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INTRODUCTION

Geography is the science that studies the lands, features, inhabitants, and phenomena of Earth. Before we discuss anything, let’s know something about the maps which are backbone of studying the Geography.

Cartography is the science and art of drawing maps and charts. Anaximander was the first to attempt making a map of the known world. *Abraham Ortelius* is recognized as the creator of the first modern atlas. Bernard J.S. Cahill was the Inventor of octahedral "Butterfly Map" of the world

Maps are symbolic depiction highlighting relationships between elements of that space such as objects, regions, and themes. Maps are as old as 9th century BC and they come from ancient Babylon. The ancient best known map is **Imago Mundi**, which dates back to 600 BC. Imago Mundi is a clay tablet map of the world, which has kept **Babylon at its center**. Imago Mundi resides at the British Museum of human history and culture in London.

Early Geographers

Iliad and the Odyssey of Homer have the earliest deal of geographical information. Homer, who is the legendary ancient Greek epic poet, describes a circular world ringed by a single massive ocean. But here is a bit controversy. The Era assigned to Homer is 1194–1184 BC by Eratosthenes; however there is much controversy, even on the existence of an epic poet called Homer. Martin West writes in "*The Invention of Homer*" (published in Classical Quarterly -1999) that "Homer" is "NOT the name of a historical poet, but a fictitious or constructed name. Most scholars agree that the Iliad and Odyssey underwent a process of standardization and refinement out of older material beginning in the 8th century BC.

So, keeping these controversies aside, Thales is considered to be the Earliest Geographer. Though our countries was well versed in astronomy and astrology, yet very few documents have been found. So we discuss the early geographers starting from Thales only.

Thales: 624-546 BC

Thales proposed that world was a **flat disc based on water**, and that all things grew out of it. Thales, whose era dates back to 624-546 BC was a Greek philosopher from Miletus in Asia Minor, and one of the **Seven Sages of Greece**. He had travelled to Egypt.

Seven Sages of Greece

Seven Sages of the Greece were the seven early 6th century BC philosophers, statesmen and law-givers of Greece. They were Thales (of Miletus), Pittacus (of Mytilene), Bias (of Priene), Solon, Cleobulus (of Lindus), Myson (of Chen), and Chilon (of Sparta).

Anaximander

Anaximander was a disciple and successor of Thales and is known to be the **first person known to have attempted to create a scale map of the known world** in which **he included all the known seas**.

👉 Anaximander was the first person to conceive a mechanical model of the world.

In this mechanical model, Earth has shape **is that of a cylinder** with a height one-third of its diameter and flat top forms the inhabited world, which is surrounded by a circular oceanic mass. He also described in his model that Earth floats very still in the centre of the infinite and is not supported by anything.

Anaximander has some more credits in his name:

- ✍ Anaximander was the first astronomer to consider the Sun as a huge mass, and consequently, to realize how far from Earth it might be, and the first to present a system where the celestial bodies turned at different distances.
- ✍ However in his Map, **Earth is in centre, surrounded by Oceans, and stars, Moon and Sun respectively.**
- ✍ Anaximander's knowledge of geometry allowed him to **introduce the gnomon in Greece.**

What is a Gnomon?

- ✍ This Babylonian instrument Gnomon is the part of a sundial that casts the shadow, and was a thin rod, or any object with a sharp tip or a straight edge.
- ☺ Our Jantar Mantars which were built in 18th century by Maharaja Jai Singh II in 5 cities viz. in Delhi, Jaipur, Ujjain, Mathura and Varanasi are actually Huge Gnomons.
- ✍ Today a 3D gnomon is commonly used in CAD and computer graphics. This 3D Gnomon aids to positioning objects in the virtual world. By convention, the X axis direction is colored red, the Y axis green and the Z axis blue.

Pythagoras: 570-495 BC

Pythagoras was the founder of the religious movement called *Pythagoreanism*. Later revivals of Pythagorean doctrines led to what is now called Neopythagorism. Pythagoras was considerably influenced by mathematics.

- ✍ He was (perhaps) the first to propose a spherical world. Pythagoras argued that a sphere is a most perfect form.
- ✍ This idea of a spherical earth was embraced by Plato and Aristotle too. Earth's shadow during an eclipse is curved, and also that stars increase in height as one moves north, these were some of the observations of Pythagoras.
- ✍ Pythagoras was (perhaps) the first person to give an idea that Earth rotates around an axis.

Pythagorean Theorem & Golden Ratio

Pythagoras is also credited to discovering the Pythagorean Theorem. Pythagorean Theorem states that in a right-angled triangle the square of the hypotenuse (the side opposite the right angle), c , is equal to the sum of the squares of the other two sides, b and a —that is, $a^2 + b^2 = c^2$.

Golden Ratio:

Pythagoras and his disciples are also credited for Golden ratio in Mathematics (Geometry). However, Euclid, a Greek mathematician who is often referred to as the "Father of Geometry, provides the first known written definition of what is now called the golden ratio in his work "Elements".

Eudoxus (410 or 408 BC – 355 or 347 BC)

Eudoxus is known to be the first person to give an idea about how the sun created differing climatic zones based on latitude. His ideas later made the Greeks to believe in a division of the world into five regions. Each Pole was extremely cold and equator was extremely hot and in between there are temperate belts which are habitable.

Hecataeus (550 BC – 476 BC)

- ✍ *Ges Periodos* was the work of Hecataeus, which literally means "*Travels round the Earth*" and "World Survey".
- ✍ He is credited as "Father of Geography". His work *Genealogiai* was a rationally systematized account of the traditions and the myths of the Greeks.

Herodotus: 484 BC-425 BC

Herodotus is regarded as the "Father of History" and was the first historian known to collect his materials systematically, test their accuracy, arrange them in a well-constructed narrative. He travelled a lot, but not much is credited in his name in Geography. However his opinion:

"All history must be treated geographically and all Geography must be treated historically"

is important as well as interesting. He travelled a lot and he termed the word "History" which in Greek means "Inquiry".

Aristotle: 384 BC - 322 BC

Greek Philosopher who is best known for a systematic observation. A mathematical Geographer and was a student of Plato and teacher of Alexander the Great. *He considered Earth as a static body and centre of the Universe as Stars revolve around it.* This was proved wrong later.

Eratosthenes 276 BC - 195 BC

The size of the Earth was an important question to the Ancient Greeks. Eratosthenes attempted to calculate its circumference by measuring the angle of the sun at two different locations.

- ✍ Eratosthenes is known to be the first person to use the word "geography" and invented the discipline of geography as we understand it as Today.
- ✍ A system called "latitude and longitude" was invented by Eratosthenes.

Some other credits to Eratosthenes

- ✍ Eratosthenes was the first person to calculate the circumference of the earth. This he did by using a measuring system using stadion, or the length of stadiums during that time period. The plural of Stadion is stadia and is a unit of length in Ancient Greek. For example: Hipparchus says the equator is 252,000 stadia long; the great circle distance from equator to pole is 63,000 stadia (Strabo).
- ✍ Eratosthenes was the first person to calculate the tilt of the Earth's axis.
- ✍ Some people credit him to attempt to calculate the distance from the earth to the sun and invention of the leap day.
- ✍ Eratosthenes was the founder of scientific chronology; his endeavor was to fix the dates of the chief literary and political events from the conquest of Troy, a city, both factual and legendary, located in what is now northwest Turkey. **In short Eratosthenes was the First Scientific Geographer.**

Strabo: 63/64 BC - AD 24

Strabo was a Greek historian, geographer and philosopher.

- ✍ Strabo was the first significant Geographer of the Roman Period.
- Strabo is mostly famous for his 17-volume work *Geographica*, which presented a descriptive history of people and places from different regions of the world known to his era. In his first book chapter 2 he writes "Homer is the founder of geography".

Ptolemy (AD 90 168 AD)

He wrote *Almagest*, which means "The Great Treatise" on mathematics. Another work was *Geographike Hyphegesis* which is a thorough discussion of the geographic knowledge of the Greco-Roman world. Another lesser known work was *Apotelesmatika*, which was related to horoscopic astrology.

Aryabhatta (476-550 AD)

Aryabhatta was a great mathematician-astronomer from the classical age of Indian mathematics and Indian astronomy. He wrote *Aryabhatiya* in 499 AD when he was 23 years old. *Arya-siddhanta* was another work.

He describes the shanku-yantra or Chhyayantra which was a series of development of what was basically the Gnomon, the angle-measuring device mentioned above.

Aryabhatta describes Dhanuryantra (semicircular device), Chakrayantra (Circular device), Yasti-Yantra (Cylindrical device), Chhatra Yantra (the umbrella device) and water clocks of two types, bow-shaped and cylindrical.

- ✍ In the *Golapada* of the Aryabhatia, he writes about Geometric/trigonometric aspects of the celestial sphere, features of the ecliptic, celestial equator, node, shape of the earth, cause of day and night, rising of zodiacal signs on horizon, etc.

In addition, some versions cite a few colophons added at the end, extolling the virtues of the work, etc.

Muhammad al-Idrisi (1099–1165 or 1166)

Arab Geographer and Cartographer who is known for his Kitab Rudjdjar or Tabula Rogeriana which was a world Map. This was an advanced map showing Eurasian continent in its entirety and northern part of the African continent.

Ibn Battuta: (1304–1368)

A Moroccan scholar and traveler.

- ✍ Ibn Battuta is best known for his work Rihla which means “**Voyages**” in Arabic.
- ✍ Rihla gives an account of his travels and excursions.

Alberuni (973-1048)

- ✍ A Persian Muslim scholar and polymath of the 11th century and the first Muslim scholar to study India and the Brahminical tradition, and has been described as an early founder of Indology and also first "Anthropologist".

Henry, the Navigator (1394-1460)

- ✍ Prince of the Kingdom of Portugal credited for the beginning of the European worldwide explorations. Set up an observatory and established the first school of navigation.

Bernhardus Varenius (1622-1650)

- ✍ Best known for his work *Geographia Generalis*, in which he endeavored to lay down the general principles and organization of the geographical knowledge. His work is divided into (1) absolute geography, (2) relative geography and (3) comparative geography.

Alexander von Humboldt (1769-1859)

- ✍ Founder of the biogeography.
- ✍ His work was *Kosmos*, a comprehensive work about different facets of geography and the natural sciences. His Latin American expedition laid the foundation of the sciences of physical geography and meteorology.
- ✍ He is also credited to devise the “isothermal lines” to compare temperatures.

Carl Ritter (1779-1859)

- ✍ Along with Alexander von Humboldt, Carl Ritter is considered one of the founders of modern geography.

Branches of Geography

Physical geography is that branch of Geography (or natural sciences precisely) which deals with the study of processes and patterns in the natural environment like atmosphere, biosphere and geosphere. Human geography is the study of human use and understanding of the Earth and the process which have affected this.

Some Branches of Physical Geography

- 1) **Geomorphology:** Surface of the Earth and the processes by which it is shaped, both at the present as well as in the past. The core processes are tectonic or climatic processes. It seeks to understand landform history and dynamics, and predict future changes.
 - ✍ Geomorphometry is quantitative land surface analysis.

- 2) **Hydrology:** Studies water in rivers, lakes, aquifers and to an extent glaciers, water tables and groundwater in which the field examines the process and dynamics involved in these bodies of water.
- 3) **Glaciology:** Study of glaciers and ice sheets
- 4) **Biogeography:** deals with geographic patterns of species distribution and the processes that result in these patterns.
- 5) **Climatology :** climate which is defined as weather conditions averaged over a long period of time.
What is the difference between meteorology and Climatology?
Meteorology studies atmospheric processes over a shorter duration.
- 6) **Pedology:** soils in their natural environment, deals with pedogenesis, soil morphology, soil classification. One branch of the Soil science. Edaphology is another branch which is concerned with the influence of soils on living things, particularly plants.
- 7) **Palaeogeography:** distribution of the continents through geologic time through examining the preserved material in the stratigraphic record.
- 8) **Coastal geography :** studies the dynamic interface between the ocean and the land, incorporating both the physical geography (i.e. coastal geomorphology, geology and oceanography) and the human geography of the coast.
- 9) **Oceanography :** Earth's oceans and seas and covers marine organisms and ecosystem dynamics (biological oceanography); ocean currents, waves, and geophysical fluid dynamics (physical oceanography); plate tectonics and the geology of the sea floor (geological oceanography); and fluxes of various chemical substances and physical properties within the ocean and across its boundaries (chemical oceanography).
- 10) **Geometrics:** Field of gathering, storing, processing, and delivering of geographic information, or spatially referenced information.

Some Branches of Human Geography

- 1) **Cultural geography or Social Geography:** Study of cultural products and norms and their variation across and relations to spaces and places. It focuses on describing and analyzing the ways language, religion, economy, government, and other cultural phenomena vary or remain constant from one place to another and on explaining how humans function spatially.
- 2) **Development Geography:** Study of the Earth's geography with reference to the Standard of living and the Quality of life of its human inhabitants, study of the location, distribution and spatial organization of economic activities across the Earth.
- 3) **Economic geography:** Economic geography examines relationships between human economic systems, states, and other actors, and the biophysical environment.
- 4) **Health geography** is the application of geographical information, perspectives, and methods to the study of health, disease, and health care.
- 5) **Historical Geography** is the study of the human, physical, fictional, theoretical, and "real" geographies of the past.
- 6) **Political geography** is concerned with the study of both the spatially uneven outcomes of political processes and the ways in which political processes are themselves affected by spatial structures.
- 7) **Population geography** is the study of the ways in which spatial variations in the distribution, composition, migration, and growth of populations are related to the nature of places

- 8) **Urban geography** is the study of urban areas with specific regards to spatial and relational aspects and theories. That is the study of areas which have a high concentration of buildings and infrastructure. These are areas where the majority of economic activities are in the secondary sector and tertiary sectors. They probably have a high population density
- 9) **Agricultural Geography:** how the different kinds of farms and farming systems have developed in particular areas.

Some Preliminary Questions**What is Orthophotography?**

It's an advanced form of "Aerial photography". The Aerial Photographs are geometrically corrected such that the scale is uniform and can be used to measure true distances, because it is an accurate representation of the Earth's surface adjusted to topographic relief, lens distortion, camera tilt etc. It is used in the Geographic Information System (GIS).

What are Onomastics, Toponymy and Gazetteers?

Study of proper names of all kinds and the origins of names is called Onomastics. Toponymy is the scientific study of place names; Gazetteer is directory or reference for information about places and place names. Newspapers titles once used to be Gazetteers, however now it is out of Fashion.

What is Geographic Targeting?

This is basically resource allocation for public expenditure and policy interventions mainly for development programmes to reach the needy people.

What is a Hermit Kingdom?

Normally a country or society which intentionally walls itself off from the rest of the world is called a "hermit Kingdom". The term has been frequently used for North Korea. Bhutan is another example, however in today's IT dominated world, and no country is a hermit Kingdom.

What are LLDCs?

LLDC means landlocked developing countries. This term is used by United Nations for the countries that are developed as well as Landlocked. They are sometimes places in the least of the least developed countries. Our neighbors Nepal and Bhutan are placed in this list. Maximum LLDC's are in Africa (15 countries), followed by Asia (12 countries). Europe (4 countries) and South America (2 countries)

What is the First Law of Geography?

Waldo Tobler gave the first law of geography which says that "Everything is related to everything else, but near things are more related than distant things."

What is the ISO 6709?

Can you explain what does Atlantic Ocean +00-025/ denotes?

Atlantic Ocean +00-025/ denotes 00 North Latitude and 025 west longitudes.

✎ This representation is fixed by International standard ISO 6709 of the International Organization for Standardization.

The ISO 6709 is standard representation of longitude, latitude and altitude (however, altitude is options and is mainly used to describe mountains, towers etc.).

The sequence is \pm Latitude \pm longitude \pm altitude.

When we say Mount Everest has +27.5916+086.5640+8850/ value we mean to say that Mount Everest is located at 27.5916 degree north latitude, 086.5640 degree east longitude and 8850 meters altitude.

In terms of latitudes + means North and - means South

In terms of longitude + means East and - means South.

What are the IATA Codes?

IATA is international industry trade group of airlines headquartered in Montreal, Canada. It is present in 150 countries. The core function of IATA is to act as a price setting body for international airfare. IATA assigns 3-letter IATA Airport Codes to Airports and 2-letter IATA airline designators to Airlines and are commonly used worldwide. These codes are mentioned on the Air tickets and represent the Airport Code. For Example: DEL is the IATA code of Indira Gandhi International Airport.

Please note that International Civil Aviation Organization which is also located in Montreal, Canada issues a 4 letter code to the airports.

- ✗ The IATA codes are normally related to the general public and flights while the ICAO codes are related to air traffic control and airline operations such as flight planning.

What is the Digital Earth?

- ✗ The concept of Digital Earth was first of all given by former US vice president Al Gore in 1998. He conceptualized a digital future where schoolchildren - indeed all the world's citizens - could interact with a computer-generated three-dimensional spinning virtual globe and access vast amounts of scientific and cultural information to help them understand the Earth and its human activities. He also conceptualized a commercial market in coexistence with the free access. The idea of Al Gore has culminated in Google Earth and Microsoft's Bing Maps 3D for commercial, social and scientific applications.
- ✗ In this context please note that The Beijing Declaration on Digital Earth was adopted in September 2009, at the 6th International Symposium on Digital Earth in Beijing and it calls for planners and decision-makers at all levels in developing plans, policies, regulations, standards and criteria related to Digital Earth, and appropriate investments in scientific research, technology development, education, and popular promotion of the benefits of Digital Earth.

What is Global Positioning System?

GPS , which is a space based global navigation satellite system was established in 1973 and provides correct location and time information in all weather and at all times and anywhere on or near the Earth when and where there is an unobstructed line of sight to four or more GPS satellites.

- ✗ It is maintained by the United States government and is freely accessible by anyone with a GPS receiver.
- ✗ GP was conceptualized by U.S. Department of Defense (DOD) and was originally based on and run with 24 satellites. However, the first satellite navigation system, **Transit** or also known as NAVSAT was the first satellite navigation system which was tested successfully in 1960 by the United States Navy. It became obsolete later. By 1994, a complete constellation of the 24 satellites was placed in the orbit and 1995 the full Operational Capability was declared by NAVSTAR in April 1995.
- ✗ The orbiting GPS satellites are called space Vehicles (SV) and the GPS requires a minimum of 4 satellites.

However, the GPS design originally called for 24 satellites and they were 8 each in three circular orbital planes number of satellites in view from a given point on the Earth's surface.

It was later changed to 6 planes with 4 satellites. the number of satellites in view from a given point on the Earth's surface keeps changing but the orbits are arranged so that at least six satellites are always within line of sight from almost everywhere on Earth's surface.

What is Distance Decay?

In Delhi, the highest cost of commercial spaces in Connaught Place, which is officially known as Rajiv Chowk.

✍ Please note that there are Connaught Places in London as well as Hong Kong also.

When we move at a distance from the Connaught Place which we assume the Central Business District (CBD), then we notice that:

1. The crowd (pedestrians) reduces when we go away from the CBD of any city for example Connaught Place in New Delhi.
2. The cost and rent of the land reduces as we go away
3. The number of buildings and their heights reduces as we go away
4. The quality of shops decreases as we go away

The above change can be seen at any place around the world and this is called as Distance Decay.

Note: Chief architect of Connaught Place was Robert Tor Russell and it was modeled after the Royal Crescent in Bath, England.

GEOLOGICAL TIME SCALE

Kindly consider the following statement:

*"We live in the **Holocene Epoch** of **Quaternary period** of **Cenozoic Era** of **Phanerozoic Eon** of the **Supereon**"*

Can you differentiate all of them?

Most of us have studied that the earliest chapter of Human Civilization dates back to the Stone Age. The technology at that time was stone, and the period has been divided into Palaeolithic, Mesolithic and Neolithic ages. The study of this chapter of Human Civilization of our history is the first milestone towards gaining historical knowledge. But also, if we study about our Earth, then we must know that when and how Earth originated and how life began even before the evolution of Human being.

Herodotus said that *all history must be treated geographically and all geography must be treated historically*, this is applicable at least in General Studies.

The Tolerant Zircon

The radiometric dating indicates that our Earth was formed sometimes around 4567.17 to 4570 million years ago. The climate was harsh, we all know. In January 2008, a paper was published in the journal "Earth and Planetary Science Letters" which showed that rocky continents and liquid water existed 4300 million years ago but were subject to heavy weathering and acrid climates.

- ✍ Due to this climate, **our study of the minerals formed at that time gets limited because** all the minerals could not resist the harsh climatic conditions & heavy weathering of that period. But, there is one mineral called **Zircon** which has a property of exceptionally resistance to the **chemical changes.**

- The **Zircon** is the oldest known material on Earth which has given us a window to know something about

the things which happened 4400 million years ago when our Earth was a new born baby.

This means that this mineral existed when our Earth was just a baby of 150 million years. The exceptionally resistant **Zircon is today a standard to determine the age of ancient rocks.**

Formation of Moon

Birth of Moon also dates back to the some 4500 million years ago. There are several theories which explain the making of moon, some of which say that Moon got separated from the Earth at that time because of the centrifugal forces. This theory was not accepted largely. Another theory says that both Moon and Earth were formed together, but this theory is also not clearly accepted.

What our geologists and scientists accept largely today about the formation of Moon is that -The Earth Moon system was formed out of a giant impact by a Mars size body on the proto Earth. It is worth note that in the early solar system, giant impacts were common. There is a debate on this theory as well but one thing is accepted that Moon was formed around 4500 million years ago.

The Age of the Moon predicted to ~ 4.36 Billion Years

- In September 2011, the Scientists claimed that the Age of the moon: ~ 4.36 billion years, i.e. nearly 200 million years less than what earlier predicted. Thus, the moon could be younger than earlier thought, as per the Scientists.
- **Existing Theory:** The existing theory of the moon's origin is that it was formed by a massive impact b/w a big planet-like object and Earth. The energy of the impact was satisfactorily high that the moon formed from melted material that was expelled into space. As the moon cooled, this magma solidified into different mineral components.
- **New Theory:** Now detailed analysis of lunar rock samples thought to have been derived from the original magma has given scientists a new estimate of the moon's age at ~4.36billion years.



As per this theory for lunar formation, a rock type called "ferroan anorthosite" or FAN - is the oldest of the moon's crustal rocks, but scientists have had difficulty dating FAN samples.

- The Research team analyzed the isotopes of the elements lead and neodymium to place the FAN sample's age at 4.36 billion years. This figure is significantly younger than earlier estimates of the Moon's age that range as old as the age of the solar system at 4.568 billion years.
- *The new, younger age obtained for the oldest lunar crust is similar to ages obtained for the oldest terrestrial minerals - zircons from Western Australia - suggesting that the oldest crusts on both Earth and moon formed at about the same time, and that this time dates from shortly after the giant impact.*
- The study is the first in which a single sample of FAN yielded consistent ages from multiple isotope dating techniques.
- The result strongly suggests that these ages pinpoint the time at which the sample crystallized.
- *The extraordinarily young age of this lunar sample either means that the moon solidified significantly later than previous estimates, or that we need to change our entire understanding of the Moon's geochemical history.*
- The research team, led by Lars Borg of the Lawrence Livermore National Laboratory in California, used newly refined techniques to determine the age of a sample of FAN from the lunar rock collection at the Nasa Johnson Space Centre.
- The results are published in the journal Nature.

Acasta Gneiss

Acasta Gneiss is in Canada. This Acasta Gneiss is the oldest known rock on Earth and it also dates back to the same era almost (4400 million Years Ago).

4700 million years : The Supereon

In the above discussion we noted that our study is based upon a timescale of 4700 million years. To do a systematic study, this time must be divided into the various chronological fractions. These Chronological fractions have various named such as **Supereon, Eons, Eras, Periods, Epochs, Ages etc.** All of these words have different meanings. The largest among them is a **Supereon which is 4700 million years time.**

- This **Supereon is 4700 million years timescale.** The Supereon has been divided into two parts which are

called Eons. One is **Precambrian Eon**. This Precambrian Eon ranges from 4570 million years ago, to 542 million years ago.

Life originated in this Eon, which covers 90% of our Earth's history. The second eon is called **Phanerozoic Eon**. Phanerozoic eon is the current Eon and life is abundant in this Eon.

A brief knowledge is required about these periods to take our study to a considerably advanced level. Kindly go through the table on the next page which represents the breakup of 4700 million years of Our Earth's history. After you have finished reading the chapters kindly go through the table again.

Supereon	Eon	Era	Period	Epoch	Starting Time
			MYA (Million Years Ago).		
	Phanerozoic (542 – till date)	Cenozoic (65.5 – till date)	Quaternary	Holocene	12000 years till date
				Pleistocene	2.588-12000 years ago
			Neogene	Pliocene	7.246-2.588
				Miocene	23.03-7.246
			Paleogene	Oligocene	33.9-23.03
				Eocene	55.8-33.9
		Paleocene		65.5-55.8	
		Mesozoic (251-67)	Cretaceous	145.5-65.5	
			Jurassic	200-145	
			Triassic	251-200	
		Paleozoic (542-251)	Permian	299-251	
			Carboniferous	359-299	
			Devonian	416-359	
	Silurian		443-416		
	Ordovician		488-443		
	Cambrian		542-488		
Precambrian (4570-542)	Proterozoic	Neo-proterozoic	1000-542		
		Meso-proterozoic	1800-1000		
		Paleo-proterozoic	2500-1800		
	Archean	Neoarchean	2800-2500		
		Mesoarchean	3200-2800		
		Paleoarchean	3600-3200		
	Hadean	Eoarchean	3800-3600		
		Early Imbrian	3850 -3800		
		Nectarian	3920-3850		
		BasinGroups	4150-3920		
		Cryptic	4570-4150		

The above Table Represents the 4700 million Years Period into various Eons, Eras, periods, Epochs etc. The numerals represent the time period assigned to each in MYA (Million years Ago) except the Holocene and Pleistocene Epochs.

Precambrian Eon

We can understand that the Precambrian Eon which covers the timescale from 4570 million years ago till 542 million years ago is too big to study systematically. So, it has been formally divided into three parts, and these parts have also been named Eons. These are Hadean, Archean and Proterozoic.

✍ **Hadean** is the oldest which covers 4570 to 3850 million years ago, followed by **Archean** which

covers 3800 to 2800 million years ago and **Proterozoic** which covers the 2500 to 630 million years ago. Each of them has been divided into several **Eras**.

Hadean Eon:

Hadean Eon is the oldest Eon and has been divided into the following 4 Eras:

1. **Cryptic Era:** The time period assigned to Cryptic Era is 4570 -4150 years ago and this was the time, since when the Zircon survives. The other events of the Cryptic Era were formation of Moon.
2. **Basin Era:** The timeperiod assigned to Basin Era is 4150-3920 million years ago.
 - ↪ Basin Era was the beginning of Self replicating RNA molecules.
 - ↪ Self-replicating RNA molecules evolved around 4000 years in the Basin Era of Hadean Eon.
 - ↪ The oldest known Acasta Gneiss belongs to this Era.
3. **Nectarian Era:** It spanned from 3920 to 3850 Million Years Ago. Our Earth was just a baby, impact events were very common in those times. These events were collisions of the meteoroids and other celestial bodies to our Earth and moon and such impact events caused the formation of various "seas" or basins on Earth and moon. On moon these were called **Lunar mares** and one such mare is "*Mare Nectaris*", which is 1 lakh square kilometers in area and 1000 meters in depth. The name of the Nectarian Era is based upon this lunar mare. This was the period of heavy bombardment of the inner solar system, which continued till the Early Imbrian Era.
4. **Early Imbrian:** This is the last era of Hadean Eon and is characterized by heavy bombardments in our solar system.

Archean Eon:

The Archean Eon started 3800 million years ago. The Archean Eon has been divided into 5 Eras.

1. **Eoarchean Era:** This corresponds to the 3850 million years ago to 3600 million years ago. Here we should note that the supercontinents started coming in shape in this era. **Vaalbara was the first super continent.** The supercontinent Vaalbara was formed in the Eoarchean Era. This period also marks the **oldest microfossils** and life was in the form of simple celled bacteria type units.
2. **Paleoarchean Era:** This Era corresponds to 3600 million years ago to the 3200 million years ago. The time was of Prokaryotic development. We must know that prokaryotes have no nucleus in their cells and they are primitive cells compared to the Eukaryotes which have a nucleus, the cell controller. The oldest known living fossil has been found in Australia and these are well-preserved bacteria older than 3460 million years ago and they have been assigned to the Paleoarchean era of the Archean Eon
3. **Mesoarchean Era:** This Era corresponds to 3200 Million years ago to 2800 million years ago and the main event of this era is breaking up of Vaalbara. We call it suturing isn't it? The Mesoarchean Era witnessed the colony formation by the early prokaryotes and cyanobacteria. These clusters or colonies were called stromatolites.
4. **Neoarchean Era:** This was the last era of the Archean Eon and the period assigned is 2800 million years ago to 2500 Million years ago. This period is very important in development of life on Earth. The first evidence of photosynthesis has been corresponded to this era. This era also marked the "**Great Oxygenation Event**" in which poisonous free oxygen was abundant in the Earth's

atmosphere which wiped out the early life forms. It is also called "Great Oxygenation catastrophe". This era was the most important environment change happened on our Earth which led to formation of 2500 new minerals (most minerals contains oxygen) out of the 4500 minerals found on Earth today. This is because, the free oxygen combined with the elements.

Proterozoic Eon

The beginning of the Proterozoic Eon marked the beginning of complex life on Earth. Proto means early and zoic means life. The Eon marked early abundant life on Earth. The time period assigned to this Eon is 2500 million years ago till 630 million years ago.

The Proterozoic eon has been divided into three eras viz. Palaeo-proterozoic Era, Mesoproterozoic Era and Neoproterozoic Era. Each era is very important in context with the development of life on Earth.

1. Palaeo-proterozoic Era

As the name suggests, it is the earliest of the eras in the Proterozoic Eon. It has been assigned the time period of 2500 million years ago to 1800 million years ago. The beginning of this era overlaps with the Neoproterozoic era and the consequences of the "**Great Oxygenation Event**" were evident in this era. The continents got little stabilized in the era but continental drift which involved movement of the continents continued till late. There were abundant cyanobacteria.

- ↳ Both Neoproterozoic Era and Palaeo-proterozoic Era give the earliest sign of photosynthesis.
- ↳ The first primitive eukaryotes evolved in the Palaeo-proterozoic Era.

The Palaeo-proterozoic Era has been divided into 4 periods. First of them was **Siderian period**. Earlier the colour of the Sea was Greenish (probably). In the Siderian period, the oxygen combined with the Iron giving rise to Ferric Oxide (Fe_3O_4) and it probably cleared the Iron from the seas. When iron got saturated, the free oxygen accumulated in the atmosphere leading to the Oxygen catastrophe. The oxygen abundant environment followed this period.

Other periods of the Palaeo-proterozoic era are **Rhyacian period**, **Orosirian period** and **Statherian period**.

2. Meso-proterozoic Era:

The period assigned to this Era is 1800 million years ago till 1000 million years ago. This era marks the beginning of sexual production, formation of the Rodinia supercontinent, the breakup of the Columbia supercontinent. The earliest known complex multicellular organisms and beginning of the sexual reproduction have been confirmed by discovery of *Bangiomorpha pubescens*, a red algae.

- Red algae are the earliest known multicellular complex organisms.

3. Neo-proterozoic Era:

Neo-proterozoic Era is the terminal Era of the Proterozoic Eon and Precambrian Eon. The period assigned is 1000 million Years ago till 542 million years ago. It has been divided into three periods viz. Tonian, Cryogenian, and Ediacaran Periods.

Among them **Cryogenian period** is very important for our point of view. We know that cryos means ice. The time period assigned to Cryogenian period is 850 to 635 million years ago. Our Earth became a "Snowball Earth", 650 million years ago in the Cryogenian period of the Neoproterozoic Era of the Proterozoic Eon.

It has been proposed and generally accepted that **two glaciations in the Cryogenian Period called Sturtian and Marinoan glaciations, occurred on Earth** and covered the entire planet during this period.

However, there is a controversy whether the whole Earth was covered or some localized events occurred. It has been debatable but, in March 2010, it was published in "Science Daily" that **Sturtian glaciation was global in extent.**

- Oldest known fossils of sponges have been assigned to this Neoproterozoic era.

Phanerozoic Eon

This is the current Eon. The period assigned is 542 million years ago till date. This Eon has been divided into three Eras. The oldest is Palaeozoic, middle is Mesozoic and latest is Cenozoic Era. We are living in the Cenozoic Era.

1. Paleozoic Era

The time period assigned to Paleozoic Era is 542 to 251 million years ago. This era has been divided into 6 periods called Cambrian, Ordovician, Silurian, Devonian, Carboniferous, and Permian. **Cambrian is oldest and Permian is latest.**

1. **Cambrian Period:** Cambrian period marks the rapid diversification in the life. This is known as **Cambrian Explosion**. The ancestors of many modern animals and plants appeared in the Cambrian period. The first Chordates (vertebrates), Coral (but not coral reefs), Trilobites, worms, sponges, fungi, algae etc. were the result of the Cambrian Explosion. Gondwana emerged in this period.
2. **Ordovician Period:** While the Cambrian Explosion marked the origin of a large number of marine flora and fauna , the subsequent Ordovician era started with an extinction event called Cambrian–Ordovician extinction event. This event led to extinction and fossilization of 60% of the marine species at that time. This lasted for 44.6 million years. The major organisms survive flourished later for more developed life.
3. **Silurian period:** During this period, the Earth entered a long warm greenhouse phase, and warm shallow seas covered much of the equatorial land masses. Coral reefs made their first appearance during this time. The Silurian was the first period to see extensive terrestrial biota such as moss forests along lakes and streams. Silurian period also is assigned to the first fossil records of Vascular Plants, in which tissues carrying food appear.
4. **Devonian Period** It was Devonian Period, when the earlier fishes evolved legs and started to walk on land as tetra pods. The time for first appearance of tetra pods is 397 million years ago. The terrestrial arthropods (arthro-joint, pods- leg) got established in this period
5. **Carboniferous period:** Carboniferous period means "coal bearing". This was again a time of glaciations. The Gondwana shifted southwards and glaciations mainly on the Polar Regions were heavy. The temperature dropped and extensive lowland swamps and forests got buried below the sea and many coal beds were laid down globally during this period. This period also marked by massive Orogeny (making of mountains) and lowering of the sea level.
 - Carboniferous period marks the highest ever atmospheric Oxygen levels.
 - First land vertebrates, amphibians living in swamps, early sharks etc. appeared and disappeared in this period.
6. **Permian period:** Permian period was the last period of Paleozoic Era. During this era, Earth's major land masses were collected into a single supercontinent known as Pangaea, which straddled the equator and extended toward the poles. Climate gradually warmed, drying the continent's interiors, Deserts appeared

which were favorable to Gymnosperms. Gymnosperms (plants with naked seeds) appeared in the Permian period. Mollusks, echinoderms, and brachiopods flourished. The fauna were dominated by pelycosaur and amphibians. The end of the Permian period and beginning of the Triassic Period of the coming Mesozoic Era is marked by the most extensive extinction event recorded in paleontology & history of Earth and that is called Permian-Triassic extinction event.

- ✍ Permian-Triassic extinction event wiped out 90%-95% of the marine life and 70% of the terrestrial life from the Earth.
- ✍ The only known mass extinction of insects happened in the Permian-Triassic extinction event.

It took 30 million years to recover from this extensive extinction event. The culprit for this massive extinction was Flood Basalt. Flood basalts have erupted at random intervals throughout geological history and Earth undergoes periods of enhanced activity rather than being in a uniform steady state. Flood Basalts were contributed by reduced coastal habitat and highly increased aridity.

Mesozoic Era

The period assigned to Mesozoic Era is 251 million Years ago to 67 million years ago. It was the age of Dinosaurs. The continents have come in their present configuration in the Mesozoic era. The era has been divided into three period's Triassic, Jurassic and Cretaceous period.

1. Triassic period:

- ✓ The time assigned to Triassic Period is 250 to 200 Million years ago. This era saw the evolution of flying vertebrates called "pterosaur".
- ✓ This period marked the flourishing and development of the flora and fauna that survived the "Permian-Triassic extinction" event and also new group's flourished which dominated the Earth for a smaller time period.
- ✓ The Triassic Period is also called "Age of Reptiles". It was during this time that Archosauromorph ("ruling") reptiles achieved dominance on land, and many types of marine reptiles flourished in the seas.
- ✓ The single Pangea continent was still there and all around Pangea was a huge ocean, Panthalassa.
- ✓ Later, the Tethys Sea intruded into Pangea from the east, leading to the division between Laurasia in the north and Gondwana in the south.
- ✓ The environment was better adapted to the arid environments and cold blooded Archosauromorph had attained prominence over the endothermic warm blooded Therapsids which were the early "mammal-like reptiles".

2. Jurassic Period:

- ✓ The major characters of this period were warm tropical greenhouse conditions on Earth, presence of shallow continental seas, the break-up of Pangea, cosmopolitan flora and fauna, and the dominance of the majestic dinosaurs and the great sea reptiles.
- ✓ Rocks of this era were first studied in the Jura Mountains which are extensions of Alps on the border of France and Switzerland. The rocks were studied by Alexander von Humboldt and he wrongly recognized them as older than even the Triassic period.
- ✓ He named them as "**Jura Kalkstein**" in 1795.
- ✓ 1839 Leopold von Buch formally named the rocks described by von Humboldt as the Jurassic System. The geological event of the early Jurassic period also includes the breaking up of

supercontinent Pangaea into the northern supercontinent Laurasia and the southern supercontinent Gondwana.

- ✓ Opening of the Gulf of Mexico in the new rift between North America and Mexico's Yucatan Peninsula and closing of the Tethys Sea.
- ✓ During this period, large dinosaurs roamed in forests of similarly large conifers. Coniferous plants were dominant among flora. Among fauna some of were
 - i. **Allosaurus**, which was one of the largest land predators during the Jurassic
 - ii. **Stegosaurus** , which was one of the most recognizable genera of dinosaurs and lived during the mid to late Jurassic.
 - iii. **Archaeopteryx** , which marks the start of the evolution of birds.
 - iv. **Plesiosaurs** , which were marine and roamed the oceans. Ichthyosaurus, the early fish kind dinosaur which was the first complete fossil to be discovered in the early 19th century

3. Cretaceous Period:

- ✓ The time period assigned to Cretaceous period is 145.5 to 65.5 million years ago.
- ✓ This 80 million years period is the youngest period of the Mesozoic Era but the longest period of the Phanerozoic Eon.
- ✓ This period saw the proliferation of the flowering plants, new types of insects, modern fishes, some new types of Dinosaurs, some modern crocodylians and modern sharks. Pterosaurs were replaced by primitive birds; marsupials appeared for the first time, early placental mammals started to appear.
- ✓ The Gondwana had broken up, Atlantic sea got widened, Orogeny of rocky mountains started and level of CO₂ came to very near to present day CO₂.
- ✓ The Mesozoic era ended 65.5 million years ago and Cenozoic era started which continues till date. The end marks an event called "Cretaceous–Tertiary extinction event" or **KT event** which wiped out the Dinosaurs from Earth. It is also known as Cretaceous–Paleogene (K-Pg event).
- ✓ There are a few theories regarding the end of Mesozoic era and extinction of Dinosaurs but the Impact Event theory is most accepted.

KT Event

This theory was explained by the Nobel prize-winning physicist Luis Alvarez and others. He discovered that the sedimentary layers found all over the world at the Cretaceous–Tertiary period have a 30-130 times more concentration of Iridium.

- Iridium is extremely rare in the Earth's crust because it is a siderophile and bonds with Iron easily.

So, most of it travelled with the iron as it sank into the Earth's core during planetary differentiation. As iridium remains abundant in most asteroids and comets, the Alvarez team suggested that an asteroid struck the Earth at the time of the K–T events. This was the first proof that KT event happened.

This event generated a dust cloud and inhibited the photosynthesis as sunlight was blocked for years. It was followed by acid rains. The infrared radiation caused by the impact might have killed the organisms exposed, global firestorms may have resulted from the heat pulse and the fall back to Earth of incendiary fragments from the blast. High O₂ levels during the late Cretaceous might have supported intense combustion. The level of atmospheric O₂ plummeted in the early Tertiary Period. If widespread fires occurred, they would have increased the CO₂ content of the atmosphere and caused a temporary greenhouse effect once the dust cloud settled, and this would have exterminated the most vulnerable organisms that survived the period immediately after the impact. Most paleontologists now agree that an asteroid did hit the Earth about 65 Ma ago, but there is an ongoing dispute whether the impact was the sole cause of the extinctions. Some of them say that it might have been a result of multi impacts.

Cenozoic Era

-: About this document:-

Cenozoic Era means new life. It is the most recent and continues till date, started 65.5 million years ago. In this era, the continents had moved to their current positions. Australia had split from the Gondwana in the early cretaceous era, moved further to current position, Antarctica moved to its current position, Atlantic Ocean had widened and the South America got attached to North America. Some 50 million years ago India collided with Asia and **Himalayan Orogeny** started, Arabia collided with Eurasia and Tethys Sea was permanently closed in next 10 million years.

The Cenozoic era has been divided into 3 periods: Paleogene period, Neogene Period and Quaternary. Paleogene Period is the oldest and Quaternary is latest.

1. **Paleogene Period:** The period assigned to Paleogene period has been 65.5 million years ago till 23 million years ago. The mammals evolved in this period. It is also known as "Lower Tertiary". The term "Lower Tertiary" refers to rocks deposited during the 'Paleogene Period' and it means a lot for the oil industry as rock formations represent the current deep-water oil discovery. The rock deposits are older sediments with lower porosities, ultra-deep water depths. The "Lower Tertiary" oil reservoirs are deeper than 26,000 feet, have high sand content (as much as 70%), may exceed thicknesses of 400 feet, and typically lie underneath thick salt sheets. The Paleogene period is divided into 3 epochs.
 1. First is Paleocene epoch whose main events are Orogeny of Alps, Orogeny of Himalayas. Himalayas started forming around 52 and 48 Million Years ago.
 2. Second is Eocene epoch in which the first modern mammals appeared. This epoch ended with a major extinction event called Grande Coupure or Great Break. In this epoch, the northern supercontinent of Laurasia began to break up, as Europe, Greenland and North America drifted apart.
 3. Oligocene is the third and final epoch of the Paleogene Period.
2. **Neogene Period:** The time period assigned to Neogene is 23 million years ago to 2.5 million years ago.
3. **Quaternary Period:** This is the most recent period and spans from 2.6 million years ago to the present. The continental drift stopped and not more than 100 kms drift occurred during the entire period. It has been divided into two epochs Pleistocene and Holocene.
 - a. **Pleistocene:** The time period assigned to Pleistocene is 2.588 million years to 12,000 years before present. Many large mammals flourished and became extinct in the Pleistocene epoch. Modern Human (anatomically) evolved in this Pleistocene era. This period marks the dawn of human stone-age cultures. This epoch marked with the repeated glacial cycles in the climate.
 - b. **Holocene:** The time period assigned to Holocene epoch is 12,000 years ago to present. Evolution of Modern Mammals happened in this period. This epoch is dominated by human civilizations, which sometimes leads to use of the **Anthropocene** as an alternative term. (This term Anthropocene which is synonym with Holocene was coined in 2000 by the Nobel Prize-winning scientist Paul Crutzen). Holocene started where last glacial period ended.


The rise of human civilization, beginning of agriculture, building cities by humans , starting of Paleolithic/Neolithic (Stone Age) cultures around 10000 BC, followed by Copper Age (3500 BC) and Bronze

Age (2500 BC), the human culture grew by leaps and bounds , taking to the next level of advancement known as Iron Age (1600 BC) and many prehistoric cultures of the world.

EARTH

Fast Facts

- ✓ Earth is third planet from the Sun and Fifth largest planet.
- ✓ It is largest among the Solar System's four terrestrial planets (Mercury, Venus, Earth, and Mars). Jupiter, Saturn, Uranus, and Neptune are gas giants.
- ✓ **Mean radius** : 6,371.0 km
- ✓ **Equatorial radius** : 6,378.1 km
- ✓ **Polar radius** : 6,356.8 km
- ✓ **Flattening** : 0.0033528
- ✓ **Equatorial Circumference** : 40,075.16 km
- ✓ **Meridional Circumference**: 40,008.00 km
- ✓ **Surface area** : 510,072,000 km²
- ✓ **Land Area**: 148,940,000 km² (29.2 %)
- ✓ **Water Area** : 361,132,000 km² (70.8 %)
- ✓ **Volume** : 1.08321 × 10¹² km³
- ✓ **Mass** : 5.9736 × 10²⁴ kg
- ✓ **Mean density** : 5.515 g/cm³
- ✓ **Equatorial surface gravity** : 9.780327 m/s²
- ✓ **Escape velocity** : 11.186 km/s
- ✓ **Sidereal rotation period** : 23h 56m 4.100s
- ✓ **Equatorial rotation velocity** : 1,674.4 km/h
- ✓ **Axial tilt** : 23°26'21".4119
- ✓ **Albedo** : 0.36
- ✓ **Surface temp: Minimum** : -89.4 °C **Median**: 14 °C **Maximum** : 58 °C
- ✓ **Surface pressure** : 101.325 kPa

 **Composition** : 78.08% nitrogen (N₂), 20.95% oxygen (O₂), 0.93% argon, 0.038% carbon dioxide, About 1% water vapor (varies with climate)

Most abundant elements in Universe?

Hydrogen is the most abundant element in the known Universe. Helium is second. Oxygen has abundance rank 3, but please note that the Oxygen in Molecules (O₂) form, which we breath is very rare. The 10 most common elements in Galaxy estimated are Hydrogen, Helium, Oxygen, Carbon, Neon, Iron, Nitrogen, Silicon, Magnesium and Sulphur.

Earth's Chemical Composition

Earth is composed mostly of Iron (32.1%), Oxygen (30.1%), Silicon (15.1%), Magnesium (13.9%), Sulphur (2.9%), Nickel (1.8%), Calcium (1.5%), and Aluminium (1.4%); with the remaining 1.2% consisting of trace amounts of other elements.

Earth's core is made up of **Iron mostly**. 88.8% of Earth's core is iron and that is because of mass segregation.

Mass segregation refers to the process by which heavier members of a gravitationally bound system or body

-: About this document:-

tend to move toward the centre, while lighter members tend to move farther away from the centre.

Earth's crust

47% of the Earth's crust consists of oxygen. Most of the rocks in Earth's crust are all oxides. The principal oxides are silica, alumina, iron oxides, lime, magnesia & potash.

Earth's Internal Heat:

Earth's internal heat comes from a combination of residual heat from planetary accretion (about 20%) and heat produced through radioactive decay (80%). The major heat-producing isotopes in the Earth are potassium-40, uranium-238, uranium-235, and thorium-232.

Some Extreme Points:

- ✓ The northernmost point of Earth is the geographic North Pole, in the Arctic Ocean.
- ✓ The northernmost point on land is Kaffeklubben Island, north of Greenland
- ✓ The southernmost point of the world and the southernmost point on land is the geographic South Pole, which is on the continent of Antarctica.
- ✓ The westernmost and easternmost points of the world along the 180th meridian are in Siberian Russia, Antarctica, or the three islands of Fiji through which the 180th meridian passes
- ✓ The westernmost point on land, according to the path of the International Date Line is Attu Island, Alaska.
- ✓ The easternmost point on land, according to the path of the International Date Line is Caroline Island, Kiribati.
- ✓ The highest point measured from sea level is the summit of Mount Everest in Nepal. 8,848 m (29,029 ft) above sea level.
- ✓ The point farthest from the Earth's centre is summit of Chimborazo at 6,384.4 km (3,967 mi). This is due to the Earth being an oblate spheroid rather than a perfect sphere. The summit of Mount Everest is at 6,382.3 km (3,966 mi).
- ✓ The lowest point underground is the 12,261 metres (40,226 ft)-deep Kola Superdeep Borehole number SG-3 drilled in the Kola Peninsula, Russia.
- ✓ The lowest human-sized point underground is 3.9 kilometers below ground at the TauTona mine, Carletonville, South Africa.
- ✓ The lowest point underwater was the 10,680 metres (35,040 ft)-deep Deepwater Horizon oil and gas well located in the Gulf of Mexico.
- ✓ The lowest point is Challenger Deep, at the bottom of the Mariana Trench: 10,911 m (35,797 ft) below sea level.
- ✓ The lowest point on dry land is the shore of the Dead Sea, 418 m (1,371 ft) below sea level.

The point closest to the Earth's centre (~6,353 km (3,948 mi)) is probably at the bottom of the Arctic Ocean (greatest depth 5,450 m (17,881 ft)) near the Geographic North Pole (the bottom of the Mariana Trench is 6,366.4 km (3,956 mi) from the centre of the Earth).

Please also note that

- ✓ Earth is only planet whose name is not derived from a Roman/ Greek deity

- ✓ Asteroids 3753 Cruithne and 2002 AA29 have a complicated orbital relationship with Earth. Further the 2010 TK7 is the first Trojan Asteroid of Earth
- ✓ Proxima centauri is the closest star to Earth.
- ✓ The rank of Earth in Solar system in fifth in terms of mean Radius

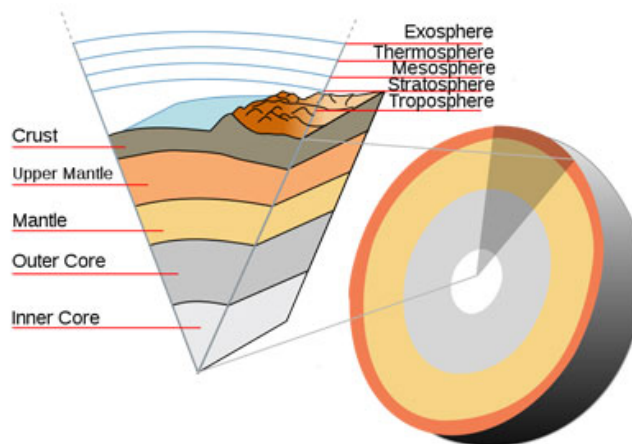
2010TK7



- ✓ Recently, it has been discovered that Earth is not alone in its orbit around the Sun. There is a small ‘Trojan’ asteroid 2010TK7 that sits in front of earth and leads it.
- ✓ This is the 1st Trojan Asteroid of Earth discovered using the **WISE Telescope**.
- ✓ It has now become the First known Trojan Asteroid in Earth’s Orbit.
- ✓ A Trojan asteroid shares an orbit with a larger planet or moon, but does not collide. So a Trojan has a particular position in a stable spot - either in front of a planet or behind it called **Lagrangian points**. Because the asteroid and planet are constantly on the same orbit, they can never collide. Trojan asteroids were anticipated in earth's orbit but never discovered yet. Nasa discovered the asteroid, which lies 80 million km from Earth, using its Widefield Infrared Survey Explorer (WISE) telescope. Astronomers have long thought that Earth did have Trojans but their discovery has proved elusive because they can't be seen in daylight.

Structure of Earth

Earth is flattened at the poles and bulging at the equator, the geometrical figure used in geodesy to most nearly approximate Earth's shape is an **oblate spheroid**. Its Equatorial radius is 6,378.1 km and polar radius is 6,356.8 km. The internal structure of earth is layered. It has outer silicate solid crust. The cutaway from earth's crust to core is shown as below:



It must be noted that the average density of Earth is 5,515 kg/m³. Since the average density of surface material is only around 3,000 kg/m³, it can be concluded that **denser materials exist within Earth's core**.

When we move from earth’s Crust to Core, the density increases.

The following table shows the depth as well as the average density of various layers:

Depth (Sq. Kms)	Layer	Density gm per cubic cm.
0-60	Lithosphere	1.2-2.9
0-35	Crust	2.2-2.9
35-60	Upper mantle	3.4-4.4
35-2890	Mantle	3.4-5.6

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100–700	Asthenosphere	NA
2890–5100	Outer core	9.9–12.2
5100–6378	Inner core	12.8–13.1

A Brief Discussion about these Layers follows:

Earth’s Crust & Lithosphere

Lithos means rock. The words Paleolithic, Mesolithic and Neolithic periods are based upon man’s utilization of stones during these periods. Lithium is an alkali metal and its name is also derived from *Lithos*. The **Lithosphere** comprises of **earth’s crust and uppermost part of the mantle**.

The uppermost part of the Lithosphere that reacts with the atmosphere, biosphere and Hydrosphere is called as **pedosphere**. *Pedos* means soil. Pedosphere is composed of soil and it is the cradle of all the chemical and biogeochemical reactions which leads to soil development.

Lithosphere is of two types

- ✓ **Oceanic lithosphere**, which is associated with Oceanic crust and exists in the ocean basins
- ✓ **Continental lithosphere**, which is associated with Continental crust

The **Oceanic lithosphere** is **denser** than the continental lithosphere.

The **Oceanic crust** is **thinner** than the Continental crust. Oceanic crust is mainly made up of silicate mineral rocks that are rich in magnesium and iron. Since Magnesium is denoted by Mg and Iron is denoted by Fe, these rocks have been named **Mafic Rocks**.

✍ Most common rock-forming Mafic minerals in the oceanic crust are olivine, pyroxene, amphibole, and biotite.

Continental crust is the layer of igneous, sedimentary, and metamorphic rocks which form the continents. It also **includes** the areas of shallow seabed close to their shores, which is also known as **continental shelves**.

This layer is **rich in silicates** and **aluminum** minerals.

✍ Since Silicon is denoted by Si and Aluminum is denoted by Al, sometimes the **continental crust** is called **Sial**.

There is no strict boundary between the Sial and Sima. At certain depth Sial becomes very close in physical properties to Sima.

✍ **Density of Sial is lower than Sima** and this is primarily **because** of the **increased amount of aluminum**.

So we can understand that the continents and the oceans rest on sial and sima respectively which compose the Lithosphere. The lithosphere is thicker (up to 40 kms) on the continental regions and thinnest (up to 12 kms) in the ocean regions.

✍ The Lithosphere contains approximately 1% of earth’s total volume and 0.4% of its mass.

Composition of Earth’s crust in Oxides is as follows:

Compound	Formula	Composition	
		Continental	Oceanic
Silica	SiO ₂	60.2%	48.6%
Alumina	Al ₂ O ₃	15.2%	16.5%
Lime	CaO	5.5%	12.3%
Magnesia	MgO	3.1%	6.8%
Iron(II) Oxide	FeO	3.8%	6.2%
Sodium Oxide	Na ₂ O	3.0%	2.6%

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Potassium Oxide	K ₂ O	2.8%	0.4%
Iron(III) Oxide	Fe ₂ O ₃	2.5%	2.3%
Water	H ₂ O	1.4%	1.1%
Carbon Dioxide	CO ₂	1.2%	1.4%
Titanium Dioxide	TiO ₂	0.7%	1.4%
Phosphorus Pentoxide	P ₂ O ₅	0.2%	0.3%
Total		99.6%	99.9%

Composition of Earth’s Crust in Chemical elements is as follows:

Element	Percent
Oxygen	47
Silicon	28
Aluminum	8
Iron	5
Calcium	3.5
Sodium	2.5
Potassium	2.5
Magnesium	2.2
Titanium	0.5
Hydrogen	0.2
Carbon	0.2
Phosphorus	0.1
Sulphur	0.1

Mohorovičić discontinuity

It is also known as Moho and refers to the boundary between the Earth's crust and the mantle. The Mohorovičić discontinuity is 5 – 10 km below the ocean floor and 20 to 90 km beneath typical continents, with an average of 35 km (22 mi). It was identified by Andrija Mohorovičić, a Croatian seismologist in 1909.

Earth’s Mantle

The mantle is a highly viscous layer between the crust and the outer core. Earth's mantle is a rocky shell about 2,890 kms. thick that constitutes about 84 percent of Earth's volume. It is predominantly solid and encloses the iron-rich hot core, which occupies about 15 percent of Earth's volume.

The mantle is divided into sections viz. the upper mantle, which starts from the Mohorovičić discontinuity around 7 to 35 km, downward to 410 km), the transition zone (410–660 km), the lower mantle (660–2891 km).

Similar to earth’s crust, Oxygen is most abundant element in Earth’s Mantle. The following table shows the composition of earth’s mantle.

Element	Amount	Compound	Amount
O	44.8		
Si	21.5	SiO ₂	46
Mg	22.8	MgO	37.8
Fe	5.8	FeO	7.5
Al	2.2	Al ₂ O ₃	4.2
Ca	2.3	CaO	3.2
Na	0.3	Na ₂ O	0.4
K	0.03	K ₂ O	0.04
Total	99.7	Total	99.1



Earth's Core

Earth's core is divided into two parts viz. a **solid inner core** with a radius of ~1,220 km and a **liquid outer core** extending beyond it to a radius of ~3,400 km.

✎ The solid inner core was discovered in 1936 by Inge Lehmann and is generally believed to be composed primarily of **iron** and some **nickel**.

The major event which led to the formation of core was **iron catastrophe**. Earth as we all know was formed approximately 4500 million years ago. After accumulation of the Earth's material into a spherical mass, the material was mostly uniform in composition. The collision of the material which formed the Earth was significant; heating from radioactive materials in this mass further increased the temperature until a critical condition was reached, when the material was molten enough to allow movement. At this point, **the denser iron and nickel evenly distributed throughout the mass sank to the centre of the planet to form the core** - an important process of planetary differentiation. The gravitational potential energy released by the sinking of the dense Ni-Fe globules increased the temperature of the protoplanet above the melting point resulting in a global silicate magma which accelerated the process. This event occurred at about 500 million years into the formation of the planet and is known as Iron catastrophe.

Recent researches show that the innermost part of the core is enriched in gold, platinum and other siderophile elements. **Siderophile elements** are those elements that tend to bond with metallic iron. Accordingly the elements are lithophile (silicate loving), siderophile (iron loving), chalcophile (sulfur loving), and atmophile (gas loving) and this classification is known as **Goldschmidt classification**.

✎ The solid inner core is too hot to hold a permanent magnetic field, but the **outer core gives rise to Earth's magnetic field**.

Geodesy: Geodesy or Geodetics is a branch of earth sciences which deals with the measurement and representation of the Earth, including its gravitational field. It also deals with Geodynamics.

Great Circle

When a sphere is divided exactly in half through its center, the circumference represents the largest circle that can be drawn on that sphere. **In Earth's case, it is Equator** because earth's is oblate spheroid and the diameter at the equator measures 12756 kms, which is 42 kms more than the polar diameter of 12714 kms.

The reason of larger equatorial diameter is the "Centrifugal Force" which is caused by the rotation of earth.

Equator is a great circle but **lines of longitudes are not great circles** because they are shorter than the equator.

Infinite number of Great Circles can be drawn on a sphere, but only one great circle can pass through two points on a sphere, unless they are opposite to each other.

Motions of Earth

There are five kinds of Earth's motions as follows:

1. Earth moves with the Milky Way, because entire Milky Way galaxy moves through the universe.
2. Earth follows Sun, while the Sun travels in the Milky way.
3. Earth's precession movement which is very much similar to a spinning top.
4. Earth revolution around the Sun
5. Earth's rotation on its axis

Earth's Rotation

Rotation is the rotation of the Earth around its own axis. The rotation is from west to east. When seen from the North Star Polaris which we called *Dhruv Tara* and which is scientifically known as Alpha Ursae Minoris, Earth turns clockwise. The phenomenon gives rise to Day and Nights.

True Solar day is earth's rotation period relative to the Sun and this is called a **Solar day**. There are 3 kinds of the days recognized and measured by the astronomer's viz. Apparent or true solar day, mean solar day and sidereal day.

Apparent Solar Day:

Apparent solar day is the **interval between two successive returns of the Sun to the local meridian**, it can be measured by a sundial to a limited precision. The length of the solar day varies throughout the year. This is because of two reasons.

- ✓ **Earth's orbit is an ellipse** and not a circle. According to Kepler's First Law of planetary Motion, the orbit of every planet is an ellipse with the Sun at one of the two foci. The second Kepler's planetary motions says that a line joining a planet and the Sun sweeps out equal areas during equal intervals of time. This means that Earth moves faster, when it is nearest to the Sun (perihelion) and moves smaller when it is farthest from Sun (Aphelion).
- ✓ **Earth's Axial Tilt:** Earth's orbital plane is known as the ecliptic plane, and so the Earth's axial tilt is called the obliquity of the ecliptic. Earth currently has an axial tilt of about 23.5°, and due to this the axis remains tilted in the same direction towards the stars throughout a year and this means that when a hemisphere (a northern or southern half of the earth) is pointing away from the Sun at one point in the orbit then half an orbit later (half a year later) this hemisphere will be pointing towards the Sun. This effect is the main cause of the seasons.

- ✓ **Due to Earth's tilt**, Sun moves along a great circle (the ecliptic) that is tilted to Earth's celestial equator. When the Sun crosses the equator at both equinoxes, the Sun is moving at an angle to the equator, so the projection of this tilted motion onto the equator is slower than its mean motion; when the Sun is farthest from the equator at both solstices, the Sun moves parallel to the equator, so the projection of this parallel motion onto the equator is faster than its mean motion. The result is that apparent solar days are shorter in March (26–27) and September (12–13) than they are in June (18–19) or December (20–21).
- ✓ The true solar day tends to be longer near perihelion taking about 10 seconds longer and is about 10 seconds shorter near aphelion.
- ✓ It is about 20 seconds longer near a solstice and shorter by 20 seconds near equinox.

Mean Solar Day:

The average of the true or apparent solar day over an entire year is called the mean solar day. It has 86400 seconds. Albeit, the amount of daylight varies significantly, the **length of a mean solar day does not change on a seasonal basis**. However, the length of the Mean Solar Day increases by **1.4 milliseconds per century**.

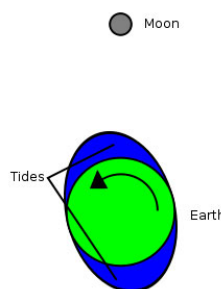
✍ The astronomers have calculated that Mean Solar Day was exactly 86,400 (24 hours × 60 minutes × 60 seconds) SI seconds in approximately 1820 AD and now it is **86400.002** SI seconds

The reason behind this slow down is the **tidal acceleration**.

Concept of Tidal Acceleration

Tidal acceleration refers to the effect of the tidal forces between an orbiting natural satellite and the primary planet that it orbits.

We know that Moon's mass is a considerable fraction of that of the Earth. **The Ratio of masses of moon and Earth is about 1:81**. So these two bodies can be regarded as a double planet system, rather than as a planet with a satellite. The large mass of moon is sufficient to raise tides in the matter of earth. The water of the oceans bulges out along both ends of the axis, passing through the centers of Moon as well as Earth. This tidal bulge is shown below.



The average tidal bulge shown in above figure closely follows the Moon in its orbit. However, since earth also rotates, the rotation drags this bulge ahead of the position directly under the Moon. The arrow shown in the earth shows the direction of this drag. Due to the simultaneously forces of moon's gravitational force giving rise to the bulges in ocean water and substantial amount of mass in these bulges of water dragged by earth's rotation, this bulge is deviated from the line through the centers of Earth and Moon. This gives rise to a Torque which is perpendicular to the earth moon line. This torque boosts moon in its orbit and decelerates earth's rotation.

The above phenomenon is responsible for the slowing Earth's rotation. Due to the tidal acceleration, Earth's mean solar day extends by 2.3 milliseconds every century.

However, due to **glacial rebound**, this extension gets reduced by 0.6 seconds per century.

✂ So the net effect on mean solar day every century is 1.7 milliseconds.

Concept of Global Glacial Rebound

The average position of water is always nearer the equator. During glaciations water is taken from the oceans and deposited as ice over the higher latitudes closer to the poles. These poles are close to the polar axis or rotational axis of the Earth. The moment of inertia of Earth-water-ice system gets reduced which is very much similar to a rotating figure skater bringing her arms closer to her body, the earth should spin faster. This process leads to an increase in the rotation speed of the Earth and therefore to a decrease of the length of day.

Sidereal Day:

The spinning of the earth on its polar axis is in fact takes 23 hours, 56 minutes and 4.09 seconds for rotation through the 360 degree. This is called **sidereal day**.

✂ During the time needed by the Earth to complete a rotation around its axis (a sidereal day), the Earth moves a short distance (approximately 1°) along its orbit around the sun. So, after a sidereal day, the Earth still needs to rotate a small additional angular distance before the sun reaches its highest point. A solar day is, therefore, nearly 4 minutes longer than a sidereal day.

Earth's Revolution

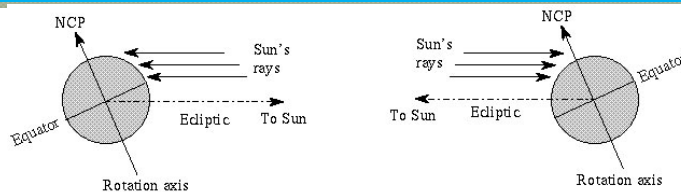
The orbit of the Earth is the motion of the Earth around the Sun every 365.242199 mean solar days.

- ✓ The orbital speed of Earth around the Sun averages about 30 kilometer per second or 108,000 kilometers per hour.
- ✓ This speed is equivalent to cover earth's orbit in 7 minutes and distance from moon to Sun in 4 hours.
- ✓ The model which presents Sun at the center and planets revolving around it is called "heliocentrism".
- ✓ A paradigm shift away from the previous model of the heavens, which postulated that Earth is at the center of the universe, towards the heliocentric model with the Sun at the center of our Solar System, was one of the turning points of the Scientific Revolution of the 16th Century and it was known as Copernican Revolution, after Nicolaus Copernicus, a Polish astronomer. His book, *De revolutionibus orbium coelestium* (On the Revolutions of the Celestial Spheres), was an epochal book on the subject.

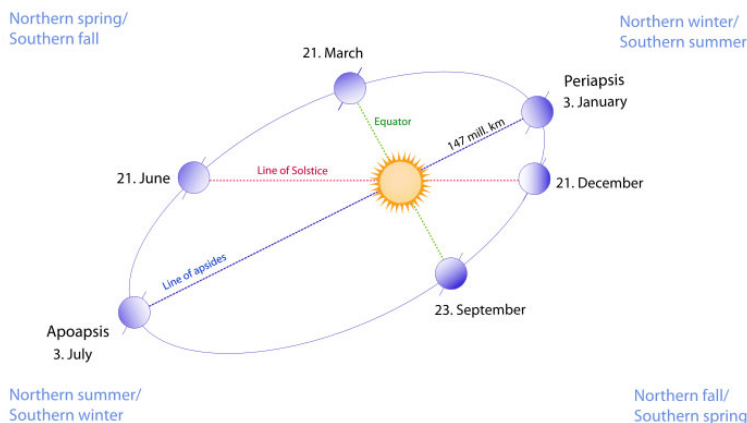
Occurring of Seasons

The path of the Earth around the Sun is elliptical and slightly irregular due to gravitational attraction of moon and other celestial bodies. A constant angle is maintained between the earth's axis and its plane of elliptic, which is called angle of inclination.

As we know that Earth's rotation axis is tilted by 23.44° with respect to the elliptic, and is always pointed towards the celestial poles when the earth moves around the Sun.



The above phenomenon gives rise to 4 seasons.



Solstice

The solstice refers to the events when the Sun's apparent position in sky reaches its northernmost or southernmost extremes. Solstice happens twice a year, and twice a year happen the equinoxes. Altogether, the four are considered to start 4 seasons.

- ✓ At the time of northern solstice, sun is perceived to be directly overhead the 23.44° north known as Tropic of Cancer.
- ✓ Likewise, at the southern solstice the same thing happens for latitude 23.44° south, known as the Tropic of Capricorn.
- ✓ The sub-solar point will cross every latitude between these two extremes exactly twice per year. The point where sun is perceived to be directly overhead is called **subsolar point**.
- ✓ The Northern solstice happens at 20-21 June and Southern solstice happens at 20-22 December.
- ✓ In 2010, Northern solstice happened at 21 June and Southern solstice will happen on 21 December.
- ✓ At Northern solstice, the places which are located at Arctic circle, posited at latitude 66.56° north will see the Sun just on the horizon during midnight. And all the places north of Arctic Circle will see Sun above horizon for 24 hours. This is called **Midnight Sun or a Polar Day**.
- ✓ At Northern solstice which are located at Antarctic circle, posited at latitude 66.56° south will see the Sun just on the horizon during midday. And all the places south of Antarctic Circle will NOT see at anytime of the day. **This is called Polar Night**.
- ✓ **At Southern solstice, Polar day occurs at Southern Pole and Polar Night occurs at Northern Pole.**

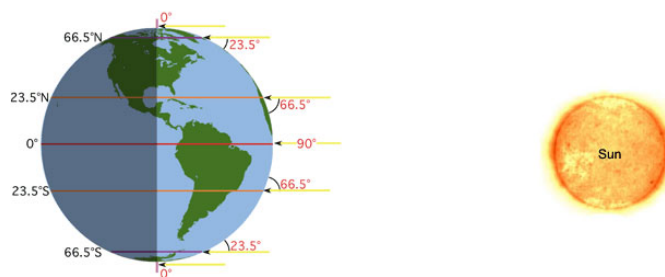
Uttarayan & Dakshinayan

For 6 months of the year, the Sun appears to be moving north . This Northward migration of Sun appears to begin after December 22 and is completed on June 21, when the Sun is directly overhead 23.44° North. Dute to this, In India we call this Uttarayan.

After June 21, for the next 6 months, Sun appears to be moving South and this southward migration appears to get finished , when Sun is directly overhead the 23.44° South. In India we call this apparent migration Dakshinayan.

Equinox

At equinox, Sun is at one of two opposite points where the celestial equator and ecliptic intersect. Sun can be observed to be vertically overhead the Equator. Equinox happens around March 20/21 and September 22/23 each year.



✍ In 2010 March equinox occurred on 20 march and September equinox will occur on 23 September.

Longest Days & Nights

When Sun is direct overhead on 23.44° north, it is called Longest Day in Northern hemisphere. So Northern Solstice represents the longest day of the Northern hemisphere and smallest night of the Southern Hemisphere.

When Sun is direct overhead on 23.44° south, it is called Longest Day in Southern hemisphere. So Southern Solstice represents the longest day of the Southern hemisphere and smallest night of the Northern Hemisphere.

Perihelion and Aphelion

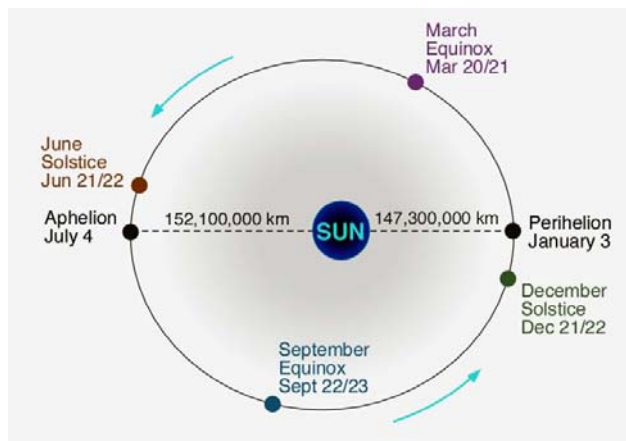
- ✓ Earth travels 939,886,400 kms along its elliptical orbit in a single revolution. The average distance is 150 million kms, but the orbit is elliptical and there is the difference if 2.5 million kms.
- ✓ **Perihelion** is the point when Earth is closest to Sun and it occurs around 3rd January. The distance is 147.5 million kms.
- ✓ **Aphelion** is the point when Earth is farthest from the Sun and it occurs on July 4. The distance is 152.5 million Kms,

Perihelion: On around January 3rd, Earth is closest to sun and distance is around 147.5 million Kilometers. This is called Perihelion.

Aphelion: On about July 4th earth is Farthest from Sun and this is called Aphelion.

✍ Speed of Earth is fastest at Perihelion and slowest at Aphelion (Kepler’s Second Law).

The following Graphic shows the Solstice, Equinoxes and Helions altogether:



Precession Movement of earth

The Precession movement of Earth is very slow and proceeds in the direction of the opposite of Earth's Rotation. The one cycle completes in 28000 years.

- ✍ The reason of precession movement is gravitational attraction of Moon as well as Sun.
- ✍ The slightly irregular movement of earth's axis due to precession is called Nutation.

Grid System: Latitudes and Longitudes

Eratosthenes was the first person to calculate the size of the earth. He realized that Earth could be located with a basic grid of lines called Longitude and latitude.

Latitudes

Latitude which is denoted by ϕ is the angle between the equatorial plane and the axis. Lines joining points of the same latitude are called parallels, which trace concentric circles on the surface of the Earth, parallel to the equator.

- ✍ The largest parallel is Equator. The North Pole is 90° N; the South Pole is 90° S.
- ✍ The 0° parallel of latitude is designated the equator. The equator divides the globe into Northern and Southern Hemispheres.
- ✍ Equator is the fundamental plane of all geographic coordinate systems.
- ✍ Latitudes tell us the temperature and climatic position of a particular place.
- ✍ Geostationary satellites are over the equator at a specific point on Earth, so their position related to Earth is expressed in longitude degrees only. Their latitude is always zero, that is, over the equator.
- ✍ There are 180° of latitudes and each degree of latitude spans around 111 kilometers or 69 miles or 60 Nautical miles. But this distance varies because Earth is NOT a perfect sphere.
- ✍ From Equator to 40° towards both poles it is slightly less than 111 kilometers and from 41° towards both poles it is slightly more than 111 kilometers.
- ✍ One nautical mile is 1,852 meters (approximately 6,076 feet) or 1.15077 miles.
- ✍ The 90° North and 90° South are not circles but only reference points.
- ✍ Each degree is divided into 60 minutes and each minute divided into 60 seconds.

Longitudes

Longitude which is denoted by λ is the angle east or west of a reference meridian between the two geographical poles to another meridian that passes through an arbitrary point. All meridians are halves of great circles, and are not parallel. They converge only at the north and south poles.

A line passing to the rear of the Royal Observatory, Greenwich (near London in the UK) has been chosen as the international zero-longitude reference line and is known as the Prime Meridian.

Places to the east are in the eastern hemisphere, and places to the west are in the western hemisphere. The antipodal meridian of Greenwich is both 180°W and 180°E.

- ✓ There are 360° of the meridians and the longitude of prime meridian is 0°.
- ✓ Length of all meridians is equal.
- ✓ The distance between two meridians is farthest at the equator and it decreases as we move towards poles and becomes zero at poles.