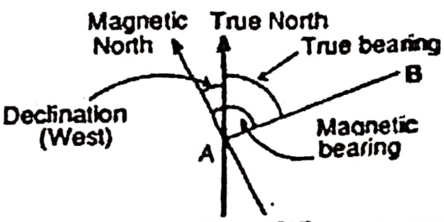
In chain surveying, the area to be surveyed is divided into a number of triangles. This method is suitable for fairly level ground covering small areas. But when the area is large, undulating and crowded with many details, triangulation is not possible. In such an area the method of traversing is adopted. In traversing the framework consists of a number of connected lines. The lengths are measured by chain or tape and the directions identified by angle measuring instruments. In one of the methods, the angle measuring instrument used is the compass. Hence, the process known as compass traversing.

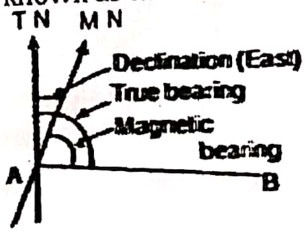
Question: What is traverse survey? (Army – 2014)

Solution:

Traversing is that type of survey in which a number of connected survey lines form the framework and the directions and lengths of the survey lines are measured with the help of an angle measuring instrument and a tape or chain respectively.

True meridian: The line or plane passing through the geographical North Pole, geographical South Pole and any point on the surface of the earth is known as the true meridian or geographical meridian. The meridian at a station is constant. The angle between the true meridian and a line is known as true bearing of the line. It is also known as the azimuth.





Magnetic meridian: When a magnetic needle is suspended freely and balanced properly unaffected by magnetic substances, it indicates a direction. This direction is known as the magnetic meridian. The angle between the magnetic meridian and a line is known as the magnetic bearing or simply the bearing of the line.

Arbitrary Meridian: Sometimes for the survey of a small area a convenient direction is assumed as a meridian known as the arbitrary meridian. Sometimes the starting line of a survey is taken as the arbitrary meridian.

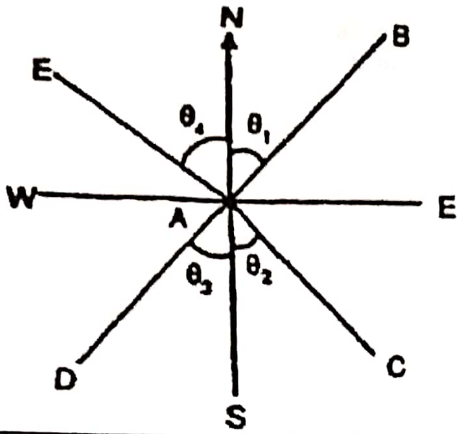
Whole circle bearing (WCB): The magnetic bearing of a line measured clockwise form the north pole towards the line is known as the whole circle bearing of that line. Such a bearing may have any value between 0^0 and 360^0.

Example: 26°, 121°, 245°, 350° etc.

Quadrantal Bearing: The magnetic bearing of a line measured clockwise or counterclockwise from the North Pole or South Pole (whichever is nearer the line) towards the East or West, is known as the 'quadrantal bearing' of the line. This system consists of four quadrants - NE, SE, SW and NW. The value of a quadrantal bearing lies between 0° and 90°

Example: N26°E, S59°E, S65°W, N10°W etc.

When the whole circle bearing of a line is converted to quadrantal bearing, it is termed the reduced bearing. Thus, the reduced bearing is similar to the quadrantal bearing. Its value lies between 0° and 90°, but the quadrants should be mentioned for proper designation. The following table should remembered for conversion of WCB to RB.



WCB between	Corresponding RB	Quadrant
0° and 90°	RB = WCB	NE
90° and 180°	RB = 180° - WCB	SE
180° and 270°	RB = WCB – 180°	SW
270° and 360°	RB = 360° - WCB	NW

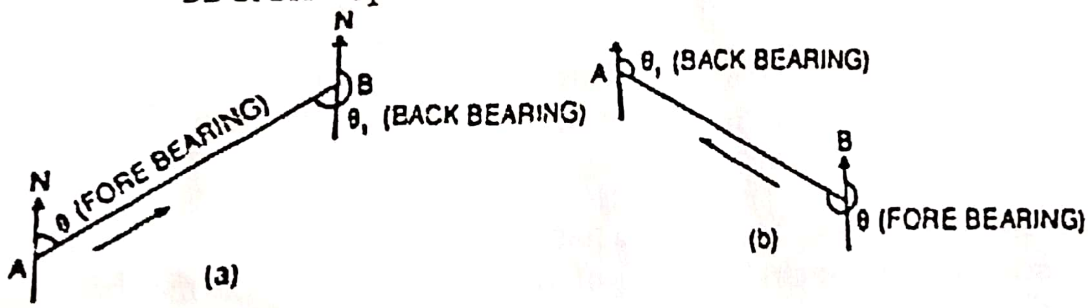
Fore and back bearing: The bearing of a line measured in the direction of the progress of survey is called the fore bearing (FB) of the line. The bearing of a line measured in the direction opposite to the survey is called the back bearing (BB) of the line.

For example in figure (a) FB of AB = θ

BB of AB = θ_1

In figure (b) FB of BA = θ

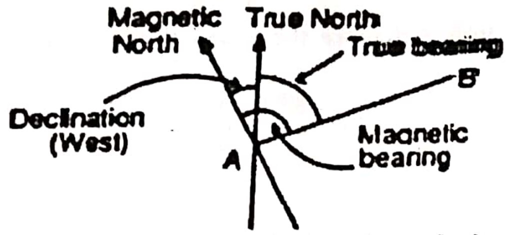
BB of BA = θ_1

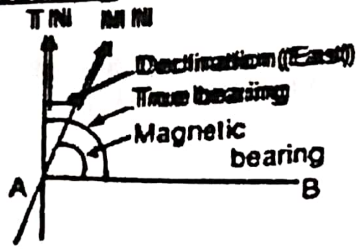


In the WCB system, the difference between the FB and BB should be exactly 180°. Remember the following relation

$BB = FB \pm 180^0$

Determination of true bearing and magnetic bearing





True bearing = magnetic bearing ± declination

Note [Use the positive sign when declination east
Use the negative sign when declination west]

Magnetic bearing = true bearing ± declination

Note [Use the positive sign when declination west
Use the negative sign when declination east]

Question: The magnetic bearing of a line AB is 135°30'. What will be the true bearing, if the declination is 5°15' W. The true bearing of a line CD is 210°45'. What will be its magnetic bearing, if the declination is 8°15'W.

Solution

True bearing of AB = magnetic bearing – declination = 135°30' – 5°15' = 130°15'

Magnetic bearing = true bearing + declination = 210°45' + 8°15' = 219°0'

Question: The magnetic bearing of a line CD is S 30°15' W. Find its true bearing, if the declination is 10°15' E.

Solution

First convert the RB to WCB, and then follow the usual procedure to find the true bearing in WCB. Finally, convert the true bearing to RB.

RB of CD = S 30°15' W

WCB of CD = 180°0' + 30°15' = 210°15'

Now, TB = MB + declination (east) = 210°15' + 10°15' = 220°30'

Required true bearing = 220°30' – 180° = S 40°30' W

Question: In 1920, the magnetic bearing was N37°30' E and the declination was 5°45' E. What will be the true bearing in 2015 if the declination in 2015 is 3°15'E? (BUET M.Sc – 2018)

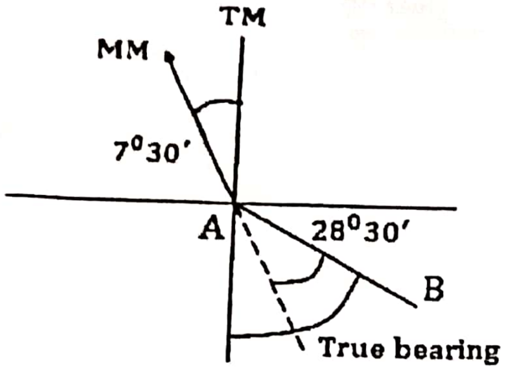
Solution:

In 1920, True bearing = 37°30' + 5°45' = 43°15'

In 2015, True bearing is 43°15', the true bearing of a line is constant

Question: The magnetic bearing of a line AB is $S\,28^0 30'E$. Calculate the true bearing if the declination $7^0 30'$ west. (BUET M.S – 2017)

Solution:



True bearing $= S\,28^0 30'E + 7^0 30' = S\,36^0 00'E$

Question: On an old map a line was drawn to a magnetic bearing of $320^0 30'$, when the declination was $3^0 30'$ W. Find the present bearing of the line, if the declination is $4^0 15'$ E.

Solution:

True bearing = Magnetic bearing - declination (west)

$= 320^0 30' - 3^0 30' = 317^0 0'$

The true bearing of a line is constant.

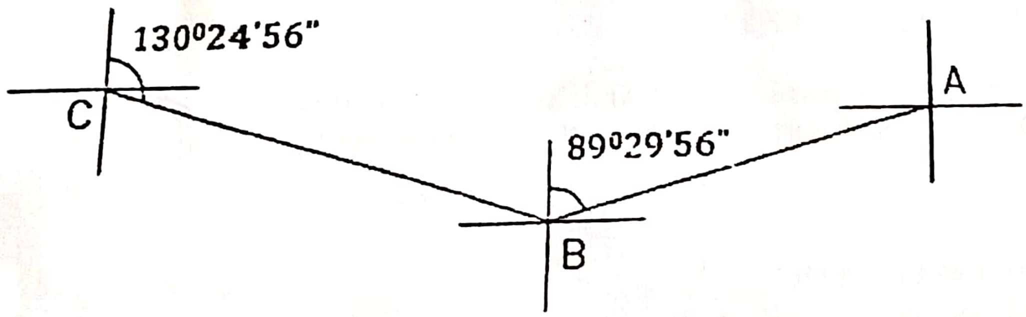
So, the present true bearing of the line is also $317^0 0'$

Magnetic bearing = True bearing - declination (east)

$= 317^0 0' - 4^0 15' = 312^0 45'$

Question: Find the angle ABC if forwarded bearing of both lines (CB & BA) are 130⁰24'56" and 89⁰29'56". (PGCL – 2017)

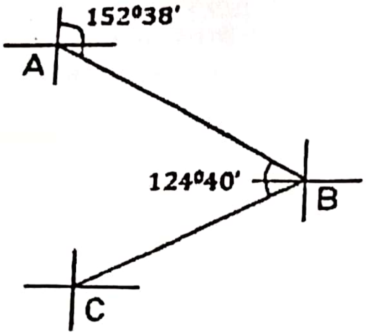
Solution:



$\angle ABC = (180^0 - 130^0 24'56'') + 89^0 29'56'' = 138^0 55'40''$.

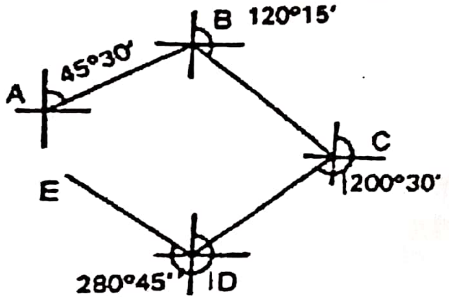
Question: The bearing of line AB is 152°38′ and the angle ABC is 124°40′. Find the bearing of BC. (DPDC – 2014)

Solution:



Bearing of BC = $180^0 + (152^0 38' - 124^0 40') = 180^0 + 27^0 58' = 207^0 58'$

Question: The fore bearings of the lines AB, BC, CD and DE are $45^0 30'$, $120^0 15'$, $200^0 30'$ and $280^0 45'$ respectively. Find angles ∠B, ∠C, ∠D.



Solution:

Interior $\angle B = \text{BB of AB} - \text{FB of BC} = (45^0 30' + 180^0 0') - 120^0 15'$
$\angle B = 225^0 30' - 120^0 15' = 105^0 15'$

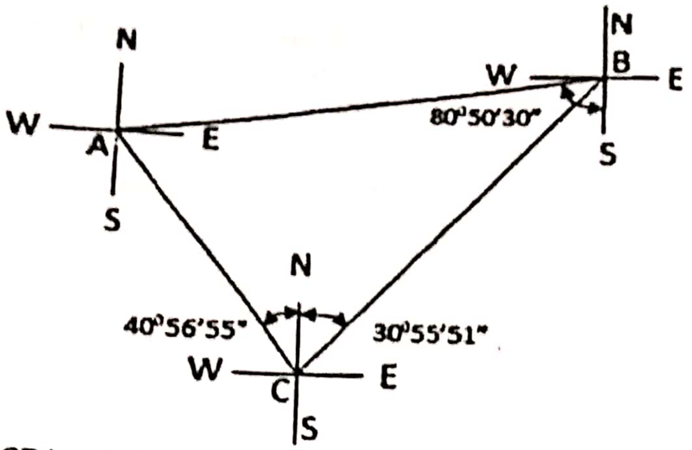
Interior $\angle C = \text{BB of BC} - \text{FB of CD} = (120^0 15' + 180^0 0') - 200^0 30'$
$\angle B = 300^0 15' - 200^0 30' = 99^0 45'$

Exterior $\angle D = \text{FB of DE} - \text{BB of CD} = 280^0 45' - (200^0 30' + 180^0 0')$
$\angle B = 280^0 45' - 20^0 30' = 260^0 15'$

Interior $\angle D = 360^0 0' - 260^0 15' = 99^0 45'$

Question: Calculate the initial angles of a closed Travers from the following bearing
BA: S 80° 50′ 30″ W
CA: N 40° 56′ 55″ W
CB: N 30° 55′ 51″ E
(PGCL – 2014, DTCA – 2018, BADC – 2020)

Solution:



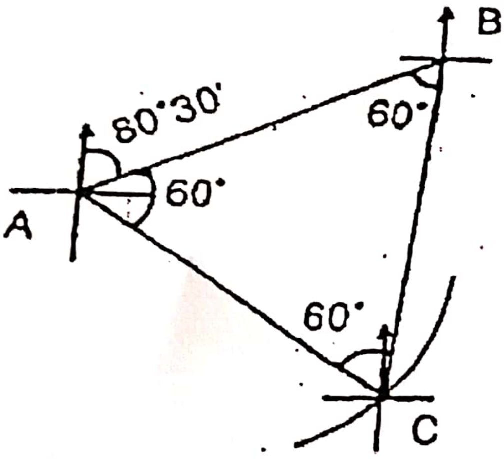
∠CBA = 80° 50' 30" – 30° 55' 51" = 49° 54' 39"
∠BAC = (90 – 80° 50' 30") + (90 – 40° 56' 55")
= 9° 9' 30" + 49° 3' 5" = 58° 12' 35"
∠ACB = 40° 56' 55" + 30° 55' 51" = 71° 52' 46"

Check:

∠CBA + ∠BAC + ∠ACB = 49° 54' 39" + 58° 12' 35" + 71° 52' 46" = 180°
(2N – 4) x 90 = (2 x 3 – 4) x 90 = 180°

Question: A traverse is done by three stations A, B and C in clockwise order in the form of an equilateral triangle. If the bearing of AB is 80°30′, find the bearings of the other sides.

Solution:



FB of AB = 80°30′
FB of BC = *BB of AB* - ∠B = (80°30′ + 180°0′) – 60°0′ = 200°30′
FB of CA = *BB of BC* + exterior ∠C = (200°30′ – 180°0′) – (360°0′ – 60°0′) = 320°30′
FB of AB = *BB of CA* - ∠A = (320°30′ + 180°0′) – 60°0′ = 80°30′ (checked)

Levelling: The art of determining the relative heights of different points on or below the surface of the earth is known as levelling. Thus, levelling deals with measurements in the vertical plane.

Levelling is done for the following purposes:

1. To prepare a contour map for fixing sites for reservoirs, dams, barrages etc. and to fix the alignment of roads, railways, irrigation canals and so on.
2. To determine the altitudes of different important points on a hill or to know the reduced levels of different points on or below the surface of the earth.
3. To prepare a longitudinal section and cross-sections of a project (roads, railways, irrigation canals) in order to determine the volume of earth work.
4. To prepare a layout map for water supply, sanitary or drainage schemes.

Level surface: Any surface parallel to the mean spheroidal surface of the earth is said to be a level surface. The water surface of a still lake is also considered to be a level surface.

Level line: Any lying lying on a level surface is called level line.

Horizontal plane: Any plane tangential to the level surface at any point is known as the horizontal plane. It is perpendicular to the plumb line which indicates the direction of gravity.

Horizontal line: Any line lying on the horizontal plane is said to be a horizontal line. It is a straight line tangential to the level line.

Datum line: This is an imaginary level surface or level line from which the vertical distances of different points above or below this line are measured.

Reduced level: The vertical distance of a point above or below the datum line is known as the reduced level of that point. The RL of a point may be positive or negative according as the point is above or below the datum.

Line of collimation: It is an imaginary line passing through the intersection of the cross hairs at the diaphragm and the optical centre of the object glass and its continuation. It is also known as the line of sight.

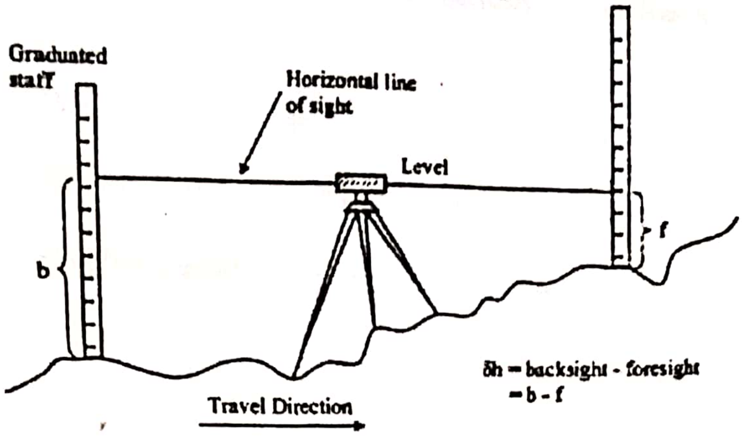
Bench marks: These are fixed points or marks of known RL determined with reference to the datum line. These are very important marks. They serve as reference points for finding the RL of new points or for conducting levelling operations in projects involving roads, railways etc.

Backside reading: This is the first staff reading taken in any set up of the instrument after the levelling has been perfectly done. This reading is always taken on a point of known RL on a bench mark or change point.

Foresight reading: It is last staff reading in any set up of the instrument and indicates the shifting of the latter.

Intermediate sight readings: It is any other staff reading between the BS and FS in the same set up of the instrument.

Change point: This point indicates the shifting of the instrument. At this point an FS is taken from one setting and a BS from the next setting.



Height of instrument: When the levelling instrument is properly levelled, the RL of the line of collimation is known as the height of instrument.

Question: What is transit theodolite? What is parallax in theodolite? (ISTT – 2015)

Solution:

A theodolite the telescope of which can be rotated completely about its horizontal axis. Primary function is the accurate measurement or layout of horizontal and vertical angles.

Parallax is a displacement or difference in the apparent position of an object viewed along two different lines of sight, and is measured by the angle or semi-angle of inclination between those two lines. Due to foreshortening, nearby objects show a larger parallax than farther objects when observed from different positions, so parallax can be used to determine distances. To measure large distances, such as the distance of a planet or a star from Earth, astronomers use the principle of parallax.

Question: Define Benchmark. (BUET M.Sc. –2011)

Solution:

A benchmark is a point of reference by which something can be measured. In surveying, a "bench mark" is a post or other permanent mark established at a known elevation that is used as the basis for measuring the elevation of other topographical points.

Question: What is leveling? Write down the methods of plane table surveying? (Army – 2014)

Solution:

Leveling is a branch of surveying, the object of which is: i) to find the elevations of given points with respect to a given or assumed datum, and ii) to establish points at a given or assumed datum.

Generally there are four methods are available to perform plane table surveying. They are

- *Radiation*
- *Intersection*
- *Traversing*
- *Resection*

Question: What is traverse survey? (ARMY – 2014)

Solution:

Traversing is the type of survey in which a number of connected survey lines form the framework and the directions and the lengths of the survey lines are measured with the help of an angle (or direction) measuring instrument and a tape (or chain) respectively. When the lines form a circuit which ends at the starting point, it is known as a closed traverse.

Methods of traversing-

- Chain traversing
- Cain and compass traversing (loose needle method)
- Transit tape traversing
- Plane-table traversing

Corrections to be applied

1. Curvature correction: For long sights, the curvature of the earth affects staff readings. The line of sight is horizontal but the level line is curved and parallel to the mean spheroidal surface of the earth. The vertical distance between the line of sight and the level line at a particular place is called the curvature correction. Due to curvature, objects appear lower than they really are.

C_c = Correction due to curvature
C_r = Correction due to curvature
D = Horizontal distance in kilometres
R = Radius of earth

In Δ OCA, $OC^2 = OA^2 + AC^2$

$(OB + BC)^2 = R^2 + D^2$

$(R + C_c)^2 = R^2 + D^2$

$R^2 + 2\,R\,C_c + C_c^2 = R^2 + D^2$

$2\,R\,C_c = D^2$

$$C_c = \frac{D^2}{2\,R}$$

C_c^2 is neglected as it is very small in comparison to the diameter of the earth

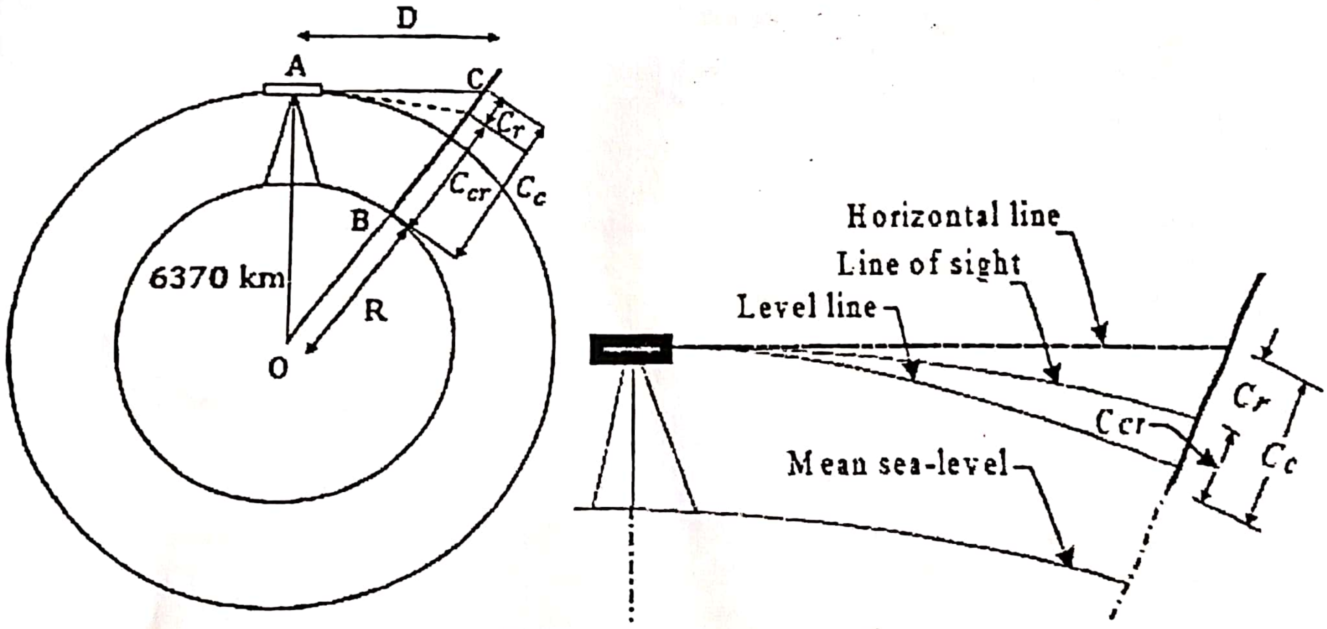


Figure: Curvature correction

$$\text{Curvature correction, } C_c = \frac{D^2}{2R}$$

$$C_c = \frac{D^2 \times 100}{12742} = 0.0785\ D^2 \text{ m (negative)}$$

True staff reading = observed staff reading – curvature correction

Curvature correction is always subtractive.

2. Refraction correction: Rays of light are refracted when they pass through layers of air of varying density. So, when long sights are taken the line of sight is refracted towards the surface of the earth in a curved path. The radius of this curve is seven times that of the earth under normal atmospheric conditions. Due to the effect of refraction, objects appear higher than they really are. But the effect of curvature varies with atmospheric conditions. On an average, the refraction correction is taken as one seventh of the curvature correction.

Refraction correction, $C_r = \frac{1}{7} \times 0.0785\, D^2$ m (positive)

Refraction correction is always additive.

True staff reading = observed staff reading + Refraction correction

3. Combined correction:

Combined correction = Curvature correction + Refraction correction

$= -0.0785\, D^2 + 0.0112\, D^2 = -0.0673\, D^2$

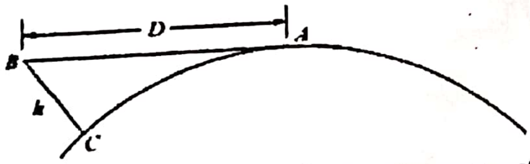
Combined correction is always subtractive.

True staff reading = observed staff reading − combined correction

Actual staff reading = Observed reading + $C_r - C_c$

<u>Visible Horizon Distance</u>

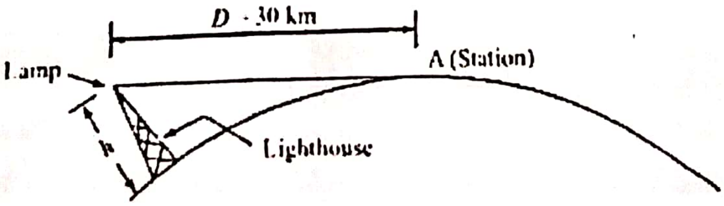
Let, AB = D = visible horizon distance in kilometres
h = height of the point above mean sea level in metres



Considering curvature and refraction corrections, h = $0.0673\, D^2$

$$D = \sqrt{\frac{h}{0.0673}}$$

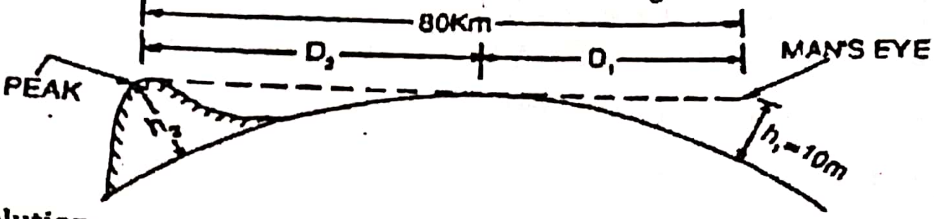
Question: A lamp at the top of a lighthouse is visible just above the horizon from a station at sea level. The distance of the lamp from the station is 30 km. Find the height of the lighthouse.



<u>Solution:</u>

We know, h = $0.0673\, D^2 = 0.0673 \times 30^2 = 60.57$ m
Hence, the height of the lighthouse is 60.57 m

Question: A man at a position 10 m above sea level observes the peak of a hill. The distance between the man and the hill is 80 km. Find the height of the hill.



Solution:

Height of man's eye $h_1 = 10$ m

$$D_1 = \sqrt{\frac{h_1}{0.0673}} = \sqrt{\frac{10}{0.0673}} = 12.19 \text{ km}$$

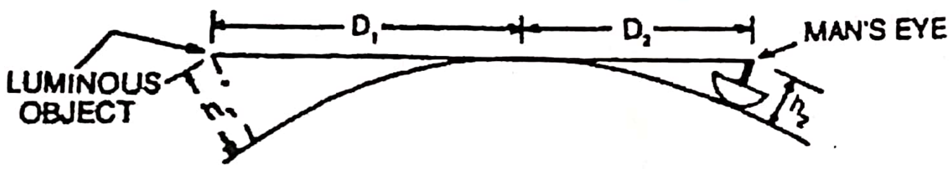
Here, $D_1 + D_2 = 80$ km

$D_2 = 80 - 12.19 = 67.81$ km

Height of the hill, $h_2 = 0.0673 \times D_2^2 = 0.0673 \times 67.81^2 = 309.46$ m

Question: Height of search light from sea level is 150 m and observers eye at 20 m from sea level. Determine the distance between the observer and search light. (BCPCL – 2016)

Solution:



Here, $h_1 = 150$ m and $h_2 = 20$ m

we know, $h = 0.0673\ D^2$

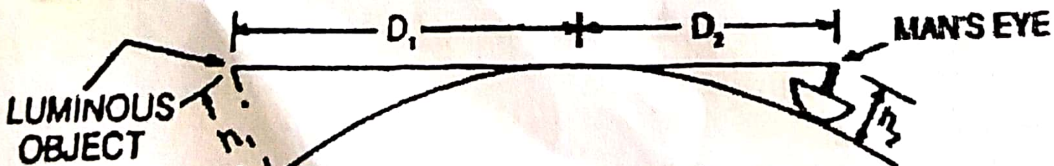
$$D_1 = \sqrt{\frac{h_1}{0.0673}} = \sqrt{\frac{150}{0.0673}} = 47.21 \text{ km}$$

$$D_1 = \sqrt{\frac{h_2}{0.0673}} = \sqrt{\frac{20}{0.0673}} = 17.23 \text{ km}$$

The required distance between them = $D_1 + D_2 = 47.21 + 17.23 = 64.44$ km

Question: A man on the deck of a ship observes the light of a lighthouse which is 150′ above sea level. If the man's eye level is 20′ above sea level. Find the actual distance between them. (SGFCL – 2017)

Solution:



Question: In an operation involving reciprocal levelling, two points A and B are taken on opposite banks of a river. When the level was set up near A, the staff readings on A and B were 2.245 and 3.375 respectively. When the level was set up near B, the respective staff readings were 1.955 and 3.055. Find the true difference of level between A and B. What is the RL of B, if that of A is 125.550?

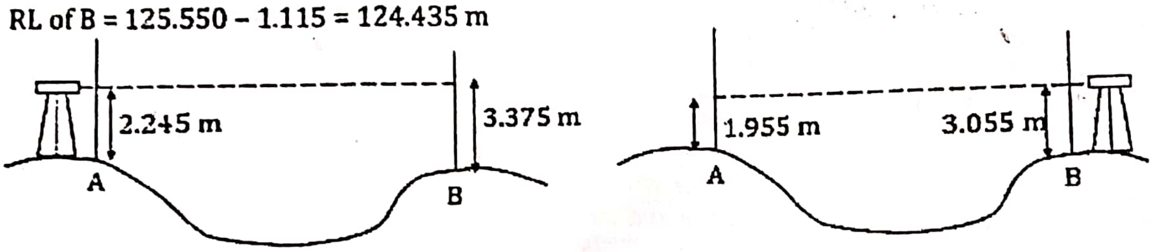
Solution:

In the first setting,
Apparent difference of level between A and B = 3.375 – 2.245 = 1.130 m (Fall from A to B)

In the second setting,
Apparent difference of level between A and B = 3.055 – 1.955 = 1.100 m (Fall from A to B)

$$\text{True difference of level between A and B} = \frac{1.130 + 1.100}{2} = 1.115 \text{ m}$$

RL of B = 125.550 – 1.115 = 124.435 m



Question: In a reciprocal levelling, two points A and B are taken on opposite banks of a river. Two station C and D & their measurement point given. Find out RL of A if the RL of B is 108.82 m. (RPGCL – 2017, BCIC – 2017)

Station	Reading station point	
	A	B
C	6.72	5.86
D	4.96	4.18

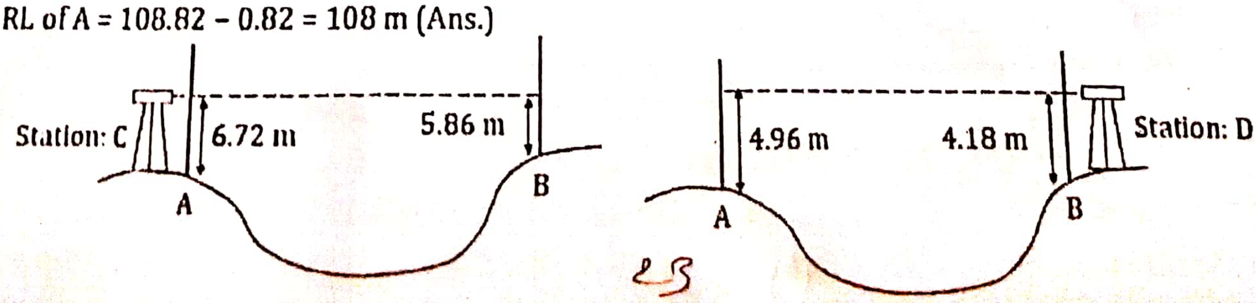
Solution:

When the instrument is at C,
Apparent difference in elevation A and B = 6.72 – 5.86 = 0.86 (B higher)

When the instrument is at D,
Apparent difference in elevation A and B = 4.96 – 4.18 = 0.78 (B higher)

$$\text{True difference of level between A and B} = \frac{0.86 + 0.78}{2} = 0.82 \text{ m}$$

RL of A = 108.82 – 0.82 = 108 m (Ans.)



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Here, h_1 = 150' = 45.73 m and h_2 = 20' = 6.09 m

we know, $h = 0.0673\ D^2$

$$D_1 = \sqrt{\frac{h_1}{0.0673}} = \sqrt{\frac{45.73}{0.0673}} = 26.06 \text{ km}$$

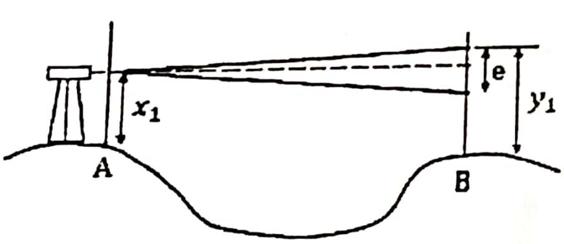
$$D_1 = \sqrt{\frac{h_2}{0.0673}} = \sqrt{\frac{6.09}{0.0673}} = 9.51 \text{ km}$$

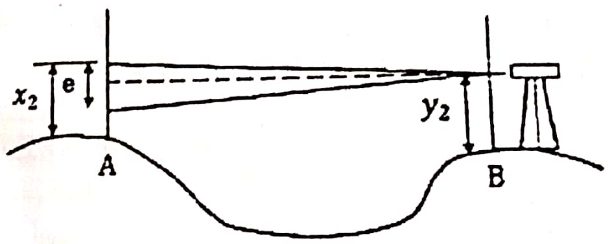
The required distance between them = $D_1 + D_2$ = 26.06 + 9.51 = 35.57 km

Reciprocal Levelling

In reciprocal levelling, the level is set up on both banks of the river or valley and two sets of staff readings are taken by holding the staff on both banks. In this case, it is found that the errors are completely eliminated and the true difference of level is equal to the mean of the two apparent differences of level.

Leveling between two widely separated points in which observations are made in both directions to eliminate the effects of atmospheric refraction and the curvature of the earth.





Let, h = True difference of level between A and B

e = combined error due to curvature, refraction and collimation.

In first case,

Correct staff reading at A = x_1

Correct staff reading at B = $y_1 - e$

True difference of level between A and B, $h = (y_1 - e) - x_1$

In second case,

Correct staff reading at B = y_2

Correct staff reading at A = $x_2 - e$

True difference of level between A and B, $h = y_2 - (x_2 - e)$

Adding both, $2h = (y_1 - e) - x_1 + y_2 - (x_2 - e)$

$$h = \frac{(y_1 - x_1) + (y_2 - x_2)}{2}$$

Question: In a reciprocal leveling find the true elevation of Q if the reduced level of P is 100 m.
(PGCL – 2017, BUET M. Sc – 2019)

Station	Reading station point	
	P	Q
P	3.69	2.48
Q	4.59	3.34

Solution:

When the instrument is at P,
Apparent difference in elevation P and Q = 3.69 – 2.48 = 1.21 (Q higher)
When the instrument is at Q,
Apparent difference in elevation P and Q = 4.59 – 3.34 = 1.25 (Q higher)

True difference of elevation $= \dfrac{1.21 + 1.25}{2} = 1.23$ m (Q higher)

True elevation of Q = 100 + 1.23 = 101.23 m

Question: In a reciprocal levelling, two points A and B are taken on opposite banks of a river. The two station C and D & their measurement point are given below table, find the reduced level of B if the reduced level of A is 108.82 m. (GTCL – 2018)

Station	Reading station point	
	A	B
C	5.79	5.12
D	4.96	4.18

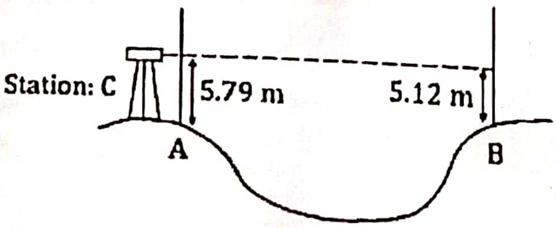
Solution:

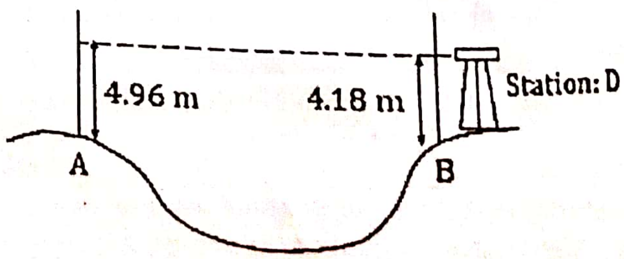
When the instrument is at C,
Apparent difference in elevation A and B = 5.79 – 5.12 = 0.67 (B higher)

When the instrument is at D,
Apparent difference in elevation A and B = 4.96 – 4.18 = 0.78 (B higher)

True difference of elevation $= \dfrac{0.67 + 0.78}{2} = 0.725$ m (B higher)

True elevation of B = 108.82 + 0.725 = 109.54 m



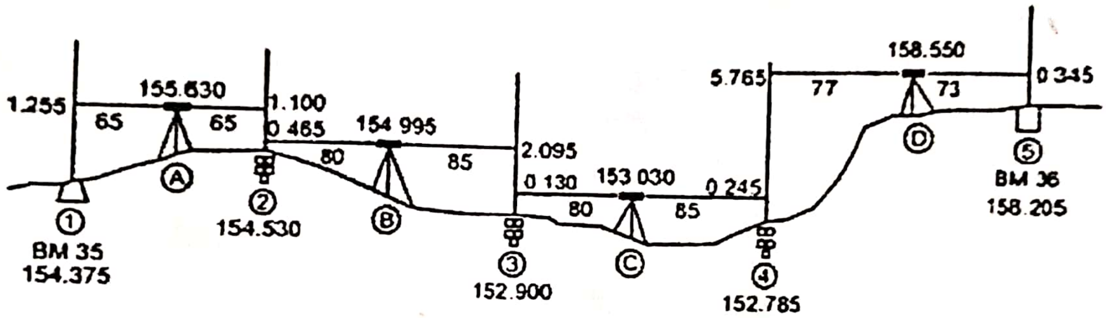


Methods of calculation of reduced level

The following are the two systems of calculating reduced level:
1. The collimation system or height of instrument system (HI)
2. The rise and fall system.

The collimation system: The reduced level of the line of collimation is said to be the height of the instrument. In this system, the height of the line of collimation is found out by adding the backsight reading to the RL of the BM on which the BS is taken. Then the RL of the intermediate points and the change point are obtained by subtracting the respective staff reading from the height of instrument. The level is then shifted for the next setup and again the height of the line of collimation is obtained by adding the backsight reading to the RL of the change point. So the height of the instrument is different in different setups of the level. It should be remembered that, in this system the RLs of unknown points are to be found out by deducting the staff reading from the RL of the height of the instrument.

Arithmetical check: Σ BS $-$ Σ FS = Last RL $-$ 1st RL



The rise and fall system: In this system, the difference of level between two consecutive points is determined by comparing each forward staff reading with the staff reading at the immediately preceding point. If the forward staff reading is smaller than the immediately preceding staff reading, a rise is said to have occurred. The rise is added to the RL of the preceding point to get the RL of the forward point.

If the forward staff reading is greater than the immediately preceding staff reading, it means there has been a fall. The fall is subtracted from the RL of preceding point to get the RL of the forward point.

Arithmetical check: Σ BS $-$ Σ FS = Σ Rise $-$ Σ Fall = Last RL $-$ 1st RL

Collimation system	Rise and Fall system
It is rapid as it involves few calculation.	It is laborious, involving several calculations.
There is no check on the RL of intermediate points.	There is a check on the RL of intermediate points.
Errors in intermediate RLs cannot be detected.	Errors in intermediate RLs can be detected.
There are two checks on the accuracy of RL calculation.	There are three checks on the accuracy of RL calculation.
This system is suitable for longitudinal levelling where there are a number of intermediate sights.	This system is suitable for fly levelling where there are no intermediate sights.

Solution:

Station point	Chainage	BS	IS	FS	Rise (+)	Fall (-)	RL	Remarks
							112.620	
1	0	2.375						
2	20		1.730		0.645		113.265	
3	40		0.615		1.115		114.380	
4	60	2.835		3.450		2.835	111.545	Change
5	80		2.070		0.765		112.310	
6	100		1.835		0.235		112.545	
7	120	0.435		0.985	0.850		113.395	Change
8	140		1.630			1.195	112.200	
9	160		2.255			0.625	111.575	
10	180			3.630		1.375	110.200	On BM
Total =		5.645		8.065	3.610	6.030		

Check:
Σ B.S - Σ F.S = 5.645 – 8.065 = - 2.420
Last R.L – First R.L = 110.200 - 112.620 = - 2.420
Σ Rise – Σ Fall = 3.610 – 6.030 = - 2.420

Question: The following consecutive staff reading was taken using a dumpy level: 0.705, 1.655, 0.890, 3.015 and 1.655. The first reading was taken on a benchmark whose RL is 150.605m. Calculate the reduced levels of the stations by the rise and fall method. (JB-2017)

Solution:

Station	B.S	I.S	F.S	Rise	Fall	R.L
01	0.705					150.605
02		1.655			0.95	149.655
03		0.899		0.756		150.411
04		3.015			2.116	148.295
05			1.655	1.36		149.655

Check:
Σ B.S - Σ F.S = 0.705 – 1.655 = - 0.95
Last R.L – First R.L = 149.655 – 150.605 = - 0.95
Σ Rise – Σ Fall = 2.116 – 3.066 = -0.95

Contour line: A line on a map joining points of equal height above or below sea level is called as contour lines. It can also be defined as a line passing through points of equal reduced levels. For example, a contour of 100 m indicates that all the points on this line have an RL of 100 m.

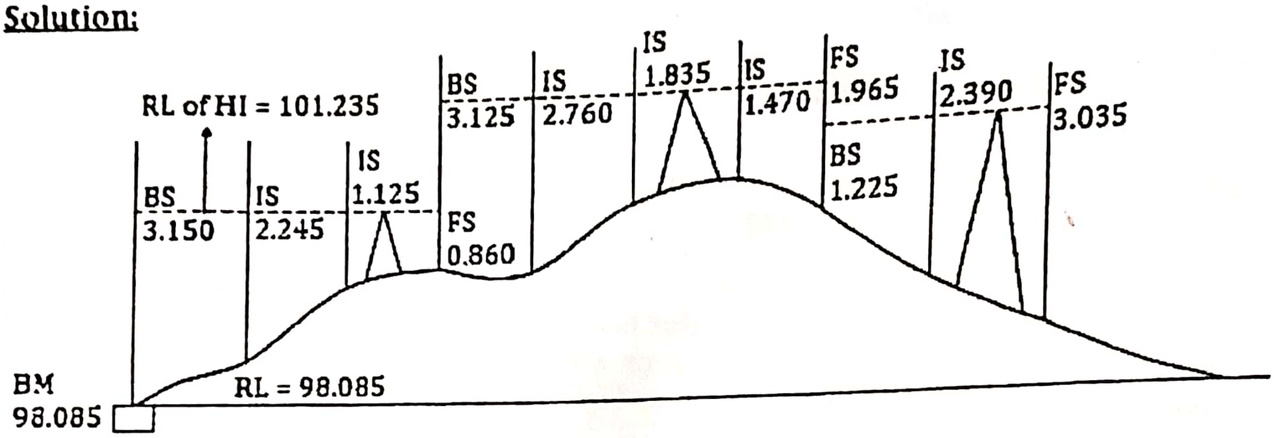
Contour Interval: The vertical distance between any two consecutive contours is known as a contour interval. Suppose a map includes contour lines 100 m, 98 m, 96 m and so on. The contour interval here is 2 m.

Horizontal equivalent: The horizontal distance between any two consecutive contours is known as horizontal equivalent. It is not constant, it varies according to the steepness of the ground. For steel slopes, the contour lines run close together and for flatter slopes they are widely spaced.

Considering the above points, the rise and fall system is always preferred as there is no possibility of error in the calculation of RLs in the intermediate points.

Question: The following consecutive readings were taken with a dumpy level along a chain line at a common interval of 15 m. The first reading was at a chainage of 165 m where the RL is 98.085. The instrument was shifted after the fourth and ninth readings. Find the RL of all points by the collimation system.
3.150, 2.245, 1.125, 0.860, 3.125, 2.760, 1.835, 1.470, 1.965, 1.225, 2.390 and 3.035m.

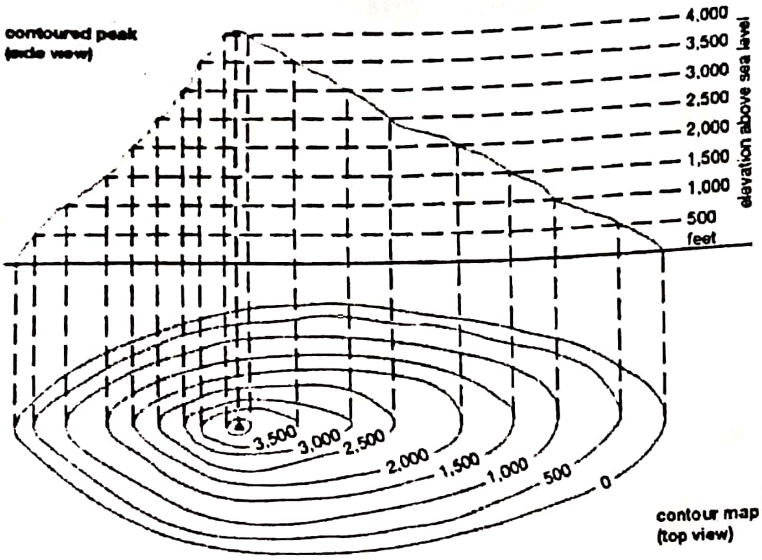
Solution:



Station point	Chainage	BS	IS	FS	RL of collimation line (HL)	RL	Remark
1	165	3.150			101.235	98.085	
2	180		2.245			98.990	
3	195		1.125			100.110	
4	210	3.125		0.860	103.500	100.375	Change point
5	225		2.760			100.740	
6	240		1.835			101.665	
7	255		1.470			102.030	
8	270	1.225		1.965	102.760	101.535	Change point
9	285		2.390			100.370	
10	300			3.035		99.725	
Total =		7.500		5.860			

Check: Σ BS − Σ FS = 7.500 − 5.860 = +1.640
Last RL − 1st RL = 99.725 − 99.085 = +1.640

Question: The following consecutive readings were taken with a levelling instrument at intervals of 20 m. 2.375, 1.730, 0.615, 3.450, 2.835, 2.070, 1.835, 0.985, 0.435, 1.630, 2.255 and 3.630 m. The instrument was shifted after the fourth and eighth readings. The last reading was taken on a BM of RL 110.200 m. Find the RLs of all the points by rise and fall method.



Object of preparing contour map

The general map of a country includes the locations of roads, railways, rivers, villages, towns, and so on. But the nature of the ground surface cannot be realized, from such a map. However, for all engineering projects involving roads, railways, and so on, a knowledge of the nature of ground surface is required for locating suitable alignments and estimating the volume of earth work. Therefore, the contour map is essential for all engineering projects. This is why contour maps are prepared.

Characteristics of Contours

1. Contour lines must close, not necessarily in the limits of the plan.
2. The horizontal distance between any two contour lines indicates the amount of slope and varies inversely on the amount of slope.
3. Widely spaced contour indicates flat surface.
4. Closely spaced contour indicates steep slope ground.
5. Equally spaced contour indicates uniform slope.
6. Irregular contours indicate uneven surface.
7. Approximately concentric closed contours with decreasing values towards centre indicate a pond.
8. Approximately concentric closed contours with increasing values towards centre indicate hills.
9. Contour lines with U-shape with convexity towards lower ground indicate ridge.
10. Contour lines with V-shaped with convexity towards higher ground indicate valley.
11. Contour lines generally do not meet or intersect each other. If contour lines are meeting in some portion, it shows existence of a vertical cliff.
12. Contours of different elevations cannot cross each other. If contour lines cross each other, it shows existence of overhanging cliffs or a cave.

Question: What are the benefits of using contour maps? (BCPCL – 2016)

Solution:

Contour are lines drawn in the map to show the areas with equal altitude from sea level.

- It depict slope and size of different landforms on map.
- By reading contour interval it is easy to determine the different elevation of the landscape.
- It provide the basis for coloring method.
- It can be used in drawing cross section of the given features on the mapped area
- From the contours, it is possible to determine the capacity of a reservoir.

Example of some contours:

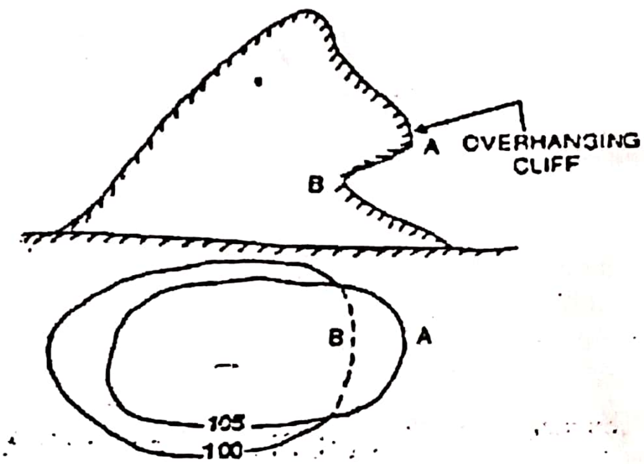


Figure: Overhanging cliff

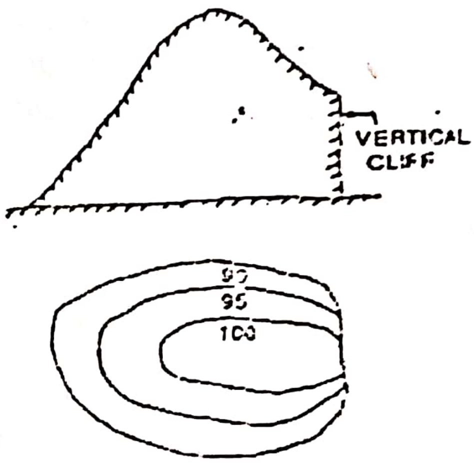


Figure: Vertical cliff

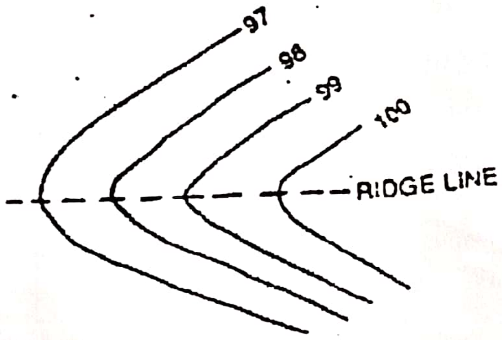


Figure: Ridge line

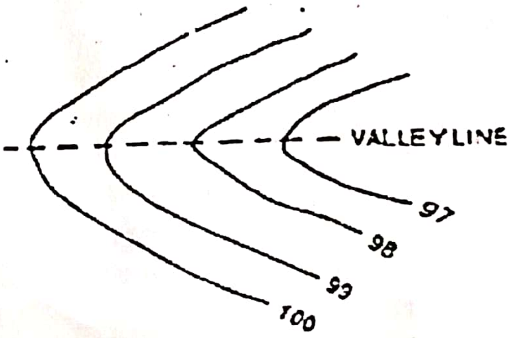
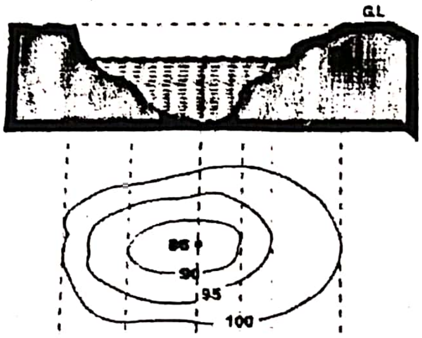


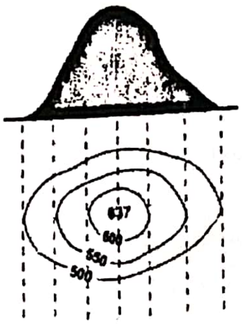
Figure: Valley line

Question: Draw contour map for pond and hill? What are the basic differences to this type of contour? (BEPZA – 2016, RRI – 2015, BUET M.Sc. –2011)

Solution:



Pond and its contour



Hill and its contour

Approximately concentric closed contours with decreasing values towards centre indicate a pond.
Approximately concentric closed contours with increasing values towards centre indicate hills.

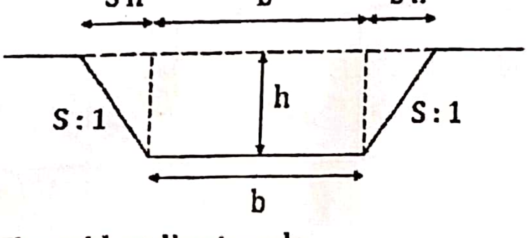
Area and volume calculation

For computation of the volume of earth work, the sectional areas of the cross section which are taken transverse to the longitudinal section during profile levelling are first calculated. Again, the cross-sections may be of different types.

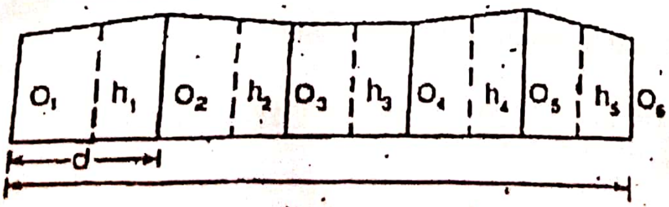
Cutting is deonoted by a positive sign and filling by negative sign.

Formula for calculating of cross sectional area for level section
When the ground is level along the transverse direction.

Cross ectional area $= \frac{b+b+2sh}{2} \times h = (b+sh)\,h$



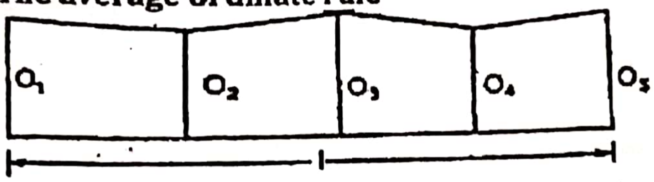
The mid-ordinate rule



Let, $O_1, O_2, \ldots O_n$ = ordinates at equal intervals
l = length of base line

$d =$ common distance between ordinates
$h_1, h_2 \dots h_n$ = mid ordinates
Area of plot $= h_1 \times d + h_2 \times d + \cdots + h_n \times d = d\,(h_1 + h_2 + \cdots + h_n)$
Area = common distance x sum of mid ordinates

The average ordinate rule

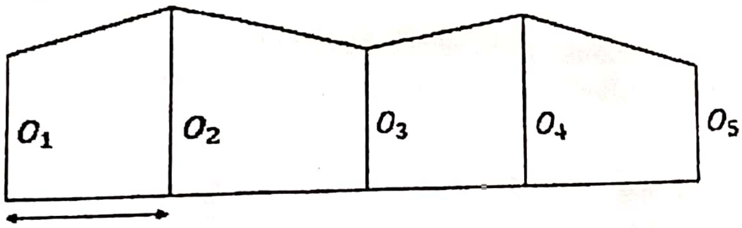


Let, $O_1, O_2, \dots . O_n$ = ordinates at equal intervals
l = length of base line
n = number of divisions
$n+1$ = number of ordinates

$$1\text{st area} = \frac{O_1 + O_2 + \ldots + O_n}{O_{n+1}} \times l$$

$$\text{Area} = \frac{\text{sum of ordinates}}{\text{no. of ordinates}} \times \text{length of base line}$$

Trapezoidal rule



Let, $O_1, O_2, \dots . O_n$ = ordinates at equal intervals
d = common distance

$$1\text{st area} = \frac{O_1 + O_2}{2} \times d$$

$$2\text{nd area} = \frac{O_2 + O_3}{2} \times d$$

$$3\text{rd area} = \frac{O_3 + O_4}{2} \times d$$

$$\text{Last area} = \frac{O_{n-1} + O_n}{2} \times d$$

$$\text{Total area} = \frac{d}{2}\,(O_1 + 2\,O_1 + 2\,O_2 + \ldots . + 2O_{n-1} + O_n)$$

$$\text{Total area} = \frac{\text{common distance}}{2}\,\{1\text{st ordinate} + \text{last ordinate} + 2\,(\text{sum of other ordinate})\}$$

Simpson's rule

$$\text{Total area} = \frac{d}{3}\,(O_1 + 4\,O_2 + 2\,O_3 + 4\,O_4 + 2\,O_5 + \ldots . . + O_n)$$

$$= \frac{d}{3}\,\{O_1 + O_n + 4(O_2 + O_4 + \ldots .) + 2\,(O_3 + O_5 + \ldots .)\}$$

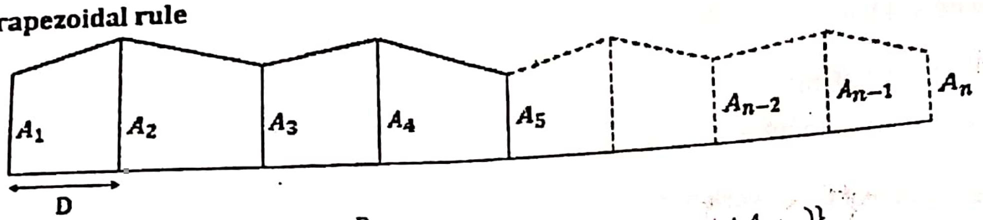
Total area = $\frac{\text{common distance}}{3}$ {1st ordinate + last ordinate + 4 (sum of even ordinate) + 2 (sum of odd ordinate)}

Limitation: This rule is applicable only when the number divisions is even, i.e. the number of ordinate is odd.

Notes: The prismoidal rule gives the correct volume directly.

<u>Formula for calculation of volume</u>

Trapezoidal rule



Volume (cutting or filling), $V = \frac{D}{2}\{A_1 + A_n + 2(A_2 + A_3 + \ldots + A_{n-1})\}$

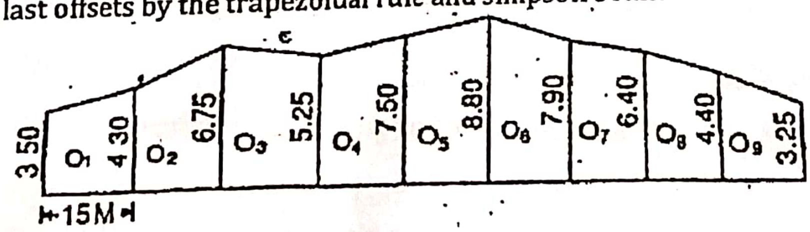
Volume = $\frac{\text{common distance}}{2}$ {Area of 1st section + area of last section + 2 (sum of area of other sections)}

Simpson's rule

Volume (cutting or filling), $V = \frac{D}{3}\{A_1 + A_n + 4(A_2 + A_4 + \ldots) + 2(A_3 + A_5 + \ldots)\}$

Total area = $\frac{\text{common distance}}{3}$ {Area of 1st section + area of last section + 4 (sum of areas of even sections) + 2 (sum of areas of odd sections)}

Question: The following offsets were taken at 15 m intervals from a survey line to an irregular boundary line: 3.50, 4.30, 6.75, 5.25, 7.50, 8.80, 7.90, 6.40, 4.40, 3.25 m
Calculate the area enclosed between the survey line, the irregular boundary line and the first and last offsets by the trapezoidal rule and simpson's rule.



<u>Solution:</u>

By trapezoidal rule:

$$\text{Area, } A = \frac{15}{2}\{3.50 + 3.25 + 2(4.30 + 6.75 + 5.25 + 7.50 + 8.80 + 7.90 + 6.40 + 4.40)\}$$

$$A = \frac{15}{2}\{6.75 + 102.60\} = 1820.125 \text{ m}^2$$

By simpson's rule:

If this rule is to be applied, the number of ordinates must be odd. But here the number of ordinate is even (ten). So, simpson's rule is applied from O_1 to O_9 and the area between O_9 and O_{10} is found out by the trapezoidal rule.

Total area, $A_1 = \frac{15}{3}\{3.50 + 4.40 + 4(4.30 + 5.25 + 8.80 + 6.40) + 2\,(6.75 + 7.50 + 7.90)\}$

$A_1 = \frac{15}{3}\{7.90 + 99.00 + 44.30\} = 756.00\ m^2$

$A_2 = \frac{15}{2}\{4.40 + 3.25\} = 57.38\ m^2$

Total area $= A_1 + A_2 = 756 + 57.38 = 813.38\ m^2$

Question: Calculate volume of earthwork necessary for a portion of an irrigation canal from the following data by trapezoidal rule. (DTCA – 2018, BB AD – 2018, BWDB – 2019)

Chainage (ft)	0	100	200	300	400	500
Area (ft^2)	850	875	860	855	860	865

Solution:

Volume, $V = \frac{D}{2}\{A_1 + A_6 + 2\,(A_2 + A_3 + A_4 + A_5)\}$

$V = \frac{100}{2}\{850 + 865 + 2\,(875 + 860 + 855 + 860)\} = 430750$ cft

Question: Calculate volume of road embankment by trapezoidal rule. (BCIC – 2019)

Interval (ft)	100	200	300	400	500
Area (ft^2)	10	25	30	50	60

Solution:

Volume, $V = \frac{D}{2}\{A_1 + A_5 + 2\,(A_2 + A_3 + A_4)\}$

$V = \frac{100}{2}\{10 + 60 + 2\,(25 + 30 + 50)\} = 14000$ cft

Question: An embankment of width 25 ft and side slopes 2.5H : 1V is required to be made on a ground which is level in a direction transverse to the centre line. Calculate the volume of earth work. The ground level along the centre line of the embankment is given below.

Chainage (ft):	0	80	200
GL (ft):	21	18	16

(SGFL – 2017, BGFCL – 2017)

Solution:

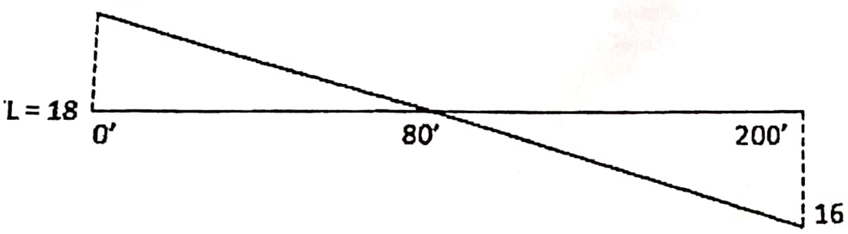
Chainage	GL	FL	Cutting (+)	Filling (–)
0	21	18	3	0
80'	18	18	0	0
200'	16	18	0	2

Area of cutting $= (25 + 2.5 \times 3) \times 3 = 97.5 \text{ ft}^2$

Area of filling $= (25 + 2.5 \times 2) \times 2 = 60 \text{ ft}^2$

$$\text{Volume of cutting} = \frac{97.5 + 0}{2} \times 80 = 3900 \text{ ft}^3$$

$$\text{Volume of filling} = \frac{60 + 0}{2} \times (200 - 80) = 3600 \text{ ft}^3$$



Question: An embankment of width 10 m and side slopes 1.5:1 is required to be made on a ground which is level in a direction transverse to the centre line. The central heights at 40 m intervals are as follows: 0.90, 1.25, 2.15, 2.50, 1.85, 1.35 and 0.85

Calculate the volume of earth work according to the trapezoidal and prismoidal formula.

Solution:

Area is calculated according to the equation, $A = (b + s\,h)\,h$

$$A_1 = (10 + 1.5 \times 0.90) \times 0.90 = 10.22 \text{ m}^2$$
$$A_2 = (10 + 1.5 \times 1.25) \times 1.25 = 14.84 \text{ m}^2$$
$$A_3 = (10 + 1.5 \times 2.15) \times 2.15 = 28.43 \text{ m}^2$$
$$A_4 = (10 + 1.5 \times 2.50) \times 2.50 = 34.38 \text{ m}^2$$
$$A_5 = (10 + 1.5 \times 1.85) \times 1.85 = 23.63 \text{ m}^2$$
$$A_6 = (10 + 1.5 \times 1.35) \times 1.35 = 16.23 \text{ m}^2$$
$$A_7 = (10 + 1.5 \times 0.85) \times 0.85 = 9.58 \text{ m}^2$$

Calculation of volume by trapezoidal formula

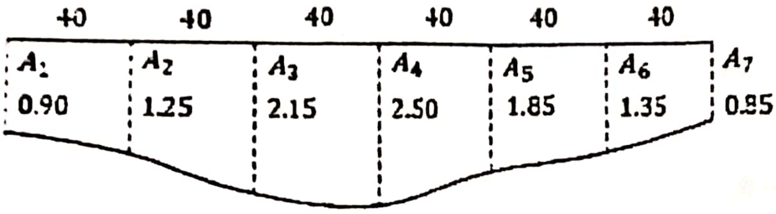
Volume, $V = \frac{D}{2}\{A_1 + A_7 + 2(A_2 + A_3 + A_4 + A_5 + A_6)\}$

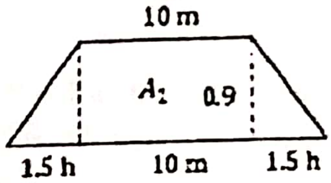
$V = \frac{40}{2}\{10.22 + 9.58 + 2(14.84 + 28.43 + 34.38 + 23.63 + 16.23)\} = 5096.4\ m^3$

Calculation of volume by prismoidal formula

Volume, $V = \frac{D}{3}\{A_1 + A_7 + 4(A_2 + A_4 + A_6) + 2(A_3 + A_5)\}$

$V = \frac{40}{3}\{10.22 + 9.58 + 4(14.84 + 34.38 + 16.23) + 2(28.43 + 23.63)\} = 5142.9\ m^3$





Question: The ground level along the centre line of a road is given below.

Chainage (m):	0	50	100	150	200	250	300
GL (m):	117.50	116.25	115.95	116.65	117.20	117.85	115.75

It is proposed that the formation level of RL 115.00 should be kept constant of starting from the chainage zero. The formation width of the road is 8 m and the side slope 1:1. The ground is level transverse to the centre line.

<u>Solution:</u>

Chaimage	GL	FL	Cutting
0	117.50	115.00	2.50
50	116.25	115.00	1.25
100	115.95	115.00	0.95
150	116.65	115.00	1.65
200	117.20	115.00	2.20
250	117.85	115.00	2.85
300	115.75	115.00	0.75

Area is calculated according to the equation, $A = (b + s\,h)\,h$

$A_1 = (8 + 1 \times 2.50) \times 2.50 = 16.25\ m^2$

$A_2 = (8 + 1 \times 1.25) \times 1.25 = 11.56\ m^2$

$A_3 = (8 + 1 \times 0.95) \times 0.95 = 8.50\ m^2$

$A_4 = (8 + 1 \times 1.65) \times 1.65 = 15.92\ m^2$

$A_5 = (8 + 1 \times 2.20) \times 2.20 = 22.44\ m^2$

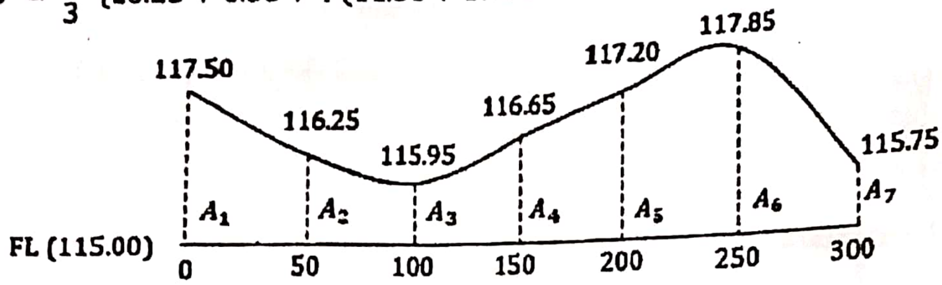
$A_6 = (8 + 1 \times 2.85) \times 2.85 = 30.92\ m^2$

$A_7 = (8 + 1 \times 0.75) \times 0.75 = 6.56\ m^2$

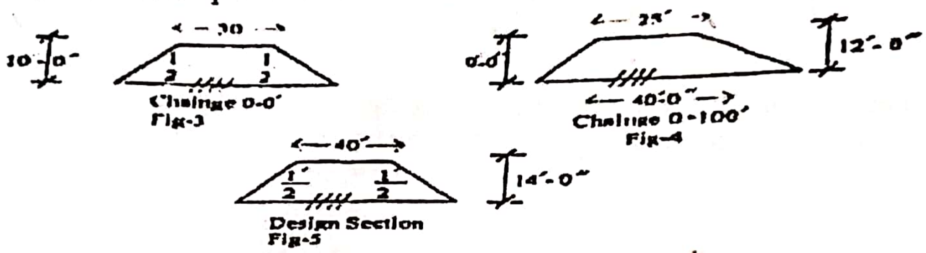
Calculation of volume by prismoidal formula

$$\text{Volume, } V = \frac{D}{3}\{A_1 + A_7 + 4(A_2 + A_4 + A_6) + 2(A_3 + A_5)\}$$

$$V = \frac{50}{3}\{26.25 + 6.56 + 4(11.56 + 15.92 + 30.92) + 2(8.50 + 22.44)\} = 5471.5 \text{ m}^3$$



Question: Figure 3 & 4 represents two highway cross section (pre work) 100 ft a part. Compute the volume of earth work to be required for the design of the section (fig 3, 4, 5) (EED – 2019)



Solution:

Area is calculated according to the equation, $A = (b + s\,h)\,h$

$A_3 = (30 + 2 \times 10) \times 10 = 500 \text{ ft}^2$

$$A_4 = \frac{(40 + 25) \times 9}{2} + \frac{1}{2} \times 25 \times 3 = 330 \text{ ft}^2$$

$A_5 = (40 + 2 \times 14) \times 14 = 952 \text{ ft}^2$

$$\text{Pre – work volume, } V = \frac{A_3 + A_4}{2} \times L = \frac{500 + 330}{2} \times 100 = 41500 \text{ ft}^3$$

Post work volume, $V = 952 \times 100 = 95200 \text{ ft}^3$

Volume of eart work $= 95200 - 41500 = 53700 \text{ ft}^3$

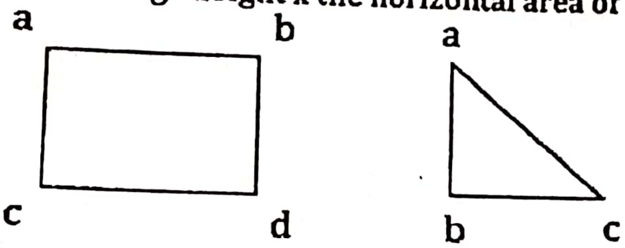
Volume from spot levels

In this method, the field work consists in dividing the area into a member of squares, rectangles or triangles and measuring the levels of their corners before after the construction. Thus, the depth of excavation or height of filling at every corner is known. Let us assume that the four corners of any one square or rectangle are at different elevations but lie in the same inclined plane.

Let us consider the rectangle abcd of figure. If h_a, h_b, h_c and h_d represent the depth of excavation of the four corners, the volume of the rectangle,

$$V = \left(\frac{h_a + h_b + h_c + h_d}{4}\right) A$$

V = average height x the horizontal area of the rectangle



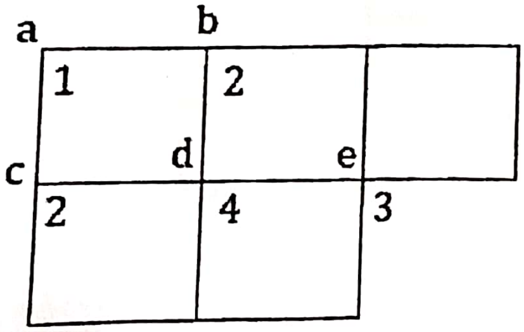
Similarly, Let us consider the triangle abc of figure. If h_a, h_b and h_c represent the depth of excavation of the three corners, the volume of the triangular,

$$V = \left(\frac{h_a + h_b + h_c}{3}\right) A$$

V = average height x the horizontal area of the triangle

Volume of a group of rectangles or squares having the same area

Let us now consider a group of rectangle of the same area, arranges as shown in figure. It will be seen by inspection that some of the heights are used once only, some heights are common to two rectangles (such as at b), some heights are common to three rectangles (such as at d) and some heights are common to four rectangles (such as at e).



$1\,\Sigma h_1$ = the sum of the heights used once.

$2\,\Sigma h_2$ = the sum of the heights used twice.

$3\,\Sigma h_3$ = the sum of the heights used thrice.

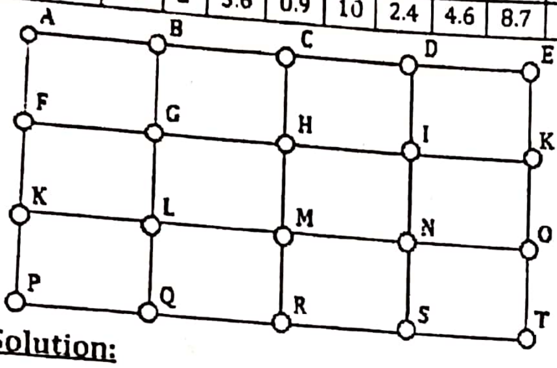
$4\,\Sigma h_4$ = the sum of the heights used four times.

A = horizontal area of the cross – section

Total volume, $V = \frac{A}{4}(1\,\Sigma h_1 + 2\,\Sigma h_2 + 3\,\Sigma h_3 + 4\,\Sigma h_4)$

Question: The area of land is 400 m x 200 m and reduced level at different point in the land is below table which is shown in figure. Determine the earth filling work? (PMO – 2015)

Point	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
RL	08	2	3.6	0.9	10	2.4	4.6	8.7	1	0.2	12	5.4	5	7.9	2.3	0.23	0	3.6	11	7



Solution:

Area of each rectangle = 100 x 66.66 = 6666 m²

Volume, $V = \frac{A}{4}(1\Sigma h_1 + 2\Sigma h_2 + 3\Sigma h_3 + 4\Sigma h_4)$

$1\Sigma h_1 = 1\,(0.8 + 10 + 0.23 + 7) = 18.03$ m

$2\Sigma h_2 = 2\,(2.4 + 12 + 0.2 + 2.3 + 2 + 3.6 + 0.9 + 0 + 3.6 + 11) = 76$ m

$3\Sigma h_3 = 0$

$4\Sigma h_4 = 4\,(4.6 + 8.7 + 1 + 5.4 + 5 + 7.9) = 130.4$ m

$$\text{Volume, } V = \frac{6666}{4}(0 + 4.6 + 18.03 + 76 + 130.4) = 374012.59 \text{ m}^3$$

Question: For aerial photography determine number of flight lines from the following data, Area = 16 miles x 20 miles, focal length = 12", photograph size = 9" x 9", photograph scale = 1:10000, overlap = 60%, side lap = 25%, flight lines in the direction of 20 miles and the outer lines coincide with the boundaries. (PGCB – 2015)

Solution:

Equivalent ground distance of photo-format, $S = 10{,}000 \times \frac{9}{12} = 7500$ ft

Distance between flight line, $D_f = S\,(1 - \text{side lap}) = 7500\,(1 - 0.25) = 5625$ ft

As flight is in the direction of 20 miles,

$$\text{No. of flight lines} = \frac{L}{D_f} + 1 = \frac{16 \times 5280}{5625} + 1 = 16.02 = 17 \text{ flights}$$

Question: Total Station Survey কী? এই পদ্ধতিতে কী কী করা হয়? (HED – 2017)

Solution:

A total station (TS) or total station theodolite (TST) is an electronic/optical instrument used for surveying and building construction. It is an electronic transit theodolite integrated with electronic distance measurement (EDM) to measure both vertical and horizontal angles and the slope distance from the instrument to a particular point, and an on-board computer to collect data and perform triangulation calculations.

Functions Performed By Total Stations

- To measure horizontal and vertical angles.
- To obtain the horizontal distance, inclined distance and vertical distance between these points.
- To get the three-dimensional co-ordinates i.e. [x, y, z] of a point in space.
- To find the length of a missing the line.
- Plotting of contours
- Illustration of detailed maps
- Carrying out controlled surveys
- Correcting electronically measured distances from prism constant, atmospheric pressure, and temperature.
- Making curvature and refraction corrections to elevations determine by trigonometric levelling.