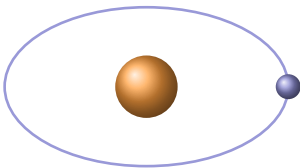


Space Physics

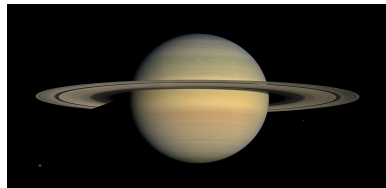
IGCSE Physics ■ Topic 6

IGCSE Physics



What we will cover

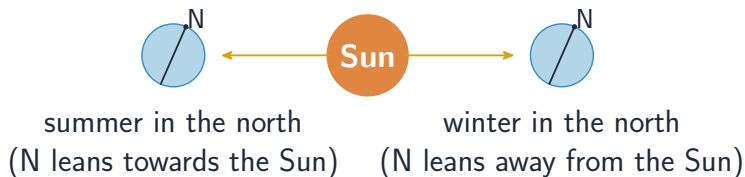
- 1 Earth Sun & Moon
- 2 The Solar System
- 3 The Sun & the stars
- 4 Life cycle of a star
- 5 The expanding Universe
- 6 Recap



1

Earth, Sun and Moon

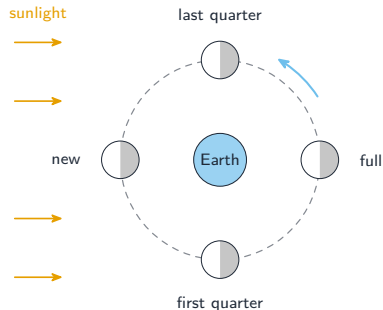
Earth, Sun and Moon



tilt → *seasons* 季节

Day (spin) < month (Moon's orbit) < year (Earth's orbit).

Explain the Moon's phases



The half facing the Sun is lit. During the Moon's orbit, we see different amounts of that lit half: this produces the phases, not Earth's shadow.

Orbital speed

For one orbit, distance = $2\pi r$.

$$v = \frac{2\pi r}{T}.$$

Works for planets, moons and satellites.

Station: $r = 7000 \text{ km}$, $T = 5800 \text{ s}$

$$v = \frac{2\pi(7.0 \times 10^6)}{5800} \approx 7600 \text{ m/s}$$

Orbital speed, and why a comet speeds up

The distance

One full orbit covers the **circumference** 周长 $2\pi r$, where r is the orbital radius.

The speed

Orbital speed is that distance divided by the **period** 周期 T :
 $v = 2\pi r / T$.

Why it changes

By **conservation of energy** 能量守恒: as an object comes closer its gravitational potential energy falls, so its kinetic energy – and its speed – rises.

The field

The **gravitational field strength** 引力场强度 $g = F/m$ says how strong gravity is at that place, and it falls off with distance.

The Sun's gravity changes a comet's velocity. As it approaches the Sun, gravitational potential energy falls and kinetic energy rises; it speeds up.

2

The Solar System

Try it: what orbits what?

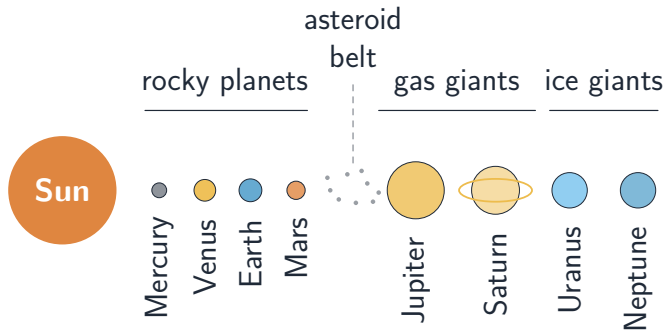
Sort these objects: the Sun, Mars, Jupiter, Pluto, the Moon, an asteroid and a **comet** 彗星.

Which is a star? Which are among the eight planets? Which orbit a planet rather than the Sun directly?

Write the eight planets in order from the Sun. Mark the boundary between the four inner **rocky** 岩石 planets and the four large outer planets.

Explain why counting the Moon and Pluto as two of the eight planets would be wrong.

The eight planets in order



The asteroid belt lies between Mars and Jupiter. The diagram shows order and groups, not true sizes or distances.

Use the orbit and the type of object

The Sun is the star. Mars and Jupiter are planets; Pluto is a dwarf planet.

Asteroids 小行星 and comets also orbit the Sun. The Moon is a natural satellite of Earth.

The four inner planets are small and rocky. The outer four are large and **gaseous** 气态 in the syllabus comparison: Jupiter and Saturn are **gas giants** 气态巨行星; Uranus and Neptune are **ice giants** 冰巨行星.

The Sun holds most of the Solar System's mass; its **gravity** 引力 keeps the planets in orbit. A moon orbits a planet, while that planet orbits the Sun.

Try it: test a pattern against the data

Selected rounded values from the handout:

Planet	Distance / million km	Density / g/cm ³	Temperature / °C
Mercury	58	5.4	170
Venus	108	5.2	460
Jupiter	779	1.3	−110
Saturn	1430	0.7	−140

Which pair supports the inner/outer density comparison? Quote both values.

A student says: “Every planet farther from the Sun is colder.” Find a counterexample.
Does distance alone explain temperature?

Give evidence, then qualify the conclusion

Mercury's density is 5.4 g/cm^3 ; Jupiter's is 1.3 g/cm^3 . This supports the comparison between a dense rocky inner planet and a less dense outer giant.

Venus is farther from the Sun than Mercury (108 versus 58 million km), yet its listed temperature is higher (460°C versus 170°C). It disproves the word "every".

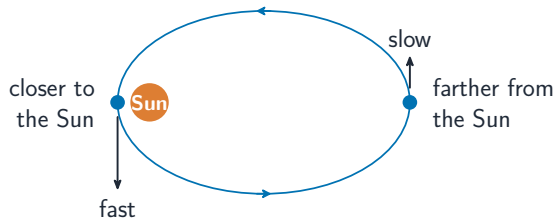
Venus has a thick atmosphere that traps heat. Temperature depends on the atmosphere as well as distance. The listed outer planets are colder, but this is not a universal rule for every pair.

Describe the pattern supported by the table. Test a universal claim against every relevant row, and report exceptions.

Orbits and gravity

Gravity is the centripetal force for an orbit.

- smaller orbital distance $\Rightarrow$ stronger solar field $\Rightarrow$ **higher** orbital speed
- most orbits are **ellipses** 椭圆, the Sun at one focus



A comet speeds up when closer to the Sun: E_p falls, E_k rises; it slows as it moves away.

Light travel time

Distances in space are huge, so we often work out how long light takes to cross them.

$$t = \frac{d}{c}$$

speed of light 光速: $c = 3.0 \times 10^8 \text{ m/s}$

Sun to Earth: $d = 1.5 \times 10^{11} \text{ m}$

$$t = \frac{d}{c} = \frac{1.5 \times 10^{11} \text{ m}}{3.0 \times 10^8 \text{ m/s}} = \mathbf{500 \text{ s}} \approx 8.3 \text{ minutes}$$

We see the Sun as it was about 8 minutes ago.

How the Solar System formed

The **accretion** 吸积 model: gravity pulled a spinning cloud of gas and **dust** 尘埃 into a disc.

- most matter formed the Sun
- planets grew from the leftover disc
- hot inner → rocky; cold outer → gaseous



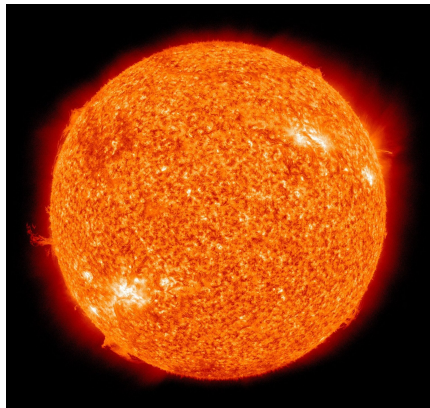
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Stars

The Sun and the stars

Stars fuse hydrogen to helium in the core. The Sun is a **main-sequence** 主序 star.

Visible colour indicates temperature:
blue-white stars are hotter than red stars.

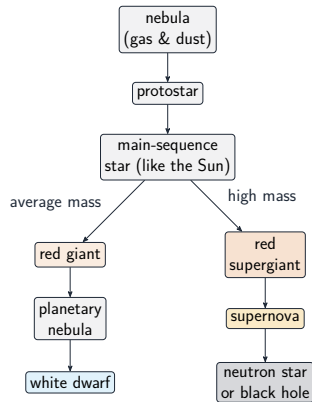


False-colour ultraviolet image of the Sun

The life cycle of a star

- nebula → protostar → main sequence
- Sun-like: red giant → planetary nebula → **white dwarf** 白矮星
- massive: red supergiant → **supernova** 超新星 → neutron star or black hole

The star's **mass** decides how it dies.

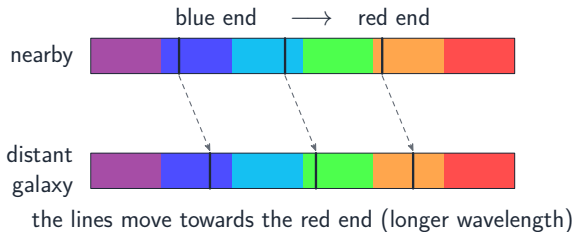


*Every star begins in a nebula; how it ends
depends on its mass*

4

The expanding Universe

The expanding Universe



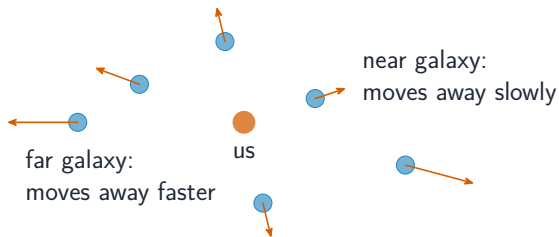
redshift 红移: lines shift red

Distant galaxies show redshift – space itself is stretching.

Redshift $\Rightarrow$ the Universe is expanding $\Rightarrow$ it began in a hot dense state (the Big Bang).

Hubble and the age of the Universe

the Universe is expanding



$$H_0 = \frac{v}{d}, \quad \text{age} \approx \frac{1}{H_0}.$$

$$H_0 = 2.2 \times 10^{-18} \text{ s}^{-1}$$

$$\frac{1}{H_0} \approx 4.5 \times 10^{17} \text{ s} \approx 14 \text{ billion yr}$$

Every galaxy is moving away from us, and the farther ones move away faster – the Universe is expanding

Redshift, Hubble and the CMBR

Receding

When a galaxy is **receding** 退行, the light we receive has a longer wavelength than normal – shifted towards the red end.

Hubble's law

The further away a galaxy is, the faster it recedes. The **Hubble constant** 哈勃常数 H_0 links the two: $v = H_0 d$.

The age

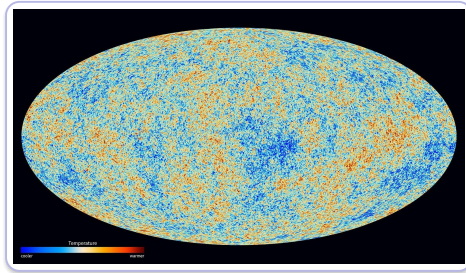
$1/H_0$ estimates the age of the Universe – how long ago everything was in the same place.

The CMBR

The **cosmic microwave background radiation** 宇宙微波背景辐射: faint microwaves from every direction, the cooled afterglow of the hot early Universe.

Two independent pieces of evidence pointing the same way – redshift and the CMBR – is what makes the Big Bang model hard to argue with.

More evidence and the age of the Universe



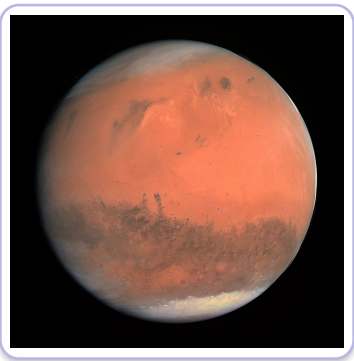
The whole sky mapped in microwaves: this faint glow reaches us from every direction as the leftover heat of the young Universe – strong evidence for the Big Bang

Orbital speed and free fall



The ISS in orbit: orbital speed is the speed that keeps a satellite in free-fall circular motion

Mars, a rocky inner planet



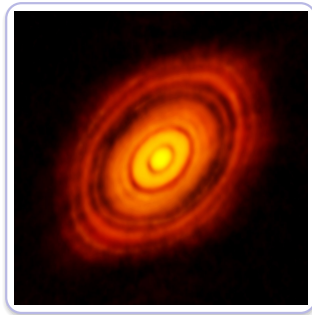
Mars, the red planet, one of the rocky inner planets

The Earth, the Sun and the Solar System

the Earth rotates 自转	on its axis 轴 once in about 24 hours – which gives day and night
the axis is tilted 倾斜	which gives the seasons as the Earth orbits the Sun in about 365 days
the four inner planets	small and rocky, close to the Sun
the four outer planets	large outer giants, described as gaseous 气态 in the syllabus comparison
the Sun	a star 恒星 of medium size , made mostly of hydrogen 氢 and helium 氦
how it shines	it radiates most of its energy in the infrared, visible and ultraviolet, from nuclear fusion of hydrogen into helium

The Milky Way is about 100 000 light-years in **diameter** 直径, and it is one of **many billions** of galaxies.

A planet-forming disc



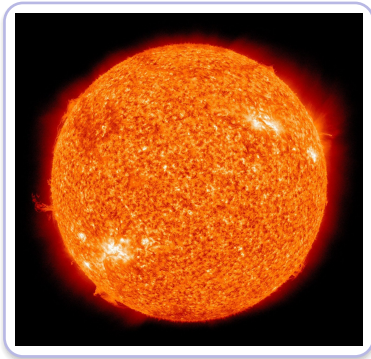
A real accretion disc around the young star HL Tauri: the dark gaps are where new planets are gathering up the dust – our Solar System began the same way

The Earth, the Sun and the Moon



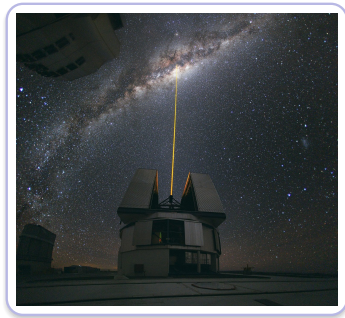
The Moon orbits the Earth about once a **month**. We see a full Moon when it is **opposite the Sun**, with its whole lit half facing us.

The Sun as a star



False-colour ultraviolet image of the Sun

Stars, galaxies and the Universe



A giant telescope studies the night sky; the laser helps it make sharp images of distant stars

How a star lives and dies, and the evidence for the Big Bang

1. a nebula	a cloud of hydrogen gas and dust
2. a protostar 原恒星	gravity pulls the cloud inwards and it heats up – the collapsing, heating cloud
3. a stable star	fusion starts, and its outward pressure balances gravity for billions of years
4a. a lighter star	swells into a red giant, then sheds its layers as a planetary nebula, leaving a white dwarf
4b. a much heavier star	swells into a red supergiant 红超巨星, then explodes as a supernova 超新星, leaving a neutron star or a black hole
the CMB	faint microwave 微波 radiation 辐射 from every direction – the cosmic microwave background 宇宙微波背景

Hubble's law gives the age because **every galaxy seems to have started from the same point at the same time**: run the expansion backwards and they all meet.

From cloud to star

Interstellar cloud

A star forms from an **interstellar cloud** 星际云 of gas and dust containing hydrogen, pulled together by gravity.

Nuclear reactions

When the core is hot and dense enough, **nuclear reactions** 核反应 begin: hydrogen fuses to helium, and the outward pressure balances gravity.

What it radiates

The star radiates most of its energy in the infrared, visible and **ultraviolet** 紫外线 parts of the **electromagnetic spectrum** 电磁波谱.

Where the elements came from

The planets formed from a giant cloud of gas and **dust** 尘埃 containing many chemical **elements** 元素 – all of them made in earlier stars.

A main-sequence star is a balance: gravity pulling in against radiation pressure pushing out. Every later stage is that balance failing.

A spiral galaxy



A spiral galaxy: billions of stars held together by gravity

Planetary data: reading the table

Planet	Distance / million km	Period	Density / g/cm ³	Temp. / °C	Surface <i>g</i> / N/kg
Mercury	58	88 days	5.4	170	3.7
Venus	108	225 days	5.2	460	8.9
Earth	150	365 days	5.5	15	9.8
Mars	228	687 days	3.9	−60	3.7
Jupiter	779	11.9 years	1.3	−110	23
Saturn	1430	29.5 years	0.7	−140	9.0
Uranus	2870	84 years	1.3	−195	8.7
Neptune	4500	165 years	1.6	−200	11

Farther out: longer period; the outer planets are colder, but Venus breaks a simple temperature rule. Inner four dense; outer four less dense. Surface *g* follows the planet's mass and size, not its distance from the Sun.

Exam tips

- In $v = \frac{2\pi r}{T}$, r is the orbit radius and T is the time for one full orbit in seconds – convert km to m and hours to seconds first.
- Planets closer to the Sun feel stronger gravity, so they orbit faster and take less time. In an elliptical orbit a body speeds up as it nears the Sun (gravitational potential energy turns into kinetic energy).
- A **light-year** is a *distance*, not a time – how far light travels in one year.
- A star is **stable** when the inward pull of gravity is balanced by the outward push from the energy released by **fusion** in its core. What it becomes when its fuel runs out depends on its **mass**.
- **Redshift** – light from distant galaxies shifted to longer (redder) wavelengths, with a bigger shift the further away – is the evidence that the Universe is **expanding**, which supports the Big Bang.

5

Recap

Topic 6 – key takeaways

1

Orbits

$v = 2\pi r/T$; ellipses, faster when closer

2

Solar System

rocky inner, gaseous outer; Sun's gravity

3

Stars

fusion; mass decides the death

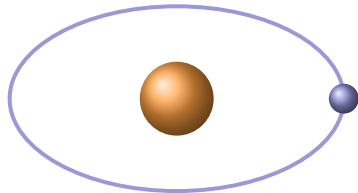
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Universe

redshift → expanding → Big Bang

Check yourself

- 1 Why do we have seasons?
- 2 Are the outer planets rocky or gaseous?
- 3 What powers a star?
- 4 What does redshift tell us about the Universe?



Answers 1. the tilted axis 2. gaseous 3. nuclear fusion 4. it is expanding