

Space physics PHYSICS ONLY

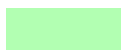
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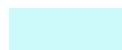
Revision notes for one topic, free to download.

These are the summary notes only. The full edition of this booklet also carries the worked examples, the required practicals and the formula sheets, with every topic in one place.

Colour Codes



Definitions



Diagrams



Notes and warnings



Sub-topic headings

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Define Solar system

- one star (the Sun) plus the eight planets, the dwarf planets and the natural satellites that orbit within it.

Define Dwarf planet

- a body orbiting the Sun that is large enough to be rounded but has not cleared its orbit, e.g. Pluto.

Define Galaxy

- a huge collection of stars held together by gravity; our solar system is a small part of the **Milky Way** galaxy.

Define Protostar

- the hot, dense clump formed as a nebula is pulled together by gravitational attraction, before fusion starts.

Define Main sequence star

- the long, stable stage of a star's life, when the inward gravitational collapse is balanced by the outward expansion due to fusion energy.

Define White dwarf

- the small, hot, dense remnant left when a star about the size of the Sun collapses.

Define Neutron star

- an extremely dense remnant left after a supernova.

Define Red-shift

- the observed increase in the wavelength of light from most distant galaxies.

Define Planet

- a large body orbiting a star, massive enough to have cleared its orbit of other objects.

Define Natural satellite

- a moon, a natural body that orbits a planet.

Define Artificial satellite

- a human-made object placed in orbit around a planet.

Define Nebula

- a cloud of dust and gas from which a star forms.

Define Nuclear fusion

- the joining of small nuclei to form larger nuclei, releasing energy; the process that powers a star.

Define Red giant / red super giant

- the swollen, cooler stage a star enters when the hydrogen in its core runs out.

Define Supernova

- the explosion of a massive star, which produces elements heavier than iron and distributes elements throughout the universe.

Define Black hole

- the remnant of the most massive stars, so dense that not even light can escape.

Define Big Bang theory

- the theory that the universe began from a very small region that was extremely hot and dense.

Define Dark mass and dark energy

- features of the universe that are not yet understood; dark mass bends light and holds galaxies together but does not emit electromagnetic radiation.

NOTE

PHYSICS ONLY The whole of Topic 8 is physics only. Every sub-topic and bullet here is tagged **PHYSICS ONLY** because none of it appears in GCSE Combined Science; content the spec marks "(HT only)" is additionally tagged **HT ONLY**.

There are also **no required practical activities** in Topic 8 (or in Topic 7) — all ten required practicals for GCSE Physics belong to other topics.

8.1 Solar system; stability of orbital motions; satellites **PHYSICS ONLY**

8.1.1 Our solar system **PHYSICS ONLY**

- **PHYSICS ONLY** Within our solar system there is **one star, the Sun**, plus the **eight planets** and the **dwarf planets** that orbit around the Sun.

PHYSICS ONLY **Natural satellites** — the **moons** that orbit planets — are also part of the solar system.

Smaller bodies such as **asteroids** (mostly between Mars and Jupiter) and **comets** (which follow long, highly elongated orbits) also orbit the Sun.

- **PHYSICS ONLY** The eight planets in order from the Sun: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune.
- **PHYSICS ONLY** Our solar system is a small part of the Milky Way galaxy — one of many billions of galaxies in the universe.
- **PHYSICS ONLY** The Sun was formed from a cloud of dust and gas (nebula) pulled together by gravitational attraction.
- **PHYSICS ONLY** At the start of a star's life cycle: 1. Gravity pulls the dust and gas of the nebula together into a **protostar**. 2. As the material falls inwards it is compressed, so the temperature and pressure **rise**. 3. When it is hot and dense enough, **nuclear fusion** reactions begin — hydrogen nuclei fuse into helium, releasing energy.
- **PHYSICS ONLY** Fusion reactions lead to an equilibrium between the gravitational collapse of a star and the expansion of a star due to fusion energy. These two effects balance, so the star stays the same size for a very long time — this stable stage is the **main sequence**.

WATCH OUT

The star is not "held up" by anything solid. Gravity is still pulling inwards the whole time — it is simply **balanced** by the outward pressure from the energy released by fusion. As soon as the fusion fuel in the core runs out, the balance is lost and the star's structure changes.

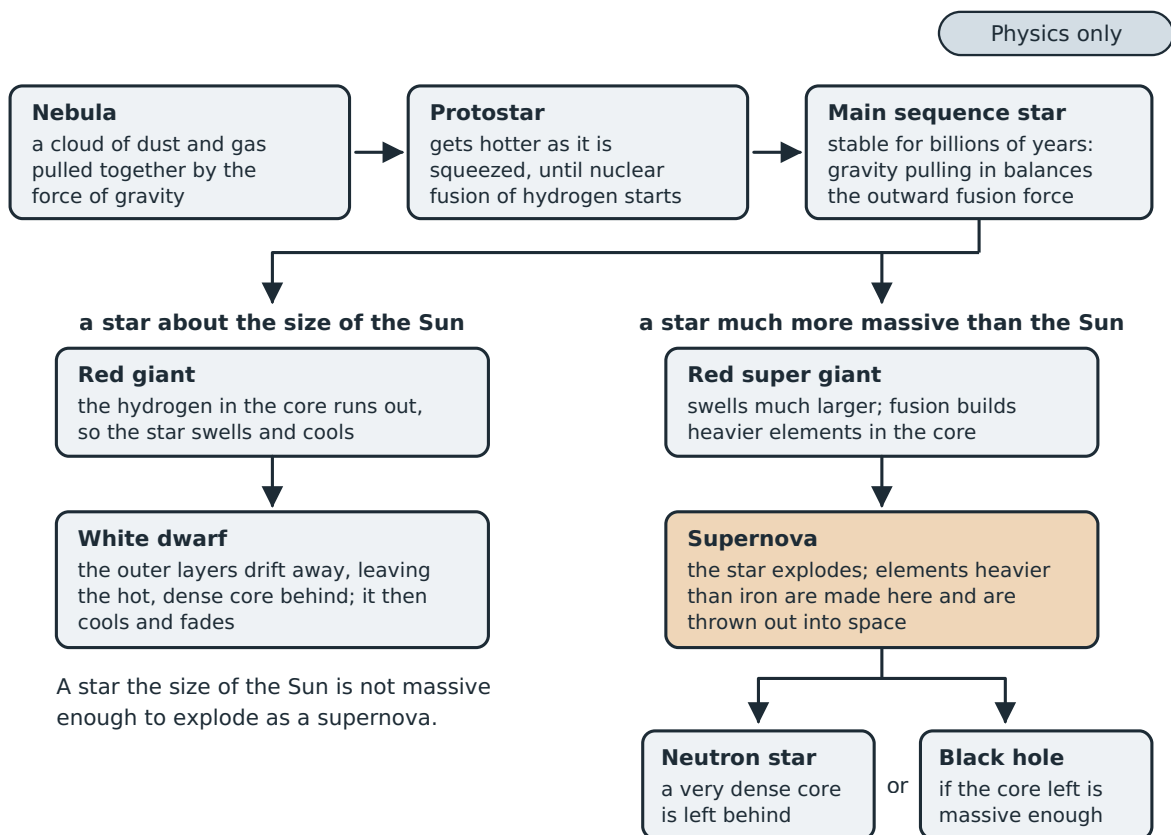
8.1.2 The life cycle of a star **PHYSICS ONLY**

- **PHYSICS ONLY** A star goes through a life cycle. The life cycle is determined by the size (mass) of the star.
- Both paths start the same way: nebula → protostar → main sequence star.

Stage	Star about the size of the Sun	Star much more massive than the Sun
1	Nebula (cloud of dust and gas)	Nebula (cloud of dust and gas)
2	Protostar — gravity compresses it, temperature rises, fusion begins	Protostar
3	Main sequence star — stable, gravity balanced by fusion energy; lasts billions of years	Main sequence star — much hotter and brighter, so it burns through its fuel much faster
4	Red giant — core hydrogen runs out, outer layers swell and cool	Red super giant
5	Outer layers are thrown off and the core collapses to a white dwarf	Supernova — a huge explosion
6	The white dwarf cools and fades (a black dwarf)	Neutron star , or a black hole if the star was massive enough

- **PHYSICS ONLY** Fusion processes in stars produce all of the naturally occurring elements.
- During the main sequence, hydrogen fuses to helium.
- In red giants and red super giants, fusion of heavier nuclei produces elements **up to iron**.
- **Elements heavier than iron are produced in a supernova** — the enormous energies of the explosion are needed to make them.
- **PHYSICS ONLY** The explosion of a massive star (supernova) distributes the elements throughout the universe. These elements can then form part of the nebula from which the next generation of stars and planets forms — the atoms in your body were made inside stars.

The life cycle of a star, for a Sun-sized star and for a much more massive star



Where the elements come from

Fusion processes in stars produce all of the naturally occurring elements. Fusion inside a star builds elements only as far as iron.

Elements heavier than iron are produced in a supernova.

The explosion of a massive star (a supernova) distributes these elements throughout the universe, so the Earth and everything on it is made from the remains of earlier stars.

8.1.3 Orbital motion, natural and artificial satellites

PHYSICS ONLY

- **PHYSICS ONLY** Gravity provides the force that allows planets and satellites (both natural and artificial) to maintain their circular orbits. The gravitational force acts towards the centre of the orbit.
- **PHYSICS ONLY** Similarities and distinctions:

	Planets	Moons (natural satellites)	Artificial satellites
What they orbit	The Sun	A planet	Usually the Earth (or another planet)
Origin	Natural	Natural	Human-made
Held in orbit by	Gravity	Gravity	Gravity
Examples / uses	Earth, Jupiter	The Moon, Io	Communications, weather, GPS, observation

HIGHER TIER

- **PHYSICS ONLY HT ONLY** For a circular orbit, the force of gravity can lead to changing velocity but unchanged speed. Gravity always acts at right angles to the direction of motion, so it changes the **direction** the object travels in but not how fast it goes. Velocity is a vector (speed *and* direction), so a constantly changing direction means a constantly changing velocity — the object is accelerating even though its speed is constant.
- **PHYSICS ONLY HT ONLY** For a stable orbit, the radius must change if the speed changes.
- If the satellite **speeds up**, a **larger** gravitational force is needed to keep it in a circular path, so it can only stay in a stable orbit at a **smaller radius** (closer in, where gravity is stronger).
- If the satellite **slows down**, a smaller gravitational force is needed, so its stable orbit is at a **larger radius** (further out).
- Consequently, satellites in **small orbits travel faster** than those in large orbits — a low Earth orbit satellite laps the planet in about 90 minutes, while the Moon takes about a month.

WATCH OUT

"Satellites are weightless because there is no gravity in space."
Wrong — gravity is exactly what keeps them in orbit. They and everything inside them are in constant **free fall** towards the Earth, but they are moving sideways fast enough that they keep missing it.

8.2 Red-shift PHYSICS ONLY

- **PHYSICS ONLY** There is an observed increase in the wavelength of light from most distant galaxies. This effect is called **red-shift** — the light is shifted towards the red (longer wavelength, lower frequency) end of the spectrum. It is seen as the dark absorption lines in a galaxy's spectrum being shifted towards the red end compared with the same lines measured on Earth.
- **PHYSICS ONLY** The further away the galaxies, the faster they are moving and the bigger the observed increase in wavelength.
- **PHYSICS ONLY** The observed red-shift provides evidence that space itself (the universe) is expanding and **supports the Big Bang theory**.
- **PHYSICS ONLY** The Big Bang theory suggests that the universe began from a very small region that was extremely hot and dense, and has been expanding ever since.
- **PHYSICS ONLY** Since 1998 onwards, observations of supernovae suggest that distant galaxies are receding ever faster — the expansion of the universe is accelerating.
- **PHYSICS ONLY** How scientists use observations to arrive at a theory such as the Big Bang:

measurements of red-shift for many galaxies gave a **pattern** (speed increases with distance); the pattern was explained by a **model** (expanding space); the model **predicted** other observations that were later confirmed. A theory is accepted because evidence supports it, and it can be revised if new evidence appears.

- **PHYSICS ONLY** There is still much about the universe that is not understood, for example dark mass and dark energy. Dark mass bends light and holds galaxies together but does not emit electromagnetic radiation, so it cannot be seen directly; dark energy is the name given to whatever is causing the expansion to accelerate. Neither is yet explained.

ANALOGY

Red-shift is often compared with the **changing pitch of a passing siren**: as an ambulance comes towards you the sound waves are squashed and the pitch is higher; as it goes away the waves are stretched and the pitch drops. Light from a receding galaxy is stretched in the same way, to a longer wavelength.

Where the analogy breaks down: the ambulance is moving *through* the air, whereas distant galaxies are not simply flying through space — **space itself is expanding** and stretching the light while it travels. That is also why almost every distant galaxy is red-shifted, whichever direction you look, whereas a siren only sounds lower once it has passed you.

ANALOGY

A better picture of the expansion: draw dots on a **balloon** and blow it up. Every dot moves away from every other dot, and the dots that started furthest apart separate fastest — which is exactly what the red-shift data show. No dot is at the "centre" of the expansion; the rubber between them is what is stretching.

Galaxy	Measured wavelength of the line	Distance from Earth
A	659 nm	4×10^{22} m
B	672 nm	2×10^{23} m
C	701 nm	6×10^{23} m
D	656 nm	(a nearby galaxy)

WATCH OUT

Red-shifted light is not literally red, and blue light from a receding galaxy does not turn red. Red-shift means **every** wavelength in the spectrum is increased by the same fraction — you spot it by seeing the whole pattern of spectral lines shifted along, not by the colour looking redder.

8.3 Key ideas in physics

Specification reference 4.9. These key ideas run through the whole course, are embedded in every topic, and are assessed across **all papers** — not just this one.

- The **use of models**, as in the particle model of matter or the wave models of light and of sound.
- The concept of **cause and effect** in explaining such links as those between force and acceleration, or between changes in atomic nuclei and radioactive emissions.
- The phenomena of '**action at a distance**' and the related concept of the **field** as the key to analysing electrical, magnetic and gravitational effects.
- That **differences** — for example between pressures, temperatures or electrical potentials — are the **drivers of change**.
- That **proportionality**, for example between weight and mass of an object or between force and extension in a spring, is an important aspect of many models in science.
- That physical laws and models are expressed in mathematical form.