

Space physics

IGCSE Physics 0625 · Unit 6 revision notes

Days, seasons and phases, the Solar System and orbits, the Sun and the life of stars, and the redshift evidence for an expanding Universe.

24 definitions to learn word for word, 8 equations in their own column, 12 diagrams and graphs. Read it, cover it, test yourself.

1. 6.1a The Earth, the Sun and the Moon
2. 6.1b The Solar System
3. 6.1c Gravity and orbits
4. 6.2a The Sun as a star
5. 6.2b Stars and galaxies
6. 6.2c The Universe

Definitions (mark-scheme wording) Equations Exam traps **Extended** = Extended tier only

6.1a The Earth, the Sun and the Moon

Definitions

Day: the time for the Earth to rotate once on its axis (about 24 hours).

Year: the time for the Earth to orbit the Sun once (about 365 days).

Month: the approximate time for the Moon to orbit the Earth once (about one month, 27 to 30 days).

Average orbital speed: **Extended** the distance travelled round the orbit divided by the orbital period, $v = 2\pi r / T$.

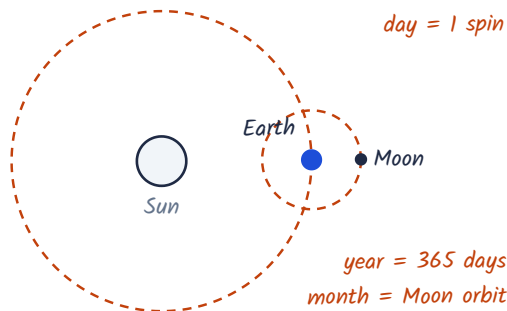
Equations

$$v = 2\pi r / T$$

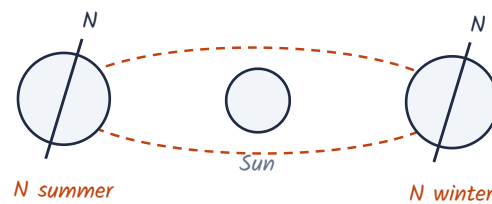
Extended average orbital speed = orbit circumference / period
m/s

Key points

- ✓ The Earth **spins** on a tilted axis: this gives **day and night** and the Sun's apparent daily motion (rises in the east, sets in the west).
- ✓ The Earth **orbits** the Sun in about 365 days.
- ✓ The axis is **tilted** (about 23°) and always points the same way, so each hemisphere leans towards the Sun for part of the year: **seasons**.
- ✓ Leaning towards the Sun: longer days and more concentrated sunlight, so **summer**.
- ✓ The Moon shines by **reflected sunlight**; half of it is always lit.
- ✓ **Phases** of the Moon: as it orbits, we see different amounts of its lit half (new, crescent, quarter, gibbous, full).

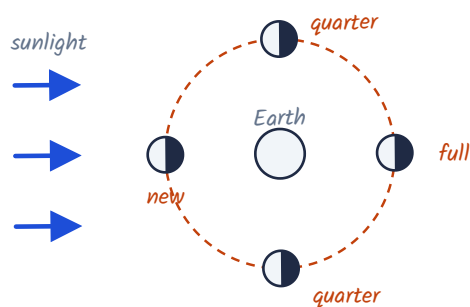


Earth orbits the Sun once a year; the Moon orbits the Earth about once a month; the Earth spins once a day.



axis always tilted the same way

Seasons: the axis keeps the same tilt, so the northern hemisphere leans towards the Sun in one half of the orbit (summer) and away in the other (winter).



Phases: half the Moon is always lit by the Sun; from Earth we see all of the lit half (full), none (new) or part (quarter).

Watch out!

- ! Seasons are caused by the **tilt** of the axis, not by the Earth being closer to the Sun in summer.
- ! Phases are **not** caused by the Earth's shadow; that is a lunar eclipse.

6.1b The Solar System

Definitions

Planet: a large body that orbits the Sun.

Moon (natural satellite): a natural body that orbits a planet.

Minor planets: smaller bodies orbiting the Sun, including dwarf planets (e.g. Pluto) and asteroids.

Comet: a small body of ice and dust in a highly elliptical orbit around the Sun.

Accretion model: the Solar System formed from a rotating interstellar cloud of gas and dust, containing many elements, that collapsed under gravity into an accretion disc; material clumped together to form the Sun and planets.

Equations

$$t = d / c$$

light travel time = distance / speed of light

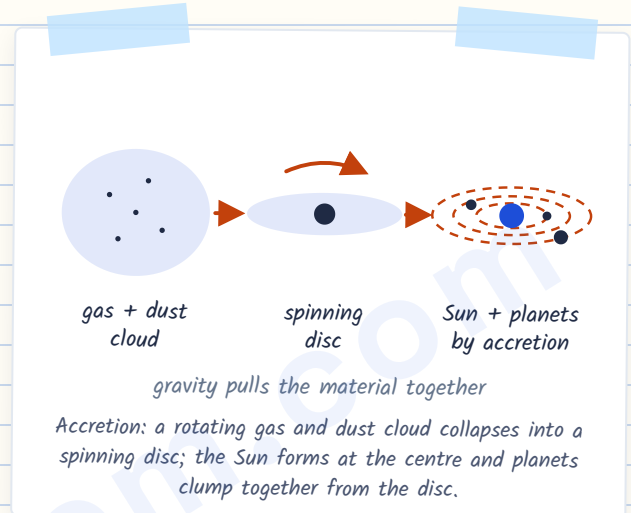
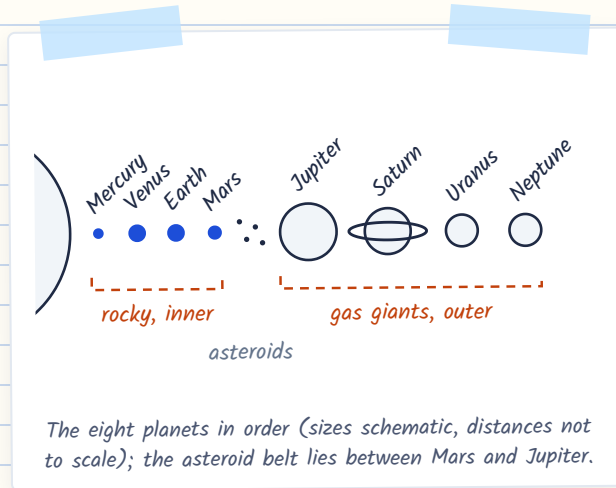
$$c = 3.0 \times 10^8 \text{ m/s}$$

speed of light in space

Key points

- ✓ Order from the Sun: **Mercury, Venus, Earth, Mars** (asteroid belt) **Jupiter, Saturn, Uranus, Neptune.**

- ✓ Inner four: small, **rocky**. Outer four: large, **gaseous** (gas giants).
- ✓ In the collapsing disc, only rocky material survived near the hot young Sun; light gases gathered further out.
- ✓ The Sun contains **most of the mass** of the Solar System, so everything orbits the Sun.
- ✓ Light takes about **8 minutes** to reach the Earth from the Sun.
- ✓ The gravitational field strength at a planet's surface depends on the planet's **mass**; around a planet it **decreases with distance**.
- ✓ **Extended** analyse planetary data (orbital distance and period, density, surface temperature, surface g): e.g. planets further from the Sun are colder and have longer orbital periods.



Watch out!

- ! The asteroid belt is between **Mars and Jupiter**.
- ! Distances in space are huge: convert km to m before using $t = d / c$.

6.1c Gravity and orbits

Definitions

Orbit: the curved path of a body around a more massive body, held by gravitational attraction.

Orbital period (T): the time taken for one complete orbit.

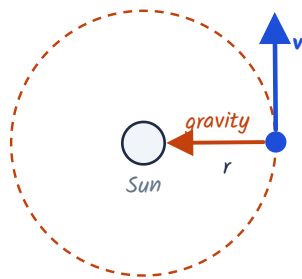
Equations

$$v = 2\pi r / T$$

Extended orbital speed = circumference / period
m/s

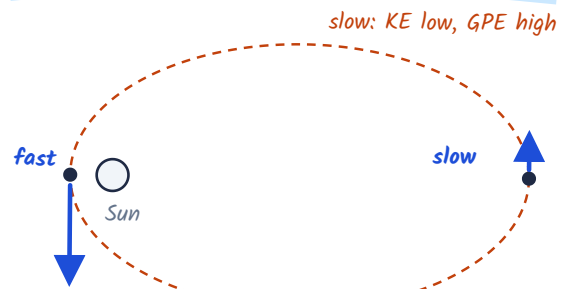
Key points

- ✓ The **gravitational attraction** of the Sun keeps planets and comets in orbit; a planet's gravity keeps its moons and satellites in orbit.
- ✓ **Extended** the Sun's gravitational field gets **weaker with distance**, so outer planets orbit more **slowly** and have **longer periods**.
- ✓ **Extended** planets, minor planets and comets have **elliptical** orbits; the Sun is **not at the centre** unless the orbit is nearly circular (as most planetary orbits are).
- ✓ **Extended** a comet speeds up near the Sun ($GPE \rightarrow KE$) and slows far away ($KE \rightarrow GPE$).
- ✓ **Extended** its total energy stays **constant** (conservation of energy).



$$v = 2\pi r / T$$

Extended: gravity acts towards the Sun; the velocity is along the tangent. One orbit is $2\pi r$ in time T .



fast: KE high, GPE low

Extended: a comet on an elliptical orbit is fastest nearest the Sun and slowest furthest away; total energy is constant.

Watch out!

- ! Extended: in an elliptical orbit the speed is **greatest nearest the Sun**, not constant.
- ! Extended: use r in metres and T in seconds to get v in m/s ($1 \text{ year} = 3.2 \times 10^7 \text{ s}$).

6.2a The Sun as a star

Definitions

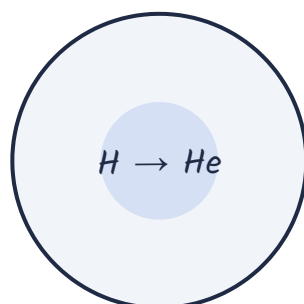
Star: a large ball of hot gas that radiates energy.

The Sun: a medium-sized star, consisting mostly of hydrogen and helium.

Key points

- ✓ The Sun radiates most of its energy as **infrared**, **visible light** and **ultraviolet**.
- ✓ It is the nearest star to Earth and the source of almost all our energy resources.
- ✓ **Extended** stars like the Sun are powered by **nuclear fusion of hydrogen into helium** in the core.
- ✓ **Extended** the Sun is **stable** because the outward pressure from fusion balances the inward pull of gravity.

fusion in the core



mostly H and He

The Sun: a medium-sized star of hydrogen and helium, radiating mainly infrared, visible and ultraviolet.

Watch out!

- ! The Sun is a **medium-sized** star, not a large one.
- ! Extended: fusion joins hydrogen into helium; it is **not** burning (no chemical reaction, no oxygen).

6.2b Stars and galaxies

Definitions

Galaxy: a collection of many billions of stars held together by gravity.

Milky Way: the galaxy that contains the Sun.

Light-year: the distance travelled in (the vacuum of) space by light in one year.

Protostar: Extended a hot, dense ball of gas forming from a collapsing interstellar cloud (nebula).

Stable (main-sequence) star: Extended a stable star fusing hydrogen into helium, with outward pressure balancing gravity.

Supernova: Extended the explosion of a red supergiant, forming a nebula containing heavy elements.

Equations

$$1 \text{ light-year} = 9.5 \times 10^{15} \text{ m}$$

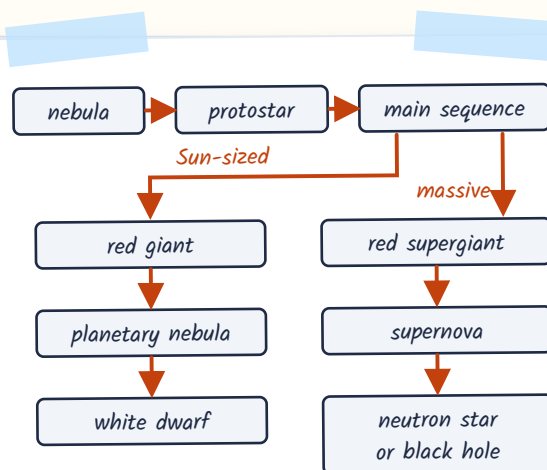
Extended distance light travels in one year
m

$$d = c \times t$$

distance = speed of light $\times$ time
m

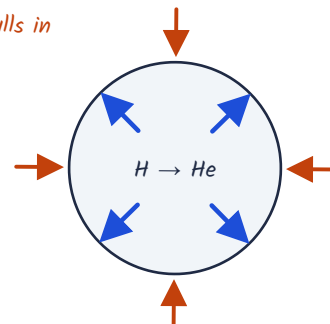
Key points

- ✓ The Sun is one of many billions of stars in the **Milky Way**; other stars in it are much further from the Earth than the Sun is.
- ✓ Distances between stars and galaxies are measured in **light-years**.
- ✓ Extended stars form from interstellar clouds of gas and dust (**nebulae**) collapsing under gravity to form a **protostar**.
- ✓ Extended when hydrogen runs out, a star **expands**: a red giant (low mass) or red supergiant (high mass).
- ✓ Extended a red giant loses its outer layers as a **planetary nebula**, leaving a **white dwarf**.
- ✓ Extended a red supergiant explodes as a **supernova**, leaving a **neutron star** or, if very massive, a **black hole**.
- ✓ Extended supernova nebulae contain heavy elements, which may form new stars and planets.



Extended: life cycle of a star. The path after the main sequence depends on the star's mass.

gravity pulls in



fusion pressure pushes out

Extended: a main-sequence star is stable because inward gravity is balanced by outward pressure from fusion.

Watch out!

- ! A light-year is a **distance**, not a time.
- ! Extended: a white dwarf comes from a **Sun-sized** star; neutron stars and black holes come from **massive** stars.

6.2c The Universe

Definitions

Universe: all of space and everything in it, including many billions of galaxies.

Redshift: the increase in the observed wavelength of electromagnetic radiation emitted from receding stars and galaxies.

Big Bang theory: the Universe began from a single point about 13.8 billion years ago and has been expanding ever since.

Cosmic microwave background radiation (CMBR): Extended microwave radiation of a specific frequency observed from all directions, produced shortly after the Big Bang and stretched by expansion.

Hubble constant (H_0): Extended the ratio of the speed at which a galaxy is moving away from the Earth to its distance from the Earth.

Equations

$$H_0 = v / d$$

Extended Hubble constant = recession speed / distance per s

$$t = d / v = 1 / H_0$$

Extended age of the Universe (about 13.8 billion years) s

Key points

- ✓ The Milky Way is one of **many billions of galaxies**; its diameter is about **100 000 light-years**.
- ✓ Light from distant galaxies is **redshifted** compared with the same light emitted on Earth.
- ✓ Redshift shows galaxies are **moving away**; the Universe is **expanding**, supporting the Big Bang theory.
- ✓ Extended more distant galaxies show **greater redshift**: they recede faster.
- ✓ Extended the CMBR is further evidence for the Big Bang.
- ✓ Extended recession speed v comes from the redshift; distance d from the brightness of a **supernova** in that galaxy.
- ✓ Extended $H_0 = 2.2 \times 10^{-18}$ per second; $d / v = 1 / H_0$ estimates the **age of the Universe**.

spectrum in the lab



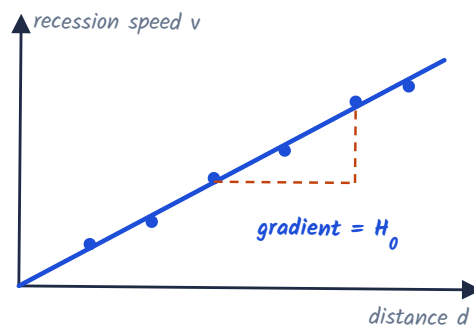
light from a distant galaxy

blue end

red end

longer wavelength: galaxy receding

Redshift: the galaxy's spectral lines keep their pattern but all move towards the red (longer wavelength) end.



Extended: recession speed is proportional to distance; the gradient of the line is the Hubble constant.

Watch out!

- ! Redshift means the wavelength gets **longer** (towards red), not that the galaxy turns red.
- ! Extended: $1/H_0$ gives the age in **seconds**; convert to years if asked.

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