

8 · Space physics (physics only)

AQA · GCSE · Physics

Space physics: the biggest picture

Stars form, release energy by nuclear fusion and evolve; light from most distant galaxies is red-shifted; and the light they send us carries the news. This reference covers **AQA GCSE Physics 8463, topic 4.8 Space physics**.

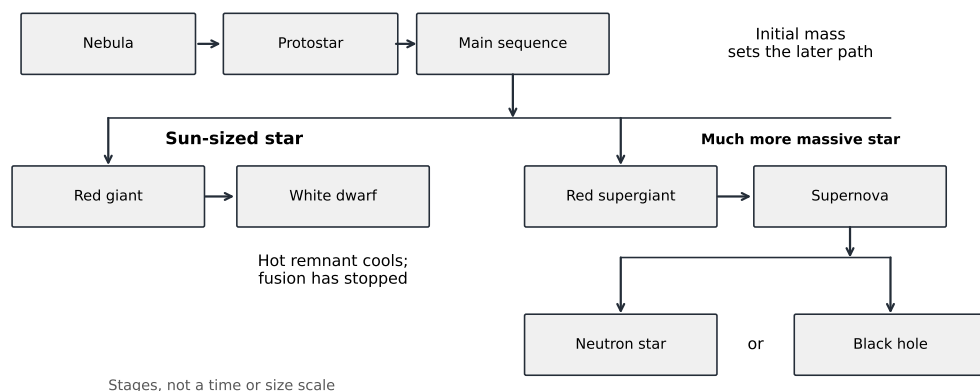
How the exam treats this topic:

- The **whole topic is physics only**, sitting on Paper 2.
- Gravity as the cause of circular orbits and comparisons of planets and satellites are common-tier content. **HT only**: explain changing velocity at constant speed and compare the radii of stable circular orbits at different speeds.
- Facts must be exact: the life-cycle sequence, the fusion story of the elements, and the red-shift chain.

Our solar system and the Sun

The solar system: **one star (the Sun)**, **eight planets**, the **dwarf planets** orbiting the Sun, and **natural satellites (moons)** orbiting planets. Our solar system is a small part of the **Milky Way** galaxy.

The Sun's formation: a cloud of dust and gas (a **nebula**) was pulled together by **gravitational attraction**. As it collapsed:



Stages, not a time or size scale

1. the dense centre heated until **fusion** began – a star lit;
2. energy released by fusion maintains the outward pressure that balances the inward gravitational pull – an **equilibrium** during the main sequence.

The life cycle of a star

The life cycle depends on the star's initial **mass**; compare a Sun-sized star with one much more massive than the Sun.

Sun-sized star: nebula → protostar → **main sequence** (fusion of hydrogen; equilibrium) → **red giant** (core hydrogen becomes depleted; the star expands and later fuses helium) → **white dwarf** (the hot remnant core; sustained fusion has stopped) → eventual cooling towards a **black dwarf**. A black dwarf is a predicted cooled remnant, not an observed present-day stage. The Sun will not fuse elements all the way to iron.

Massive star (much more massive than the Sun): nebula → protostar → **main sequence** → **red supergiant** → **supernova** (explosion) → **neutron star**, or – for the most massive – a **black hole**.

Where the elements come from (a favourite sequence):

- Fusion joins light **nuclei** to make heavier nuclei: hydrogen forms helium, and later fusion stages in sufficiently massive stars build elements up to **iron**.
- In the AQA GCSE model, elements **heavier than iron** are produced in a **supernova**. This is the exam explanation; it is not a claim that every heavy atom forms only in supernovae.
- The supernova **distributes** the elements throughout the universe – the stuff of planets and people.

■ Worked data reading: mass, prefixes and travel time

These examples follow AQA June 2024 8463/2H Q03.2, Q03.3 and Q03.5 and their official mark scheme.

Compare mass: Betelgeuse has mass 2.2×10^{31} kg, while the Sun has mass 2.0×10^{30} kg. First compare powers of ten: Betelgeuse is the much more massive candidate in that question, so it is the star most likely to form a black hole. The ranking does not predict an exact remnant from mass alone.

Convert the prefix: $1 \text{ Gm} = 10^9 \text{ m}$, so $s = 1.1 \times 10^8 \text{ Gm} = 1.1 \times 10^{17} \text{ m}$. A unit conversion does not change the physical distance.

Find light-travel time: Arcturus is $3.6 \times 10^{14} \text{ km}$ away; light travels at $3.0 \times 10^8 \text{ m/s}$. Convert the distance and use the definition of speed.

$$s = 3.6 \times 10^{14} \text{ km} = 3.6 \times 10^{17} \text{ m}$$

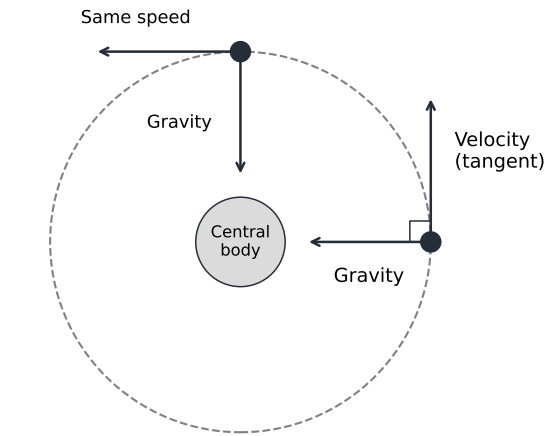
$$v = \frac{s}{t} \quad t = \frac{s}{v}$$

$$t = \frac{s}{v} = \frac{3.6 \times 10^{17}}{3.0 \times 10^8} = 1.2 \times 10^9 \text{ s}$$

The unit is seconds because metres divided by metres per second gives seconds.

Orbital motion and satellites

Gravity provides the centripetal force keeping planets and satellites in circular orbits.



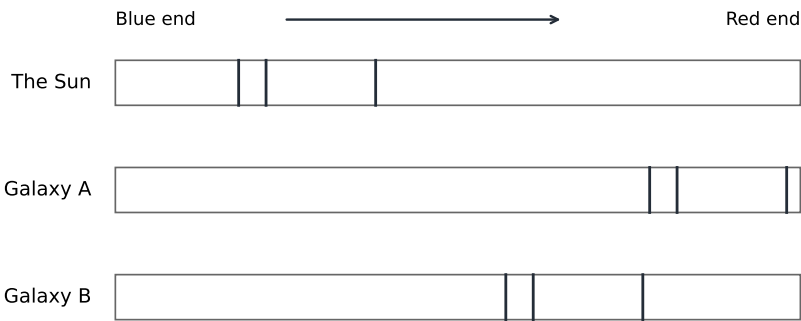
HT: velocity direction changes; speed stays constant

- **Planets:** orbit the Sun. **Moons:** natural satellites orbiting planets. **Artificial satellites:** made by us, orbiting the Earth. Gravity holds all of these in orbit. Compare what they orbit and whether they formed naturally or were made by humans; artificial satellites can orbit bodies other than Earth.
- (HT) A circular orbit has **changing velocity but unchanged speed** – velocity is a vector, and the direction changes continuously; the gravitational force acts at right angles to the motion, changing direction but not speed.
- (HT) Compare **stable circular orbits around the same central body:** a smaller radius requires a higher speed; a larger radius requires a lower speed. This compares completed circular orbits. It does not mean that firing an engine to speed up instantly moves a satellite into a lower circular orbit.

Worked explanation: gravity acts towards the centre → the satellite accelerates towards the centre → its direction, and therefore its velocity, changes even if its speed stays constant.

Red-shift and the Big Bang

Light from **most distant galaxies** shows an **increase in wavelength** – a shift towards the red end: **red-shift**.



Match the same pattern on one common wavelength scale

Schematic redrawing of AQA June2024 8463/2H Q03.4

- For the distant-galaxy expansion trend, the **further away** the galaxy, the **faster** it is receding and the **bigger** the red-shift. Compare matching spectral lines on the same wavelength scale, not the apparent colour or brightness of whole galaxies.
- Red-shift means the universe is **expanding**. Played backwards, everything was once in a **very small, extremely hot and dense region** – the **Big Bang**.

No measured shift suggests no recession along the line of sight in the simple school model; it does not prove the object has no sideways motion.

The credited chain: observed red-shift → galaxies receding → further = faster → space itself expanding → Big Bang. And the scientific-method point: observations (red-shift surveys, and since **1998** supernovae supporting **accelerating expansion**) are the evidence from which the theory is built; much remains unknown, e.g. **dark matter** and **dark energy**.

Checklist before you call this topic done

- List the solar system's contents and the Sun's formation from a nebula by gravity.
- Draw or order both life cycles; state where every element forms.
- Explain orbits with gravity; (HT) explain changing velocity at constant speed and radius changes for stable orbits.
- State the red-shift chain and its Big Bang conclusion, the 1998 supernova observation, and one open unknown.