9th Science Lesson 9 Notes in English

9] Universe

Introduction

- In the earlier days, before the invention of astronomical instruments, people thought that Earth is the centre of all the objects in the space.
- This was known as **the geocentric model**, held by Greek astronomer Ptolemy (2nd Century), Indian astronomer **Aryabhatta** (5th Century) and many astronomers around the world.
- Later Polish astronomer **Nicolaus Copernicus** proposed the heliocentric model (helios = Sun), with Sun at the centre of the solar system.
- Invention of the telescope in the Netherlands, in 1608, created a revolution in astronomy.
- In this lesson, we will study about the building blocks of the universe, **Kepler's laws** of motion, time period of **satellites** and **International Space Station** (ISS).

Building block of the Universe

- The basic constituent of the universe is **luminous matter** i.e., galaxies which are really the collection of billions of stars.
- The universe contains everything that exists including the Earth, planets, stars, space, and galaxies.
- This includes all **matter, energy** and even **time**. No one knows how big **the universe** is.
- It could be infinitely large. Scientists, however, measure the size of the universe by what they can see. This is called the **'observable universe'**.
- The observable universe is around 93 billion light years (1 light year = the distance that light travels in one year, which is 9.4607 × 1012 km) across.
- One of the interesting things about the universe is that it is currently expanding. It is growing larger and larger all the time.
- Not only is it growing larger, but the edge of the universe is expanding at a faster and faster rate.
- However, most of the universe what we think of is empty space. All the atoms together only make up around four percent of the universe.
- The majority of the universe consists of something scientists call **dark matter** and **dark energy**.

Age of the Universe

- Scientists think that the universe began with the start of a massive explosion called **the Big Bang.**
- According to Big Bang theory, all the matter in the universe was concentrated in a single point of hot dense matter.

- About 13.7 billion years ago, an explosion occurred and all the matter were ejected in all directions in the form of galaxies.
- Nearly all of the matter in the universe that we understand is made of hydrogen and helium, the simplest elements, created in the Big Bang.
- The rest, including the oxygen, the carbon, calcium, and iron, and silicon are formed in the cores of stars.
- The gravity that holds these stars together generally keeps these elements deep inside their interiors.
- When these stars explode, these fundamental building blocks of planetary systems are liberated throughout the universe.

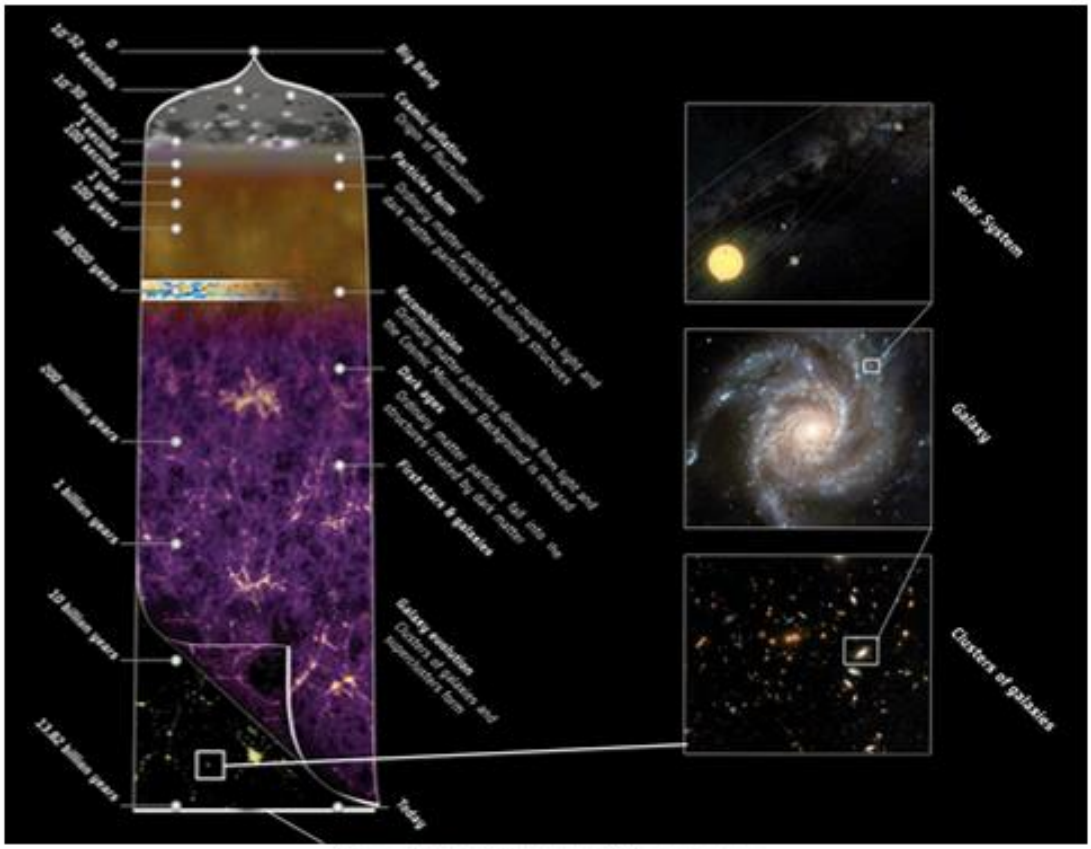
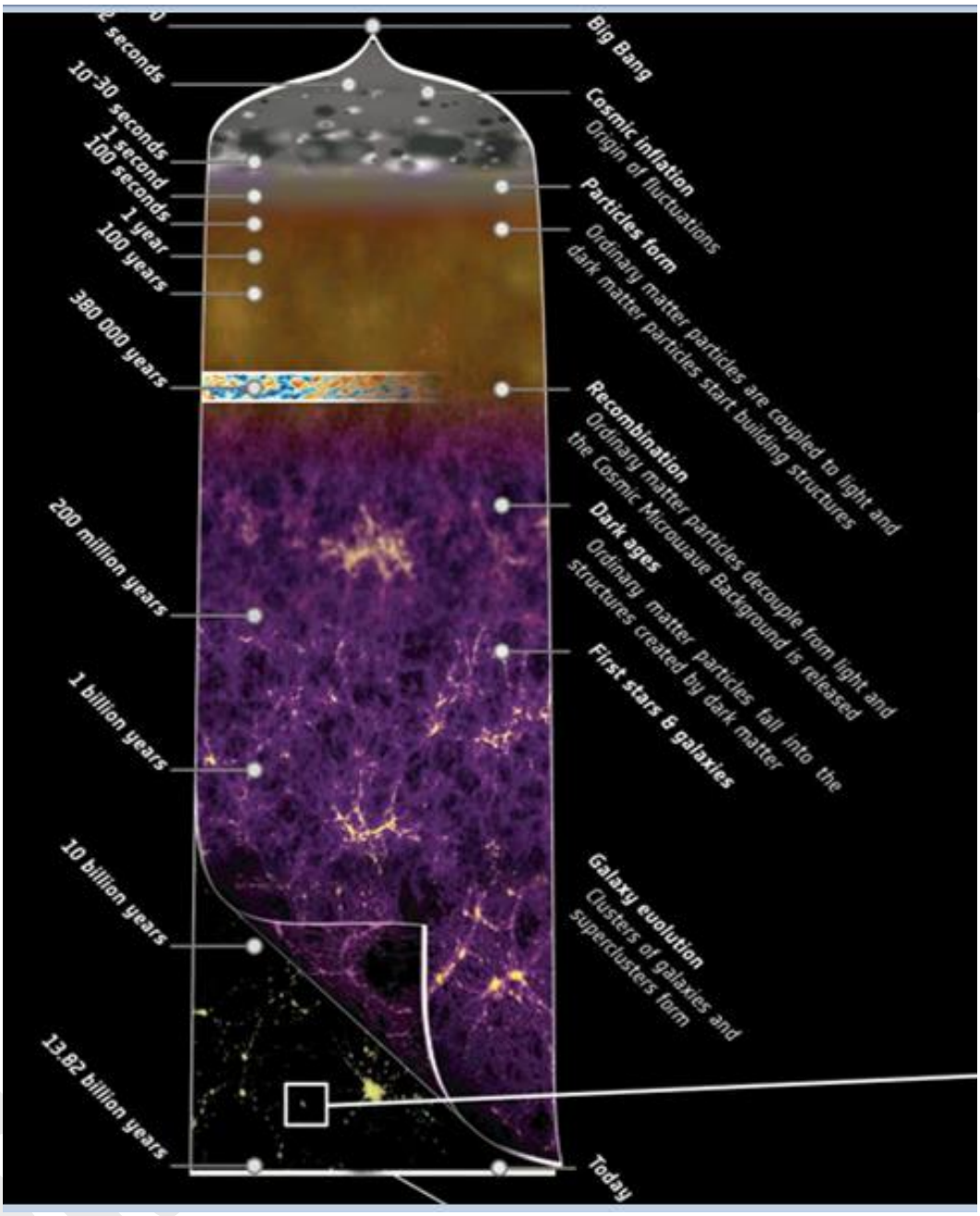


Figure 9.1 Formation of the universe



Galaxies

- Immediately after the Big Bang, clouds of gases began to compress under gravity to form the building blocks of galaxies.
- A galaxy is a massive collection of gas, dust, and billions of stars and their solar systems.
- Scientists believe that there are one hundred billion (1011) galaxies in the observable universe.
- Galaxies are also in different shapes. Depending on their appearance, galaxies are classified as spiral, elliptical, or irregular.

- Galaxies occur alone or in pairs, but they are more often parts of **groups, clusters**, and **super clusters**.
- Galaxies in such groups often interact and even merge together.
- Our Sun and all the planets in the solar system are in the Milky Way galaxy.
- There are many galaxies besides our Milky Way. **Andromeda galaxy** is our closest neighbouring galaxy.
- The Milky Way galaxy is spiral in shape.
- It is called **Milky Way** because it appears as a milky band of light in the sky.
- It is made up of approximately 100 billion stars and its diameter is 1,00,000 light years.

Figure 9.2 Milky Way Galaxy

- Our solar system is 25,000 light years away from the centre of our galaxy.
- Just as the Earth goes around the Sun, the Sun goes around the centre of the galaxy and it takes 250 million years to do that.

Stars

- Stars are **the fundamental building blocks of galaxies**. Stars were formed when the galaxies were formed during the Big Bang.
- Stars produce heat, light, ultraviolet rays, x-rays, and other forms of radiation.
- They are largely composed of **gas** and **plasma** (a superheated state of matter).
- Stars are built by **hydrogen gases**.
- Hydrogen atoms fuse together to form **helium atoms** and in the process they produce large amount of heat.
- In a dark night we can see nearly 3,000 stars with the naked eye. We don't know how many stars exist.
- Our universe contains more than 100 billion galaxies, and each of those galaxies may have more than 100 billion stars.

- Though the stars appear to be alone, 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.
- Hot stars are white or blue, whereas cooler stars are orange or red in colour.
- They also occur in **many sizes**.
- A group of stars forms an imaginary outline or meaningful pattern on the space.
- They represent an animal, mythological person or creature, a god, or an object.
- This group of stars is called **constellations**.

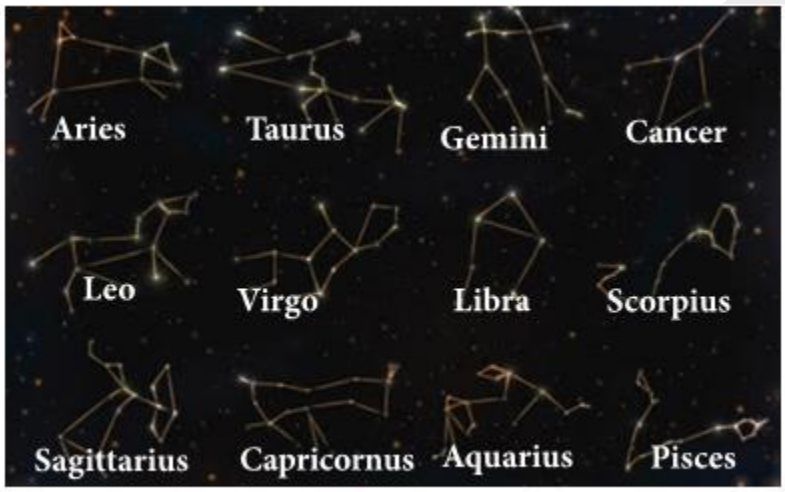


Figure 9.3 Constellations

- People in different cultures and countries adopted their own sets of constellation outlines.
- There are 88 formally accepted constellations. Aries, Gemini, Leo, Orion, Scorpius and Cassiopeia are some of the constellations.

The Solar System

- **Sun** and **the celestial bodies** which **revolve** around it form the solar system.
- It consists of large number of bodies such as **planets, comets, asteroids** and **meteors**.
- **The gravitational force of attraction** between the Sun and these objects keep them revolving around it.

The Sun

- The Sun is a medium sized star, a very fiery spinning ball of hot gases.
- Three quarters of the Sun has hydrogen gas and one quarter has helium gas. It is over a million times as big as the Earth.
- Hydrogen atoms combine or fuse together to form helium under enormous pressure.
- This process, called **nuclear fusion** releases enormous amount of energy as light and heat.
- It is this energy which makes Sun shine and provide heat. Sun is situated at the centre of the solar system.

- The strong gravitational fields cause other solar matter, mainly planets, asteroids, comets, meteoroids and other debris, to orbit around it.
- Sun is believed to be more than 4.6 billion years old.

Formation of the Sun

- At the time of the Big Bang, hydrogen gas condensed to form huge clouds, which later concentrated and formed the numerous galaxies.
- Some of the hydrogen gas was left free and started floating around in our galaxy.
- With time, due to some changes, this free-floating hydrogen gas concentrated and paved way for the formation of the Sun and solar system.
- Gradually, the Sun and the solar system turned into a slowly spinning molecular cloud, composed of hydrogen and helium along with dust.
- The cloud started to undergo the process of compression, as a result of its own gravity.
- Its excessive and high-speed spinning ultimately resulted in its flattening into a giant disc.

Planets

- A planet revolves around the Sun along a definite curved path which is called an **orbit**. It 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 on Earth is taken as 24 hours.

Table 9.1 Length of a day on each planet

Planets	Length of a day
Mercury	58.65 days
Venus	243 days
Earth	23.93 hours
Mars	24.62 hours
Jupiter	9.92 hours
Saturn	10.23 hours
Uranus	17 hours
Neptune	18 hours

- Table 9.1 tells about the length of a day on each planet. The planets are spaced unevenly.

- **The first four planets** are relatively close together and close to the Sun. They form **the inner solar system**.
- Farther from the Sun is the **outer solar system**, where the planets are much more spread out.
- Thus the distance between Saturn and Uranus is much greater (about 20 times) than the distance between the Earth and the Mars.
- The four planets grouped together in the inner solar system are Mercury, Venus, Earth and Mars. They are called **inner planets**.
- They have a surface of solid rock crust and so are called **terrestrial or rocky planets**.
- Their insides, surfaces and atmospheres are formed in a similar way and form similar pattern.
- Our planet, Earth can be taken as a model of the other three planets.
- The four large planets Jupiter, Saturn, Uranus and Neptune spread out in the outer solar system and slowly orbit the Sun are called **outer planets**.
- They are made of hydrogen, helium and other gases in huge amounts and have very dense atmosphere.
- They are known as gas giants and are called **gaseous planets**.
- The four outer planets **Jupiter, Saturn, Uranus** and **Neptune** have **rings** whereas the four inner planets do not have any rings.
- The rings are actually tiny pieces of rock covered with ice.
- Now let us learn about each planet in the solar system.

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** from the Sun, 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.
- 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**).

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 **65 moons**.
- Its moon **Ganymede** is **the largest moon** of our solar system.

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.
- At least 60 moons are present - 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 axis of rotation**.
- As a result, in its **orbital motion** it appears to **roll** on its side.
- Due to its **peculiar tilt**, it has the longest summers and winters each lasting 42 years.

Neptune:

- It appears as **Greenish star**.
- It is the **eighth planet** from the Sun and is the windiest planet. Every 248 years, Pluto crosses its orbit.
- This situation continues for 20 years.
- It has **13 moons** – **Triton** being the largest.
- Triton is the only moon in the solar system that moves in the opposite direction to the direction in which its planet spins.

Other Bodies of the Solar System

- Besides the eight planets, there are some other bodies which revolve around the Sun.

- They are also members of the solar system.

Asteroids

- There is a large gap in between **the orbits of Mars and Jupiter**.
- This gap is occupied by a broad **belt containing** about **half a million pieces of rocks** that were left over when the planets were formed and now revolve around the Sun. These are called **asteroids**.
- The biggest asteroid is **Ceres** – 946 km across.
- Every 50 million years, the Earth is hit by an asteroid nearing 10 km across.
- Asteroids can only be seen through **large telescope.**

Comets

- Comets are **lumps of dust and ice** that revolve around the Sun in highly elliptical orbits. Their period of revolution is very long.
- When approaching the Sun, a comet vaporizes and forms a **head** and **tail**.
- Some of the biggest comets ever seen had tails 160 million (16 crores) km long.
- This is more than the distance between the Earth and the Sun.
- Many comets are known to appear periodically.
- One such comet is **Halley's Comet**, which appears after nearly every 76 years.
- It was last seen in 1986.
- It will next be seen in 2062.

Meteors and Meteorites

- Meteors are **small piece of rocks** scattered throughout the solar system.
- Travelling with high speed, these small pieces come closer to the Earth's atmosphere and are attracted by the gravitational force of Earth.
- Most of them are **burnt up by the heat** generated due to friction in **the Earth's atmosphere.**
- They are called **meteors**.
- Some of the bigger meteors **may not be burnt completely** and they **fall** on the **surface of Earth**. These are called **meteorites**.

Figure 9.4 Meteors and Meteorites

Satellites

- A **body moving in an orbit** around a planet is called **satellite**.
- In order to distinguish them from the man made satellites (called as artificial satellites), they are called as **natural satellites** or **moons**.
- **Satellite of the Earth** is called **Moon** (other satellites are written as moon).
- We can see the Earth's satellite Moon, because it reflects the light of the Sun.
- Satellite moves around the planets due to gravity, and the centripetal force.
- Among the planets in the solar system all the planets have moons except Mercury and Venus.

Orbital Velocity

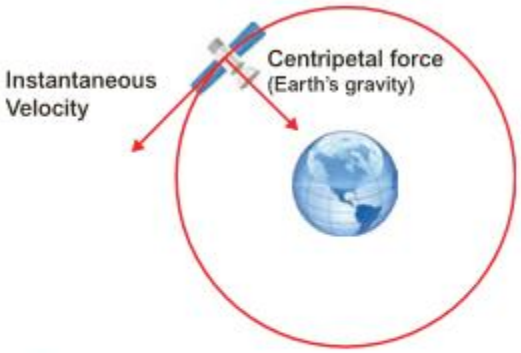


Figure 9.5 Orbital velocity

- We saw that there are **natural satellites** moving around the planets.
- There will be gravitational force between the planet and satellites.

- Nowadays many artificial satellites are launched into the Earth's orbit.
- **The first artificial satellite Sputnik** was launched in 1956.
- India launched its first satellite **Aryabhatta** on April 19, 1975.
- Artificial satellites are made to revolve in an orbit at a height of few hundred kilometres.
- At this altitude, the friction due to air is negligible.
- The satellite is carried by a rocket to the desired height and released horizontally with a high velocity, so that it remains moving in a nearly circular orbit.
- The horizontal velocity that has to be imparted to a satellite at the determined height so that it makes a circular orbit around the planet is called **orbital velocity**.
- The orbital velocity of the satellite depends on its altitude above Earth.
- Nearer the object to the Earth, the faster is the required orbital velocity.
- At an altitude of 200 kilometres, the required orbital velocity is little more than 27,400 kph.
- That orbital speed and distance permit the satellite to make one revolution in 24 hours.
- Since Earth also rotates once in 24 hours, a satellite stays in a fixed position relative to a point on Earth's surface.
- Because the satellite stays over the same spot all the time, this kind of orbit is called '**geostationary**'.
- Orbital velocity can be calculated using the following formula.

$$v = \sqrt{\frac{GM}{(R+h)}}$$ where,

G = Gravitational constant (6.673×10^{-11} Nm^2kg^{-2})
M = Mass of the Earth (5.972×10^{24} kg)
R = Radius of the Earth (6371 km)
h = Height of the satellite from the surface of the Earth.

Problem 1

Can you calculate the orbital velocity of a satellite orbiting at an altitude of 500 km?

Data: $G = 6.673 \times 10^{-11}$ SI units;
$M = 5.972 \times 10^{24}$ kg; R = 6371000 m;
h = 500000 m.

Solution:

$$v = \sqrt{\frac{6.67 \times 10^{-11} \times 5.972 \times 10^{24}}{(6371000 + 500000)}}$$

Ans: $v = 7613$ ms^{-1} or 7.613 kms^{-1}

Time period of a Satellite

- Time taken by a satellite to **complete one revolution round the Earth** is called time period.

$$\text{Time period, } T = \frac{\text{Distance covered}}{\text{Orbital velocity}}$$

$$T = \frac{2\pi r}{v}$$

Substituting the value of v, we get

$$T = \frac{2\pi(R+h)}{\sqrt{\frac{GM}{(R+h)}}}.$$

Problem 2

At an orbital height of 500 km, find the orbital period of the satellite.

Solution:

$h = 500 \times 10^3$m, $R = 6371 \times 10^3$m,
$v = 7616 \times 10^3$ kms^{-1}.

$$T = \frac{2\pi(R+h)}{v} = 2 \times \frac{22}{7} \times \frac{(6371+500)}{7616}$$

$$= 5.6677 \times 10^3 \text{s} = 5667 \text{ s.}$$

This is $T \approx 95$ min

Kepler's Laws

- In the early 1600s, **Johannes Kepler** proposed three laws of planetary motion.
- **Kepler** was able to summarize the carefully collected data of his mentor, **Tycho Brahe** with three statements that described the motion of planets in a **Sun-centered solar system.**
- Kepler's efforts to explain the underlying reasons for such motions are no longer accepted; nonetheless, the actual laws themselves are still considered an accurate description of the motion of any planet and any satellite.
- Kepler's three **laws of planetary motion** can be described as below.

First Law –

- **The Law of Ellipses:** All planets revolve around the Sun in elliptical orbits with Sun at one of their foci.

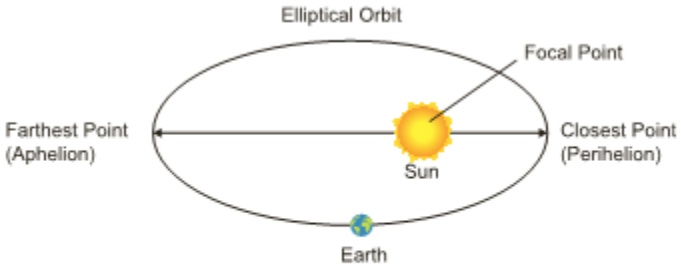


Figure 9.6 The Law of Ellipses

Second Law –

- **The Law of Equal Areas**: The line connecting the planet and the Sun covers equal areas in equal intervals of time.

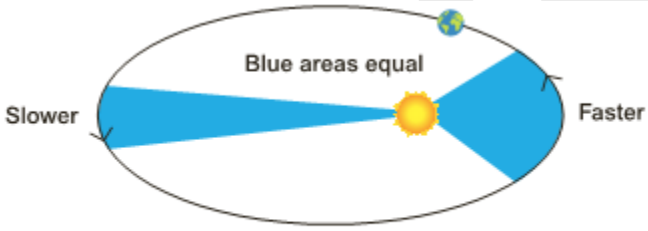


Figure 9.7 The Law of Equal Area

Third Law –

- **The Law of Harmonies**: The square of time period of revolution of a planet around the Sun is directly proportional to the cube of the distance between sun and the planets.

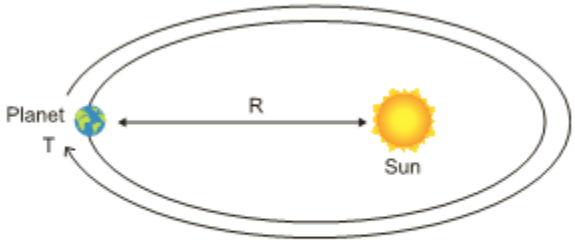


Figure 9.8 The Law of Harmonics

International Space Station

- **ISS** is a large spacecraft which can house astronauts.
- It goes around in low Earth orbit at approximately 400 km distance.
- It is also a **science laboratory**.

- Its very first part was placed in orbit in 1998 and its core construction was completed by 2011.
- It is the **largest man-made object in space** which can also be seen from **the Earth through the naked eye.**
- The first human crew went to the ISS in 2000. Ever since that, it has never been unoccupied by humans.

Figure 9.9 International Space Station

- At any given instant, at least six humans will be present in the ISS.
- According to the current plan, ISS will be operated until 2024, with a possible extension until 2028.
- After that, it could be deorbited, or recycled for future space stations.

Benefits of ISS

- According to NASA, the following are some of the ways in which the ISS is already benefitting us or will benefit us in the future.

Supporting water-purification efforts

- Using the technology developed for the ISS, areas having **water scarcity** can gain access to advanced **water filtration** and **purification systems**.
- **The water recovery system (WRS)** and **the oxygen generation system (OGS)** developed for the ISS have already saved a village in Iraq from being deserted due to lack of clean water.

Eye tracking technology

- The Eye Tracking Device, built for a **microgravity experiment**, has proved ideal to be used in many **laser surgeries**.
- Also, eye tracking technology is helping **disabled people** with limited movement and speech.

- For example, a kid who has **severe disability in body movements** can use his eye-movements alone and do routine tasks and lead an independent life.

Robotic arms and surgeries

- Robotic arms developed for research in the ISS are providing significant help to the surgeons in **removing inoperable tumours** (e.g., brain tumours) and taking biopsies with great accuracies.
- Its inventors say that the robot could take **biopsies** with remarkable precision and consistency.
- Apart from the above-mentioned applications, there are many other ways in which the researches that take place in the ISS are helpful.
- They are: development of improved **vaccines**, **breast cancer detection** and **treatment, ultrasound machines** for remote regions etc,.

ISS and International Cooperation

- As great as **the ISS' scientific achievements** are, no less in accomplishment is the international co-operation which resulted in **the construction of the ISS.**
- **An international collaboration** of five different space agencies of 16 countries provides, maintains and operates the ISS.
- They are: **NASA (USA), Roskosmos (Russia), ESA (Europe), JAXA (Japan) and CSA (Cananda).**
- Belgium, Brazil, Denmark, France, Germany, Italy, Holland, Norway, Spain, Sweden, Switzerland and the UK are also part of the consortium.

MORE TO KNOW:

Andromeda

- The distance of Andromeda, our **nearest galaxy** is approximately 2.5 million light-years.
- If we move at the speed of the Earth (30 km/s), it would take us 25 billion years to reach it!

The Sun

- The Sun travelling at a speed of 250 km per second (9 lakh km/h) takes about 225 million years to **complete one revolution around the Milky Way.**
- This period is called a **cosmic year.**

Microgravity

- Microgravity is the condition in which **people or objects appear to be weightless.**
- The effects of microgravity can be seen when **astronauts** and **objects float in space.**
- Micro- means very small, so microgravity refers to the condition where gravity **'seems'** to be very small.

Stars

- All stars appear to us as moving from east to west, where as there is one star which appears to us stationary in its position.
- It has been named as **Pole star**.
- The pole star appears to us as **fixed in space** at the same place in the sky in the north direction because it lies on the axis of rotation of the Earth which itself is fixed and **does not change its position in space.**
- It may be noted that the pole star is not visible from the southern hemisphere.

EXTRA POINTS:

- **Asteroid**: Small, rocky object orbiting the Sun.
- **Comet**: A chunk of dirty, dark ice, mixed with dust which revolves around the Sun.
- **Constellation**: A group of stars that can be seen as a pattern from Earth.
- **Galaxy**: A group of stars, nebulae, star clusters, globular clusters and other matter.
- **Meteor**: A meteoroid that travels through the Earth's atmosphere.
- **Meteorite**: A meteor that hits the Earth's surface.
- **Milky Way**: A broad band of light that looks like a trail of spilled milk in the night sky.
- **Moon**: Any natural object which orbits a planet.
- **Planet**: A relatively large object that revolves around a star, but which is not itself a star.
- **Satellite**: Any object in outer space that orbits another object.
- **Space station**: A large, manned satellite in space used as a base for space exploration.
- **Star**: A ball of constantly exploding gases, giving off light and heat.
- **Universe**: Everything in space, including the galaxies and stars, the Milky Way and the Solar System.