

Edexcel GCSE Physics — Physics

Topic 7

Astronomy

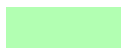
Specification 1PH0 · Pearson Edexcel

Free edition

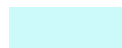
Revision notes for one topic, free to download.

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 Star

- a body large enough for nuclear fusion in its core, emitting its own light.

Define Planet

- a large body orbiting a star that has cleared other objects from its orbital path.

Define Natural satellite (moon)

- a natural body orbiting a planet or dwarf planet.

Define Geocentric model

- the Earth is at the centre and everything orbits it.

Define Gravitational field strength (g)

- the force of gravity on each kilogram of mass, N/kg.

Define Big Bang theory

- the Universe began from a very small, hot, dense point and has expanded ever since.

Define CMB radiation

- low-level microwave radiation from every direction in space, left over from the early Universe.

Define Main sequence star

- the long, stable stage when fusion balances gravitational collapse.

NOTE

The whole of Topic 7 is physics only. Every statement carries a P (7.1P–7.19P), so none of it is in GCSE Combined Science (1SC0), which drops Astronomy and Static electricity. Everything below

PHYSICS ONLY .

is tagged

There are no core practicals in Topic 7. Edexcel's eight physics core practicals are 2.19, 4.17, 5.9, 5.19P, 10.17, 14.3, 14.11 and 15.6 — none is astronomical.

Define Dwarf planet

- roughly spherical, orbits a star, but has *not* cleared its orbit.

Define Comet

- a body of ice and dust in a highly elliptical orbit around the Sun.

Define Heliocentric model

- the Sun is at the centre and the planets orbit it.

Define Red-shift

- the increase in observed wavelength of light from a source moving away from the observer.

Define Steady State theory

- the Universe has always existed and is expanding, with new matter created in the gaps so its density stays constant.

Define Nebula

- a cloud of dust and gas from which stars form.

Define Supernova

- the explosion of a high-mass star at the end of its life.

7.1 Weight and g on different bodies in space (7.1P)

PHYSICS ONLY Gravitational field strength g is not the same everywhere. It depends on the **mass** of the body producing the field and on the distance from its centre (its **radius**).

- On the Earth's surface $g \approx 10 \text{ N/kg}$; on the Moon $g \approx 1.6 \text{ N/kg}$, about one sixth, because the Moon is far less massive.
- **Mass never changes**, but **weight does**, because weight is a force caused by the gravitational field: $W = m \times g$. This is why an astronaut can jump much higher on the Moon — the same muscle force lifts a much smaller weight.
- More massive planets (Jupiter) have a larger surface g ; on asteroids and comets g is almost negligible.

WATCH OUT

"Astronauts float because there is no gravity in space." There *is* gravity — it holds the ISS in orbit. They appear weightless because they and the station are falling around the Earth together.

7.2 What the Solar System contains (7.2P, 7.3P)

PHYSICS ONLY **Recall** that our Solar System consists of the Sun (our star), eight planets and their natural satellites, dwarf planets, asteroids and comets.

The eight planets **in order of distance from the Sun** (7.3P): **Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune**. The first four are small and rocky, the outer four gas giants; the asteroid belt lies between Mars and Jupiter.

Object	What it is	Orbits	Example
Star	Ball of hot gas releasing energy by fusion; emits its own light	Centre of the system	The Sun
Planet	Large body that has cleared its orbit; reflects starlight	A star	Earth, Jupiter
Dwarf planet	Roughly spherical, has <i>not</i> cleared its orbital path	A star	Pluto, Ceres
Natural satellite (moon)	Natural body orbiting a planet	A planet	The Moon, Europa
Asteroid	Small irregular rocky body, mostly in the asteroid belt	The Sun	Vesta
Comet	Ice and dust; grows a tail pointing away from the Sun	The Sun, very elongated orbit	Halley's Comet

Note that planets and moons do not make their own light — we see them because they **reflect** sunlight. Only stars emit their own light.

7.3 How ideas about the Solar System have changed (7.4P)

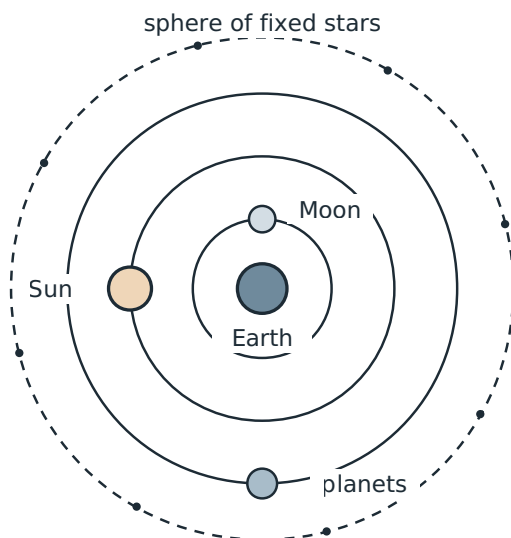
PHYSICS ONLY Marks here are for the *change in the model and the evidence that forced it*, not just for names.

- **Geocentric model** (Ptolemy): the Earth is stationary at the centre; the Sun, Moon, planets and stars move around it in circles. It explained day and night, but needed complicated extra circles ("epicycles") to explain why planets sometimes appear to move backwards against the stars.
- **Heliocentric model** (Copernicus, 16th century): the Sun is at the centre and the Earth is one of the planets orbiting it, with the Moon orbiting the Earth. Retrograde motion is then explained by the Earth overtaking an outer planet.
- **New evidence changed minds.** With better telescopes Galileo saw four moons orbiting Jupiter — proof that not everything orbits the Earth — and the full phases of Venus, which the geocentric model could not explain.
- Later work showed the orbits are **ellipses**, and that the Sun is one ordinary star in one of billions of galaxies.

The geocentric and heliocentric models of the Solar System

Geocentric model (Ptolemy)

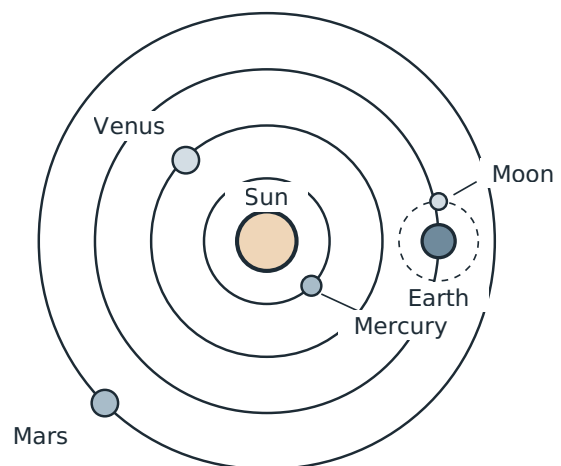
The Earth is fixed at the centre



The Moon, the Sun, the planets and the stars all move in circles around a fixed Earth. Accepted for about 1400 years.

Heliocentric model (Copernicus)

The Sun is at the centre



The Earth and the other planets orbit the Sun. Only the Moon orbits the Earth. The stars are very distant. This is the model accepted today.

The evidence that changed the accepted model: Galileo's telescope observations

Four moons orbiting Jupiter



These moons orbit Jupiter, not the Earth, so the Earth is not the centre of everything.

A full set of phases of Venus



crescent



half



gibbous



full

Venus shows every phase, and changes size, so it must orbit the Sun and not the Earth.

The examinable point: a model is accepted while it explains the observations, and is replaced when better instruments produce evidence it cannot explain — the same argument as 7.10P and 7.15P.

7.4 Orbits of moons, planets, comets and artificial satellites (7.5P)

PHYSICS ONLY All orbits are caused by the **gravitational force of attraction** between the two bodies, which always acts towards the centre of the body being orbited.

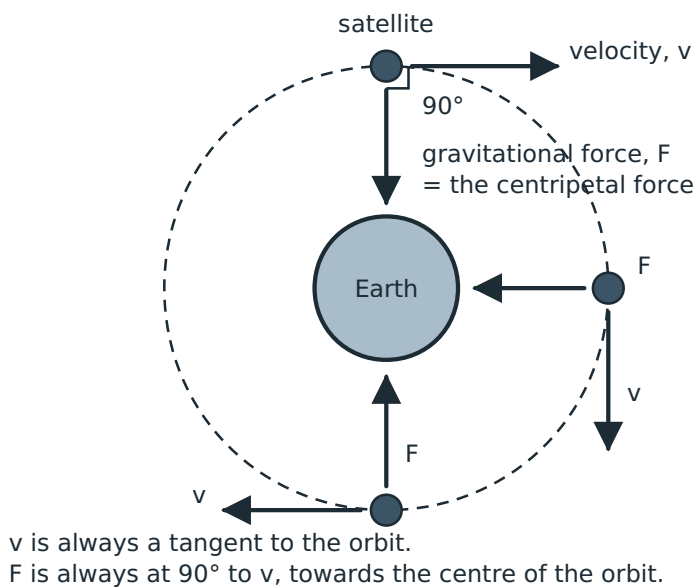
- **Planets** orbit the Sun in slightly elliptical (almost circular) orbits; the further out, the slower the planet and the longer the orbit takes.
- **Moons (natural satellites)** orbit planets in roughly circular orbits.
- **Comets** orbit the Sun in **highly elliptical** orbits, so a comet's distance from the Sun changes enormously and its **speed changes**: fastest when closest to the Sun (gravitational force largest), slowest when far away.
- **Artificial satellites** orbit the Earth. Low-orbit satellites (imaging, ISS) move fast, orbiting in about 90 minutes; geostationary satellites (communications) sit far out over the equator with a period of 24 hours, so they appear fixed in the sky.

7.5 Circular orbits: velocity changes but speed does not (7.6P)

PHYSICS ONLY Learn this as a sentence, because the wording matters. Gravity acts **towards the centre** of the orbit, i.e. at **right angles to the direction of motion**. A force at right angles cannot speed the body up or slow it down; it only changes the **direction** of motion. **Velocity is a vector** (size *and* direction), so continually changing direction means the velocity is continually changing — the body is accelerating. **Speed is a scalar** (size only), so in a circular orbit the speed stays constant.

A circular orbit: constant speed but continually changing velocity

A satellite in a circular orbit



Speed — constant

The force is at right angles to the velocity, so it cannot speed the satellite up or slow it down.

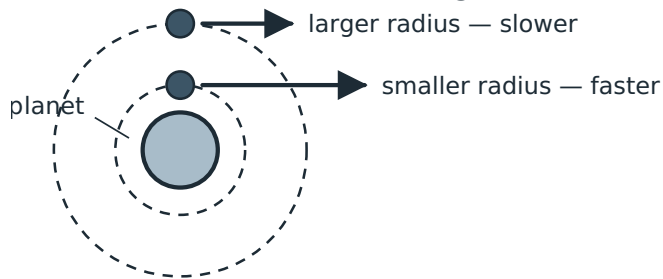
Velocity — changing

The force does change the direction of motion. Velocity is a vector, so a change of direction is a change of velocity.

Acceleration

A changing velocity means the satellite is accelerating all the time, even though its speed never changes. The acceleration acts towards the centre of the orbit.

A stable orbit: the radius must change if the orbital speed changes



At any one radius there is only one orbital speed that gives a stable orbit.

If the satellite speeds up, it must move in to a smaller orbital radius.

If it slows down, it must move out to a larger orbital radius.

Change the speed, change the radius.

ANALOGY

Whirling a ball on a string. Swing a ball round your head at a steady rate. The string pulls the ball inwards, always at right angles to its motion, and that inward pull stops it flying off in a straight line: the speed stays the same but the direction changes every instant. Gravity is the "string" for a planet.
Where it breaks down: a string only pulls when taut and can snap, whereas gravity acts continuously at a distance and weakens with distance.

7.6 Orbital speed and orbital radius (7.7P)

PHYSICS ONLY Statement 7.7P is **qualitative only** — explain the relationship, do not derive it.

For a **stable orbit** at a given radius there is only **one** speed that works, because the gravitational force at that radius must exactly match what is needed to keep the body turning in that circle.

- If the orbital **speed increases**, the radius must **decrease** (a lower, tighter orbit); if the **speed decreases**, the radius must **increase** (a higher, wider orbit).
- So objects in **smaller orbits move faster**: Mercury far faster than Neptune, a low-orbit satellite far faster than a geostationary one. A satellite losing speed to drag drops to a smaller radius and spirals in.

NOTE

WHAT EDEXCEL DOES NOT GIVE YOU

There is **no orbital-speed equation** in Appendix 2. A calculation question gives you the orbital radius and the time for one orbit; use the ordinary speed relationship (2.6b) with the circumference $2 \times \pi \times r$ as the distance.

7.7 A moving source changes the observed frequency and wavelength (7.11P)

PHYSICS ONLY If a wave source is **moving relative to an observer**, the observed frequency and wavelength are different from those emitted:

- Source moving **towards** you: waves bunched up — observed **wavelength decreases, frequency increases**.
- Source moving **away**: waves stretched out — observed **wavelength increases, frequency decreases**.
- The faster the source, the bigger the change. The wave speed itself does not change.

ANALOGY

The passing siren. An ambulance coming towards you sounds high-pitched; the instant it passes, the pitch drops. Approaching, the sound waves are squashed into a shorter wavelength (higher frequency); receding, they are stretched to a longer wavelength (lower frequency). Light from a receding galaxy is stretched the same way, towards the red end of the spectrum.

Where it breaks down: the siren changes pitch because the ambulance moves **through** the air, whereas cosmological red-shift is not galaxies rushing through space but **space itself expanding** and stretching the light on its journey. Also, the siren's pitch rises then falls as it passes, while distant galaxies are all receding, so we only see the "moving away" half. Use the siren for the effect, not the cause.

7.8 Red-shift of galaxies (7.12P, 7.13P)

PHYSICS ONLY Light from a distant galaxy shows dark **absorption lines** at wavelengths characteristic of elements such as hydrogen. Compared with the same lines measured in a laboratory on Earth:

- The galaxy's lines are shifted towards **longer wavelengths**, towards the red end of the spectrum. This is **red-shift**, and it means the galaxy is **moving away** from us.
- **The more distant the galaxy, the greater its red-shift** (7.12P), so the faster it is moving away.

Why this is evidence for an expanding Universe (7.13P):

- Almost every galaxy is red-shifted, so almost every galaxy is receding from us.
- Recession speed increases with distance, so galaxies are moving apart everywhere, not just away from the Earth. We are **not** at a special centre — this is what you would see from any point in a uniformly expanding Universe, like dots on an inflating balloon.

Red-shift in the light from distant galaxies

Red-shift in the light received from galaxies

Each dark line is an absorption line. The pattern of lines is the same — the whole pattern is moved along.

Light source in the laboratory on Earth



→ shifted a little towards the red end

A nearby galaxy — small red-shift



→ shifted much further towards the red end

A distant galaxy — large red-shift



blue end — shorter wavelength wavelength red end — longer wavelength

The more distant the galaxy, the greater its red-shift. Galaxies are moving away from us, and the most distant ones are moving away fastest — evidence that the whole Universe is expanding.

Big Bang theory

All the matter and energy in the Universe began in a very small, very hot, very dense region and has been expanding ever since.

The Universe had a beginning, so it has a finite age, and it has been cooling as it expands.

The amount of matter stays the same while the Universe gets bigger.

Steady State theory

The Universe has always existed and has always looked much the same. It had no beginning.

It is expanding, but new matter is created in the gaps as it expands, so its density stays constant.

This theory explains red-shift too, so red-shift alone cannot separate the two.

The evidence

1 Red-shift of galaxies

Light from galaxies is red-shifted, and more distant galaxies show a greater red-shift, so the Universe is expanding. Both the Big Bang and the Steady State theory account for this.

2 Cosmic microwave background (CMB)

Microwave radiation arriving from every direction in space. It is radiation left over from the hot early Universe, stretched to microwaves. Only the Big Bang predicts it.

There is more evidence supporting the Big Bang theory than the Steady State theory, so the Big Bang is the currently accepted model for the origin of the Universe.

7.9 Big Bang and Steady State theories (7.8P, 7.14P)

PHYSICS ONLY Both theories explain the origin of the Universe, and **both** accept that it is expanding, so **both account for red-shift** (7.14P).

	Big Bang theory	Steady State theory
Origin	Began at a single, extremely hot, dense point about 13.8 billion years ago	Has always existed — no beginning
Expansion	Yes, from the initial explosion	Yes
Explains red-shift?	Yes — galaxies move apart as the Universe expands	Yes — galaxies move apart as the Universe expands
Density over time	Decreases as it expands	Constant — new matter is continuously created in the gaps
Age of the Universe	Finite	Infinite

Because both predict red-shift, **red-shift alone cannot decide between them**. That is a very common exam question, and the CMB is the answer.

7.10 Evidence for the Big Bang and the CMB (7.9P, 7.10P, 7.15P)

PHYSICS ONLY Statement 7.9P limits the evidence to two things: **red-shift** and the **cosmic microwave background (CMB) radiation**.

- The CMB is low-intensity microwave radiation detected from **every direction in space**, almost exactly the same in all directions.
- The Big Bang **predicted** it: the very hot early Universe was filled with high-energy, short-wavelength radiation, which has been stretched to microwave wavelengths as the Universe expanded and cooled.
- The **Steady State theory cannot explain it** — a Universe that has always looked the same has no hot dense early stage to produce it.

Why the Big Bang is accepted (7.10P, 7.15P): the discovery of the CMB gave it evidence the Steady State theory could not account for, while both explained red-shift equally well. Since there is **more evidence supporting the Big Bang**, it is the **currently accepted model**. Note "currently accepted" — new unexplained evidence would force another change, exactly as in 7.4P.

7.11 The life cycle of stars (7.16P, 7.17P, 7.18P)

PHYSICS ONLY The balance that controls a star's life (7.17P). In a stable star two effects are in equilibrium:

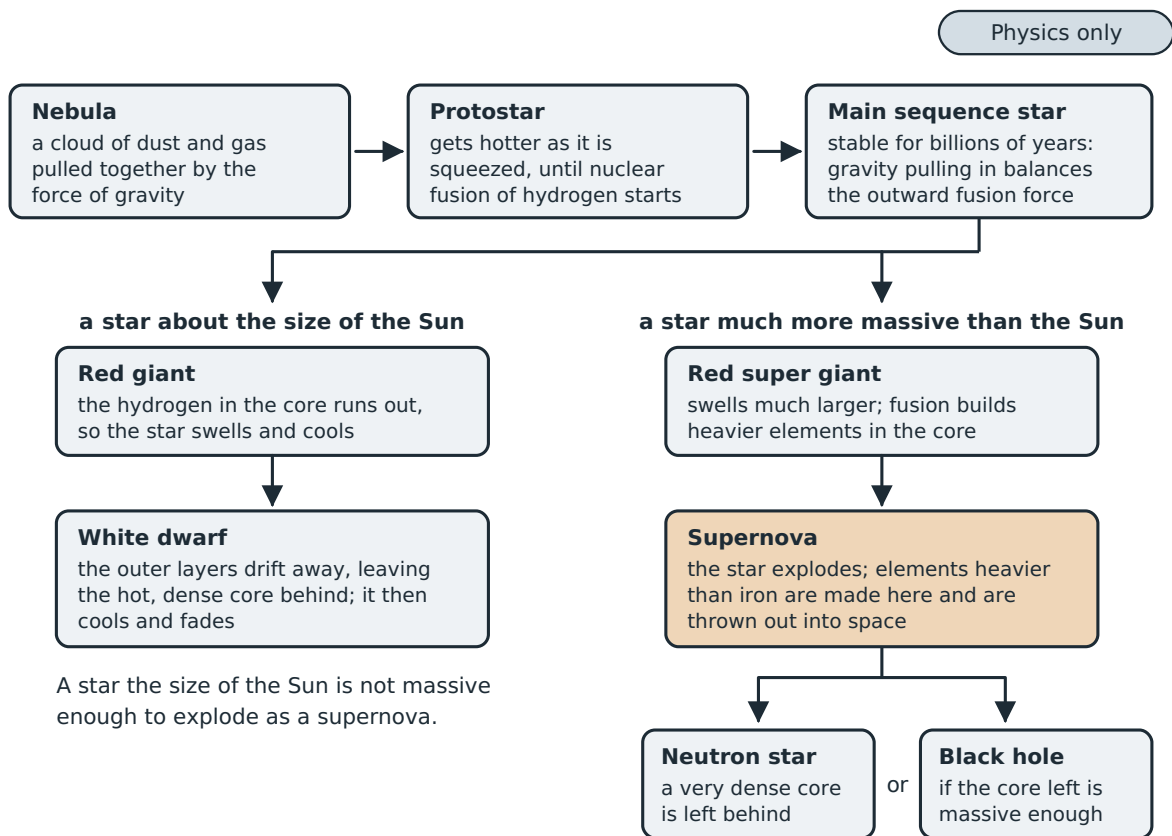
gravity pulling the matter inwards, and **thermal expansion** — the outward pressure from the enormous temperature produced by fusion in the core. While they are balanced the star's size is constant and it is a **main sequence** star. Every later change happens when this balance is upset, usually because core fuel runs out, so fusion slows, outward pressure falls and gravity wins.

Stars of similar mass to the Sun (7.16P) — learn the four named stages in order: **a nebula** → **b main sequence star** → **c red giant** → **d white dwarf**. **Stars more massive than the Sun (7.18P)** follow a different route after the main sequence.

Stage	Star of similar mass to the Sun (7.16P)	Star of larger mass (7.18P)
1	Nebula — cloud of dust and gas pulled together by gravity, heating as it contracts	Nebula — same start
2	Protostar ; when hot enough, hydrogen fusion begins	Protostar , larger and hotter
3	Main sequence star — stable for billions of years	Main sequence star — brighter, burns fuel far faster, much shorter life
4	Red giant — core hydrogen runs out, core contracts, outer layers swell and cool	Red supergiant — same cause, much larger
5	Outer layers drift away, leaving the hot dense core	Supernova — huge explosion throwing the outer layers into space
6	White dwarf — very hot and dense, no fusion; slowly cools and fades	Remnant becomes a neutron star , or a black hole if massive enough

Points examiners look for: the **more massive** the star, the **shorter** its main sequence lifetime; a supernova scatters heavier elements into space, so later nebulae and planets are built from that material; a black hole forms only from the most massive stars, its gravity so strong that not even light escapes.

The life cycle of stars



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.

NOTE

YOU ARE NOT REQUIRED TO DRAW AN H-R DIAGRAM

The 1PH0 specification does **not** require the Hertzsprung–Russell diagram. Statements 7.16P–7.18P ask only for the **named stages in order** for a Sun-like star (nebula, main sequence, red giant, white dwarf) and for a more massive star (red supergiant, supernova, neutron star or black hole), plus the gravity-versus-thermal-expansion explanation in 7.17P. Treat any temperature–luminosity plot as unfamiliar data to interpret, not as recall.

7.12 How methods of observing the Universe have changed (7.19P)

PHYSICS ONLY How methods have developed:

- **Naked eye** — a few thousand stars and the movements of the planets.
- **Optical telescopes** (from the 17th century) — collect much more light, so fainter, more distant objects become visible; better lenses and mirrors revealed Jupiter's moons and, later, other galaxies.
- **Photography and digital detectors (CCDs)** — long exposures record far more detail than the eye can.
- **Other parts of the electromagnetic spectrum** — radio, infrared, ultraviolet, X-ray and gamma telescopes reveal objects emitting little visible light; the CMB was found by microwave detection.
- **Space telescopes** — placed in orbit, outside the Earth's atmosphere.

Why some telescopes are outside the Earth's atmosphere:

- The atmosphere **absorbs** much of the electromagnetic spectrum — most ultraviolet, X-rays, gamma rays and much infrared never reach the ground, so those wavelengths can only be observed from space.
- The atmosphere **refracts and distorts** light, because moving layers of air of different temperature and density blur images (why stars twinkle). Above it, images are sharper.
- Space telescopes also avoid light pollution and cloud; the drawbacks are cost and difficulty of repair.

NOTE

USE OF MATHEMATICS IN THIS TOPIC

The maths skills flagged against Topic 7 are **5b** (visualise and represent 2D and 3D forms — orbit diagrams, the layout of the Solar System) and **2g** (use a scatter diagram to identify a correlation — recession speed against distance).