MUhy
090092

Astronomical surveying

Celestial Sphere: An imaginary sphere of infinite radius with the earth at its centre and other celestial bodies studded on its inside surface is known as celestial sphere.

Terrestrial Sphere: The terrestrial sphere is a concept derived from Greek astronomy and is supposedly the region of space from the earth to the moon, consisting of the four classical elements: earth, water, air and fire.

Great circle divides the sphere in two equal hemispheres.

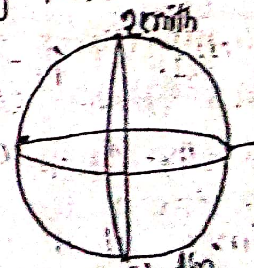
Great Circle: (G.C): The imaginary line of intersection of an infinite plane, passing through the centre of the earth and the circumference of the celestial sphere is known as Great circle.

Terrestrial Poles: The terrestrial poles are the two points in which the earth's axis of rotation meets the earth's sphere.

Celestial poles: If the earth's axis of rotation is produced indefinitely, it will meet the celestial sphere in two points called the north and south celestial poles.

Terrestrial equator: The terrestrial equator is the great circle, the plan of which is at right angles to the axis of the earth, the plan of rotation. The two poles are equidistant from it.

Celestial Equator: The celestial equator is the great circle of the celestial sphere in which it is represented by intersection of the plane of terrestrial equator.



Zenith: Zenith is the point on the upper portion of celestial sphere above the observer.

Nadir: Nadir is the point on the lower portion of celestial sphere below the observer.

Horizon always perpendicular to the Zenith Nadir line.

Altitude (α) The altitude of celestial or heavenly body is its distance above the horizon, measured in the vertical circle to the body.

Lattitude: It is the angular distance of any place on the earth's surface north or south of the equator and is measured on the meridian of the place. It is marked + or − or N or S according as the place of north or south of the equator. The lattitude may also be defined as the angle between the zenith and the celestial sphere. It is denoted by θ. **Co-lattitude** The co-lattitude of a place is the angular distance from the zenith to the pole. It is the complement of the lattitude and equal to $(90°-\theta)$

Longitude: The longitude of a place is the angle between a fixed reference meridian called the prime or first meridian and the meridian of the place. The prime meridian universally adopted is that of Greenwich. The longitude of any place varies between 0° to 180°, and is marked by $\phi°$ east or west of Greenwich.

Problem Difference in longitude between two place of A and B

A = 20° E

B = 15° W

East	− (+)	Longitude
West	− (−)	

Solution Given $\phi_1 = +20°$

$\phi_2 = -15°$

N − (+) > Lattitude
S − (−)

Difference in longitude between A and B

$$\phi_1 - \phi_2 = 20 - (-15) = \boxed{35°}$$

Problem $\phi_1 = 40°E$, $\phi_2 = 150°W$

$$\phi_1 - \phi_2 = 40° - (-150°) = 190°$$

Since it is greater than 180°. it represents the obtuse angular difference. The acute angular difference between A and B is equal to $(360° - 190°) = 170°$.

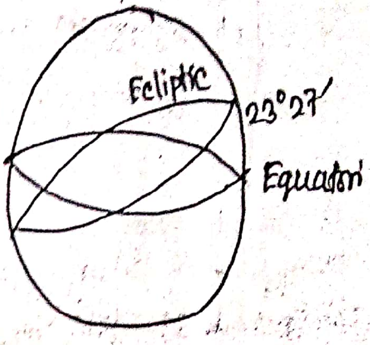
Observer's meridian

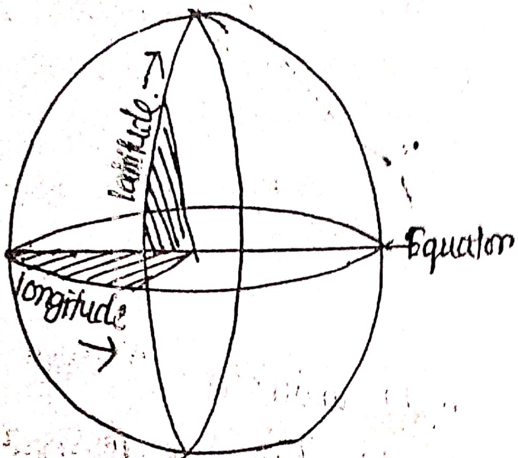
The meridian of any particular point is that circle which passes through the zenith and Nadir of the point as well as through the poles. It is thus a vertical circle.

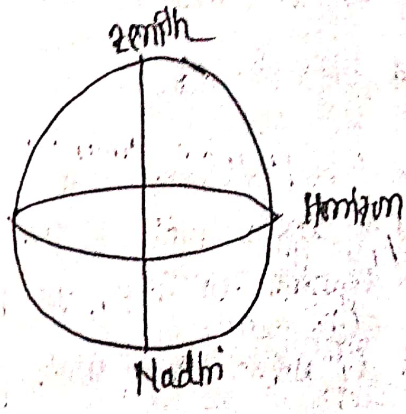
Ecliptic is a great circle of heavens.

Obliquity of Ecliptic

The angle in which the plane of the ecliptic is inclined to the plane of the equator is called obliquity of Ecliptic. The angle is about $\boxed{23^\circ 27'}$.







The Nautical mile

A nautical mile is equal to the distance on arc of the great circle corresponding to angle of 1 minute subtended by the arc at the centre of the earth.

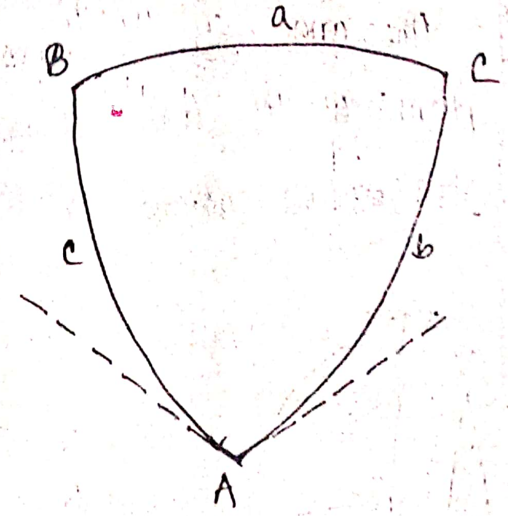
Radius of earth = 6370 km

$$\text{One nautical mile} = \frac{\text{Circumference of the great circle}}{360^\circ \times 60}$$

$$= \frac{2\pi \times 6370}{360 \times 60} = 1.852\ \text{km}.$$

Spherical triangle

A spherical triangle is that triangle which is formed upon the surface of the sphere by intersection of three arcs of great circles and the angle formed by the arcs at the vertices of the triangle are called the **spherical triangle**.



Properties of spherical triangle

(I) Any angle is less than two right angles or π

(II) The sum of three angles is less than six right angles or 3π and greater than two right angles or π.

(III) The sum of any two sides is greater than the third.

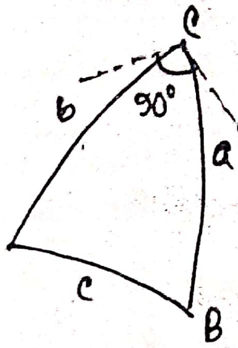
(IV) If the sum of any two sides is equal to two right angles or π, the sum of the angles opposite them is equal to two right angles or π.

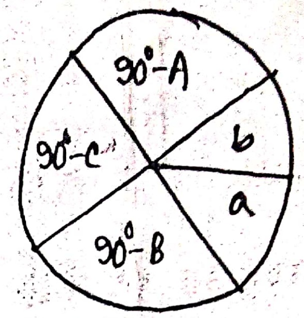
(V) The smaller angle is opposite the smaller side and vice versa.

pier Rule

olution of Right angled spherical triangle

let ABC be a spherical triangle, right angled at C. Napier defines the
rcular part as follows.





(I) the side a to one side of the right angle

(II) The side b to other side of right angle.

(III) The complement $(90°-A)$ of the angle A

(IV) The complement $(90°-c)$ of the side c

(V) The complement $(90°-B)$ of the angle B.

Napier rule

sine of middle part = product of tangent of adjacent part.

sine of middle part = product of cosine of opposite part

Thus;

$$\sin b = \tan a \tan(90°-A)$$

$$\sin b = \cos(90°-B)\cos(90°-c)$$

Sidereal time

The sidereal day is the interval of time between two successive upper transits of the first point of Aries.

Solar Apparent Time

A solar day is the interval of time that elapses between two successive lower transits of the sun's centres over the meridian of the place. The lower transit is chosen in order that the date may change at mid-night. The solar time at any instant is the hour angle of the sun's centre reckoned westward from 0^h to 24^h. This is called the **apparent solar time**

Mean Solar Time

The mean solar day may be defined as the interval between successive transit of the mean sun. The mean solar day may be defined as the interval between successive transit of the mean sun. The mean solar day is the average of all the apparent solar days of the year.

Equation of time = Apparent solar time − Mean solar time.

Standard Time

In order to avoid confusion arising from the use of different local mean time it is necessary to adopt the mean time on a particular meridian as the standard time for the whole of the country.

For places East of the standard meridian, local mean time is later (greater) than standard time.

For places West of the standard meridian, local mean time is earlier. (lesser).

Civil Time	universal time ⇒	Astronomical time
0 hr − 15 min − 30 sec PM		0 hr − 15 min − 30 sec
0 hr − 15 min − 30 sec PM		12 hr − 15 min − 30 sec.

The Earth: The Earth is considered approximately spherical in shape. But actually it is very approximately an oblate spheroid. The earth is flattened at poles- its diameter along the polar axis being lesser than its diameter at the equator. The diameter along the polar axis is 6357 km and the diameter at the equator is 6378 km.

The sun: The sun is at a distance of 93005000 miles from the earth. The distance is only about $\frac{1}{250000}$ of that of the nearest star. The diameter of the sun is about 109 times the diameter of the earth. The mass of the sun is about 332050 times that of the earth. The temperature at the centre of the sun is computed to be about 20 million degrees.

Measurement of time

Time is the interval which lapses between any two instants.

G.M.T. = Greenwich Mean Time

G.A.T = Greenwich Apparent Time

L.A.N = Local Apparent Noon

L.Std.T = Local Standard Time.

L.M.T = Local Mean Time

L.A.T = Local Apparent Time.

L.S.T = Local Sidereal Time

L.M.M = Local Mean Midnight

AM = Antimeridian
PM = Postmeridian

$\boxed{360^\circ = 24\,hr}$

$1\,hr = \frac{360}{24} = \boxed{15^\circ}$

$1\,min = \frac{15 \times 60}{60} = \boxed{15'}$

$1\,sec = \frac{15 \times 60}{60} = \boxed{15''}$

$1^\circ = \frac{24 \times 60}{360} = \boxed{4\,min}$

Units of Time

There are the following systems used for measuring time

(i) Sideral Time

(ii) Solar Apparent Time

(iii) Mean solar time

(iv) Standard Time.

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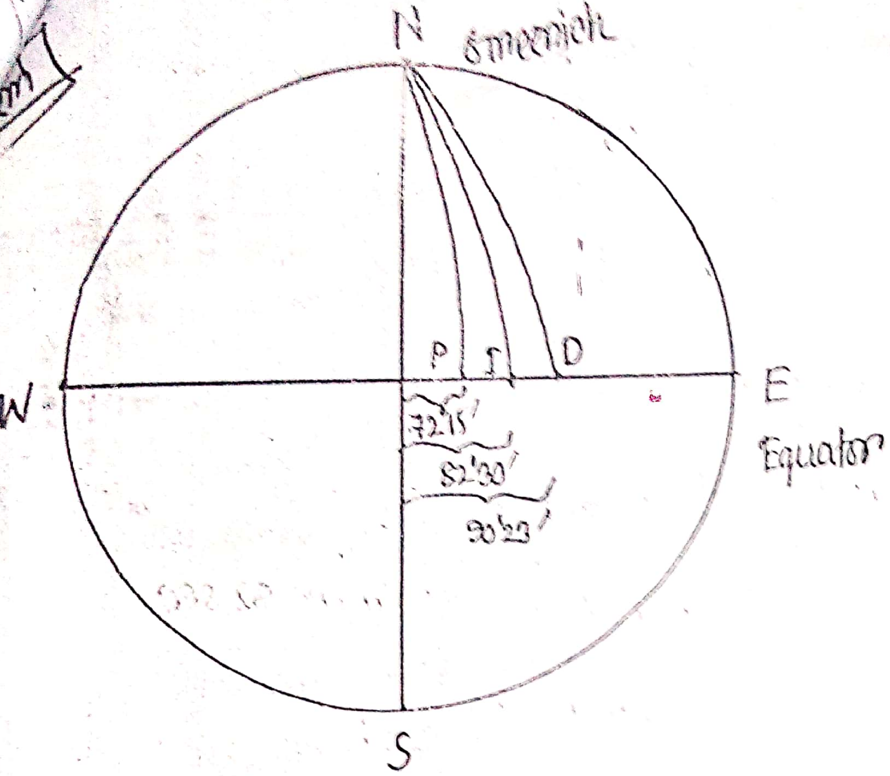
Civil Time (universal time ⇒)	Astronomical time
0 hr − 15 min − 30 sec AM	0 hr − 15 min − 30 sec
0 hr − 15 min − 30 sec PM	12 hr − 15 min − 30 sec



WS - longitude
NS = lattitude

Parallel lattitude same
But different longitude

P = longitude 72°15' E
L = longitude 82°30' E
D = longitude 90°23' E

India র standard time 20hr 24m 6sec হলে Pakistan এবং Dhaka র সময়

India = 20hr 24m 6sec (Astronomical time)
= 8hr 24m 6sec PM (civil time)

$360° = 24 hr$
$1° = \frac{24 \times 60}{360}$
$= \boxed{4 min}$

Difference in longitude = 82°30' − 72°15'
= 10°15'

$1 hr = 15°$
$1 min = 15'$
$1 sec = 15''$

$10° = \frac{10°}{15} = 0^h 40^m 0^s$

$15' = 1 min$

$10°15' = 41^m$

Time at Pakistan = 8hr 24m 6sec − $0^h 41^m 0^s$
= $\boxed{7 hr\ 43 min\ 6 sec}$

Difference in longitude $= 90°23' - 82°30'$
$= 7°53'$

$7° = \frac{7°}{15} = 0hr\ 28m\ 0s$

$53' = 3min\ 32sec$

$7°53' = 31min\ 32sec.$

Time at Dhaka = 8hr 24min 6sec + 31min 32sec
= $\boxed{8hr\ 55min\ 38sec}$

$\boxed{\text{convert to hour, } \cancel{\text{degree}}\text{, minute second.}}$

$\boxed{50°12'48''} =$

$50° = \frac{50°}{15} = 3hr\ 20min\ 0sec$

$12' = \frac{12'}{15} = 0min\ 48sec$

$48'' = \frac{48''}{15} = 3.2sec$

$\boxed{50°12'48'' = 3hr\ 20min\ 51.2sec}$

$\boxed{4hr\ 34min\ 13sec}$

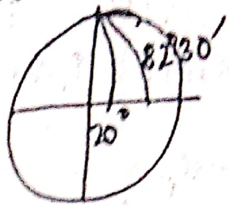
$\boxed{15°}$ — 4hr = $4 \times 15 = \cancel{60°}$ $60°0'0''$

$\boxed{0°15'}$ — 34min = $34 \times 15' = 8°30'$

$\boxed{0°0'15''}$ — 13sec = $13 \times 15'' = 0°3'15''$

$\boxed{68°33'15''}$

The standard time meridian in India is 82°30′E. If the standard time at any instant is 20 hours 24 minutes 6 sec. Find the local mean time for two places having longitudes a) 20°E b) 20°W



solution

(a) Difference in longitude $= 82°30' - 20°$
$= 62°30'$

20 hr 24 m 6 sec (Astro)
= 8 hr 24 m 6 sec PM (C.T)

$62° = \frac{62°}{15} = 4^{hr}\ 8^{min}\ 0\,sec$

$30' = \frac{30'}{15} = 2\ min$

$62°30' = \boxed{4\ hr\ 10\ min\ 0\ sec.}$

S.T থেকে যেদিকে যাবো

East এ হলে যোগ
West এ হলে বিয়োগ

LMT = Standard time ± Longitude (E/W)

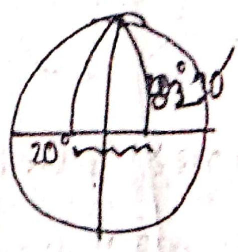
East হলে (+)
West হলে (−)

~~LMT = ~~ ~~standard time~~

L.M.T = 8 hr 24 m 6 sec − 4 hr 10 min 0 sec

$= \boxed{4\ hr\ 14\ min\ 6\ sec\ PM}$

(b) Difference in longitude $= 82°30' + 20°$
$= 102°30'$



The meridian is $\boxed{west}$ to the standard meridian.

LMT = 8 hr 24 m 6 sec − 6 hr 50 min 0 sec

$= \boxed{1\ hr\ 34\ min\ 6\ sec.\ PM}$

102° = 6 hr 48 min 0 sec

30′ = 2 min

$102°30' = \boxed{6\ hr\ 50\ min\ 0\ sec}$

Example

Find the G.M.T corresponding to following L.M.T.

(a) 9hr 40min 12sec AM at a place in longitude 42° 36' W

(b) 4hr 32min 10sec AM at a place in longitude 56° 32' E

$$\boxed{GMT = LMT \pm longitude \left(\frac{W}{E}\right)}$$

West (+)

East (−)

(a) $\boxed{42° 36'}$ 42° = 2hr 48min 0sec

36' = 2min 24sec

42° 36' = $\boxed{\text{2hr 50min 24sec.}}$

GMT = ~~9hr 40min 12 sec~~ L.M.T + longitude (W)

= 9hr 40min 12sec + 2hr 50min 24sec

= 12hr 30min 36 sec.

= $\boxed{\text{0hr 30min 36sec}}$ PM

(b) 56° 32' 56° = 3hr 44min 0sec 32' = 2min 8sec

56° 32' = 3hr 46min 8sec

GM.T = LM.T − longitude (E)

= ~~9hr 40min 12sec~~ ~~− 3hr 46min 8sec~~

= 4hr 32min 10sec − 3hr 46min 8sec

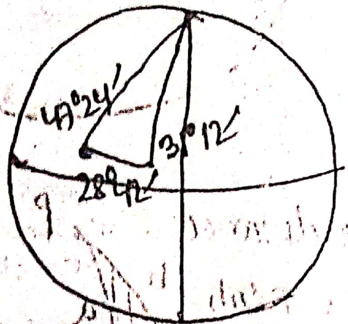
= $\boxed{\text{0hr 46m 2s}}$ (AM).

Calculate the distance in kilometers between two points A and B along the parallel of latitude, given that;

① Lat. of A, 28°42′N ; longitude of A, 31°12′W
Lat. of B, 28°42′N longitude of B, 47°24′W

② lat. of A 12°36′S longitude of 115°6′W
lat of B, 12°36′S longitude of 150°24′E

①



The distance in nautical miles between A and B along along the parallel of lattitude
= Difference in longitude in minute × cos lattitude

Difference in longitude = (47°24′ − 31°12′) = 16°12′
= 972 minute.

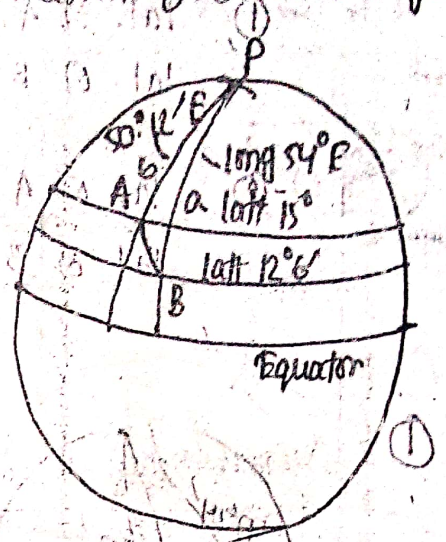
Distance = 972 cos 28°42′ = 852.58 nautical miles
= 852.58 × 1.852
= 1578.98 Km.

| 1 nautical mile = 1.852 Km |

② Difference in longitude = 360° − (150°24′ (−115°6′)) = 94°30′ = 5670 min

Distance = 5670 cos 12°36′ = 5533.44 nautical mile
= (5533.44 × 1.852) Km
= $\boxed{10247.94 \text{ Km}}$

Example 4. Find the shortest distance between two places A and B, given that the latitudes of A and B are 15°0'N and 12°6'N and their longitudes are 50°12'E and 54°0'E respectively. Find also the direction of B on the great circle route.



Solution In spherical triangle ABP,

$b = AP = 90° - 15° = 75°$

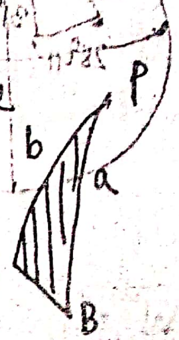
$a = BP = 90° - 12°6' = 77°54'$

$P = \angle APB =$ difference in longitude

$= 54°0' - 50°12'$

$= 3°48'$

The shortest distance between two points is the distance along the great circle passing through the two points



Knowing the two sides one angle, the third side AB = P can be easily computed by the cosine rule

$$\cos P = \frac{\cos P - \cos a \cos b}{\sin a \sin b}$$

$\cos p = \cos P \sin a \sin b + \cos a \cos b$

$= \cos 3°48' \sin 77°54' \sin 75° + \cos 77°54' \cos 75°$

$= 0.99661$

$P = \cos^{-1}(0.99661) = 4.7°$

$$arc = radius \times central\ angle = \frac{6370 \times 4.7° \times \pi}{180°}$$

distance AB = 522.54 km.