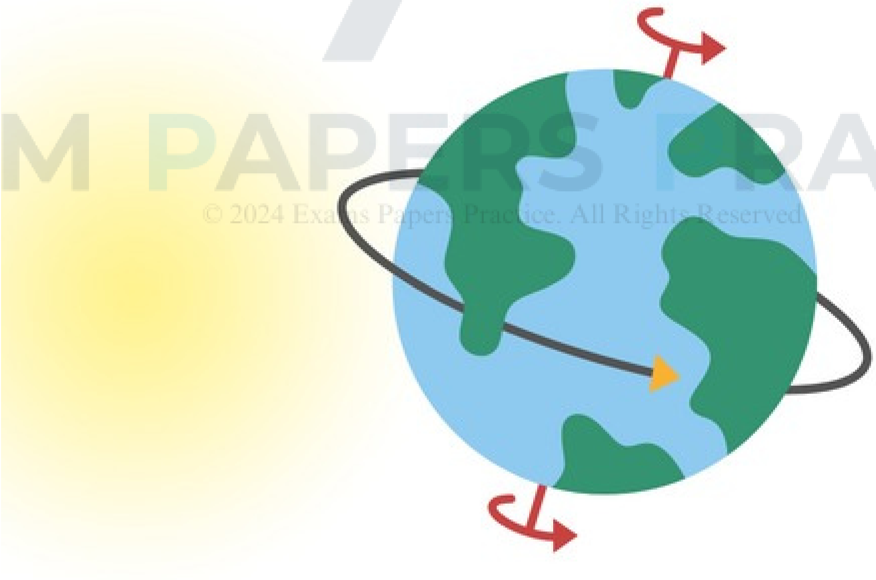
Chapter 24

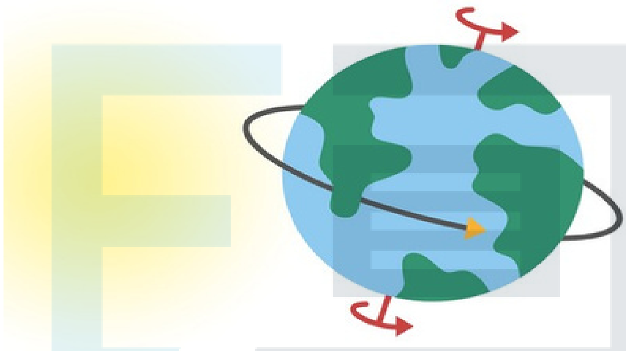
Earth and the Solar System



24.1 Earth, Sun, and Moon

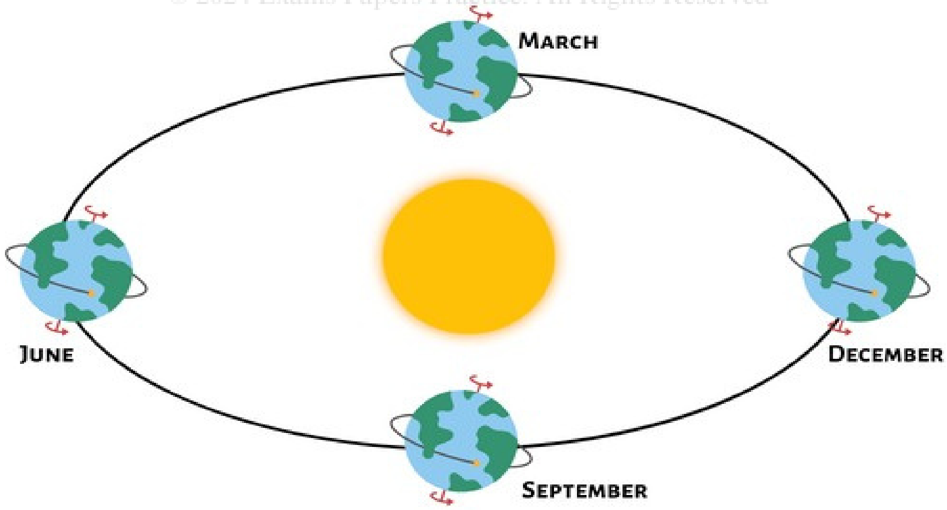
24.1.1 Day and night

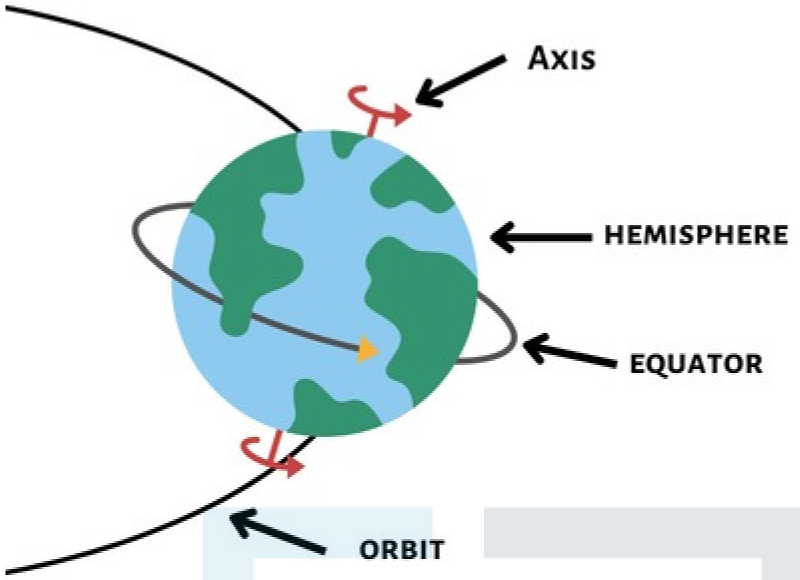
1. The Sun appears to move across the sky daily, rising in the east and setting in the west.
2. This phenomenon is explained by the Earth's rotation on its axis.
3. As the Earth rotates, one hemisphere faces the Sun, experiencing daylight, while the opposite hemisphere experiences darkness.



24.1.2 Years

1. The Earth orbits around the Sun, completing one full revolution in slightly over 365 days.
2. Seasons are caused by the tilt of the Earth's axis.

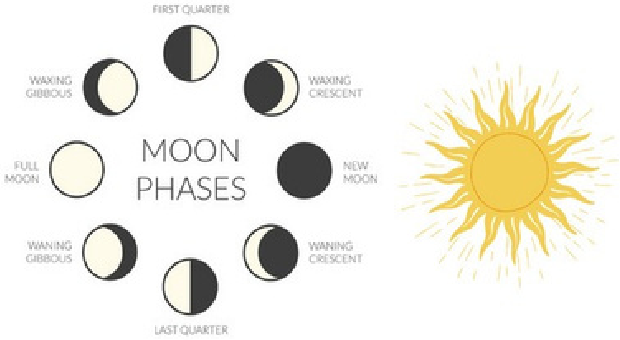




Countries located on the Equator experience minimal seasonal changes because the Sun's rays strike them at a consistent angle throughout the year. In contrast, regions farther from the Equator experience more pronounced differences between seasons.

24.1.3 Months

1. The Moon is the second most prominent celestial body visible in our sky, after the Sun.
2. We can observe the Moon because it reflects sunlight.
3. The Moon completes its orbit around the Earth every 27.5 days, and its position relative to the Earth changes, causing varying amounts of sunlight to illuminate different parts of its surface.
4. The illuminated portions of the Moon visible from Earth at any given time create the distinct phases of the Moon that we observe.



24.2 The Solar System

1. The Solar System consists of the Sun, which is our star, and all the objects which orbit it.
2. It includes the following:

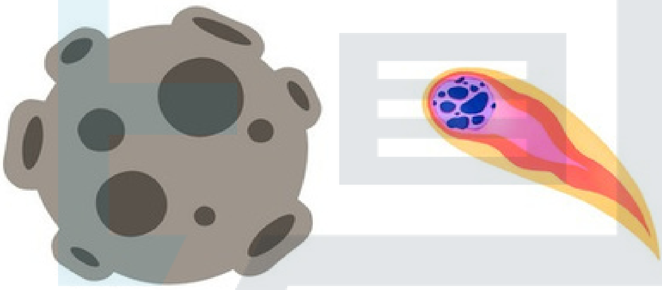
   a. Eight **planets** (Mercury, Venue, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune).

   b. **Minor planets** (Pluto and Eris), also known as dwarf planets.

   c. Moons that orbit planets and dwarf planets.

   d. Millions of **asteroids and meteoroids**.

      i. They are lumps of rock which orbit the Sun

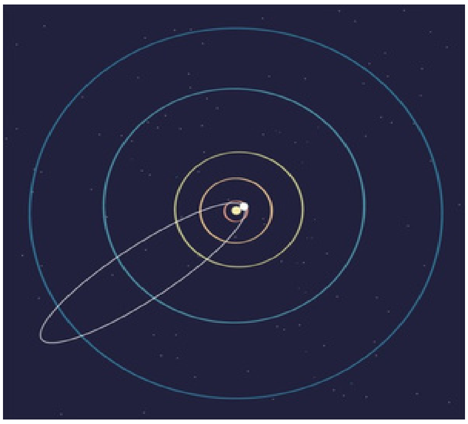


   e. **Comets**

      i. Comets are celestial objects often described as enormous snowballs that orbit the Sun in highly irregular paths.

      ii. At their farthest distance from the Sun, comets primarily consist of frozen gases, rocks, and dust.

      iii. As comets approach the Sun, they warm up and begin to release a trail of gases and dust behind them.



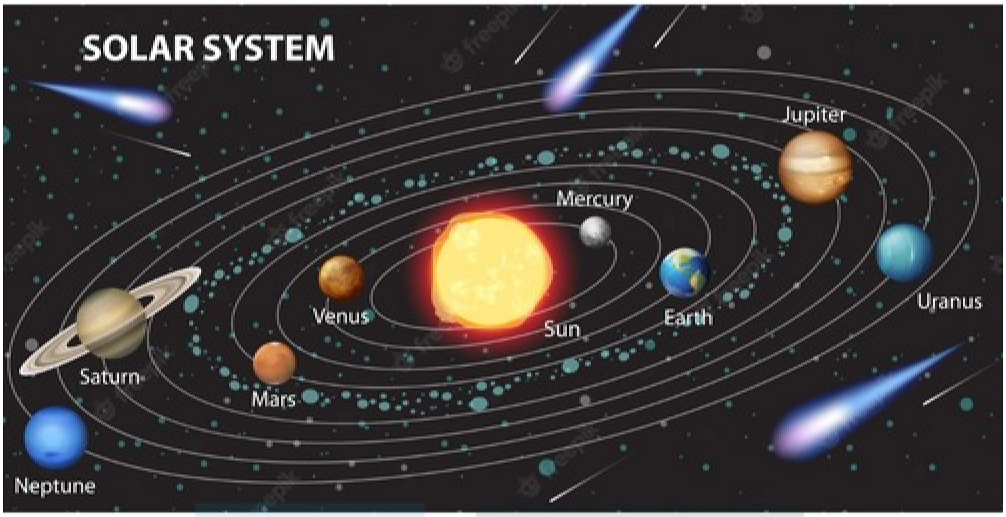
24.2.1 The Sun's gravitational pull

1. The paths of the planets around the Sun are nearly circular.
2. Objects traveling in circular paths require a force directed towards the center of the circle.
3. The gravitational pull exerted by the Sun is responsible for keeping the planets in orbit around it.

24.2.2 The formation of the planets

How the Solar System begin:

1. The Solar System originated from a nebula, a large, rotating cloud of gas and dust.
2. Planets formed from the remnants of the nebular material that did not fall into the Sun's gravitational pull.
3. The rotational motion of the nebula caused the formation of a flat, spinning disk called an accretion disk.
4. Through accretion, smaller particles like dust and gas clumped together under gravity, forming larger rocks. This process contributed to the formation of the inner, rocky planets.
5. Due to the intense heat near the Sun, lighter materials were pushed farther away, eventually forming the outer planets, also known as gas giants.



24.2.3 Distances and times in the Solar System

1. Distances in the Solar System are incredibly vast.
2. These distances are often measured in terms of how long it takes for light to travel.
3. **One light year is the distance traveled by light in a year.**

Worked Example:

Determine the time it takes for light from the Sun to reach Earth, given the distance of 150,000,000 km between them.

Worked Example

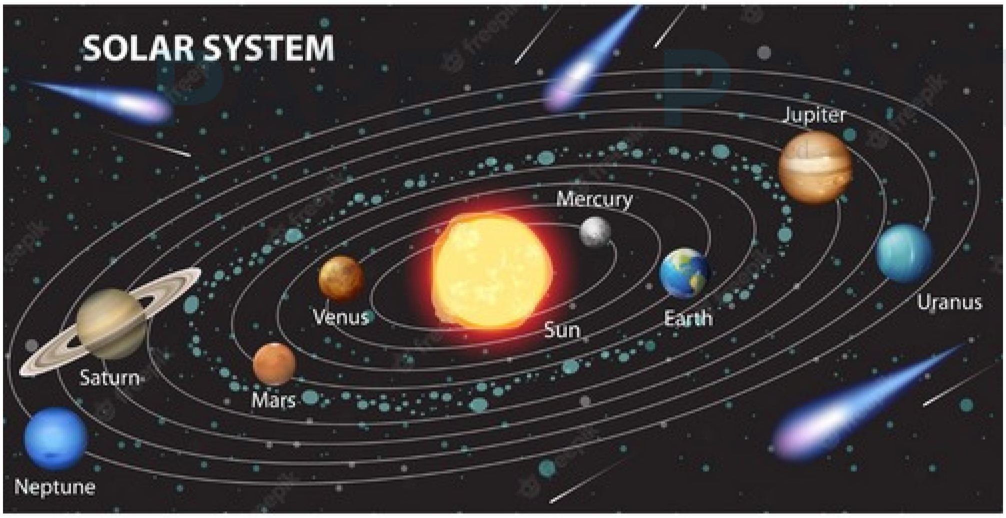
Calculate the duration for light to travel from the Moon to Earth, considering the Moon is approximately 390,000 km away.

24.2.4 Forces

1. The Sun occupies the central position in the Solar System and accounts for approximately 99.8% of its total mass, making it the most massive object by a significant margin.
2. The Sun's gravitational field is substantially stronger than any other object in the Solar System due to its immense mass, as gravitational attraction is directly related to mass.
3. The Sun's gravitational force governs the orbits of all celestial bodies, including planets, asteroids, meteoroids, and comets.
4. Gravitational attraction weakens with increasing distance, resulting in weaker gravitational forces experienced by the outer planets compared to the inner planets. Additionally, a planet's size also influences the gravitational force it encounters.

24.2.5 Orbits and energy

1. The orbits of planets are described as **elliptical.**
2. The amount the orbit is squashed is called its **eccentricity.**



Why are orbits elliptical?

1. Initially, the object was moving rapidly past the Sun, driven by its momentum from the Big Bang.
2. As the object approaches the Sun, the Sun's gravitational pull starts attracting it towards itself.
3. This gravitational attraction causes the object to accelerate, with its kinetic energy carrying it to the farthest point of its orbit.
4. Eventually, the object decelerates and is pulled back towards the Sun once more.

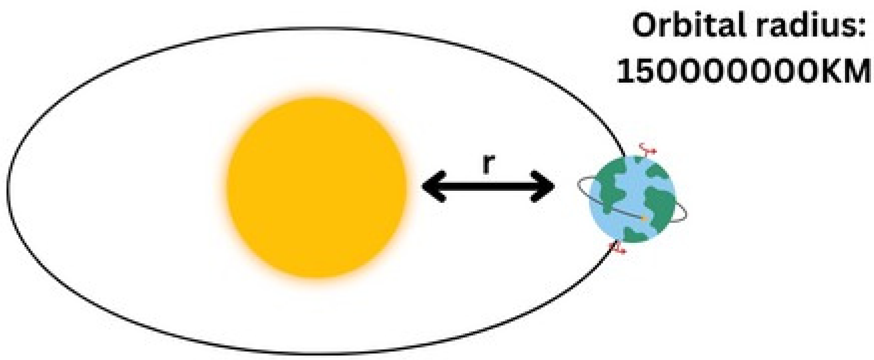
Takeaways:

1. Initially, the object moves swiftly past the Sun due to its momentum from the explosive start of the universe. However, the Sun's gravitational force pulls it towards itself, increasing its speed and enabling it to reach the farthest point in its orbit.
2. Consequently, the object moves fastest when closest to the Sun and slowest when farthest away because its speed varies with its position in the orbit.

Energy involved:

1. Kinetic energy
   a. Highest when nearby the Sun, lowest when furthest away from the Sun.
2. Gravitational potential energy
   a. Lowest when nearby the Sun, highest when furthest away from the Sun.

24.2.6 Speeds



Calculate the orbital speed

1. The speed of a planet in orbit around a star is called its orbital speed (v).
2. We can calculate the orbital speed if we know the orbital radius.

Orbital radius refers to the average distance between the center of mass of an orbiting body (such as a planet, satellite, or electron) and the center of mass of the body it orbits (such as a star or nucleus).

3. Formula

average orbital speed = $\frac{2\pi R}{T}$

T = Orbital Period

24.2.7 Planetary patterns

1. This table is useful for analysing and comparing properties and behaviours of planets, facilitating detailed examination across various criteria.
2. By graphing the data on a scatter plot, it is possible to determine if there is a relationship or correlation between the two sets of data being compared, visually representing potential patterns or trends.

Planet	Average orbital distance / million km	Orbital duration / years	Density / kg/m3	Surface temperature	Gravitational field strength N/kg	Number of Moons
Mercury	58	0.2	5500	-18 to 460	4	0
Venus	108	0.6	5200	470	9	0
Earth	150	1	5500	-8 to 58	10	1
Mars	228	1.9	4000	-8 to -5	4	2
Jupiter	778	12	1300	15 to 20	26	16
Saturn	1427	30	700	-140	11	20
Uranus	2870	84	1300	-200	11	15
Neptune	4497	165	1700	-220	12	8

Worked Example

Using the table above, draw and comment on scatter graphs to investigate the relationship between:

a. orbital distance and average temperature

b. gravitational field strength and the number of moons