Edexcel GCSE Physics

The Solar System & Lifecycles of Stars

Contents

Your notes

Gravity & Weight

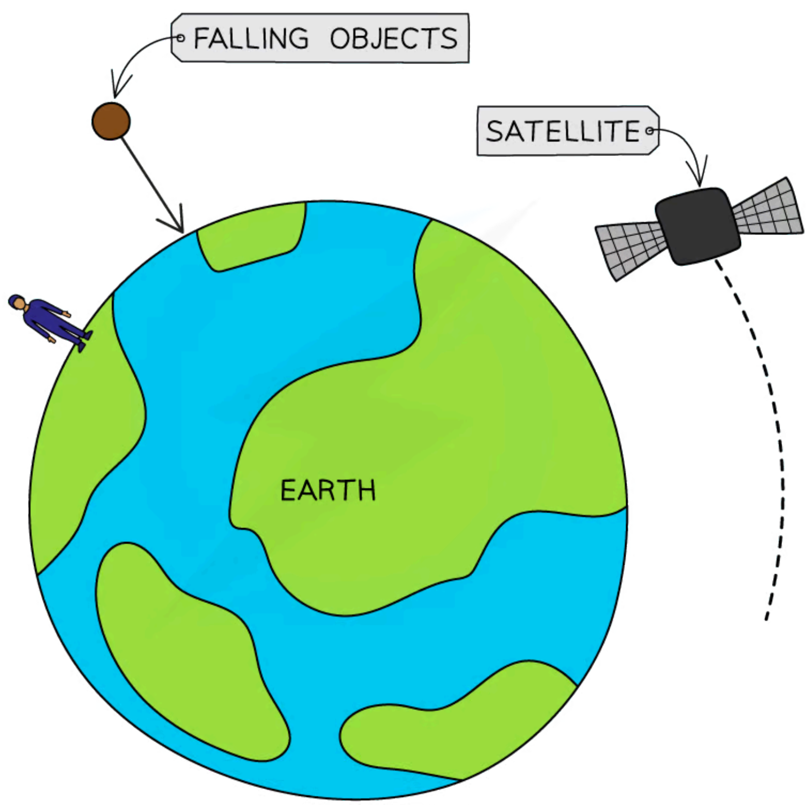
Your notes

Gravity on Different Planets

- The strength of gravity on different planets after an object's weight on that planet
- Weight is defined as:

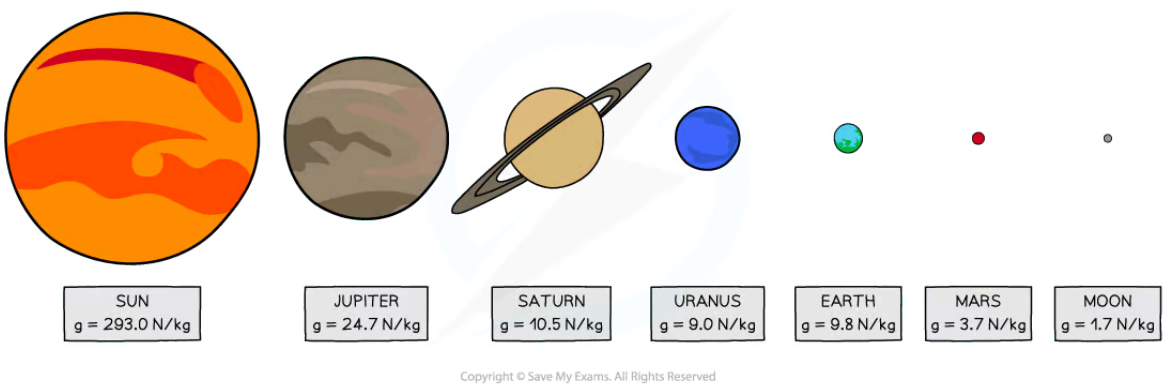
  The force acting on an object due to gravitational attraction

- Planets have strong gravitational fields
  - Hence, they attract nearby masses with a strong gravitational force
- Because of weight:
  - Objects stay firmly on the ground
  - Objects will always fall to the ground
  - Satellites are kept in orbit



Objects are attracted towards the centre of the Earth due to its gravitational field strength

- Both the weight of any body and the value of the gravitational field strength *g* differs between the surface of the Earth and the surface of other bodies in space, including the Moon because of the planet or moon's **mass**
  - The greater the mass of the planet then the greater its gravitational field strength
  - A higher gravitational field strength means a larger attractive force towards the centre of that planet or moon
- The gravitational field strength (*g*) on the **Earth** is approximately 10 N/kg
- The gravitational field strength on the surface of the **Moon** is **less** than on the Earth
  - This means it would be **easier** to lift a mass on the surface of the Moon than on the Earth
- The gravitational field strength on the surface of the gas giants (eg. Jupiter and Saturn) is **more** than on the Earth
  - This means it would be **harder** to lift a mass on the gas giants than on the Earth

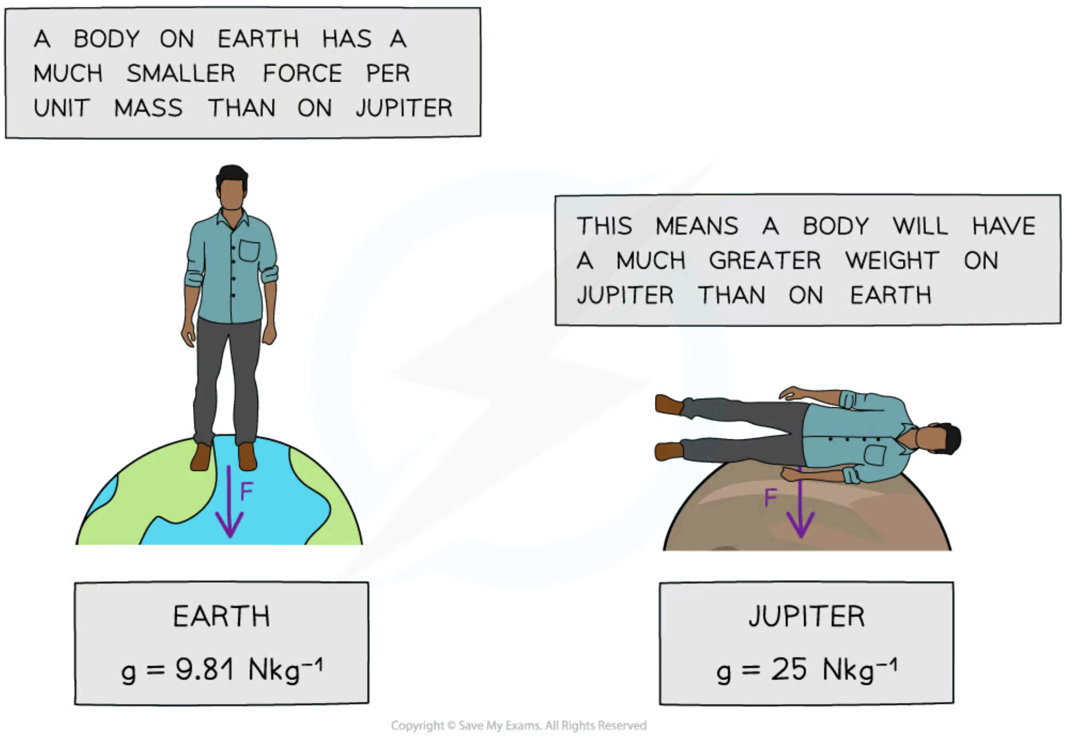


Value for g on the different objects in the Solar System

- On such planets such as Jupiter, an object's mass remains the same at all points in space
- However, their weight will be a lot greater meaning for example, a human will be unable to fully stand up

Your notes

Your notes



A person's weight on Jupiter would be so large a human would be unable to fully stand up

Examiner Tips and Tricks

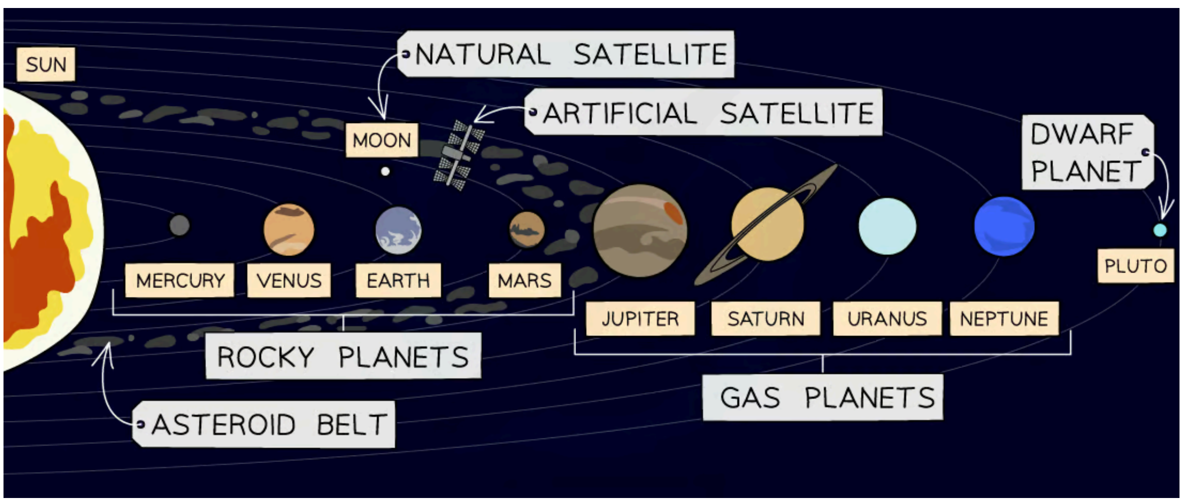
You do not need to remember the value of *g* on different planets for your exam, the value of *g* for Earth will be given in the exam question.

Your notes

The Solar System

Objects in the Solar System

- The Solar System consists of:
  - The Sun
  - Eight planets
  - Natural and artificial satellites
  - Dwarf planets
  - Asteroids and comets



The objects in our solar system

The Sun & the Planets

- The **Sun** lies at the centre of the Solar System
  - The Sun is a **star** that makes up over 99% of the mass of the solar system
- There are **8 planets** and an unknown number of **dwarf planets** which orbit the Sun
  - The **gravitational field** around planets is strong enough to have pulled in all nearby objects with the exception of natural satellites
  - The gravitational field around a **dwarf planet** is **not strong enough** to have pulled in nearby objects

Your notes

Satellites

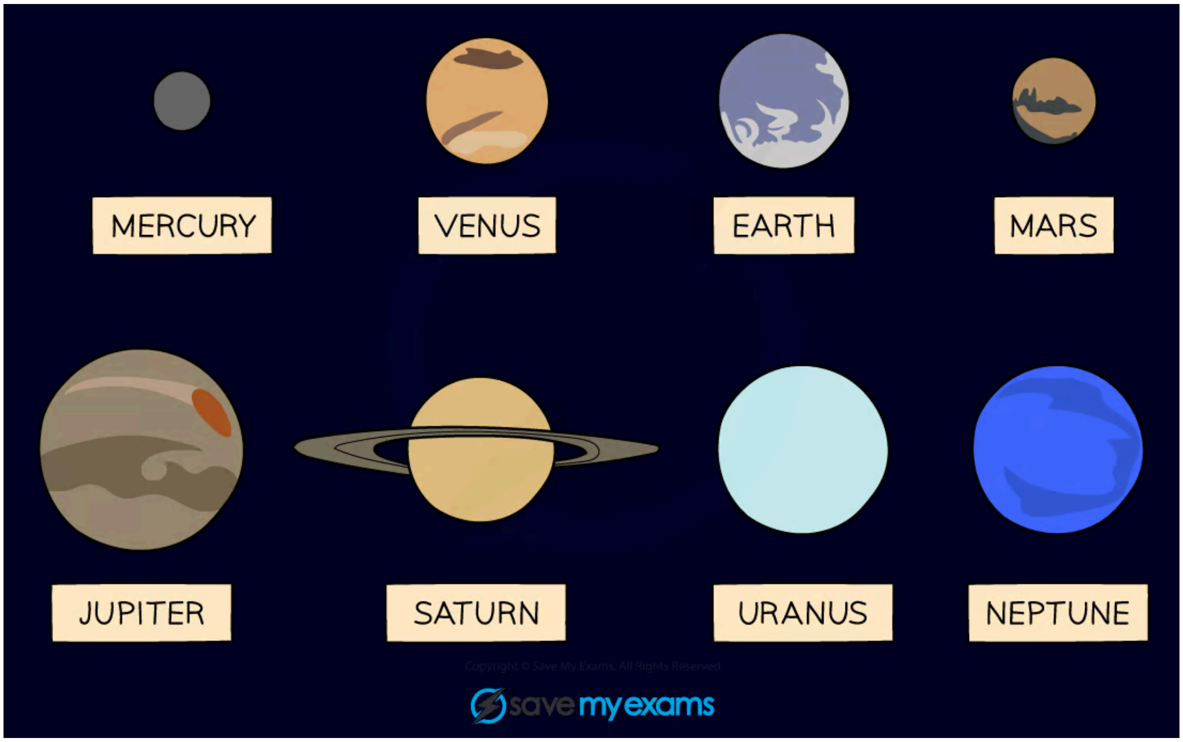
- There are two types of satellite:
  - Natural
  - Artificial
- Some planets have **moons** which orbit them
  - Moons are an example of **natural satellites**
- **Artificial satellites** are man-made and can orbit any object in space
  - The International Space Station (ISS) orbits the Earth and is an example of an artificial satellite

Asteroids & Comets

- **Asteroids** and **comets** also orbit the sun
- An **asteroid** is a small **rocky object** which orbits the **Sun**
  - The **asteroid belt** lies between **Mars and Jupiter**
- **Comets** are made of **dust and ice** and orbit the **Sun** in a different orbit to those of planets
  - The ice melts when the comet approaches the Sun and forms the comet's **tail**

The Planets

- The 8 planets in our Solar System in ascending order of the distance from the Sun are:
  - Mercury
  - Venus
  - Earth
  - Mars
  - Jupiter
  - Saturn
  - Uranus
  - Neptune
- There are **4 rocky planets**: Mercury, Venus, Earth and Mars
- There are **4 gas planets**: Jupiter, Saturn, Uranus and Neptune



The eight planets of our Solar System

Your notes

Distances between Planets in the Solar System

- The planets and moons of the Solar System are visible from Earth when they **reflect light** from the Sun
  - The outer regions of the Solar System are around 5 × 10^{12} m from the Sun, which means even light takes some time to travel these distances
- The light we receive on Earth from the Sun takes **8 minutes** to reach us
  - The nearest star to us after the Sun is so far away that light from it takes **4 years** to reach us
  - The Milky Way galaxy contains billions of stars, huge distances away, with the light taking even longer to be seen from Earth
- The speed of light is a constant 3 × 10^8 m/s
  - Therefore, using the equation:

$$\text{speed} = \frac{\text{distance}}{\text{time}}$$

- The time taken to travel a certain distance can be calculated by rearranging to:

$$\text{time} = \frac{\text{distance}}{\text{speed}}$$

Your notes

Worked Example

The radius of Mercury's orbit around the Sun is 5.8×10^9 m.

Calculate the time taken for light from the Sun to reach Mercury.

Answer:

Step 1: State the equation for the time taken for light to travel a certain distance

$$\text{time} = \frac{\text{distance}}{\text{speed}}$$

Step 2: Substitute in the values

- The distance travelled is the radius of the orbit
  - Distance, $d = 5.8 \times 10^9$ m.
- Speed = the speed of light, $v = 3.0 \times 10^8$ m/s

$$\text{time} = \frac{5.8 \times 10^9}{3.0 \times 10^8} = 1.933333$$

Step 3: Round up the answer and include units

$$\text{time} = 19.3 \text{ s}$$

Examiner Tips and Tricks

You need to know the order of the 8 planets in the solar system. The following mnemonic gives the first letter of each of the planets to help you recall them:

My **V**ery **E**asy **M**ethod **J**ust **S**peeds **U**p **N**aming (**P**lanets)

Mercury, **V**enus, **E**arth, **M**ars, **J**upiter, **S**aturn, **U**ranus, **N**eptune, (**P**luto)

Of course, Pluto has been classed as a dwarf planet since 2006, so you shouldn't include it as one of the 8 planets, but old mnemonics still include it so that the mnemonic makes sense!

The Creation of the Solar System

- The way humans have thought about the solar system has changed many times throughout history
- Before the development of the telescope, these ideas were based on what could be seen with the naked eye
- This restricted the details that could be gathered about the solar system, as asteroids, most of the satellites of other planets, and the most distant planets are not visible to the naked eye

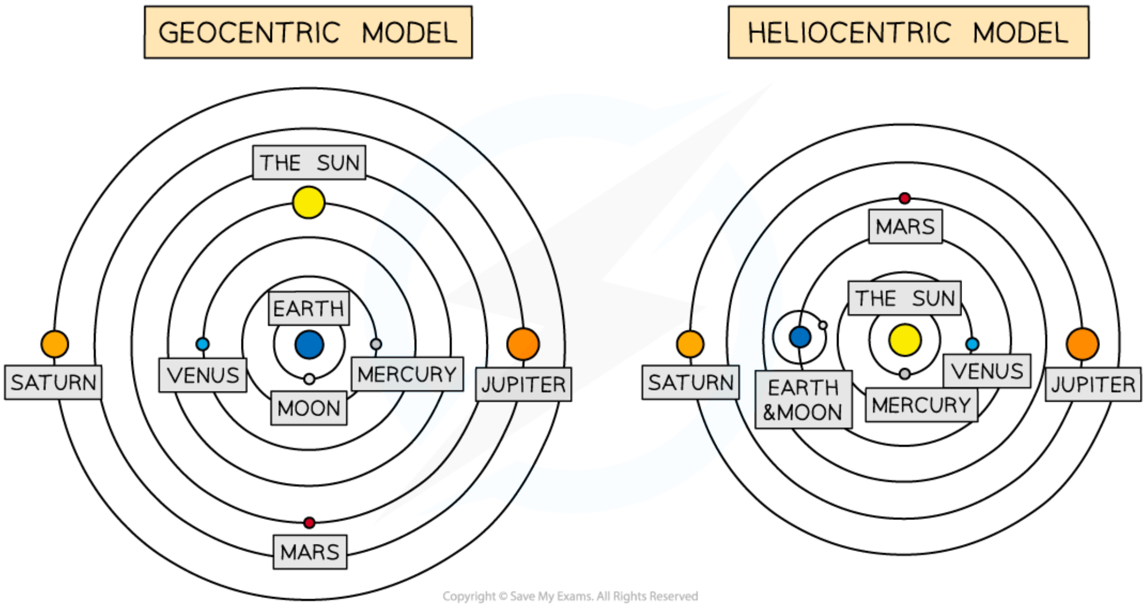
Ancient Model of the Solar System

- An Egyptian astronomer called Ptolemy (AD 100–168) described one of the earliest ideas for how the solar system is structured
- Ptolemy's model and many earlier ideas from scholars of the solar system had the Earth at the centre of it
- Over time, though, it became apparent that the old model did not quite fit with observation due to more detailed observations of the motions of the planets
  - This was called the **geocentric** model of the solar system

Modern Model of the Solar System

- Placing the Sun at the centre of the solar system and having the Earth and other planets orbit it gave a much more accurate explanation of astronomical observations
- Nicolas Copernicus (1473–1543) first suggested changing the model of the solar system to one with the Sun at the centre
- Detailed observations with telescopes have given us evidence that this is the correct idea
  - This is now the accepted **heliocentric** model of the solar system

Your notes



The geocentric model vs. the heliocentric model

Your notes

Worked Example

A long time ago, astronomers thought that the Earth was the centre of the Universe. This was called the geocentric model.The evidence for this model came from observations of the sky using the naked eye. After the telescope was invented, astronomers quickly gathered evidence that showed that the geocentric model is not correct. Describe the evidence both for the geocentric model and against the geocentric model.

Answer:

Step 1: Describe the evidence supporting the geocentric model

- When observing the Sun, Moon, stars or planets with the naked eye, they appear to be moving across the sky and not just orbiting the Sun
- Instead, they seem to appear to be going around the Earth
- From simple observation, objects appear to move in the same direction and in a predictable pattern of movement which is the same each day

Step 2: Describe the evidence against the geocentric model

- The moons of other planets (such as Jupiter) can clearly be seen to be orbiting the other planet and **not** the Earth

- Careful observations of the Sun (and other objects) show their movements are, in fact, not quite the same each day
- Detailed telescope observations show the planets of the Solar System do not move in a simple orbital path around the Earth
- This is evidenced by the **retrograde** motion of planets, which can only be explained by a **heliocentric model**

Your notes

Circular Orbits

Your notes

Orbiting Bodies

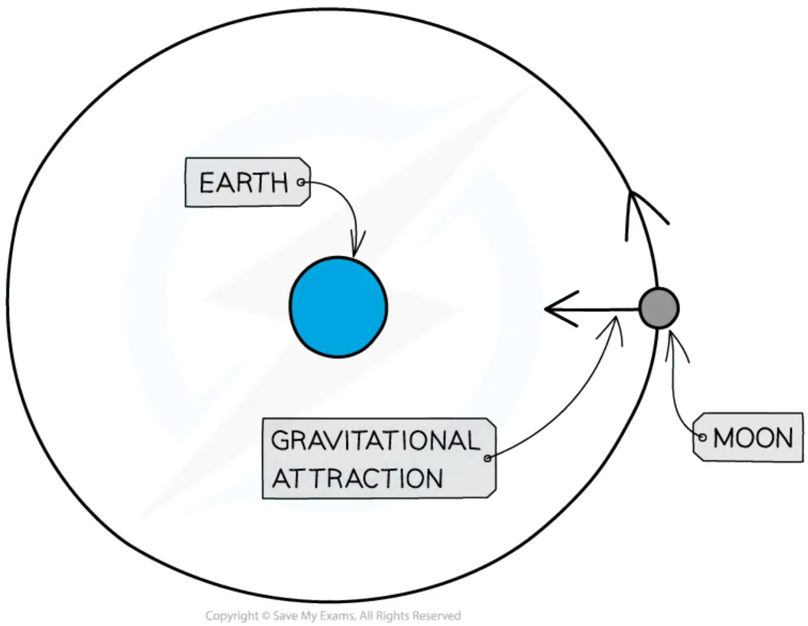
- There are many orbiting objects in our solar system and they each orbit a different type of planetary body

Orbiting Objects or Bodies in Our Solar System Table

Body or Object	What it Orbits
Planet	Sun
Moon	Planet
Comet	Sun
Asteroid	Sun
Artificial satellite	Any object or body in solar system

- A **smaller** body or object will **orbit** a **larger** body
  - For example, a planet orbiting the Sun
- In order to orbit a body such as a star or a planet, there has to be a **force** pulling the object **towards** that body
  - **Gravity** provides this force
- The gravitational force exerted by the larger body on the orbiting object is **always attractive**
  - Therefore, the gravitational force always acts **towards the centre** of the larger body
- The gravitational force will cause the body to move and maintain in a **circular path**

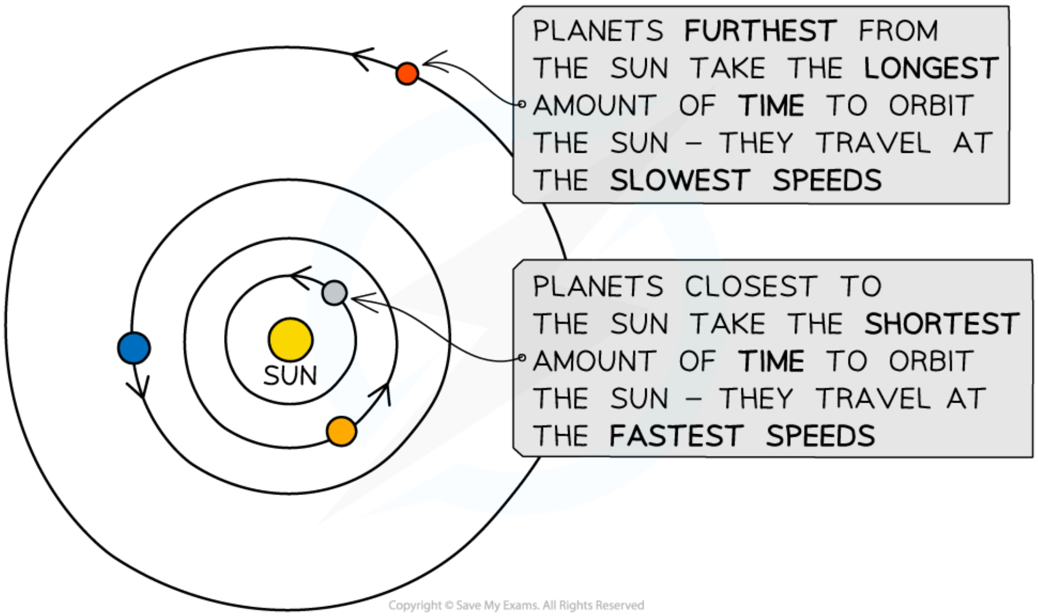
Your notes



Gravitational attraction causes the Moon to orbit around the Earth

Orbits of Planets

- There are several **similarities** in the way different planets orbit the Sun:
  - Their orbits are all **slightly elliptical** (stretched circles) with the Sun at one focus (approximately the centre of the orbit)
  - They all orbit in the **same plane**
  - They all travel the **same direction** around the Sun
- There are also a few differences:
  - They orbit at **different distances** from the Sun
  - They orbit at **different speeds**
  - They all take **different amounts of time** to orbit the Sun



The orbits of planets around the Sun

Orbits of Moons

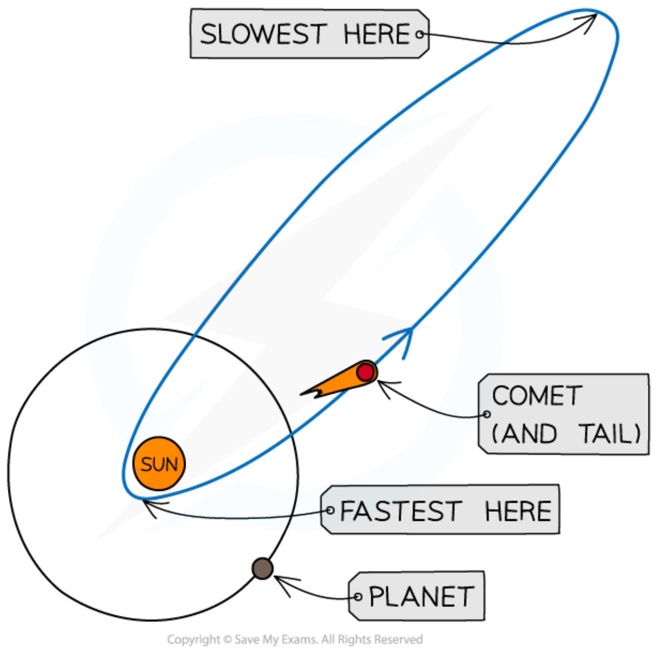
- Moons orbit planets in a **circular path**
- Some planets have more than one moon
- The **closer** the moon is to the planet:
  - The **shorter** the **time** it will take to orbit
  - The **greater** the **speed** of the orbit

Comets

- The orbits of comets are very different to those of planets:
- Their orbits are highly **elliptical** (very stretched) or hyperbolic
  - This causes the speed of the comets to change significantly as their distance from the Sun changes
  - Not all comets orbit in the same plane as the planets and some don't even orbit in the same direction

Your notes

Your notes



The elliptical orbit of a comet

Artificial Satellites

- A satellite needs to travel at a **specific speed** to maintain a **circular orbit** at a **particular distance** from the object
- If the speed of the satellite is too **large**:
  - The **radius** of the orbit will **increase** and the satellite will **spiral into space**
  - This is because the **gravitational attraction** cannot provide enough **force** to keep it in orbit
- If the speed of the satellite is too **low:**
  - The **radius** of the orbit will **decrease** and the satellite will **move towards the object** it should be orbiting
  - This is because the **gravitational attraction** is too **strong** to maintain a constant orbital radius

Your notes

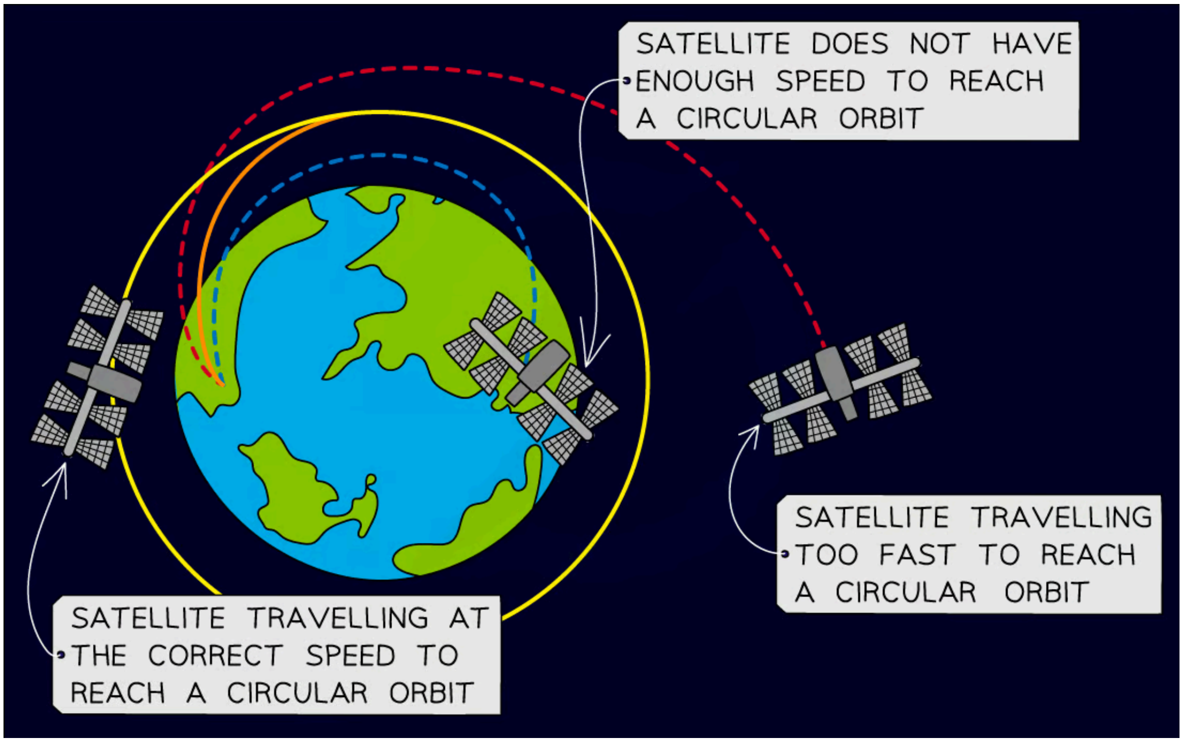


Diagram showing how the speed of an artificial satellite affects its orbit

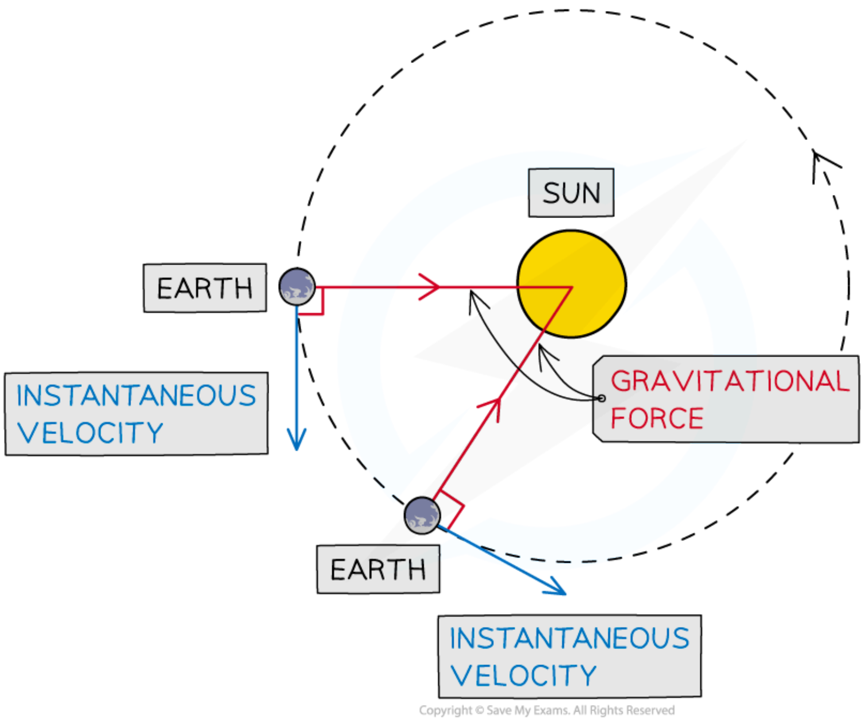
- If an artificial satellite is to change the **radius** at which it is orbiting then the **speed** at which it is travelling **must change**
- To maintain a **stable** orbit:
  - If the speed **increases** the radius must **decrease**
  - If the speed **decreases** the radius must **increase**

Circular Orbits

- Planets travel around the Sun in orbits that are (approximately) circular
  - Objects in circular orbit are travelling at a **constant speed** but a **changing velocity**
- In a **circular path**, the **direction** in which the object is travelling will be **constantly changing** direction
  - A change in direction causes a change in **velocity**
- **Acceleration** is the **rate of change of velocity**

Your notes

- Therefore, if the object is constantly changing direction then its **velocity** is **constantly changing** and so the object in orbit is **accelerating**
- A **resultant force** is needed to cause an acceleration
- This resultant force is **gravity** and it must act at right angles to the **instantaneous velocity** of the object to create a circular orbit
  - This is always towards the **centre** of the orbit
  - The instantaneous velocity of the object is the velocity at a **given time**



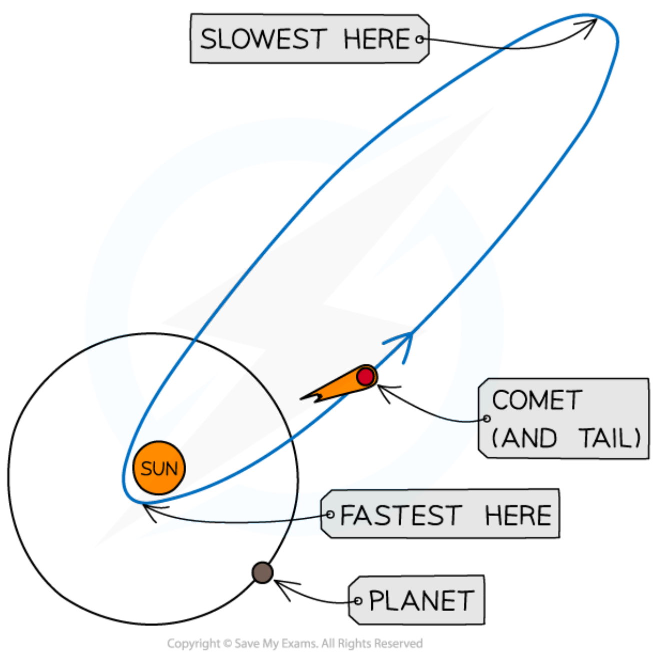
The direction of the instantaneous velocity and the gravitational force at different points of the Earth's orbit around the sun

Your notes

Non-Circular Orbits

Non-Circular Orbits

- Some orbits, such as those of comets, are **non-circular**
  - These are often more **elliptical**
- However, their orbits are still **stable**
- For a stable orbit, the **radius** must change if the comets **orbital speed** changes
- For example, for a comet in an elliptical orbit around the Sun:
  - As the comet approaches the Sun, the radius of the orbit **decreases** and the orbital speed **increases** due to the Sun's strong gravitational pull
  - As the comet travels further away from the Sun, the radius of the orbit **increases** and the orbital speed **decreases** due to a weaker gravitational pull from the Sun



Comets travel in highly elliptical orbits, speeding up as they approach the Sun

- As a comet approaches the Sun:
  - It **loses** gravitational potential energy and **gains** kinetic energy

- The icy body of the comet also starts to melt, and forms a tail that always points away from the Sun

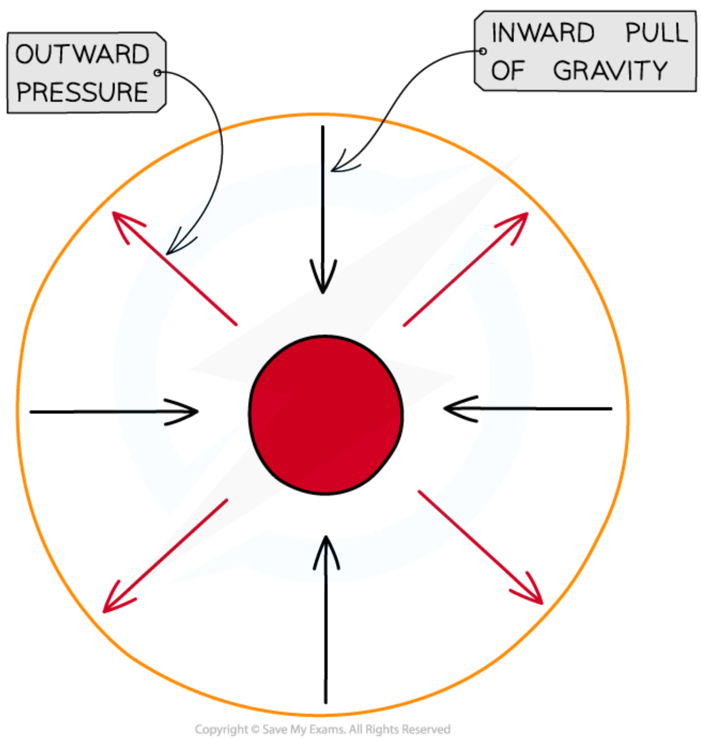
Your notes

Your notes

Equilibrium in Stars

Equilibrium in Stars

- Stars are held together by a delicate balance of inwards and outwards forces
- One of these forces is the force of **gravity**
  - This is an **attractive** force which pulls the outer layers **inwards**
- The other force is the force from the **pressure** caused by the **thermal expansion**
  - This is an **outward** force which is exerted from the **expanding hot gases** inside the star
- When the inward pull of **gravity** and the force from the **outward thermal expansion** acting on the star are **equal,** the star will be in **equilibrium**
- This is how the stars in the **main sequence** remain stable for millions of years



Forces acting within a star. The centre red circle represents the star's core and the orange circle represents the stars outer layers

- If the **temperature** of a star **increases**, the **outward pressure** will also **increase**
  - This will cause the star to **expand**
- If the **temperature drops** the **outward pressure** will also **decrease**
  - This will cause the star to **contract**
- As long as these two forces balance, the star will remain **stable**
- Once these forces are **unbalanced**, then they will no longer be in equilibrium causing the star to **expand** or **contract**
  - This happens when **fusion** in the core of stars, and hence thermal expansion, **ceases** at the end of the star's life

Your notes

Your notes

The Life Cycle of Solar Mass Stars

The Life Cycle of Solar Mass Stars

1. Nebula

- All stars form from a giant cloud of **hydrogen gas** and **dust** called a **nebula**

2. Protostar

- The force of **gravity** within a nebula pulls the particles **closer together** until it forms a hot ball of gas, known as a **protostar**
- As the particles are pulled closer together the **density** of the protostar will **increase**
  - This will result in **more frequent collisions** between the particles which causes the **temperature** to **increase**

3. Main Sequence Star

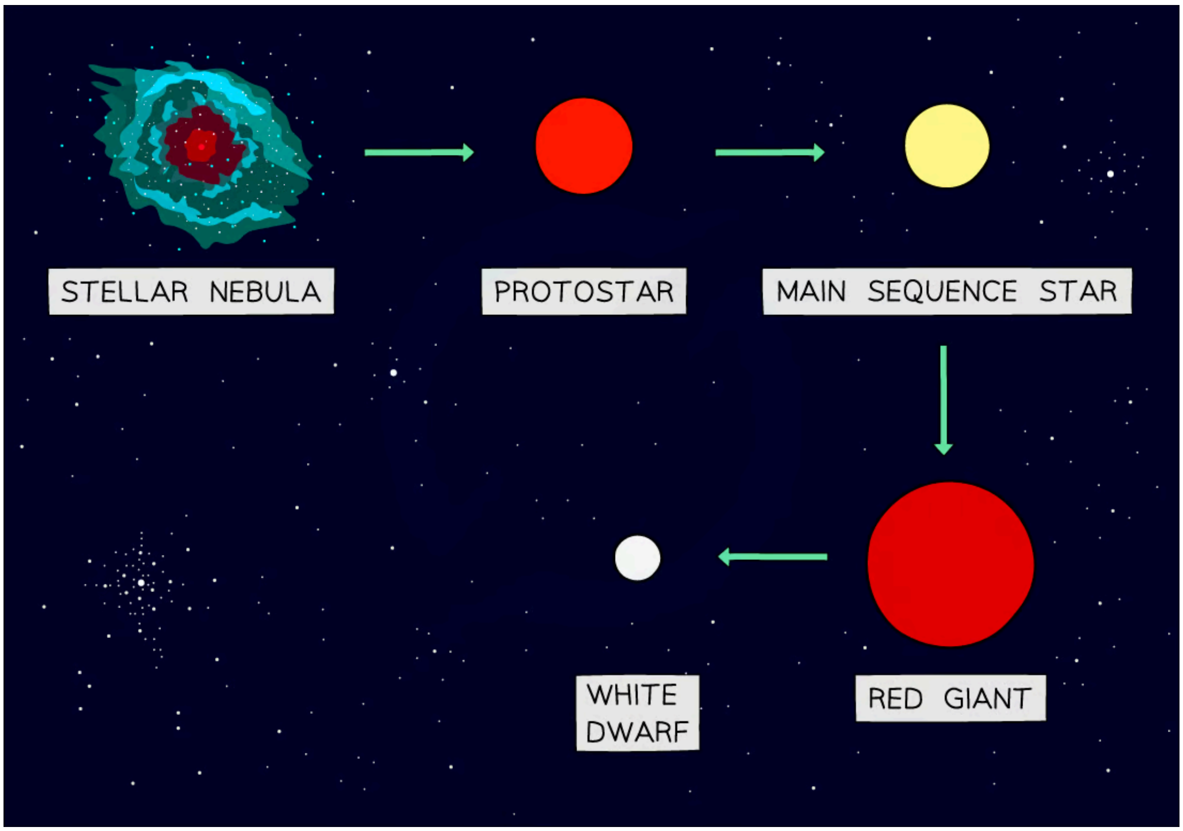
- Once the protostar becomes hot enough, thermal expansion from **fusion** reactions occur within its core and the force of gravity keeps the star in equilibrium
- At this point, the star is born, and it becomes a **main-sequence star**
- During the main sequence, the star is in **equilibrium** and said to be **stable**
  - The **inward force** due to **gravity** is **equal** to the **outward pressure force** which results from the expanding hot gases inside the star

4. Red Giant

- After several billion years the reactions in the star eventually die down as it runs out of fuel
- This causes the core to **shrink** and **heat up**
  - The core will shrink because the inward force due to gravity will become **greater** than the outward force due to the pressure dies down
- As the core shrinks, more reactions will cause the outer part of the star to **expand**
- It will become a **red giant**
  - It is red because the **outer surface** starts to **cool**

5. White Dwarf

- The star will eventually become **unstable** and eject the outer layer of dust and gas as a **planetary nebula**
- The core which is left behind will **collapse completely**, due to the pull of **gravity**, and the star will become a **white dwarf**
- The white dwarf will be **cooling** down and as a result, the amount of **energy** it emits will **decrease**



The lifecycle of a solar mass star

Examiner Tips and Tricks

Make sure you remember the life cycle for a solar mass star and ensure you can describe the sequence in a logically structured manner in case a 6 marker comes up in the exam!Ensure you can remember the end stages for a solar mass star clearly (red giant, planetary nebula, white dwarf) as this is different for a star that is much larger than our Sun!

Your notes

The Life Cycle of Larger Stars

Your notes

The Life Cycle of Larger Stars

- A **large star** is one that is much **larger** than the **Sun**
  - Stars that are larger than the Sun have much **shorter lifespans** – in the region of hundreds of millions of years (instead of billions)
- The life cycle of a star larger than the Sun starts in the same way as a solar mass star

1. Nebula

- All stars form from a giant cloud of **hydrogen gas** and **dust** called a **nebula**

2. Protostar

- The force of **gravity** within a nebula pulls the particles **closer together** until it forms a hot ball of gas, known as a **protostar**
- As the particles are pulled closer together the **density** of the protostar will **increase**
  - This will result in **more frequent collisions** between the particles which causes the **temperature** to **increase**

3. Main Sequence Star

- Once the protostar becomes hot enough, thermal expansion from **fusion** reactions occur within its core and the force of gravity keeps the star in equilibrium
- At this point, the star is born, and it becomes a **main-sequence star**
- During the main sequence, the star is in **equilibrium** and said to be **stable**
  - The **inward force** due to **gravity** is **equal** to the **outward pressure force** which results from the expanding hot gases inside the star

4. Red Supergiant

- Eventually, the main sequence star will reach a stage when it starts to **run out** of fuel in its core
- This causes the core to **shrink** and **heat up**
  - The core will shrink because the **inward force** due to **gravity** is **greater** than the **outward force** due to the **pressure** of the expanding gases
- This will cause more reactions in the core will cause the outer part of the star to **expand** and it will become a **red supergiant**

Your notes

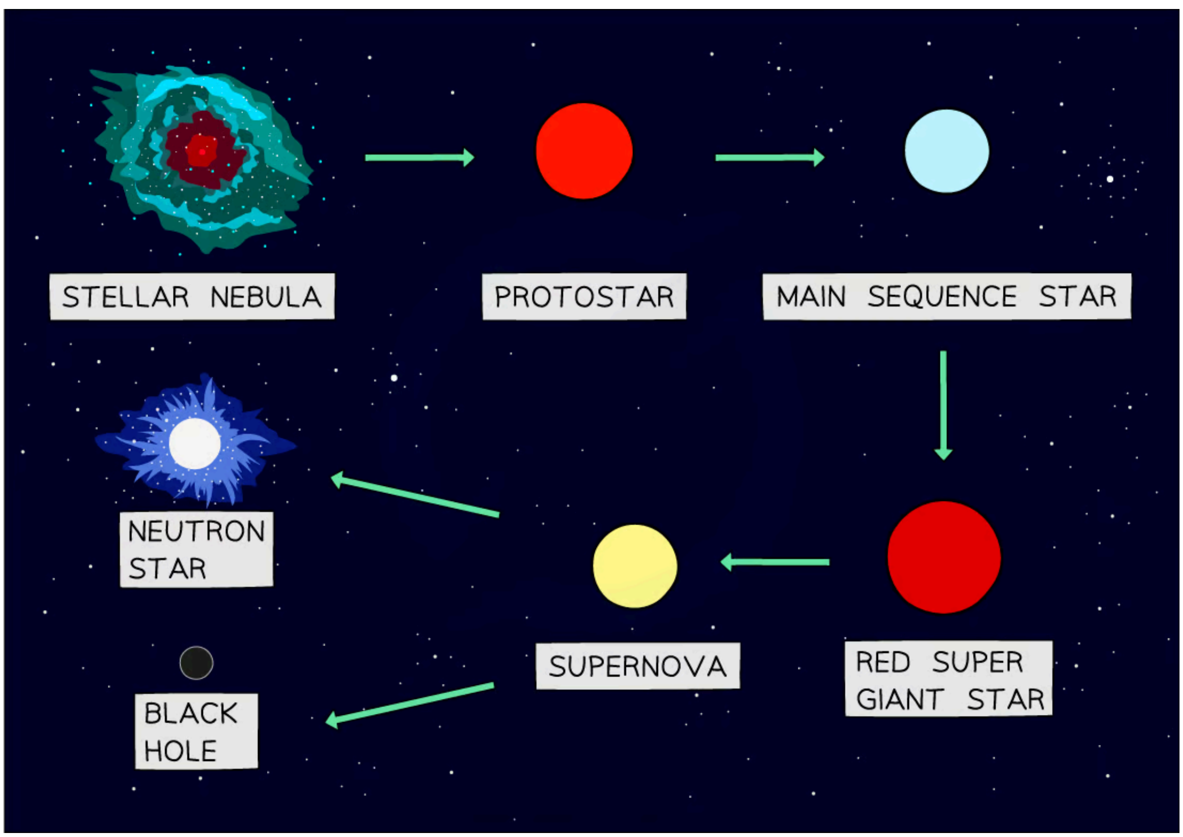
- A red supergiant is **much larger** than a **red giant**

5. Supernova

- Once the reactions inside the red supergiant finally finish, the core of the star will **collapse suddenly** and rebound causing a **gigantic explosion**
  - This is called a **supernova**
- The **outer remnants** of the star will be **ejected** into space during the supernova explosion

6. Neutron Star (or Black Hole)

- At the centre of this explosion a **dense body**, called a **neutron star** will form
- In the case of the **largest stars**, the neutron star that forms at the centre will continue to **collapse** under the force of **gravity** until it forms a **black hole**
  - A black hole is an **extremely dense** point in space that not even **light** can escape from



Lifecycle of stars much larger than our Sun

Your notes

Examiner Tips and Tricks

Make sure you remember the life cycle for a high mass star and ensure you can describe the sequence in a logically structured manner in case a 6 marker comes up in the exam!Ensure you can remember the end stages for a high mass star clearly (red supergiant, supernova, neutron star/black hole) as this is different for a star that is a similar size to the Sun!