5.4 Sun and Planets

The Solar System is a celestial family bound by gravity, with the Sun at its center and a diverse collection of planets, moons, dwarf planets, asteroids, and comets orbiting it. Below is an extremely detailed and technical explanation of the Sun and its planets, including their shape, size, period of rotation, period of revolution, and distances from the Sun.

1. The Sun: The Stellar Anchor of the Solar System

Shape and Structure

- **Shape**: Nearly a perfect sphere due to hydrostatic equilibrium, with slight oblateness caused by its slow rotation.
- **Diameter**: ~1,391,000 km (~109 Earth diameters).
- **Volume**: ~1.41×10^{18} km^3, capable of holding about 1.3 million Earths.
- **Mass**: ~1.989×10^{30} kg (~99.86% of the total Solar System mass).
- **Composition**: Primarily hydrogen (~73%) and helium (~25%), with trace amounts of heavier elements.

Rotational Dynamics

- **Differential Rotation**:
  - **Equator**: Completes one rotation in ~24-25 Earth days.
  - **Poles**: Completes one rotation in ~35 Earth days.
  - **Mean Rotational Period**: ~27 Earth days as observed from Earth.

Energy Production

- **Nuclear Fusion**: In its core, the Sun converts 600 million tons of hydrogen into helium every second, releasing enormous enery ($3.846x10^{26}$ W)

2. The Planets: A Detailed Technical Overview

The planets (8 in total) in the Solar System are classified as **terrestrial planets** (rocky and smaller) and **gas giants** (larger and composed mainly of gases).

Mercury: The Swift Planet

- Innermost planet in the solar system
- It is the second densest planet
- Mercury has a molten core
- It is the most cratered planet in the solar system
- **Shape**: Spherical, slightly oblate due to weak rotational forces.
- **Diameter**: ~4,880 km (smallest planet in the Solar System).
- **Mass**: ~3.301×10^{23} kg.
- **Rotational Period**: 59 Earth days.
- **Orbital Period**: ~88 Earth days (fastest orbital period).
- **Distance from Sun**: ~0.39 AU (~57.91 million km).
- **Surface Characteristics**: Rocky, heavily cratered, no atmosphere to speak of.
- **Temperature**: Daytime ~427°C, nighttime ~-173°C (largest temperature variation).

Venus: Earth's Twin in Size but Opposite in Conditions

- Has the longest rotation period of any planet in the solar system and roates in the opposite direction to most other planets.
- Sometimes called as morning/evening star
- **Shape**: Spherical, slightly oblate.
- **Diameter**: ~12,104 km (similar to Earth).
- **Mass**: ~4.867×10^{24} kg.
- **Rotational Period**: ~243 Earth days (retrograde, rotates opposite to most planets).
- **Orbital Period**: ~225 Earth days.
- **Distance from Sun**: ~0.72 AU (~108.2 million km).
- **Atmosphere**: Dense, composed of ~96.5% carbon dioxide, with thick clouds of sulfuric acid.
- **Surface Temperature**: ~462°C (hottest planet due to runaway greenhouse effect).

Earth: The Cradle of Life

- Was once believed to be the centre of the universe
- The first life on earth developed in the ocean
- The gravity between the moon and earth causes tides on earth
- 70% of earth surface is covered by water
- **Shape**: Oblate spheroid (flattened at the poles due to rotation).
- **Diameter**: ~12,742 km.
- **Mass**: ~5.972×10^{24} kg.
- **Rotational Period**: 24 hours (1 Earth day).
- **Orbital Period**: ~365.25 days (1 Earth year).
- **Distance from Sun**: ~1 AU (~149.6 million km).
- **Unique Features**: Presence of liquid water, oxygen-rich atmosphere, and life.
- **Atmosphere**: Nitrogen (~78%) and oxygen (~21%) with trace gases.

Mars: The Red Planet

- Sometimes called as red planet because of the brownish red color of its surface.
- The land mass of mars and earth is very similar
- **Shape**: Spherical, slightly oblate.
- **Diameter**: ~6,779 km.
- **Mass**: ~6.417×10^{23} kg.
- **Rotational Period**: ~24.6 hours (similar to Earth's day).
- **Orbital Period**: ~687 Earth days.
- **Distance from Sun**: ~1.52 AU (~227.9 million km).
- **Surface Features**: Dust storms, the largest volcano (Olympus Mons), and canyons.
- **Temperature**: ~-63°C (average).

Jupiter: The Giant Planet

- Named after the Roman King of Gods

- It is the shortest day of the 8 planets
- Has a faint ring system around it
- Jupiter has a very strong magnetic field and Jupiter is the 4th brightest object in our solar system

- **Shape**: Oblate spheroid (prominent bulge at the equator).
- **Diameter**: ~139,820 km (largest planet).
- **Mass**: ~1.898×10^{27} kg (~318 Earth masses).
- **Rotational Period**: ~9.9 hours (fastest spinning planet).
- **Orbital Period**: ~11.86 Earth years.
- **Distance from Sun**: ~5.2 AU (~778.5 million km).
- **Atmosphere**: Hydrogen (~90%) and helium (~10%).
- **Unique Features**: Great Red Spot, powerful magnetic field, 79 moons.

Saturn: The Ringed Giant

- Was named after the father of the father of the God Jupiter in roman mythology
- Common nickname is the ringed planet
- Saturn gives of more energy than it receives from the sun
- Saturn is the flattest of eight planets and the least dense planet in the solar system
- **Shape**: Oblate spheroid.
- **Diameter**: ~116,460 km.
- **Mass**: ~5.683×10^{26} kg (~95 Earth masses).
- **Rotational Period**: ~10.7 hours.
- **Orbital Period**: ~29.5 Earth years.
- **Distance from Sun**: ~9.58 AU (~1.43 billion km).
- **Rings**: Composed of ice, dust, and rock particles.
- **Moons**: 83 confirmed, including Titan.

Uranus: The Sideways Planet

- Named after the father of Roman god Saturn
- A collision may have caused the unusual tilt of Uranus
- It is often refer red to as the ice giant
- It is the coldest planet in the solar system
- The uranium moons are named for character created by Alexander pope and William Shakespeare
- **Shape**: Oblate spheroid.
- **Diameter**: ~50,724 km.
- **Mass**: ~8.681×10^{25} kg.
- **Rotational Period**: ~17.2 hours (retrograde rotation).

- **Orbital Period**: ~84 Earth years.
- **Distance from Sun**: ~19.2 AU (~2.87 billion km).
- **Tilt**: Axial tilt of ~98°, causing extreme seasonal variations.

Neptune: The Windy Blue World

- It is name after Roman God of the Sea due to its blue coloration
- It has a storm similar to the great red spot-on Jupiter
- It spins very quickly on its axis
- **Shape**: Oblate spheroid.
- **Diameter**: ~49,244 km.
- **Mass**: ~1.024×10^{26} kg.
- **Rotational Period**: ~16.1 hours.
- **Orbital Period**: ~165 Earth years.
- **Distance from Sun**: ~30.1 AU (~4.5 billion km).
- **Unique Features**: Supersonic winds (~2,100 km/h), Great Dark Spot.

3. Measurement and Observational Techniques

- **Distances**: Measured in astronomical units (AU), light-years, or parsecs.
- **Rotation Periods**: Determined using spectroscopic and telescopic observations.
- **Orbital Dynamics**: Calculated using Kepler's laws and modern celestial mechanics.