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PHYSICS

NATURE OF UNIVERSE AND SPACE SCIENCE

Introduction :

- In ancient days, it was believed that the earth was at the centre of the universe and the moon, the planets, the sun and stars were orbiting around it. This model was put forth by the Greek philosopher Plato and his disciple Aristotle in 6th century B.C. It was standardized by a Greeco Roman mathematician Ptolemy in the 2nd Century A.D. In India a similar model can be seen in the Siddhanthic astronomy in Aryabhata's Aryabhateeyam.
- In 16th century, a polish priest and astronomer named **Nicolaus Copernicus (1473-1543 AD),** stated that the sun was at the centre of the solar system and the planets revolves around it. This theory is known as **heliocentric model (helios = sun).** Even Copernicus hesitated to publish his work. His theory was however published in the year of his death in 1543 AD.
- Invention of the telescope in the Netherlands, in 1608 AD created a revolution in astronomy. In 1608, Galileo designed his own telescope, through this telescope he observed moons of Jupiter, phases of Venus and rings of Saturn. He argued that all the planets orbits the sun and not the earth.

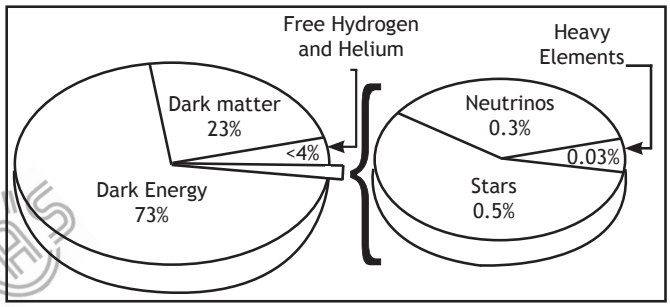
Building block of the Universe

The universe contains everything that exists today including planets, stars, space and galaxies. This includes all matter, energy and even time. **Galaxies are collection of billions of stars.** It is beyond the bounds of possibility to know exact size of the universe. It could be infinitely large. However, scientists to some extent tried to measure the size of the universe by what they can actually see. This is called the '**observable universe**'. The observable universe is around 93 billion light years (1 light year is equal to the distance that light travels in one year, which is 9.4607×10^{12} km).

It is interesting to know that the universe is just expanding. It is growing larger and larger all the time. In 1929, Edwin Hubble, an astronomer at California Institute of Technology, made a critical discovery that universe is expanding. Once scientists understood that the universe was expanding, they immediately realized that it would have been smaller in the past. At some point in past, the entire universe would have been a single point. This point, later exploded with unimaginable force called event of **big bang,** and it was the beginning of the universe as we understand it today. However, most of the universe what we think of is empty space. All the atoms together make up only around **4% of the universe.** The majority of the universe consists of something scientists call as **dark matter and dark energy.**

Difference between normal matter and dark matter

Normal matter	Dark matter
Normal matter or baryonic matter can be broken down into sub-atomic particles called leptons (for example electron) and quarks (the building blocks of protons and neutrons). These are what make up the atoms and molecules which are the components of everything from humans to stars.	In contrast with normal matter, dark matter is material that is non-luminous. That is, it does not interact electromagnetically and therefore it appears dark (i.e it will not reflect or give off light).
Normal matter is Luminous, that is, it interacts electro magnetically and gravitationally with other matter and with radiation. It doesn't necessarily shine like star. It may give off other radiation (such as infrared).	The exact nature of dark matter is not well known, although its effect on other masses (such as galaxies) has been noted by astronomers such as Dr. Vera Rubin and others. However, its presence can be detected by the gravitational effect it has on normal matter. For instance, its presence can constrain the motions of star in galaxy.



Cosmological Composition

Age of the Universe :

- Scientists believe that the universe came into being after a massive explosion called the **Big Bang.** According to Big Bang Theory ; In the beginning, all matter forming the universe existed in one place in the form of a "**tiny ball**" **(singular atom)** with an unimaginably small volume, infinite temperature and infinite density. After several years the "tiny ball" exploded violently. This led to huge expansion. It is now generally accepted that the event of big bang took place **13.7 billion years before the present.**

We know that expansion continues even to the present day. As it grew, some energy was converted into matter. There was particularly rapid expansion within fractions of a second after the bang. Thereafter, the expansion has slowed down. Within first three minutes from the Big Bang event, the first atom began to form.

- Within 300,000 years from the Big Bang, temperature dropped to 4,500K (Kelvin) and gave rise to atomic matter. The universe became transparent. The expansion of universe means increase in space between the galaxies. An alternative to this was **Hoyle's concept of steady state.** It considered the universe to be roughly the same at any point of time. However, with greater evidence becoming available about the expanding universe, scientific community at present favours argument of expanding universe.

Formation of Universe

Time/year	Event
0	Big Bang
10^{-32} seconds	Cosmic Inflation (origin of fluctuations)
1 second	Particles formation
100 seconds	Ordinary matter particles are coupled to light. And dark matter particles start building structures.
380000 years	Recombination (ordinary matter particles decouple from light and the cosmic microwave background is released)
From 380000 years to 200 million years	Dark ages (ordinary matter particles fall into the structures created by dark matter)
200 million years	First stars & galaxies
10 billion years	Galaxy evolution (Clusters of galaxies and super clusters formation)
13.82 billion years	Today

Galaxies

- In the beginning, all matter forming the universe existed in one place in the form of tiny ball. The distribution of matter and energy was not present in the early universe. These initial density differences gave rise to differences in gravitational forces and it caused the matter to get drawn together. These formed the bases for development of galaxies.
- A galaxy is a massive collection of gas, dust and billions of stars. Galaxies spread over vast distances that are measured in thousands of light-years. The diameters of individual galaxies range from 80,000 – 150,000 light years.
- **Scientists believe that there are one hundred billion (10^{11}) galaxies in the observable universe.** Galaxies are also in different shapes. Depending on their appearance, galaxies are classified as spiral, elliptical or irregular. Galaxies may present alone or in pairs and also in parts of groups, clusters and super clusters. Galaxies in groups would interact and even merge together.
- Our solar system is a part of the "**Milky way galaxy**". In ancient times, it was imagined to be a river of light flowing in the sky. Thus, it was named **Akash Ganga.** There are several galaxies besides our milky way galaxy. **The Andromeda Galaxy,** also known as Messier 31, (M31) or NGC 224 is a spiral galaxy approximately 780 kiloparsecs from Earth and the nearest major galaxy to the milky way galaxy. Milky way galaxy is spiral in shape. Our solar system is 25,000 light years away from the centre of our galaxy.

A light year is a measure of distance and not of time. Light travels at a speed of 300,000 km/second. Considering this, the distance the light that travels in one year is taken to be one light year. This equals to 9.461×10^{12} km. The mean distance between the sun and the earth is 149,898,000 km. In terms of light years, it is 8.311 minutes.

Stars

- The formation of stars is believed to have taken place some 5-6 billion years ago. Stars are the most widely recognized astronomical objects and represent the most fundamental building blocks of galaxies.
- Stars are formed within the clouds of dust and scattered throughout in most galaxies. Stars produce heat, light, ultraviolet rays, x-rays and other forms of radiation. However, stars are responsible for the formation and distribution of heavy elements such as carbon, nitrogen and oxygen. Stars are largely composed of gas and plasma (a superheated state of matter) and are built by hydrogen gases. Over 3,000 stars can be seen in a dark night with the naked eye. It is impossible to predict the exact number of stars. It is generally believed our universe constitutes more than 100 billion galaxies and each of those galaxies may have more than 100 billion stars.
- Stars may appear to be alone, however most of the stars exist as pairs. The brightness of a star depends on their intensity and the distance from the Earth. Stars also appear to be in different colours depending on their temperature. Stars with higher temperature looks white or blue, whereas cooler stars looks orange or red in colour.

Constellations

- The stars forming a group that has a recognisable shape is called a constellation. They represent an animal, mythological personalities or creature, a god or an object. One of the most famous constellations which we can see during summer time in the early

part of the night is **Ursa Major.** It is also known as the Big Dipper, the Great Bear or the Saptarshi.

- Ursa minor is sometimes informally called the little Dipper, because it looks like a smaller and fainter version of the Big Dipper (ursa major). Its brightest star, at the tip of the ladle's handle is polaris, the pole star. There are formally 88 constellations as accepted. Some of them are ; **Aries, Gemini, Leo, Orion, Scorpius and Cassiopeia.**

Polestar

- A pole star also known as polar star, preferably bright, closely aligned to the axis of rotation of an astronomical object. Currently, '**Polaris' (ursae minoris)** is designated as the north star or pole star. (It is the brightest star in the constellation of ursa minor). It is very close to the north celestial pole, making it the current northern pole star. Sailors and travellers have used it for navigational purposes for centuries because of its constant - seeming position in the sky.
- There is no such pole star for the southern celestial pole.

The solar system

- The Sun and the celestial bodies which revolve around it form the solar system. It consists of many number of bodies such as planets, comets, asteroids and meteors. The gravitational attraction between the sun and these objects keeps them revolving around it.
- Our solar system consists of eight planets. The nebula from which our solar system is supposed to have been formed, started its collapse and core formation started, some time (5-5.6 billion years) ago and planets were formed about 4.6 billion years ago.

The Sun

- The Sun is a yellow dwarf star, a hot ball of glowing gases at the heart of our solar system. Its gravity holds the solar system together, keeping everything – from the biggest planets to the smallest particles of debris - in its orbit. The connection and interactions between the Sun and Earth drive the seasons, ocean currents, weather, climate, radiation belts and auroras. The sun accounts for 99.8% of the mass of the entire solar system.

Inner planets - very close to the sun. They are made up of rocks.	**Outer Planets - Very-very far from the sun and are huge planets made up of gases and liquids.**
Mercury : One orbit around sun - 88 days, One spin on axis - 58.65 days.	**Jupiter :** One orbit around sun - 11 years, 11 months (around 12 years). One spin on axis - 9.92 hours, number of moons - 79
Venus : One orbit around sun - 255 days, One spin on axis - 243 days	**Saturn :** One orbit around sun - 29 years, 5 months. One spin on axis - 10.23 hours, number of moons - 82.
Earth : One orbit around sun - 365 days. One spin on axis - 23.93 hours, Number of moons - 1	**Uranus :** One orbit around sun - 84 years. One spin around axis - 17 hours, number of moons - about 27.
Mars : One orbit around sun - 687 days, One spin on axis - 24.62 hours, number of moons - 02	**Neptune :** One orbit around sun - 164 years. One spin on axis 18 hours, number of moons - 14.

- In terms of the number of atoms, three quarters of the sun has hydrogen gas (91.1%) and one quarter has helium gas (8.9%). By mass, the Sun is about 70.6% hydrogen and 27.4% helium. The Sun's enormous mass is held together by gravitational attraction, producing immense pressure and temperature at its core. **The Sun has six regions: the core, the radiative zone and the convective zone in the interior, the visible surface, called the photosphere, the chromosphere and the outermost region, the corona.**
- **The sun and the rest of the solar system formed from a giant, rotating cloud of gas and dust called as solar nebula about 4.5 billion years ago. As the nebula collapsed because of its overwhelming gravity, it spun faster and flattened into a disk.**
- Sun is over a million times as big as the Earth. Hydrogen atoms combined or fuse together to form helium under enormous pressure. This process is called **nuclear fusion.** It releases enormous amount of energy as light and heat. Sun is believed to be formed 4.6 billion years ago.
- Like all stars, the Sun will someday run out of energy. When the Sun starts to die, it will swell so big that it will engulf Mercury and Venus and may be even Earth. Scientists predict the Sun is a little less than halfway through its life time and will last another 6.5 billion years before it shrinks down to be a white dwarf.

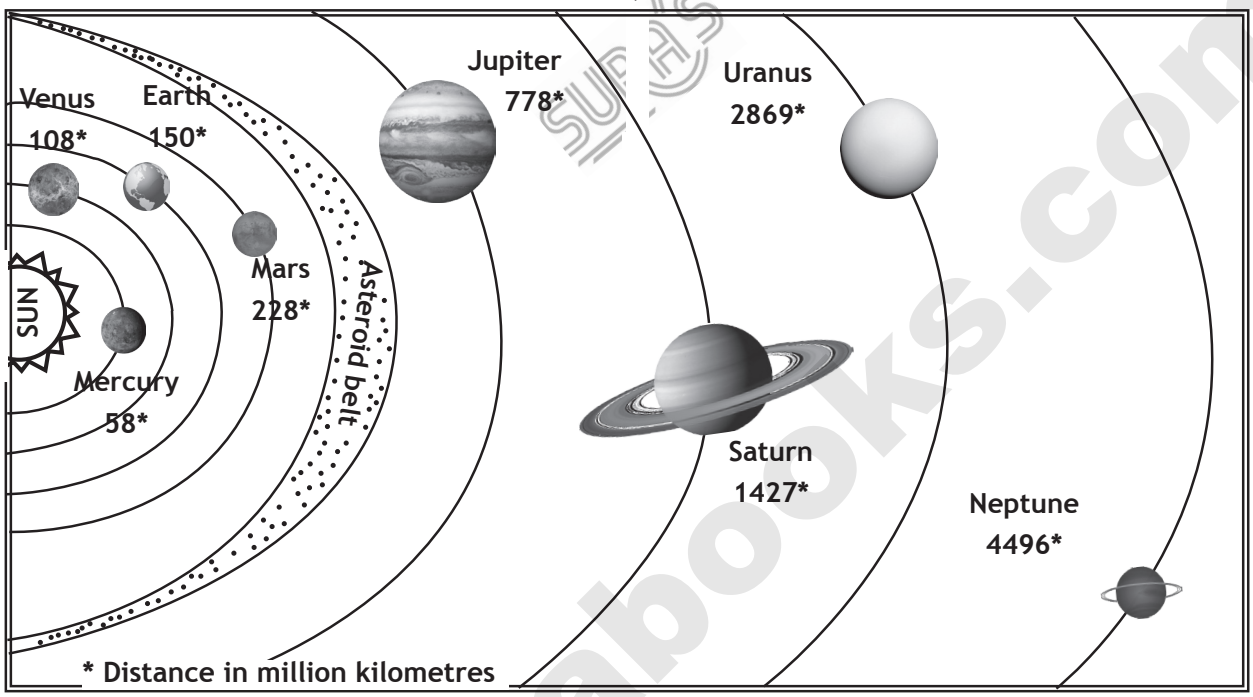
Quick facts about Sun

Radius : 432,168.6 miles / 695,508 kilometres
Star Type : Yellow dwarf
Distance from Earth : 92.92 million miles / 149.60 million Kilometres / 1 astronomical unit

Planets

- A planet revolves around the Sun along a definite curved path is called an orbit, which is elliptical. The time taken by a planet to complete one revolution is called its period of revolution.
- Besides revolving around the Sun, a planet also rotates on its own axis like a top. The time taken by a planet to complete one rotation is called its period of rotation.

- The period of rotation of the Earth is 23 hours and 56 minutes and so the length of a day of Earth is approximately taken as 24 hours.
- Out of the eight planets, Mercury, Venus, Earth and Mars are called as the inner planets as they lie between the Sun and the belt of asteroids. The other four planets are called the outer planets. Also, the first four planets are called **Terrestrial,** meaning earth-like as they are made up of rock and metals and have relatively high densities. The rest four are called **Jovian or Gas Giant planets**. Jovian means Jupiter-like. Most of them are much larger than the terrestrial plants and have thick atmosphere, mostly of helium and hydrogen. All the planets were believed to be formed in the same period sometime about 4.6 billion years ago.



Mercury

Mercury is a rocky planet nearest to the Sun. It is very hot during day but very cold at night. Mercury can be easily observed thorough telescope than naked eye since it is very faint and small. It always appears in the eastern horizon or western horizon of the sky.

Venus

- Venus is a special planet in the solar system. The planet is almost the same size as the Earth. It is the hottest planet in our solar system. After our moon, it is the brightest heavenly body in our night sky.
- This planet spins in the opposite direction to all other planets (east to west). So, unlike Earth, the Sun rises in the west and sets in the east here. Venus can be seen clearly through naked eye. It always appears in the horizon of eastern or western sky.

The Earth

The Earth where we live is the only planet in the solar system which supports life. Due to its right distance from the Sun it has the right temperature, the presence of water and suitable atmosphere and a blanket of ozone. All these have made continuation of life possible on the Earth. From space, the Earth appears bluish green due to the reflection of light from water and land mass on its surface.

Mars

The first planet outside the orbit of the Earth is Mars. It appears slightly reddish and therefore it is also called the **red planet.** It has two small natural satellites (Deimos and Phobos). There are no rings around Mars.

Jupiter

- Jupiter is called as **Giant planet.** It is the largest of all planets (about 11 times larger and 318 times heavier than Earth). It has 3 rings and 79 moons. Its moon Ganymede is the largest moon of our solar system.
- In 1979 the voyager mission discovered Jupiter's faint ring system. All four giant planets in our solar system have ring systems.

Saturn

Known for its bright shiny rings, Saturn appears yellowish in colour. It is the second biggest and a giant gas planet in the outer solar system. Saturn has atleast 82 moons - the largest being **Titan.** Titan is the only moon in the solar system with clouds. Having least density of all (30 times less than Earth), this planet is so light.

Uranus

Uranus is a cold gas giant and it can be seen only with the help of large telescope. It has a greatly tilted