# WJEC (Wales) Physics GCSE

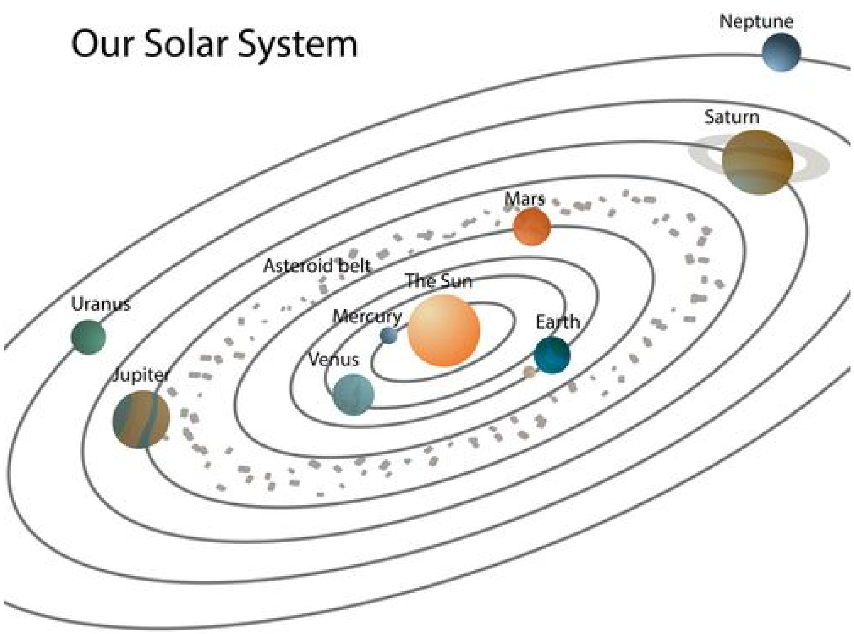
## 2.5: Stars & Planets

### Detailed Notes

(Content in **bold** is for higher tier **only**)

## The Solar System

Earth is part of the **solar system**: a set of planets and bodies that **orbit** the Sun (our nearest star). They are kept in orbit by **gravitational forces**. The solar system consists of **eight planets**, four inner rocky ones and four outer gaseous ones. These two main groups are separated by a band of rocky material and debris called the **asteroid belt**. This belt also contains smaller **dwarf planets** and **comets**.




***Our Solar System (edplace.com).***

The solar system formed from a **cloud of dust and gas**, rich in **hydrogen**. This cloud began to contract under gravity, causing the gas to be **compressed**, making it **hotter**. Eventually the cloud began to **spin**. A **protostar** was formed at the centre of this spinning cloud. As more dust and gas accumulated at the centre of the cloud, the protostar continued to get hotter until it was hot enough for **nuclear fusion** to occur. Once this had taken place, the Sun was born.

The cloud continued spinning around the Sun and **accretion** of this material due to gravitational forces gradually led to the formation of **planets**. Denser material generally migrated closer towards the Sun, due to the stronger **gravitational pull** felt by denser material. Less dense material felt a less strong gravitational pull and so remained in the outer solar system. This partially explains why the **inner planets are rocky** (more dense) whereas the **outer planets are gaseous** (less dense).

The mechanism of formation described applies generally to the formation stars and solar systems similar in size to ours.

## Inner Planets

The four inner planets **Mars, Mercury, Earth** and **Venus** were formed from the accumulation of generally **denser** non-volatile material. The inner rocky planets have **solid surfaces** that can, in theory, be walked on.

## Outer Planets

The outer four planets: **Jupiter, Saturn, Uranus** and **Neptune** are known as the **gas giants**. They are made up of accumulated gaseous material from the dust and gas cloud.

The outer gas giants are much **larger** (radii in the order of $10^4$km) than the inner rocky planets (radii in the order of $10^3$km). Although the inner rocky planets are **denser** than the gas giants, the gas giants are still far **more massive** ($10^{26}$-$10^{27}$kg) than they are ($10^{23}$-$10^{25}$kg).

## Pluto

Pluto used to be classed as the outermost planet, however it is now only classified as a **dwarf planet** because of its small mass (~$10^{22}$kg) and very **irregular, elliptical orbit**: the orbit of a planet becomes longer as distance from the sun increases.

## Moons

Some planets have moons which orbit them individually. Earth has one moon whereas Saturn has 53 confirmed moons and a further 29 awaiting classification! Mercury and Venus have no moons at all. Moons can also be thought of as **natural satellites**. Moons have a mass that is generally $<10^{23}$kg.

## Comets & Asteroids

These are often thought to be the same thing, however they have different compositions and movement characteristics.

**Comets** are large balls of **rock and ice** from space. As they near the Sun, heat from the Sun melts the ice and **vaporizes** it. This is seen as a **vapour 'tail'** when they move across the sky. Comets have highly **elliptical** and **irregular** orbits meaning they can travel far outside of our solar system.

**Asteroids** are **large rocks** moving through space. They are mainly found in the **asteroid belt** between Mars and Jupiter (mass of belt ~= $10^{21}$kg). These rocks can be remnants of former planets that never formed completely or were projected into space during collisions of planets in the early solar system.

Although 'large', comets and asteroids are far less massive than planets or moons (in the order of $10^6$-$10^{18}$kg).

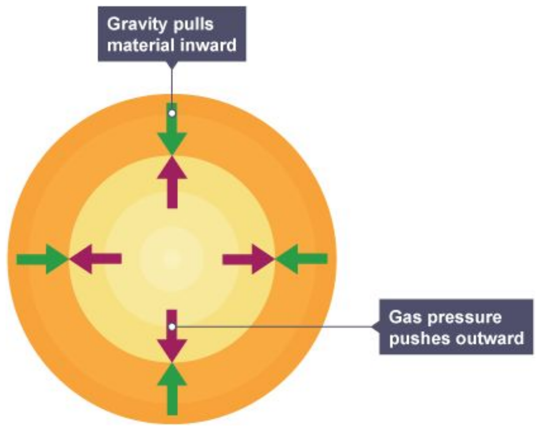
## Galaxies

Galaxies are composed of hundreds of millions of solar systems each orbiting the galaxy's centre of mass. For most galaxies this centre of mass is thought to be a **supermassive black hole**.

## Life Cycles of Stars

Stars are born from a cloud of **dust and gas** in a galaxy. **Gravitational attraction** between the particles draws them together so the cloud becomes **denser**. The temperature and pressure of the cloud increases as the particles move together. Eventually the pressure gets so great that the particles can **fuse together**. **Nuclear fusion** occurs as hydrogen nuclei fuse together to form helium nuclei, also releasing a large amount of **energy** in the form of heat and radiation.

The heat energy released causes **gaseous expansion** which is felt as an **outward force**, opposing collapsing forces of the cloud due to gravity. Radiation pressure provides another outward force. Eventually an **equilibrium** is established, where the fusion-derived expansional forces balance with the forces promoting gravitational collapse.




***Equilibrium of a star (bbc.co.uk).***

Once this balanced state is established a star has formed which will remain for billions of years.

Eventually the star **runs out of gas** nuclei that can undergo fusion. Therefore the outward gas pressure decreases so the system is **no longer in equilibrium**. **Gravitational collapse** results, and the star nears the end of its life. The mechanism with which this collapse takes place depends on the size of the star.

### Massive Stars

Massive stars, **much larger** than our Sun become **red supergiants** when they begin to collapse. Eventually, **heavier elements** begin to fuse in order to sustain the fusion process and maintain equilibrium.

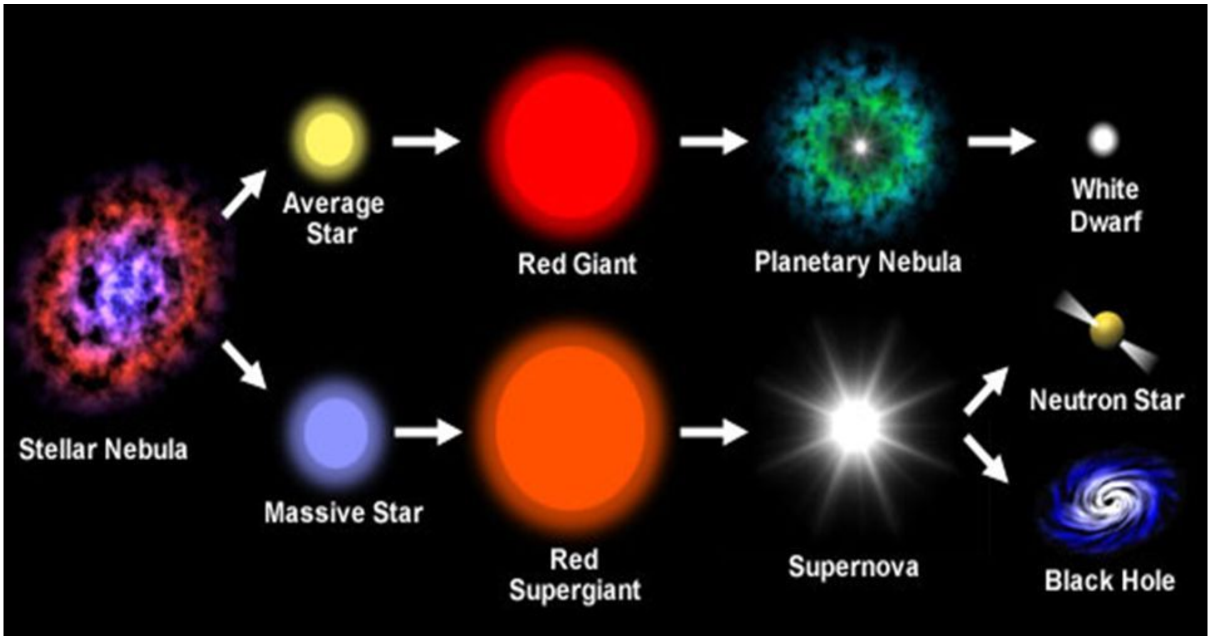
Once all possible fusion of elements has occurred, an **iron core** forms in the star, fusion ceases and the star **contracts** under gravity. The star is too massive to be stable, so it collapses in on its centre and explodes into a **supernova** leaving a **neutron star**.

During collapse into a supernova, much heavier elements such as Uranium are formed. These elements are then **distributed** into space via the **supernova explosion**, explaining why these elements are found on planets like Earth.

**Very massive** stars collapse form a **red supergiant** with such force that they form a **black hole**. These are regions of such **high density** that even **light can't escape** the force of gravity.

### Low Mass Stars

If the star has relatively **low mass** (is a similar size to the sun or smaller), a similar process occurs however **less fusion occurs** as there is less fuel to fuse. As a result, a **red giant** forms. This eventually collapses to produce a **planetary nebula** before cooling to become a **white dwarf**.




***The life cycle of stars (Hortense O'Brien).***

## Measuring Distances in Space

The diameters of planets, moons and asteroids can be measured in **meters** or **kilometers**. However the distances between these are so great, they are measured in **astronomical units (AU)**.

$$1\ AU = 150{,}000{,}000\ km = 1.5 \times 10^{11}\ m$$

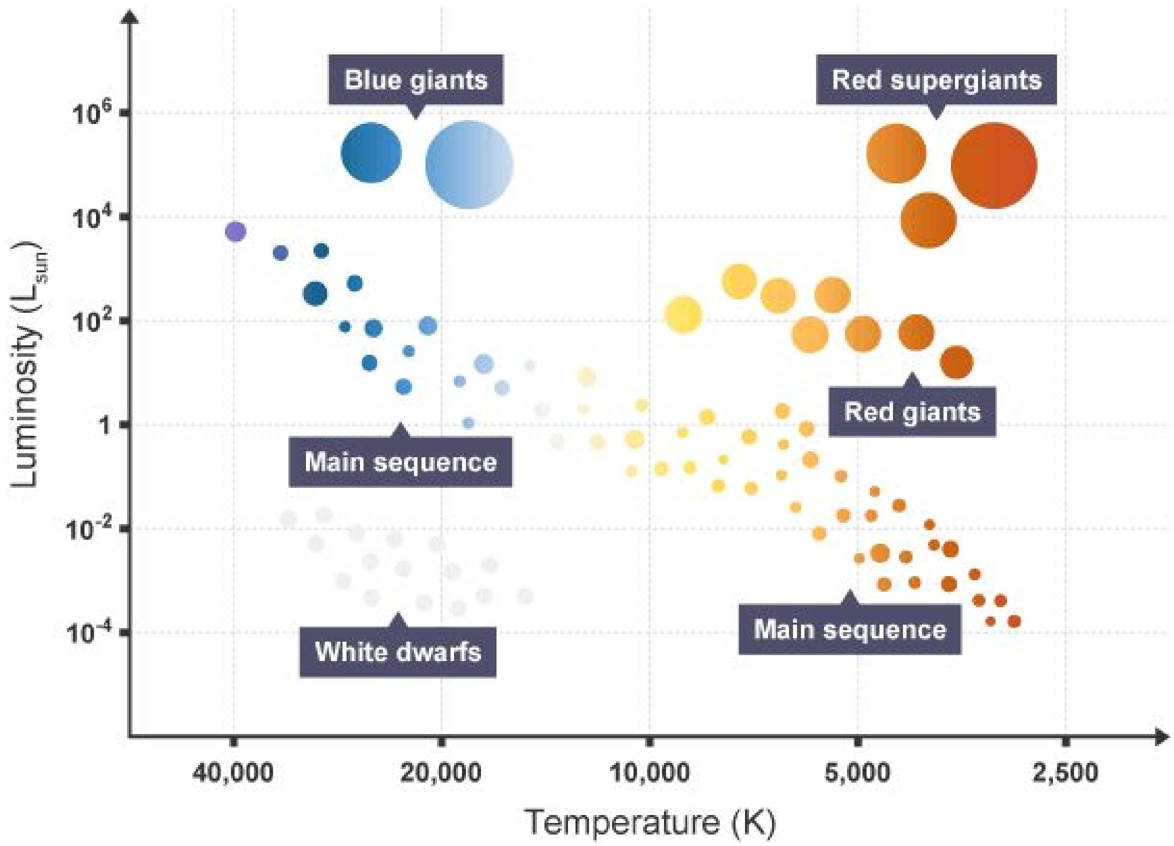
Another unit of measurement for distance is **light years (l-y)**. 1 light year is the distance that light will travel in 1 year.

$$1\ light\ year = 9.46 \times 10^{15}\ m$$

Speed-distance-time calculations can be done with distances in light years or light seconds by converting them into meters.

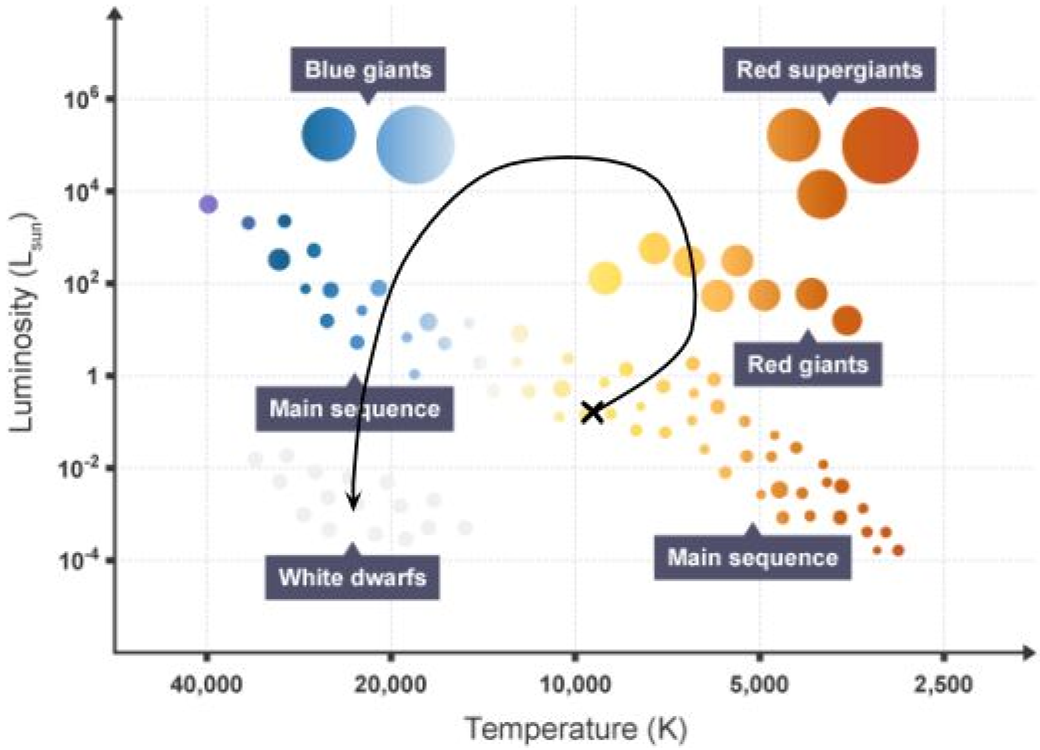
## Hertzsprung-Russell (H-R) Diagram

**These diagrams help to classify stars by comparing their temperature and brightness (luminosity). Stars lying on the diagonal of H-R diagrams are in the main sequence stages of their life.**




*Hertzsprung-Russell diagram for classifying stars (bbc.co.uk).*
*[Note the temperature axis goes from high to low.]*

**The paths of star life cycles can be shown on H-R diagrams by drawing arrows on. For a star the size of our sun, they will become red giants, then white dwarfs.**




***Hertzsprung-Russell diagram with a path for the life cycle of our sun (adapted from bbc.co.uk).***