CAIE Physics IGCSE

Topic 6: Space Physics

Summary Notes

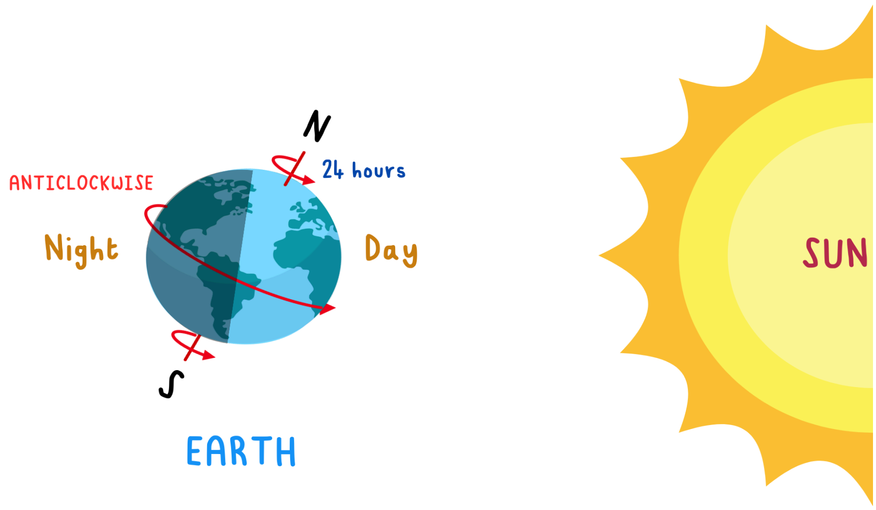
*Definitions in **bold** are for extended students only*

6.1 Earth and the Solar System

6.1.1 The Earth

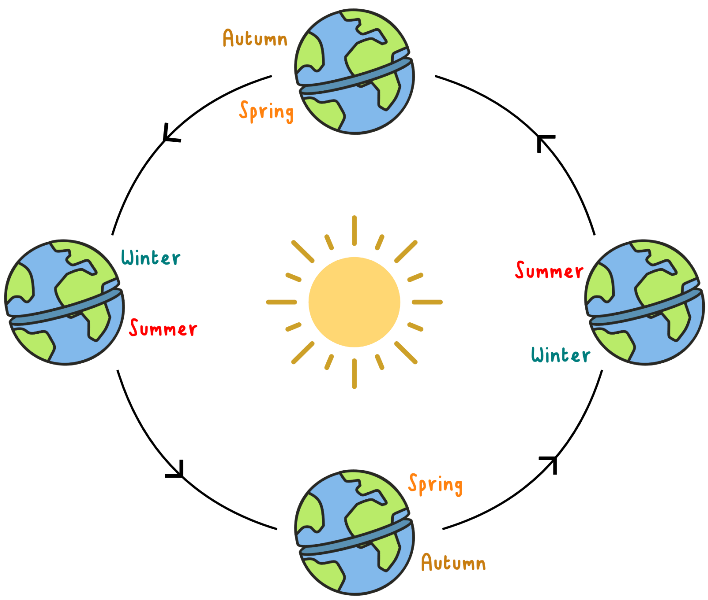
The Earth is a planet that rotates on its tilted axis every 24 hours.

- The Earth's rotation changes the position of each place on Earth relative to the sun, in a pattern which repeats every 24-hour period (periodic cycle of day and night).
    - Day is experienced by the half of the Earth's surface facing the Sun.
    - Night is the other half of the Earth's surface, facing away from the Sun.
- The rotation is anticlockwise (when looking from the north pole), causing the Sun to appear to move across the sky from east (at sunrise) to west (at sunset).



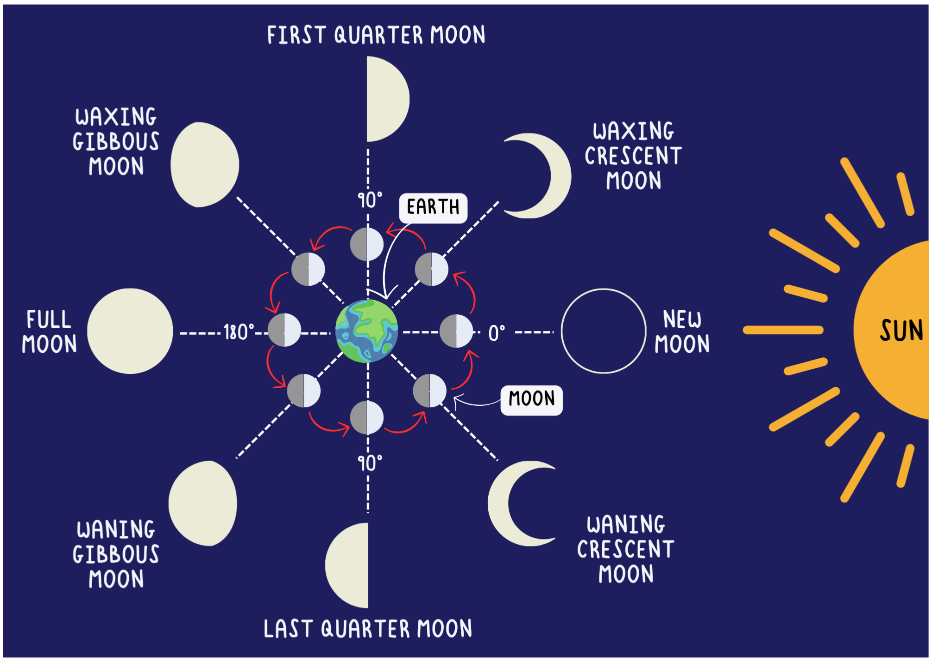
The Earth orbits the Sun once in approximately 365 days.

- The Earth's orbit, combined with the tilt of the Earth's axis, results in varying sunlight exposure in a pattern which repeats every one-year period, creating the seasons.
    - Whilst one hemisphere is tilted towards the Sun for half of the orbit, the other hemisphere is tilted away, so the opposite hemisphere experiences the opposite season.
    - When tilted towards the sun, daylight hours are more than hours of darkness and it is spring or summer.
    - When tilted away from the sun, daylight hours are less than hours of darkness and it is autumn or winter.
    - Daylight hours and darkness are equal in both hemispheres at two points in orbit; these are called the equinoxes.



The Moon orbits the Earth, which takes approximately 1 month.

- The moon is visible from Earth by the light it reflects from the Sun. The amount of reflected light that is visible, varies as the moon orbits the earth, in a pattern which repeats every one month (the Moon's periodic cycle of phases).
    - In the new Moon phase, the sunlight is only on the half of the Moon which is not visible from Earth.
    - At the Full Moon phase, the sunlight covers the half of the Moon which is visible from Earth.
    - In between these phases, the visible surface is only partly illuminated - either by half (a quarter moon), mostly illuminated (a gibbous moon), or mostly not illuminated (a crescent moon).



The average speed of a body in orbit (such as the earth or moon) can be calculated:

$$velocity = \frac{2 \times \pi \times average\ radius\ of\ orbit}{orbital\ period} \quad v = \frac{2\pi r}{T} \quad units = m/s^2$$

6.1.2 The Solar System

The solar system is a gravitationally bound system made up of the Sun and everything that orbits it.

Like the moon, all the Solar System's components are visible from Earth when they reflect light from the Sun.

- The Sun's light travels at a constant of 3×10^8 m/s (the speed of light).
- The time taken for light to travel between objects in the Solar System can be calculated by rearranging the equation for calculating speed from distance and time:

$$time = \frac{distance}{speed\ of\ light} \quad units = seconds$$

The Solar System contains:

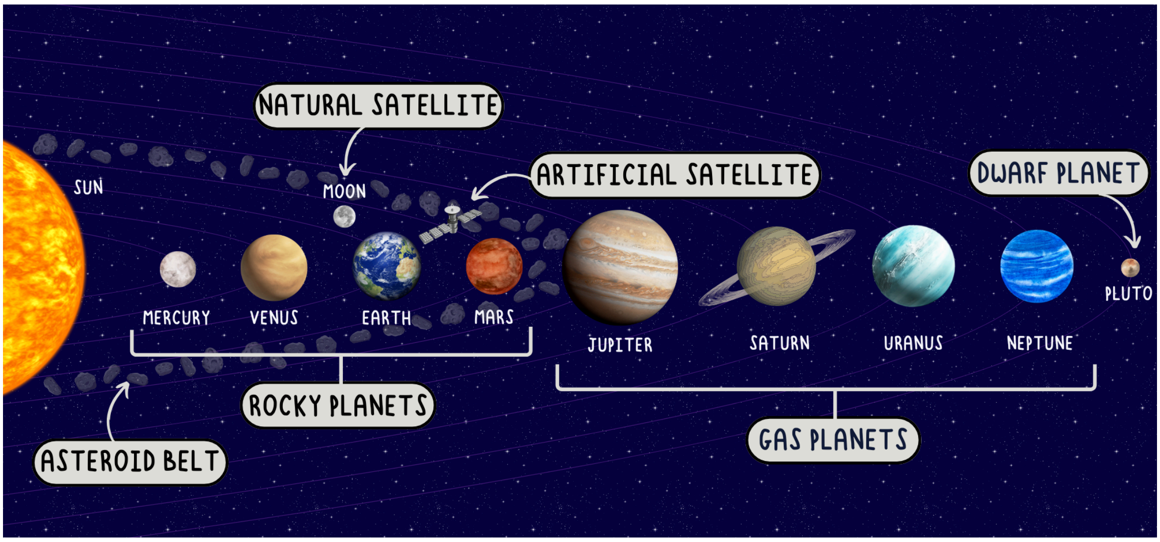
- The Sun - The only star in the Solar System; it provides light and heat to the planets and accounts for most of the mass in the solar system.
  - This disproportionation in mass is why the planets orbit the Sun.
  - The gravitational attraction of the Sun keeps objects in orbit around it.
- The eight planets - orbit the sun and have gravitational fields strong enough to pull in all nearby objects.
  - The mnemonic for remembering the planets in ascending distance from the sun - 'My Very Easy Mnemonic Just Speeds Up Naming'.
  - Mercury
  - Venus
  - Earth
  - Mars

    } Rocky and small
  - Jupiter
  - Saturn
  - Uranus
  - Neptune

    } Gaseous and large
  - The difference in the composition of the planets is explained by the accretion model of Solar System formation:
    - The Sun's nebula was a massive cloud of dust and gas, composed of many elements (See Topic 6.2.2).
    - After the Sun formed from this nebula, gravity caused the rest of the nebula's matter to collapse and spin around the Sun.
    - The gravitational attraction brought all the small particles together, forming planets in an accretion disc.

- The first four planets formed in the accretion disc's inner region so were exposed to the Sun's higher temperatures and are made of heavier elements with higher melting points. They are small because very little of the nebula is formed of such elements.
- The outer planets were in cooler regions where light molecules could exist as a solid, so they grew large and incorporated most of the nebula's matter.

- Minor planets - orbit the sun but, unlike the eight planets, do not have a gravitational field strong enough to pull in all nearby objects.
    - Dwarf planets, such as Pluto.
    - Asteroids (large rocks) in the asteroid belt between Mars and Jupiter.
- Comets - balls of dust and ice that orbit the sun.
- Natural satellites - naturally occurring bodies (as opposed to man-made satellites like the space station) that form an exception and are not pulled in by the strong gravitational field of the eight planets, but instead orbit a planet.
    - Moons (several planets have their own moons, not just Earth).



Data collected about the planets, moons and the Sun can tell us:

- **Their orbital distance (larger for planets further from the sun).**
- **Their orbital duration (longer for planets further from the sun).**
- **Their orbital speed (slower for planets further from the sun because the Sun's gravitational field strength becomes weaker with distance).**
- **Their density (the furthest four planets are less dense as they are gaseous).**
- **Their surface temperature (higher for planets closer to the sun).**
- **The uniform gravitational field strength.**
    - The strength of the gravitational field at the surface depends on mass (higher on the surface of the gas giants as they have greater mass).
    - The strength of the gravitational field surrounding a planet or the Sun decreases as distance increases.

Bodies orbiting the sun (planets, minor planets, comets) have **elliptical** orbits (**oval-shaped**).

- **The Sun is only at the orbital's centre when it is approximately circular.**
- **These bodies travel faster when closer to the Sun because the orbital radius decreases. This is explained using the conservation of energy (see Topic 1.7):**
    - **As the radius decreases, gravitational potential energy decreases and is converted to kinetic energy, increasing the orbital speed.**

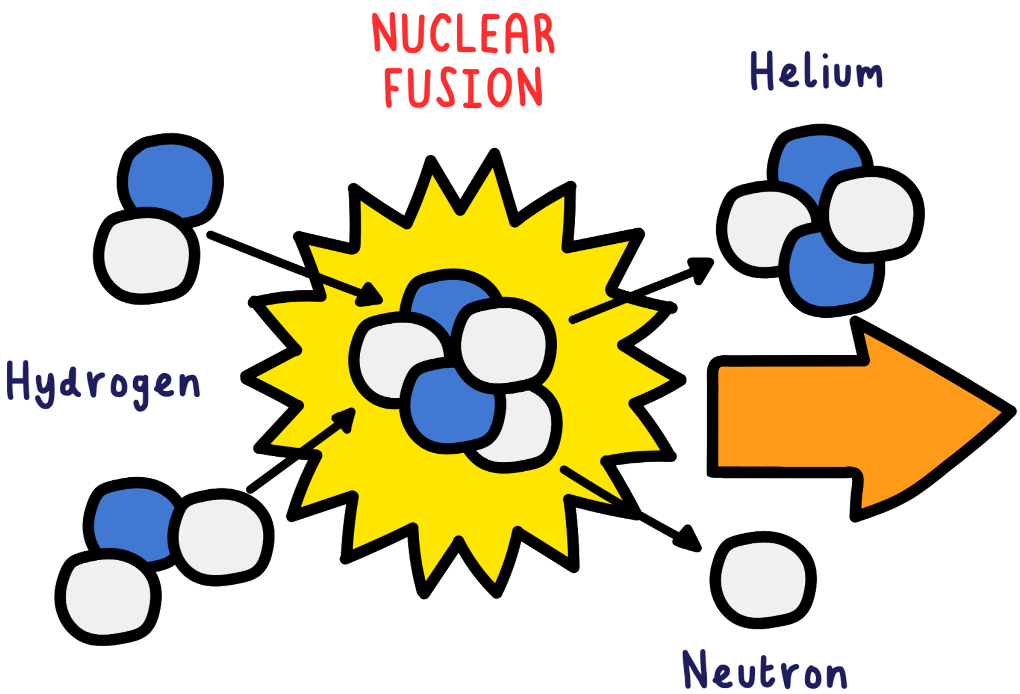
6.2 Stars and the Universe

6,2,1 The Sun as a star

The Sun is a star of medium size, consisting mostly of hydrogen and helium.
It radiates most of its energy in the infrared, visible and ultraviolet regions of the electromagnetic spectrum.

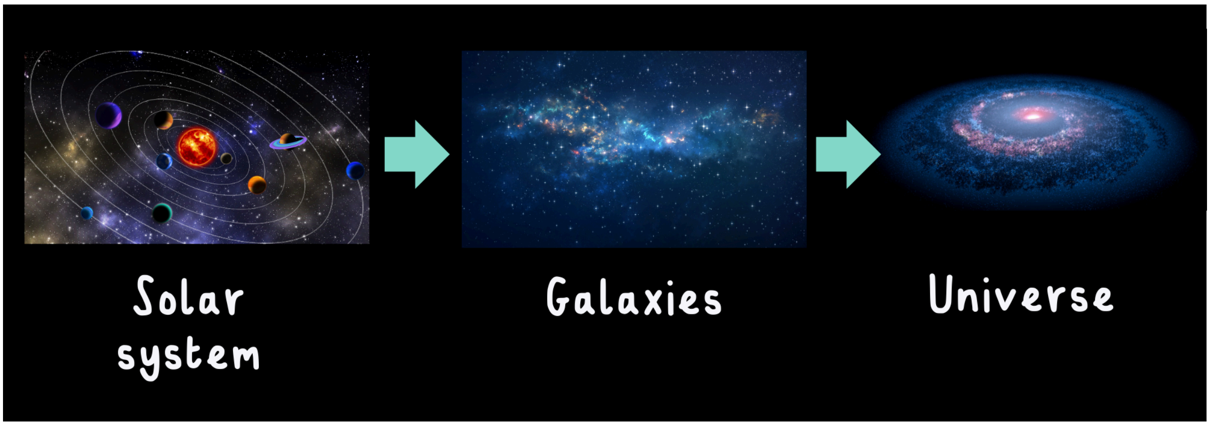
This energy is released by nuclear reactions.

- **In stable stars (such as The Sun), the nuclear reactions involve the fusion of hydrogen into helium (nuclear fusion).**



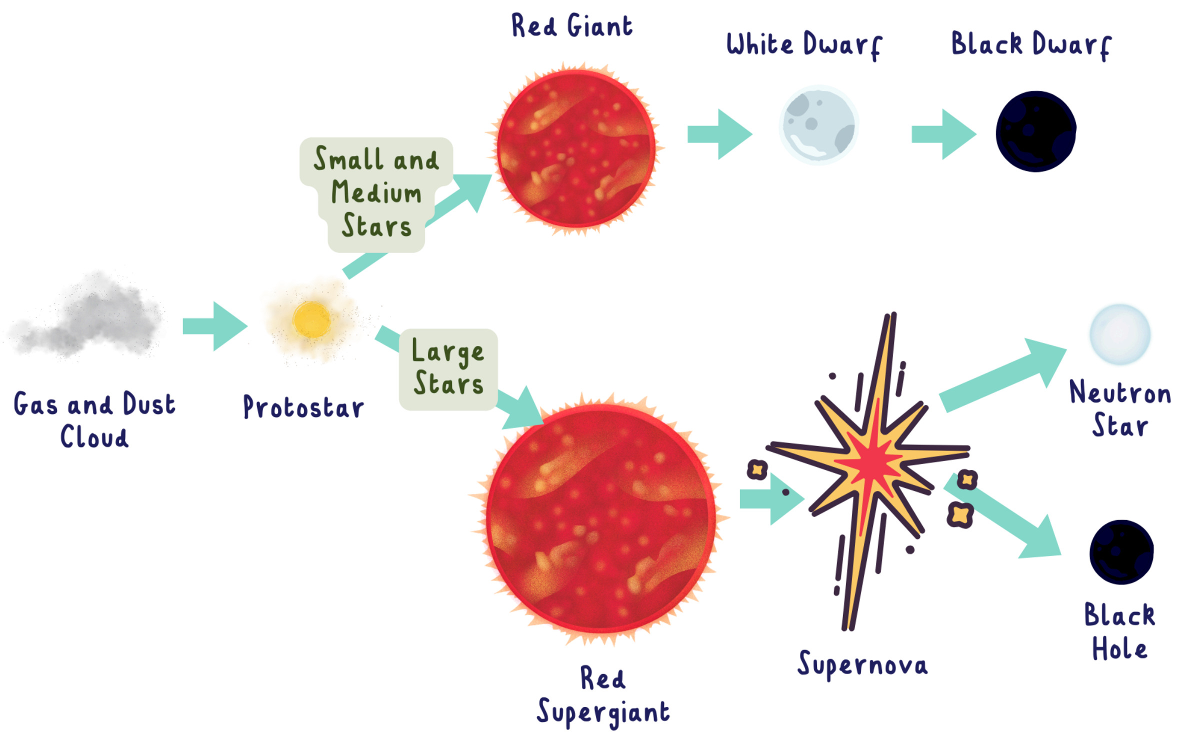
6.2.2 Stars

Billions of stars (like the Sun) make up galaxies.
- The Sun belongs to the Milky Way galaxy.



The Sun is the closest star to Earth in the Milky Way; other stars are further away.
- The distance between objects in Space (astronomical distances) can be calculated by measuring the number of years it takes light to travel between them (because light travels at the constant speed of 3×10^8 m/s).
  - This means astronomical distances are measured in light-years.
  - **One light-year is equal to 9.5×10^{15} m.**

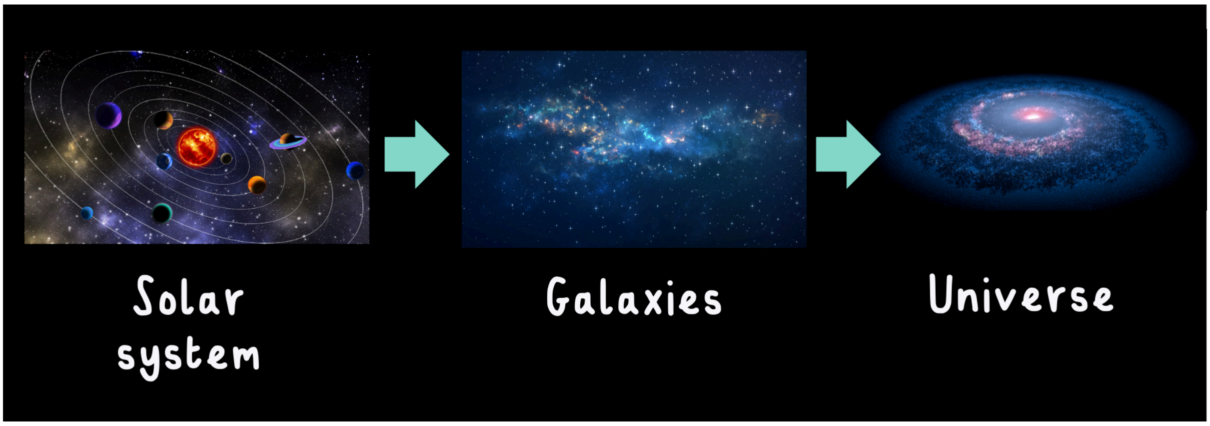
The life cycle of a star:
- **Stars form from interstellar clouds of gas and dust that contain hydrogen (a nebula).**
- **Gravity collapses the dust and gas into a protostar, which undergoes nuclear reactions, releasing energy and increasing temperature.**
- **A stable star forms when the inward gravitational attraction is balanced by the outward force of gas pressure (which increases with temperature) from nuclear fusion.**
- **When stars run out of hydrogen as a fuel for the nuclear reaction, most expand to form red giants.**
  - **As the balance of forces has been lost, a red giant contracts under the pull of gravity. This forms a planetary nebula with a white dwarf star at its centre.**
- **More massive stars continue to undergo nuclear fusion and expand to form red supergiants.**
  - **As the outward force outweighs the gravitational attraction, it explodes as a supernova.**
  - **The supernova creates a nebula containing hydrogen and new heavier elements, leaving behind a neutron star or a black hole at its centre.**
  - **The nebula from a supernova may form new stars with orbiting planets.**



6.2.3 The Universe

The Milky Way is one of many billions of galaxies making up the Universe.

- The diameter of the Milky Way is approximately 100,000 light-years.



Redshift is an increase in the observed wavelength of electromagnetic radiation emitted from an object which is receding and travelling faster the further away it is.

- The light emitted from distant galaxies appears redshifted in comparison with light emitted on the Earth.
- Redshift in the light from distant galaxies means they are moving further away so shows the Universe is expanding, supporting the Big Bang Theory.

The **Hubble constant** explains how a galaxy's speed changes as it recedes:

- It is a ratio that can be calculated using the equation:

$$Hubble\ constant = \frac{the\ speed\ of\ a\ galaxy\ moving\ away\ from\ the\ Earth}{the\ galaxy's\ distance\ from\ the\ Earth} \quad H0 = \frac{v}{d} \quad \text{units} = \text{per second}$$

  - The **speed** at which a **galaxy is moving away** from the Earth can be found from the **change in wavelength** of the galaxy's starlight due to redshift.
  - The galaxy's distance from the Earth can be determined using the brightness of a supernova in that galaxy.
- The current estimate for H0 = 2.2×10^{-18} per second.
- The Hubble constant can be used to estimate the age of the universe:

$$\frac{d}{v} = \frac{1}{H0}$$

  - Finding an age for the universe shows all the matter in the Universe was present at a single point.

Cosmic microwave background radiation (CMBR) is microwave radiation of a specific frequency, which is observed at all points in space around us.

- CMBR was **produced** shortly after the **Universe** was **formed** and expanded into the electromagnetic spectrum's microwave region as the Universe expanded.
- The Big Bang Theory predicted CMBR, so its existence strongly supports it.