Lesson - 3

Earth : Form, Motions, Location and Calculation of Time

Man has been a curious creature since the beginning. Along with the development of civilization man tried to know more about his environment, earth and sky. In ancient period entire Universe was considered to be 'earth centric' and earth was considered, to leg fixed, flat and disc shaped. In Indian texts like 'Vedas', 'Aryabhatta' (text written by Aryabhatta) earth was described as round ("Khagol, Bhugol") in shape. Great Indian astronomer Aryabhatta described earth round in shape as a ball and inclined on its axis, moving from west to east direction. This causes day and night formation. Aryabhatta and Bhaskaracharya presented scientific fact about sun and moon eclipses and gravity, about which the European scholars came to know in 15th-16th century. Although European scholars, Pythagoras and Aristotle described earth a round in shape but this was later forgotten by the scientists. After this astronomers named Copernicus and Galileo in 16th century, described sun to be in the center of the solar system, earth and other celestial bodies to be round in shape and the daily and annual movements to be from west to east direction.

It is a scientific fact that earth is spherical in shape, which can be proved with number of examples like round shaped shadow during every eclipse, visibility of round shape of all celestial bodies from different angles, all celestial bodies to be in a curve during horizontal position. After the study by Apollo and many other artificial satellites it has been proved that earth is round in shape but as its also flat at the poles is considered to be in 'Oblate Spheroid' form. Similarly the circumference of the earth was calculated through on easy technique by a greek scholar Eratosthenes in 256 B.C. which was equal to present day scientific calculation. Indian scholars too presented their calculations related to age, perimeter, diameter and radius of the earth which are very similar to present day scientific calculations.

The facts of the earth based on scientific calculations are presented in the Table No. 3.1.

Table No. 3.1.
Some important facts about earth

1. Equatorial linear diameter	12,756 km
2. Polar diameter	12,713 km
3. perimeter	Equatorial Linear 40,077 km
4. Polar Perimeter	40,000 km
Total area (i) Land area (ii) Oceanic area	510 million sq. km 149 sq. km (29.22%) 361 sq. km (70.78%)
Volume of earth	416 million cubic km
Density of earth	5.517
Mass of earth	5.882×10^{21} tonne
Weight of earth	6.600 billion tonne
Curvature on earth's surface	7.98" per mile

The Motion of the Earth :

There are two important movements of the

earth which causes formation of day and night and seasons. (Fig. 3.1)

1. Rotation :

The earth rotates in 24 hours on its axis which causes day and night. The part of earth which faces sun experiences day and other part has night. This movement is form west to east due to which sun rises in east and sets in west. As the earth rotates west to east the direction of the movement of all stars and constellations appear to move in east to west direction. The bulge on the equatorial region and flatness on the poles is caused due to this motion of the earth. (Centrifugal force). Beside this, these motions of the earth causes changes in the direction of winds and currents. The daily motion is maximum on equator (1600 km per hour), it gets reduced on 45º North and South latitudes (1120 km per hour) and becomes almost zero on poles.

The axis of the earth instead of making right angle with its orbital plane, makes on inclination of 23½º. This inclination of 23½º remains in the same direction as the earth revolves round the sun. As a result of this inclination of the earth, north and south pole faces sun turn by turn, due to this, both the hemispheres get the benefit of different seasons. If this inclination would have not been there, the duration of day and night would have been same and the change of seasons also would not have been possible.

2. Revolution :

The second important movement of earth is its yearly journey around the sun in west to east direction, on its axis. The orbit of the earth is about 965 million km long which is been completed with a speed of 29.6 km per second in 365¼ days. The orbit of earth is elliptical instead of being round due to which the distance between earth and sun keeps on changing. The average distance between earth and sun is 150 million km. When earth is at the maximum distance from the sun (152 million kms) it is called (147 million kms) Perihelion position. In the Perihelion position the earth completes its journey comparatively much faster around the sun. Contrary to this, the earth takes longer time to revolve round the sun in Aphelion position. Change of seasons are possible because of revolution. Due to the changes in the motions and positions of the

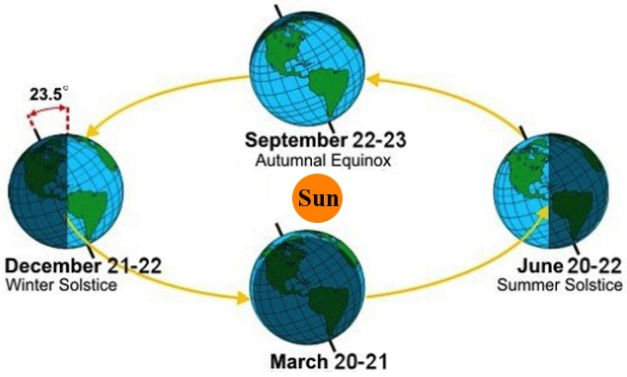

Fig. 3.1
Position of the earth

earth, there is distribution of solar radiation on the earth.

3. Solstices and Equinoxes :

There is light on one part of the earth and the other part remains in darkness. The illuminated part is separated, from darker part through 'circle of Illumination'. The earth remains in the position of Summer Solstice and Winter Solstice on 21st June and 22nd December respectively. The sun shines vertically on 21 June and 22 December on Tropic of Cancer and Tropic of Capricorn respectively. As the earth is inclined on an angle of 23½º, these positions are witnessed in both the hemispheres. As the sun shines vertically over Tropic of Cancer. There is summer season in northern hemisphere and vice versa in southern hemisphere. There is influence of winter season in the southern hemisphere. The position is reversed on 22 December. The sun rays vertically shines over Tropic of Capricorn, due to which there is summer in southern hemisphere and winters in northern hemisphere. The vertical rays of the sun effect the central part between Tropic of cancer and Tropic of Capricorn (23½º Northern Hemisphere - 23½º Southern Hemisphere). These two points work as conducting points.

Solstices provide mobility to earth and the positions of sun, stars and constellations also undergo changes. These changes are indicators of life, benevolence and newness. During Solstices many countries in the world celebrate many festivals. 'Makar Sakranti' has special significance

in our country. Our entire country celebrates this transforming festive days with lot of hilarity. Sun is worshiped on this day and sesame and jaggery is eaten.

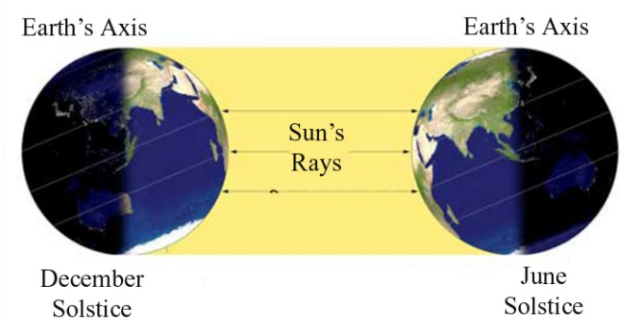

Fig. 3.2 : Solstice Positions

Equinoxes : On the earth, the sun is perpendicular to the equator on 21st March and 23rd September. In this equinox position the day and night on earth are of equal duration. Spring begins in the Northern Hemisphere from 21st March, and that is why its called Spring Equinox.

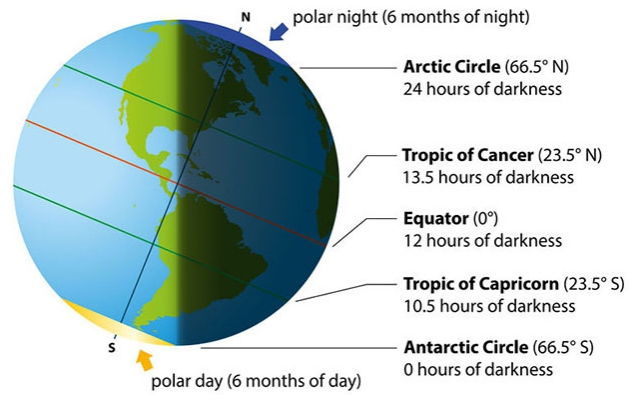

Fig. 3.3 : Position on Winter Solstice

In this stage the circle of illumination divides the entire earth in equal parts from pole to pole. The part that faces the earth, remains in light while the other part, opposite to it remains in dark. During the equinox the sun rises before 6 am in the east and sets almost at the same time in the west. (Fig. 3.1, 3.3)

Latitudes and Longitudes :

Latitudes and longitudes are imaginary lines on the globe, which runs from east to west and from north to south respectively. The grid formed due to these lines are important to find ones location, its called earth's grid". Latitudes and Longitudes intersect each other on right angles.

Latitude :

Equator divides the earth into two equal hemispheres, northern and southern hemispheres. The latitudes are determined north and south, parallel to the equator.

Their angles are determined from the centre of the earth. As the latitudes move away north and south to the equator, the size of these latitudinal circles is reduced equator is indicated as 0º and north and south pole 90º latitude is found in northern hemisphere and 90º in southern hemisphere. The distance between the latitudes is 111 km which is increased at the poles due to their flatness. To find the accurate location of a place, degrees are divided into minutes, minutes into seconds. Like the location of Mumbai will be written as 18º55'08" (18 degrees, 55 minute and 8 seconds).

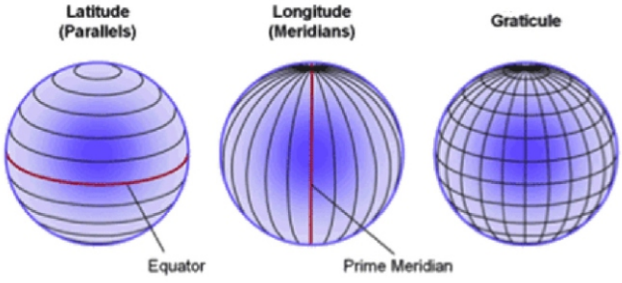

Fig. 3.4 : Latitude, Longitude and Earth Grid

The latitudinal globe is divided into equal divisions by 0º Equator, North of this is 23½º North latitude as Tropic Cancer, 66½º north latitude as Arctic circle and 90º North pole in the form of centre or point. In the same, south of equator 23½º southern latitude as 'Tropic of Capricorn, 66½º southern latitude as 'Antarctic Circle and 90º south in form of centre or point. The area between 0º to 30º north and south is called 'Lower Latitudinal Area' and the area north and south between 60º to 90º is

called 'Higher latitudinal Area'. Similarly, 'Tropical Climatic Belt' lies between 0º to 23½º north and south latitudes, the region between 23½º to 66½º north & south latitudes lies in North & South Temperate Climatic Zone and from 66½º to 90º north and south latitudes, lies the Cold Climatic Zone

In the same way the zones of plants and living organisms are also determined through the instruments positions of sun, stars and moon etc. Presently the correct position of latitude is determined with the help of GPS (Global Positioning System)

Latitude : The imaginary lines which runs from north to south direction on the globe are called Longitude. The line that runs from north to south near London is called 'Greenwich' or 'Prime Meridian' which in indicated with 0º. There are 180º-180º east and west longitudes on both of its sides which is 360º in total number. These longitudes are determined at the angular distances from the centre of the globe. The opposite of the Prime Meridian (0º) is the 180º 'International Date Line' Longitudes have the maximum distance between them, near the equator. As the longitudes move away from the equator towards the poles, their distances starts decreasing. All longitudes meet at a central point which is at the poles. It means that the difference between the two longitudes at the equator is 111 kms. This difference at 30º North and South latitudes is 96.5 kms, at 60º North and South longitude it is 55.4 km, at 80º north and south it is 19.3 km and this difference turns to be zero at 90º North and South centres of poles.

Similar to latitudes, longitudes are divided into degrees minutes and seconds. For example the longitudinal extent of Mumbai is '72º54'10" (72 degrees, 54 minutes and 10 seconds). When we move in towards east from Central or Prime Meridian, 4 mins at every longitude and an hour (60 mins/ at 15º longitude is increased. The local time at every longitude remains the same. In the same way when every 360º longitude changes into a complete circle, it makes 'Great Circle' Equator is also considered as a 'Great Circle'. 'Great Circles' are those circles which divide the earth into equal divisions they are 181 in total number.

Time : Earth is circular and there are 360º in this circle. Every degree is called longitude. Longitudes are considered to be those imaginary lines which runs from North pole to South pole. All the places located at a longitude will have noon at the same time therefore we also call longitudes as Meridians.

Earth rotates 360º in 24 hours. In this way it moves 15º in an hour. In the same way it covers one longitude in 4 minutes. Earth rotates from west to east. Therefore the place which is located in the east will observe the sunrise first. Madras city of our country is situated on 80ºE longitude when its 6:00 am during a sunrise in Madras it will be 5:00 am at the place which is situated 65º West of Madras. The sunrise will be observed at that place after an hour. If we know Greenwich and our local time, we can easily calculate our longitude, for example if presently its 12:00 noon at Greenwich and in our local watches it is 6:00 pm, and as we are definitely east of Greenwich and our longitude is 15×6=90º.

Local Time : The time of every place which is calculated according to its longitudes, is called local time of that place. At this point, the sun-dial shows almost exact time. The local time is related to the position of the sun during noon. Due to this all the places located on the same longitude will observe noon on the same time and there is no difference in their local timings. Cities situated on east and west will be on different meridians. Therefore these places will observe noon at different timings. It is obvious that places situated at east and west locations will observe differences in their local time. Local time will always be according to noon (when sun shines overhead) of sun dial.

Standard Time : Local time of a place is may be suitable for its own city but when we travel and reach to other place, there may be difference in timing. In this position, in order to maintain the timings, as we move in east or west directions, we have to adjust are watches 4 mins ahead or behind, as we cross every longitudes. A standard time in considered in every nation to resolve this problem.

For standard time, for a nation a longitude is considered as a standard Meridian "The standard meridian of England is 0º which crosses over Greenwich. Mostly a nation considers the local time

of a suitable place, as the standard time for whole nation. The longitude of that city is very important for it. All the watches of the nation are adjusted according to the time of that city. In this way when the timing of the special place is considered for the whole country, its called standard time. In our country the timing 82½ºE longitude is considered as the standard time for the whole country, if you are at a fixed place which is at 82½º longitude, then the noon at your place and your watch will show 12:00 noon same time.

But if your location is in the east of this line, then your watch will show 12:00 after its noon at the local place and if the place is in the west, then it will be earlier. If local time is considered instead of standard time for a place, then it will create lot of inconvenience in day to day activities. In every country the standard time and international time i.e. Greenwich time, difference is kept always as whole or one and a half hour for example the time difference from Greenwich of Pakistan is of 5 hours and that of India is 5½ hours.

Time Zones : If a country has more east and west extension, considering one standard time for the whole country will not solve the problem as the places which are situated to the east and to the west will have time difference of 4 to 5 hours. This time difference in local time can be observed in the countries like Canada and USA. It is difficult for ships to keep a record of the local time of places. In order to remove this inconvenience the entire earth is divided into 24 divisions. Each division is called

Fig. 3.5 : Time Zones

zone. In each zone there is a standard time. These time zones are divided in 24 parts, so that there is an hour difference within every zone. Every time zone has 15º longitudes.

Canada is extended more in east to west direction. Therefore it has 5 time zones. Every time zone has one standard parallel and the local time at that meridian is the standard time of that entire time zone. The local time of 60º, 75º, 90º, 105º and 120º of 5 regions of Canada are considered as the standard times of those 5 time zones. USA has four time zones, in its major region. These are called Eastern, Central. Mountainous and Pacific time. In this 75º, 90º, 105º and 120º longitudes are considered to be standard meridians. Alaska and Hawai Island, which are the parts of USA, fall in different time zones. In the same way Europe is also divided into 3 different time zones and Russia in 11 time zones with a difference of an hour each.

The time zones are broadest at the equator. It becomes narrower towards the poles, even the time zones joins at poles in form of a centre or a point.

International Time : The longitude, which crosses near a place called Greenwich, in London is internationally considered as prime meridian.

Prime Meridian

It is considered as 0º longitude and the calculation of longitudes to its east and west is done from this meridian, like 15º East longitude and 15º West longitude. Its important to note that 180º east and west longitude are the same line.

The calculation of all the time zones are done on the basis of this Prime Meridian. The uniformity in timings at Global level is done with the help of Greenwich, that is the reason why its called International time.

International Date Line : You are acquainted with the fact that, as we travel west of Prime Meridian, we have to deduct 4 minutes for each longitude as we cross if we are traveling in the east we have to add 4 minutes as we cross each longitude therefore if we complete one circle around the earth i.e. cross 360º longitude, by the time we complete, we would have adjusted our watches 24 hours ahead. Therefore this creates a difference of a day. When we are moving from east

to west, a day will be deducted and when we are moving west to east, a day will be added, something similar happened with Captain Cook, when he returned home after completing his world tour, he thought he made a mistake in calculation by one day. To get over this inconvenience all nations unanimously considered International date line with 180º longitude. A day starts with this line. When imagined in this way. The error in calculation of a day while traveling across the world, was also rectified.

If its Monday for a place which is situated west of this line that is Asia, then it will be Sunday for the places situated on east like America.

When a ship crosses this line and sails towards America. The people on the ship have to repeat the same day, on which they have crossed the 'date line, it means that if they have crossed the International date line on Sunday. So the next day will be Sunday for them instead of Monday and if they cross the line and sails towards Asia then they have to subtract a day from their calendar. If they crossed the line on Sunday, so the next day for them would lie Tuesday, instead of Monday.

Position of the International Date Line :

If we look carefully, we will observe that this is not a straight line. (Fig. 3.6) What is the reason behind it? This line does not cross over 180º longitude from its one end to the other in a straight way. It is a Zig Zag line as it avoids many islands which are been crossed over by 180º longitude in Pacific Ocean which are under the administration of a single country. Therefore if international date line would have been considered as 180º longitude. some places on the island would witness two different dates on the same day which could have created a great confusion, and due to this reason International date line is in Zig Zag shape as required instead of straight line of 180º longitude.

When we look carefully at picture of international late line we will observe that its first bend is towards east. In Bering strait, which is between Siberia and Alaska, it moves away from 180º and turns towards east. To its further south, it turns towards west to avoid the Aluetian Islands. This causes difference in the dates of Siberia and Alaska. If its 15 July in Siberia then its only 14 July in Alaska 180º longitude almost passes through the

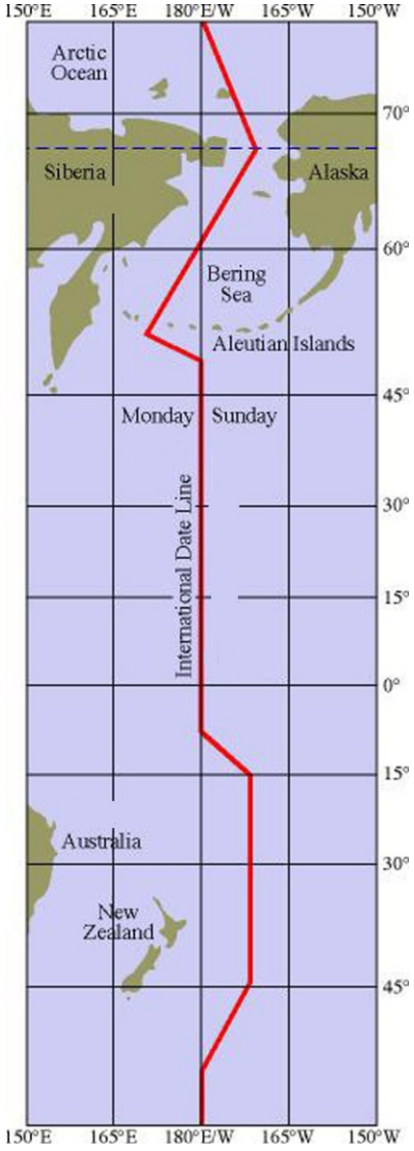

Fig. 3.6
International Date Line

centre of an island in an Fiji island groups which causes lot of inconvenience in the island. So in southern hemisphere this line avoids the Fiji and Togo Islands and runs across them. These island have to mark the date which is followed in New Zealand.

Equation of Time : The duration during which a planet completes its one revolution on its axis and comes back at its place, where sun is shining over head is called a Solar Day. But the orbit of earth is elliptical in shape instead of being round. Due to this, the earth is sometimes very near to the sun and sometimes its very far from sun. During the winter season, when earth is comparatively near to the sun its called Perihelion position. Exactly opposite to this, when earth is at maximum distance from the sun its called Aphelion position. Its important to note that these positions do not effect the change of seasons. It depends on the position on the elevation of the sun in the sky, that is the angular position and solar radiation which is being received. When the earth is in Winter Solstice the speed of revolution of the earth is bit faster. Contrary to this the duration of Solar day keeps on increasing and decreasing.

Therefore two types of time may be witnessed.

Apparent Time : When sun shines vertically over a central meridian. Then all the places situated on that line will observe the time to be 12:00 noon.

Due to this constant increase and decrease, in reference to calculation of time the solar day will not be very convenient. To calculate time with the help of sun, Sun Dial is used. We have to bear the inconvenience of keeping the time, completely consistent, according to the position of the sun because the clocks need to be adjusted ahead or behind according to the sun.

Mean Time :

In daily day to day practice, the clocks cannot be frequently adjusted ahead or behind in terms of time. It means that the clocks do not show the time according to the position of the sun but shapes the mean time. Thus, time calculated like this is not considered as real time and the duration of the observed day also varies, Yes, if the duration of all such days of the year is added and their mean is calculated, the duration of real day be will be certain. This day is the Mean Solar Day and the time we use is based on this. Our clocks are also adjusted according to this Mean time. This time is called the Clock Time.

In comparison to Mean Solar Day, normal Solar day may be of longer or shorter duration. The difference which is calculated between them is called time equation. This is mostly given in marine records.

It is clear that the speed of the sun is not always the same. Sometimes its ahead of apparent time and sometimes it is behind it. If the sun vertically shines overhead after (2:00 the time equation will be positive (+) and if the sun is shining vertically overhead before its 12:00 the time will be negative (–). These four dates are 16 April, 15 June, 1 September and 25 December. The time equation of these dates is zero. On these dates when its 12:00 in watches, the sun dial also shows the same time, therefore Apparent time and Mean time are same. To indicate the values of time equation, a special table is prepared. Ships sailing on the sea routes specially need to know this.

Important Points

1. The earth has two main movements - Daily or Rotation, Second, Yearly or Revolution. Both these movements cause lot of changes on the earth's surface, like formation of day and night and change of seasons.
2. The sun remains fix and the earth revolves round it from west to east direction on its elliptical orbit, through which the positions of Summer and Winter Solstice are formed. During Summer Solstice, sun shines vertically over the tropic of Cancer and summers season prevails in northern nemisphere and winter prevails in southern hemisphere. Exactly opposite to this happens during Winter Solstice.
3. Latitudes and Longitudes are imaginary lines marked on the globe. Latitudes run from east to west and Longitudes run from north to south. These lines forms 'Geo Grid' through which exact location on earth could easily be determined.
4. All longitudes are circles (360º) and then form great circles (180º). 181th Great circle is Equator.

Exercise

1. The international date line passes through the longitudes is :
   (A) 0º longitude (B) 150º longitude
   (C) 180º longitude (D) 82½º longitude

2. The time at which, the clocks of the entire country are set, is called :
   (A) Local Time (B) Mean Time
   (C) Apparent Time (D) Standard Time

3. Which country has maximum number of time zones?
   (A) Russia (B) Canada
   (C) China (D) USA

4. Equinox means :
   (A) Sun shines vertically over Tropic of Cancer
   (B) Sun shines vertically over Tropic of Capricorn
   (C) Sun shines vertically over Equator

(D) Sun shines vertically on Tropic of Cancer and Capricorn

5. The time is calculated for all time zones through :
   (A) From 180º longitude
   (B) From '0' Prime Meridian
   (C) From 90º E longitude
   (D) From Greenwich Place

Very Short Type Questions :

6. What is the angle of inclination of the earth?
7. When does the speed of rotation is maximum on the earth?
8. What is the maximum distance between the sun and the earth called?
9. What is the speed of revolution?
10. What is the total number of longitudes?

Short Type Questions :

11. Which longitude is the basis of drawing International Date Line?
12. What is the location determined for Prime Meridian?
13. What is the total number of time zones of Canada and why?
14. Which device is used to find the local time?
15. Mention the name of the line on which a new day is observed towards its west and towards its east when the previous day is still there.

Essay Type Questions :

16. Compare local and Standard time.
17. 'The authentic time of a country or region is actually a local time of a particular meridian, Clarify this statement in reference to India.
18. What is International Date Line? Explain its importance.

Answer Key

1. C 2. D 3. A 4. C 5. B