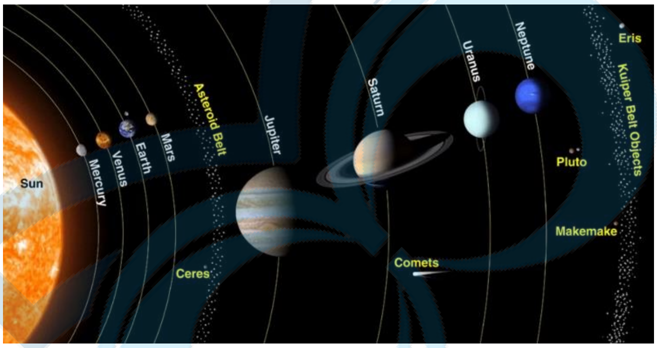
# Chapter 1: The Earth and the Universe

**Exploring the Universe**

- Stars are far bigger than the earth on which we live. Some of the larger ones have been estimated to be many millions of times the size of the earth.
- They occur in cluster as galaxies or nebulas. Each galaxy may contain as many as 100 million stars.
- Earth's own galaxy (the Milky Way) alone contains as many as 100,000 million stars.
- The light from the nearest star travelling at the speed of light (i.e., 186,000 miles per second) takes something like four years to reach us.
- A ray of light from the sun takes about eight minutes to reach the earth. Light takes only a second to reach us from the moon.

**The Solar System**

- The solar system comprises the Sun and its nine planets which are believed to have been developed from the condensation of gases and other lesser bodies.
- All the planets revolve round the Sun in elliptical orbits. Like the earth, they shine only by the reflected light of the sun.




- **Mercury**
  - Amongst the Eight planets, it is the smallest and closest to the sun, only 36 million miles away.
  - A year in Mercury is only 88 days.

- **Venus:**
  - It is the next closest planet, twice the distance away from the sun.
  - It is often considered as 'Earth's twin' because of their close proximity in size, mass (weight) and density.

- **Earth**
  - It has a natural satellite, the Moon, 238,900 miles away, that revolves eastward around the Earth once in every 27 days.

- **Mars**
  - It has dark patches on its surface and is believed by most professional astronomers to be the next planet after Earth to have the possibility of, some plant life.

- **Jupiter**
  - The largest planet in the solar system.
  - Its surface is made up of many gases like hydrogen, helium, and methane
  - It is distinguished from other planets by its circular light and dark bands, and the twelve satellites that circle round it.
  - It is more than 485 million miles from the Sun, its surface is very cold, probably about -200°F. (-130°C.).

- **Saturn**
  - It has three rings and nine satellites around it.
  - It is the second largest after Jupiter. It is so far from the Sun that it takes 29+ years to complete its orbit.

- **Uranus**
  - It is another giant planet, 50 times larger than Earth and 15 times as heavy.
  - Unlike other planets, Uranus orbits around the sun in a **clockwise direction** from **east to west** with five satellites revolving round it.

- **Neptune**
  - It is the outermost planets in the solar system.
  - It has only two known satellites and is probably much colder.

***Note***: *Till recently (August 2006), Pluto was also considered a planet. However, in a meeting of the International Astronomical Union, a decision was* *taken that Pluto like other celestial objects (2003 UB313) discovered in recent past may be called 'dwarf planet'.*

*The most recent definition of a planet was adopted by the International Astronomical Union in 2006. It says a planet must do three things:*

*1. It must orbit a star (in our cosmic neighbourhood, the Sun).*

*2. It must be big enough to have enough gravity to force it into a spherical shape.*

*3. It must be big enough that its gravity cleared away any other objects of a similar size near its orbit around the Sun.*

*Pluto did not fulfil the last criterion; hence it was excluded from being a planet.*

### The Shape of the Earth

- The earth is round, it is not a perfect sphere.
- It is a little flattened at both ends like an orange. It can, in fact, be called a geoid ('earth-shaped').
- The **spherical shape** of the earth is also masked by the intervening highlands and oceans on its surface.

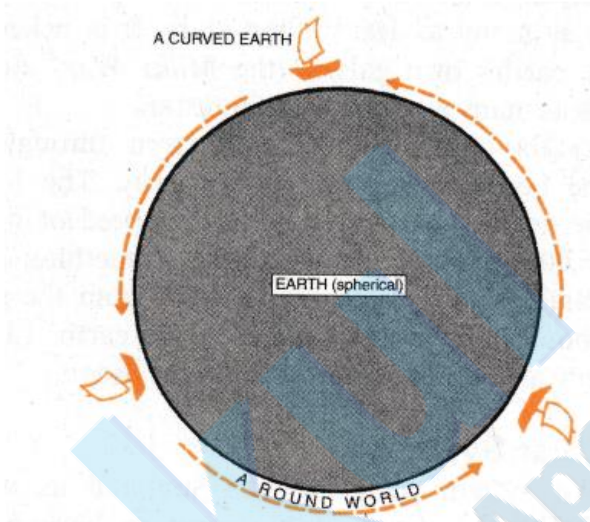
### Evidence of the Earth's Sphericity

There are many ways to prove that the earth is spherical. The following are some of them:

- **Circumnavigation of the earth**: The first voyage around the world by Ferdinand Magellan and his crew, from 1519 to 1522 proved beyond doubt that the earth is spherical.

  No traveller going round the world by land or sea has ever encountered an abrupt edge, over which he would fall.

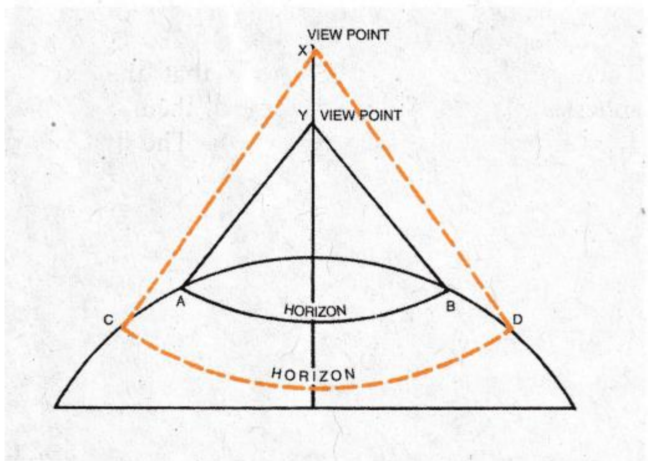
  Modern of routes and ocean navigation are based on the assumption that the earth is round



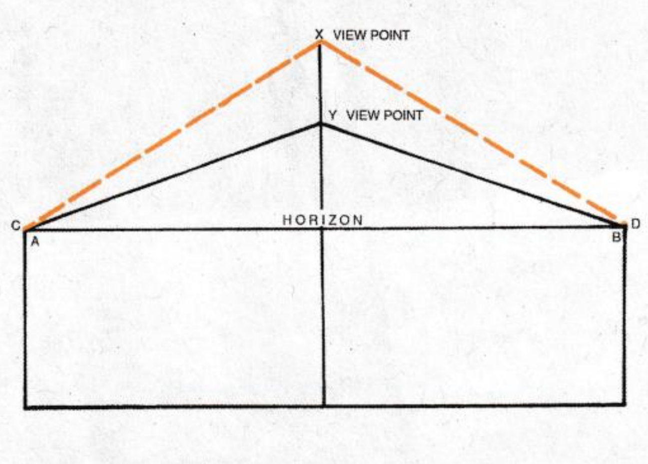

Circumnavigation of the earth


(b) Abrupt drop at the edge of a table-like earth

- **The circular horizon:** The distant horizon viewed from the deck of a ship at sea, or from a cliff on land is always and everywhere circular in shape. This circular horizon widens with increasing altitude and could only be seen on a spherical body.

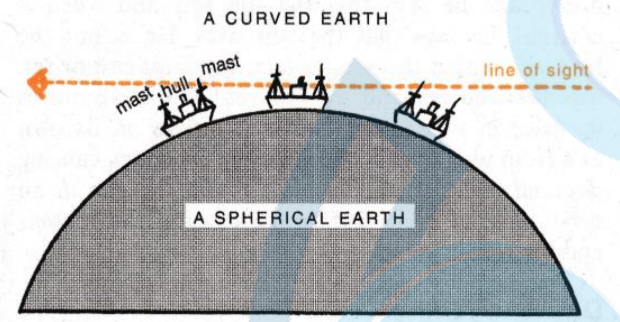



(a) Increasing altitude widens the circular horizon. Viewed from Y the horizon would be AB but from a higher viewpoint (X) a wider horizon (C, D) would be seen




(b) Visible horizon remains the same regardless of altitude. If the earth were flat the horizon seen from either Y or X would be the same

- **Ship's visibility:** When a ship appears over the distant horizon, the top of the mast is seen first before the hull. In the same way when it leaves harbour, its disappearance over the curved surface is equally gradual. If the earth were flat, the entire ship would be seen or obscured all at once.




The mast of a ship is seen before the hull on curved horizon

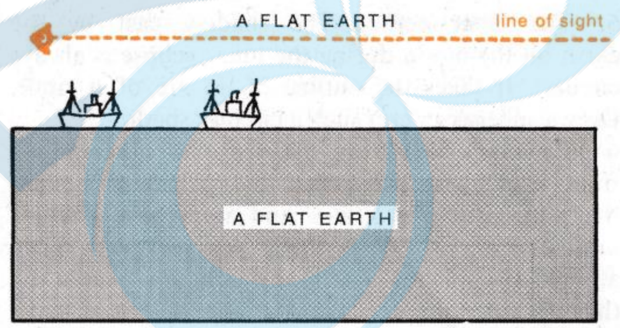
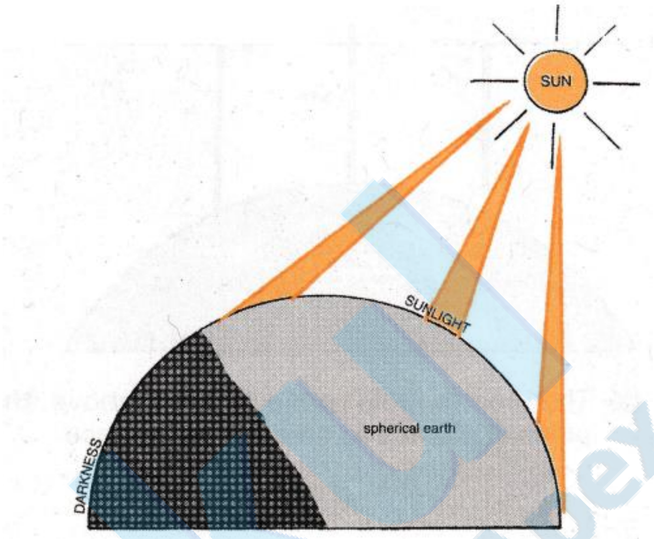
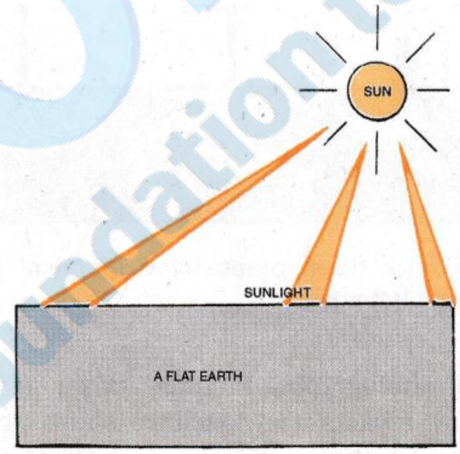



Fig. 4 (b) A flat earth, the entire ship is seen at once on a flat surface

- **Sunrise and sunset:** The sun rises and sets at different times in different places. As the earth rotates from west to east, places in the east see the sun earlier than those in the west. If the earth were flat, the whole world would have sunrise and sunset at the same time. But we know this is not so




(a) Sun rises and sun sets at different times for different places

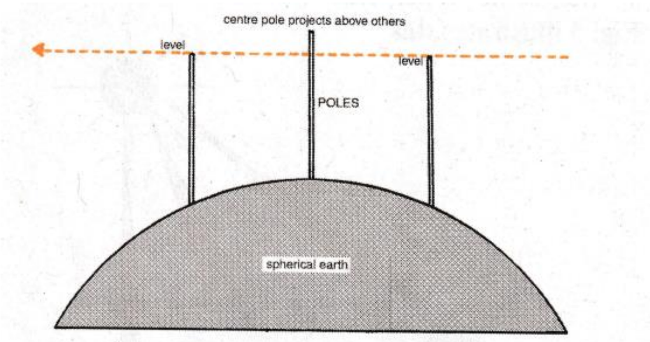



(b) The whole world will have sun rise or sun set at the same time

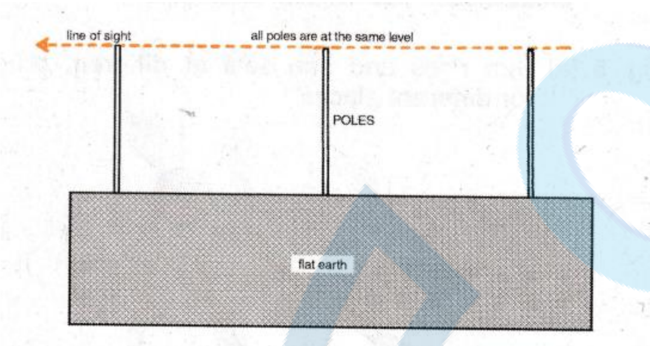
- **The lunar eclipse:** The shadow cast by the earth on the moon during the lunar eclipse is always circular. It takes the outline of an arc of a circle. only a sphere can cast such a circular shadow.

- **Planetary bodies are spherical**: All observations from telescopes reveal that the planetary bodies, the Sun, Moon, satellites and stars have circular outlines from whichever angle you see them. They are strictly spheres. Earth, by analogy, cannot be the only exception.

- **Driving poles on level ground on a curved earth:** Engineers when driving poles of equal length at regular intervals on the ground have found that they do not give a perfect horizontal level. The centre pole normally projects slightly above the poles at either end because of the curvature of the earth. Surveyors and field engineers therefore have to make certain corrections for this inevitable curvature, i.e., 8 inches to the mile.




(a) The centre pole projects well above the poles at either end on a curved surface




(b) All the three poles have identical heights on a flat surface

- **Aerial photographs:** Pictures taken from high altitudes by rockets and satellites show clearly the curved edge of the earth. This is perhaps the most convincing and the most up-to-date proof of the earth's sphericity.

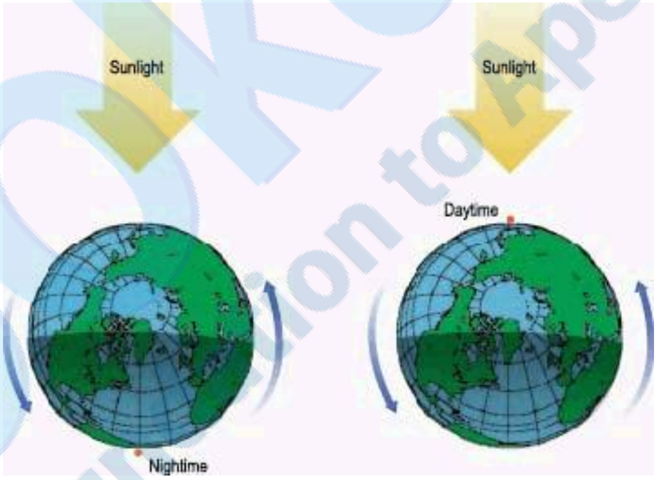
### The Earth's Movement

The earth moves in space in two distinct ways:

- It **rotates** on its own axis from west to east once in every **24 hours**, causing day and night.
- It also **revolves** round the sun in an orbit once in every **$365\frac{1}{4}$ days** causing the seasons and the year.

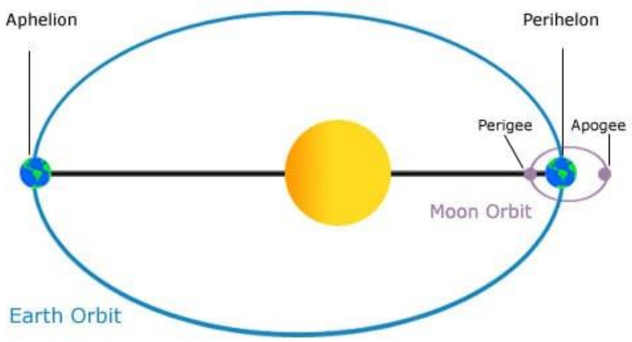
### Day and Night

- When the earth rotates on its own axis, only one portion of the earth's surface comes into the rays of the sun and experiences **Daylight.**
- The other portion which is away from the sun's rays will be in **Darkness.**
- As the earth rotates from west to east, every part of the earth's surface will be brought under the sun at sometimes or the other.
- A part of the earth's surface that emerges from darkness into the sun's ray experience **sunrise.**
- Later, when it is gradually obscured from the sun's beams it experiences **sunset.**
- **The sun is, in fact stationary and it is the earth which rotates.**



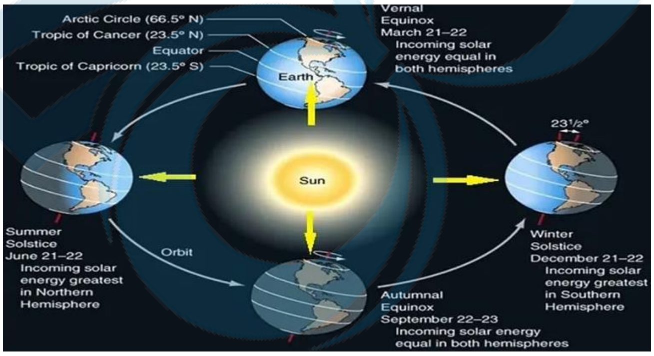

### The Earth's Revolution

- When the earth revolves round the sun, it spins on an **elliptical orbit** at a speed of 18.5 miles per second or 6,600 Milles per hour.
- One complete revolution takes **$365\frac{1}{4}$** days or a year. A normal year is taken to be 365 days, and an extra day is added every four years as a Leap year.



### Varying Lengths of Day and Night

- The axis of the earth is inclined to the plane of the **Ecliptic** (the plane in which the earth orbits round the sun) at an angle of **$66\frac{1}{2}°$**, giving rise to different seasons and varying lengths of day and night.
- If the axis were perpendicular to this plane, all parts of the globe would have equal days and nights at all times of the year, but we know this is not so.
- In the **northern hemisphere in winter** (December) as we go northwards, the hours of darkness steadily increase.
- At the Arctic Circle ($66\frac{1}{2}°$ N), the sun never 'rises' and there is darkness for the whole day in mid-winter on 22 December.
- Beyond the Arctic Circle the number of days with complete darkness increases, until we reach the North Pole (90°N.) when half the year will have darkness.
- In the **summer** (June) conditions are exactly reversed. Daylight increases as we go poleward.
- At the Arctic Circle, the sun never 'sets' at mid-summer (21 June) and there is a complete 24-hour period of continuous daylight.
- In summer the region north of the Arctic Circle is popularly referred to as 'Land of the Mid night Sun'.
- At the North Pole, there will be six months of continuous daylight.

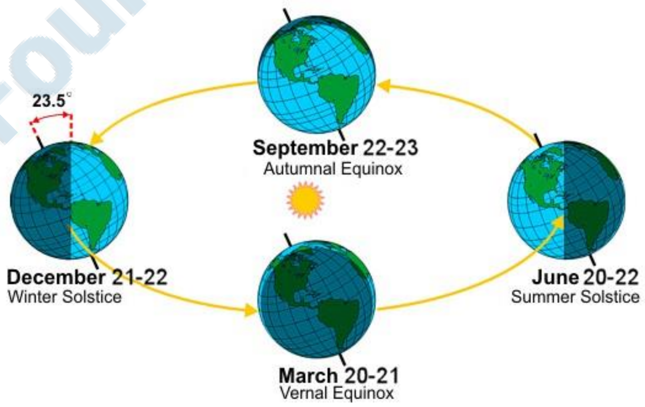



*Above figure illustrates the revolution of the earth and its inclination to the plane of the ecliptic which causes the variation in the length of day and night at different times of the year.*

- In the **South Hemisphere**, the same process takes place, except that the conditions are reversed.
- When it is summer in the northern hemisphere, the southern continents will experience winter. Mid-summer at the North Pole will be mid-winter at the South Pole.

### The Altitude of the Midday Sun

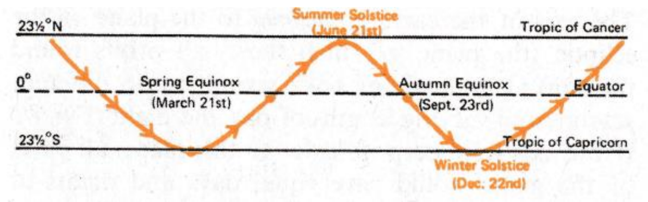
- In the course of a year the earth's revolution round the sun with its axis inclined at $66\frac{1}{2}°$ to the plane of the ecliptic changes the apparent altitude of the midday sun.
- The sun is **vertically overhead** at the equator on two days each year. These are usually 21 March and 21 September though the date changes because a year is not exactly 365 days.
- These two days are termed **Equinoxes** meaning 'equal nights' because on these two days all parts of the world have equal days and nights.
- After the March equinox the sun appears to move north and is vertically overhead at the Tropic of Cancer ($23\frac{1}{2}°$N.)




- On about 21 June. This is known as **the June or summer solstice**, when the northern hemisphere will have its longest day and shortest night.
- By about 22 December, the sun will be overhead at the Tropic of Capricorn ($23\frac{1}{2}°$S). This is the **Winter Solstice** when the southern hemisphere will have its longest day and shortest night.
- The Tropics thus mark the limits of the overhead sun, beyond these the sun is **never overhead** at any time of the year. Such

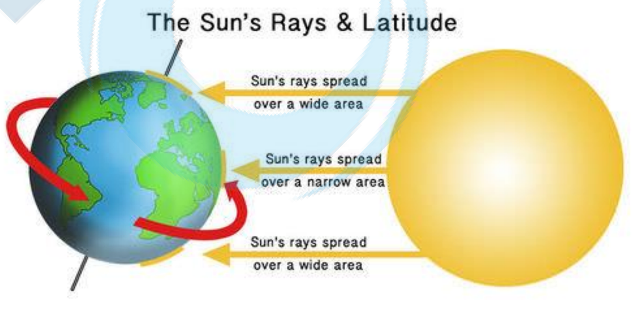
regions are marked by distinct seasonal change spring, summer, autumn and winter

- Beyond the Arctic Circle ($66\frac{1}{2}$°N) and the Antarctic Circle ($66\frac{1}{2}$°S) where darkness lasts for 6 months and daylight is continuous for the remaining half of the year, it is always cold, for even during the short summer the sun is never high in the sky.
- Within the tropics, as the midday sun varies very little from its vertical position at noon daily, the four seasons are almost indistinguishable. Days and nights are almost equal all the year round.




## Seasonal Changes and their Effects on temperature

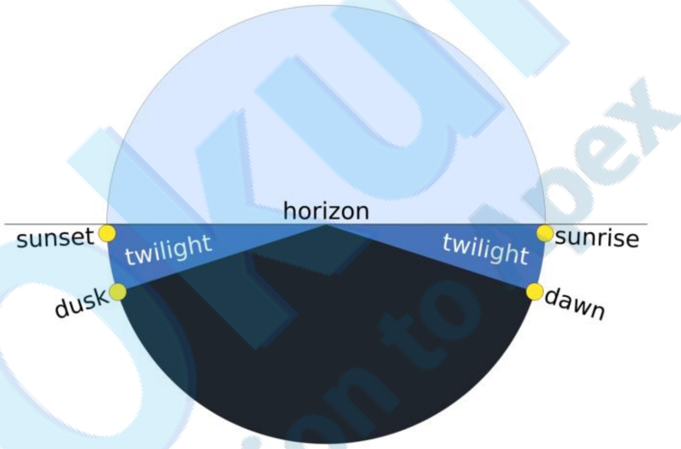
- Summer is usually associated with much heat and brightness whereas winter with cold and darkness. In summer, the sun is **higher in the sky** than in winter.
- When the sun is overhead, its rays fall almost vertically on the earth, **concentrating** its heat, on a small area, temperature therefore rises and summers are always warm.
- In winter, the **oblique rays** of the sun, come through the atmosphere less directly and have much of their heat absorbed by atmospheric impurities and water vapour. The sun's rays fall **faintly** and spread over a great arca. There is thus little heat, and temperatures remain low.




- In addition, days are longer than nights in summer and more heat is received over the longer daylight duration. Nights are shorter and less heat is lost.
- There is a **Net gain** in total heat received and temperature rises in summer. Shorter days and longer nights in winter account for the reverse effects.

## Dawn and Twilight

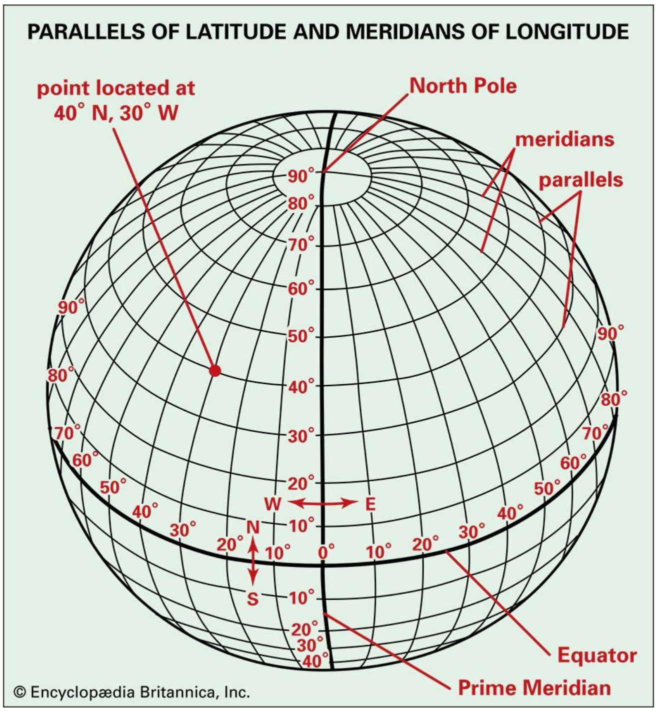
- The brief period between sunrise and full daylight is called **Dawn** and that between sunset and complete darkness is termed **Twilight.**




- This is caused by the fact that during the periods of dawn and twilight the earth receives **diffused or refracted light** from the sun whereas it is still below the horizon.
- Since the sun rises and sets in a vertical path at the equator the period during which refracted light is received is short.
- But in temperate latitudes, the sun rises and sets in an oblique path and the period of refracted light is longer.
- It is much longer still at the poles, so that the winter darkness is really only twilight most of the time.

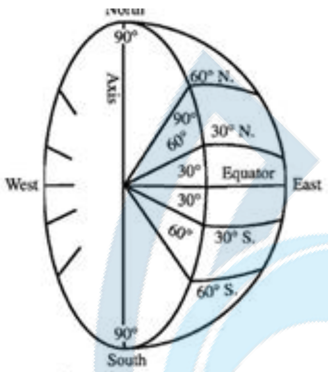
## Mathematical Location of Places on the Globe

- The earth's surface is so vast, it is impossible to locate any place on it. For this reason, imaginary and longitude pin-points any place on the earth's surface.
- For example, Delhi is **28°37'** N. and **77°10'E**; London is **51°30'N** and **0°5'W** and Sydney is **33°55' S** and **151°12' E**.



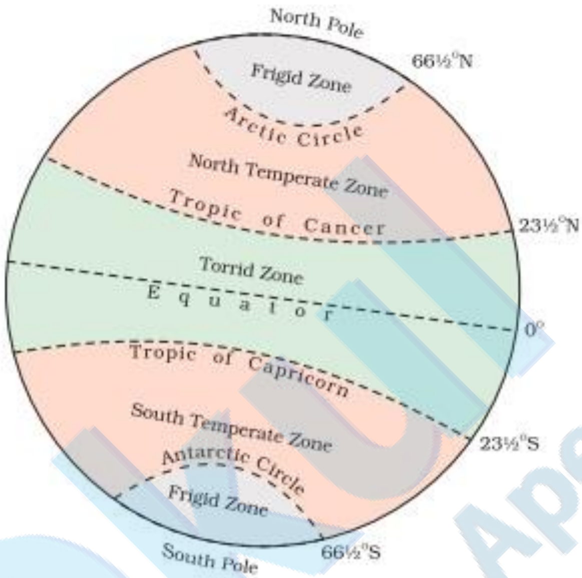

## Latitude

- Latitude is the **Angular distance** of a point on the earth's surface, measured in degrees from the centre of the earth.



Angular distance from equator

- It is **Parallel** to a line, the equator, which lies midway between the poles.
- These lines are therefore called parallels of latitude, and on a globe are actually circles, becoming smaller pole-wards.
- The equator represents 0° and the North and South Poles are 90°N. and 90°S. Between these points lines of latitude are drawn at intervals of 1°. Each degree is sub divided into 60 minutes and each minute into 60 seconds.
- The most important lines of latitude are the equator, the Tropic of Cancer ($23\frac{1}{2}$°N), the Tropic of Capricorn ($23\frac{1}{2}$°S), the Arctic Circle ($66\frac{1}{2}$°N) and the Antarctic Circle ($66\frac{1}{2}$°S).



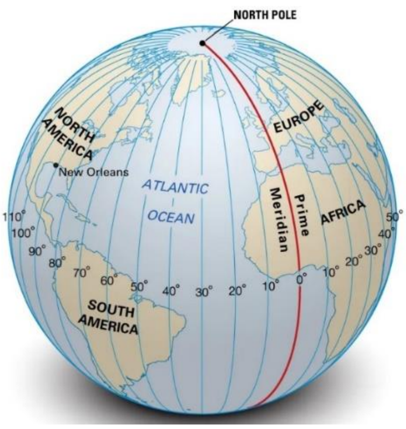

- As the earth is slightly flattened at the poles, the linear distance of a degree of latitude at the pole is a little longer than that at the equator.
- For example, at the equator (0°) it is 68.704 miles, at 45° it is 69.054 miles and at the poles it is 69.401 miles. The average is taken as 69 miles.

## Longitude

- Longitude is an **Angular distance**, measured in degrees along the equator east or west of the prime (or First) Meridian.
- on the globe longitude is shown as a series of semi-circles that run from pole to pole passing through the equator. Such lines are also called **Meridians.**
- In 1884, by international agreement choose the zero meridian which passes through the Royal Astronomical observatory at Greenwich, near London.
- This is the **Prime Meridian** (0°) from which all other meridians radiate eastwards and westwards up to 180°.
- As the parallels of latitude become shorter pole-wards, so the meridians of longitude, which **converge at the poles**, enclose a narrower space. The degree of longitude therefore decreases in length.
- It is longest at the equator where it measures 69.172 miles. At 25° it is 62.73 miles, at 45°

it is 49 miles, at 75° 18 miles and at the poles 0 mile.

- There is so much difference in the length of degrees of longitude outside the tropics, that they are not used for calculating distances as in the case of latitude.
- But they have one very important function, they determine in relation to G.M.T. or Greenwich Mean Time, which is sometimes referred to as World Time.



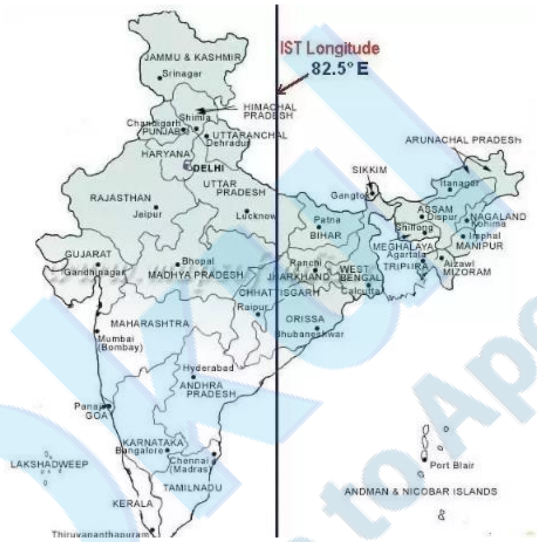

**Longitude and Time**

**Local Time**

- Since the earth makes one complete revolution of 360° in one day or 24 hours, it passes through 15° in one hour or 1° in 4 minutes.
- The earth rotates from west to east, so every 15° we go eastwards, local time is **Advanced** by 1 hour.
- conversely, if we go west wards, local time is **retarded** by 1 hour. Thus, places east of Greenwich see the sun earlier and gain time, whereas places west of Greenwich see the sun later and lose time.
- Hence when it is noon, in London (Longitude 0°5'W), the local time for Madras (80°E) will be 5 hours 20 minutes ahead of London. But the local time for New York (74°W) will be 4 hours 56 minutes behind London or 7.04 a.m.

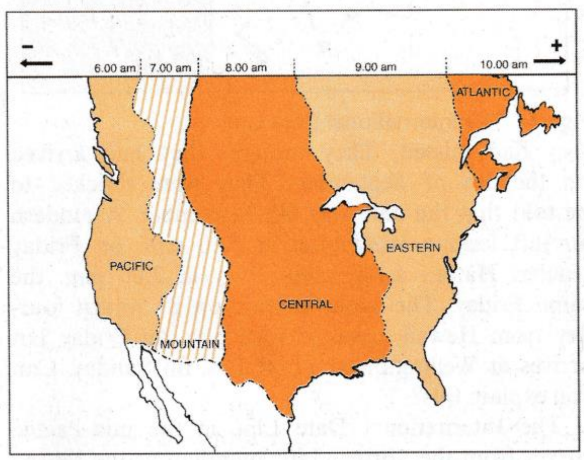
**Standard Time and Time Zones**

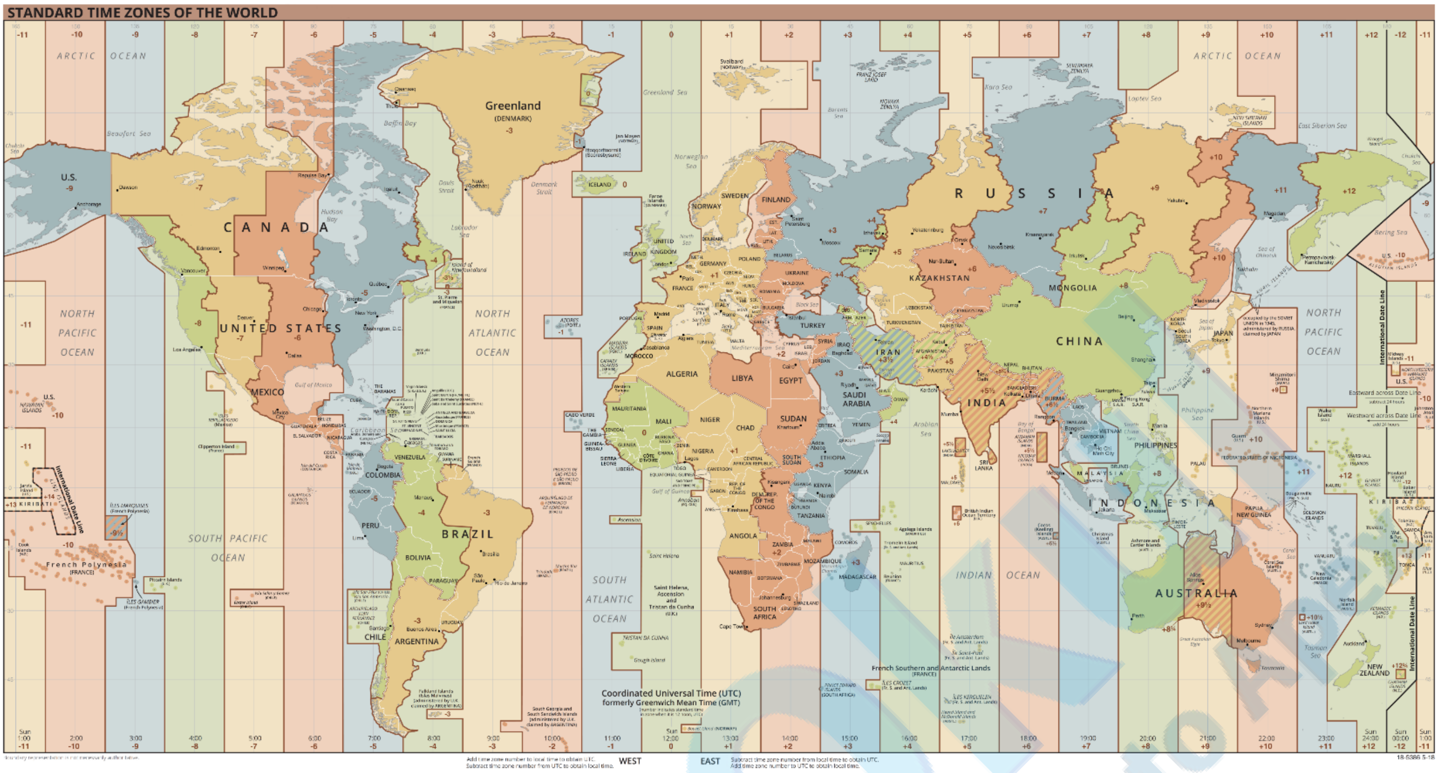
- If each town were to keep the time of its own meridian, there would be much difference in local time between one town and the other.
- To avoid these difficulties, a system of **Standard time** is observed by all countries. Most countries adopt their standard time from the central meridian of their countries.
- The Indian Government has accepted the meridian of 82.5° east for the standard time which is 5 hrs 30 mins ahead of Greenwich Mean Time.




- The whole world has in fact been divided into 24 Standard Time Zones, each of which differs from the next by 15° in longitude or one hour in time.
- Larger countries like U.S.A., Canada and U.S.S.R. which have a great east-west stretch have to adopt several time zones for practical purposes.
- U.S.S.R. the largest country, which extends through almost 165° of longitude is divided into eleven time zones.
- Both Canada and U.S.A. have five time zones- the Atlantic, Eastern, Central, Mountain and Pacific Time Zones. The difference between the local time of the Atlantic and Pacific coasts is nearly five hours.

**The five time zones of North America**






**Standard Time Zones of the World**

## The International Date Line

- A traveller going eastwards gains time from Greenwich until he reaches the meridian 180°E. when he will be 12 hours ahead of G.M.T. Similarly, in going westwards, he loses 12 hours when he reaches 180°W.
- There is thus a total difference of 24 hours or a **Whole day** between the two sides of the 180° meridian.
- This is the International Date Line where the date changes by exactly one day when it is crossed.
- A traveller crossing the date line from east to west **loses** a day (because of the loss in time he has made) and while crossing the dateline from west to east he **Gains** a day (because of the gain in time he encountered).
- Thus, when it is midnight, Friday on the Asiatic side, by crossing the line eastwards, he gains a day, it will be midnight Thursday on the American side, i.e., he experiences the same calendar date twice.


International date line

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