Cambridge IGCSE · Physics 0625 · Notes

The Earth and the Solar System

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Read first: **Motion**, **Mass and weight**, **Energy, work and power**, **Transfer of thermal energy**

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What you need to know

This topic is about our own corner of space: how the Earth spins and moves round the Sun, what else is in the Solar System, how it formed, and how gravity holds it together. It uses speed $= \text{distance} \div \text{time}$ from Motion, weight and gravitational field strength from Mass and weight, and energy stores from Energy, work and power. The parts marked **Extended only** are tested on Papers 2 and 4 only. By the end of it you should be able to:

The Earth

1. **Know that the Earth is a planet that spins on a tilted axis once in about 24 hours**, and use this to explain day and night and why the Sun seems to cross the sky each day.
2. **Know that the Earth orbits the Sun once in about 365 days**, and use this (with the tilt) to explain why the seasons repeat every year.
3. **Know that the Moon takes about one month to orbit the Earth**, and use this to explain why the Moon's phases repeat every month.
4. **Extended only:** define average orbital speed with $v = \dfrac{2\pi r}{T}$, where r is the average radius of the orbit and T is the orbital period, and use it.

The Solar System

5. **Describe what is in the Solar System**: one star (the Sun); the eight planets, in order from the Sun; minor planets that orbit the Sun, such as dwarf planets like Pluto and the asteroids in the asteroid belt; moons, which orbit planets; and smaller bodies such as comets and natural satellites.
6. **Know that the four planets nearest the Sun are small and rocky and the four furthest away are large and gaseous**, and explain the difference with the accretion model: gravity, clouds of gas and dust containing many elements, and a rotating cloud flattening into an accretion disc.
7. **Know that the strength of a gravitational field** at a planet's surface depends on the planet's mass, and gets weaker further from the planet.
8. **Calculate how long light takes to travel** a large distance, such as between objects in the Solar System.
9. **Know that the Sun has most of the Solar System's mass**, which is why the planets orbit the Sun, and that the Sun's gravitational attraction is the force that keeps them in orbit.
10. **Extended only:** know that planets, minor planets and comets have elliptical orbits, and that the Sun is not at the centre of an elliptical orbit (unless the orbit is almost a circle).

11. **Extended only:** analyse and interpret planetary data: orbital distance, orbital period, density, surface temperature and gravitational field strength at the surface.
12. **Extended only:** know that the Sun's gravitational field gets weaker, and planets' orbital speeds get smaller, the further they are from the Sun.
13. **Extended only:** know that an object in an elliptical orbit moves faster when it is closer to the Sun, and explain this with conservation of energy.

Questions in this topic also ask what the Sun is made of: **mostly hydrogen and helium**, and it gives out most of its energy as **infrared, visible light and ultraviolet**. The syllabus lists this under "The Sun as a star" (6.2.1), but the papers ask it inside Solar System questions, so it is here too.

Understand it

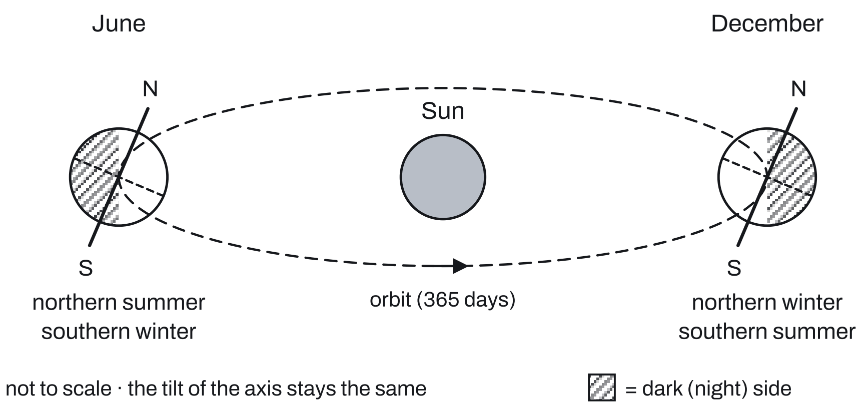
A spinning, tilted Earth: day, night and the Sun's path

The Earth spins on its **axis**, an imaginary line through the North and South Poles, once in about **24 hours**. At any moment the half of the Earth facing the Sun has **day** and the other half has **night**. As the Earth turns, you are carried from the night side into the day side (sunrise) and back again (sunset), so day and night repeat every 24 hours.

The Earth spins from west to east. Standing on it, you don't feel the turning, so it looks as if the Sun is moving the other way: it **rises in the east, crosses the sky and sets in the west**. The Sun is not going round the Earth; this **apparent** daily motion comes from the Earth's spin.

Orbiting the Sun: the year and the seasons

The Earth also travels round the Sun, once in about **365 days** (one year). Its axis is **tilted**, and the tilt always points the same way in space as the Earth goes round.



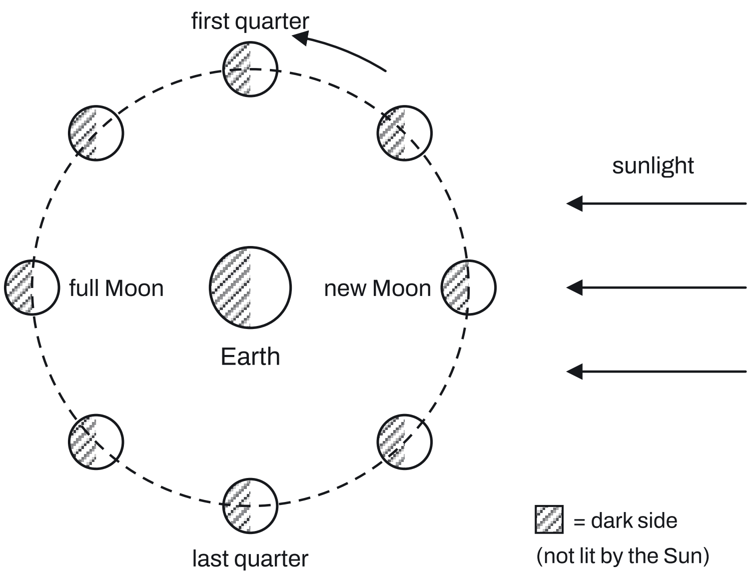
- For part of the year the northern hemisphere leans **towards** the Sun. The Sun climbs higher in the sky there, its rays hit the ground more directly (the energy is concentrated on a smaller area), and days are longer than nights. That is **summer** in the north.

- Half a year later the Earth is on the other side of the Sun. The northern hemisphere now leans **away** from the Sun: the Sun stays low, its rays are spread out, and days are short. That is **winter** in the north, and summer in the south.

Because the orbit takes 365 days, the seasons repeat every year. The seasons are **not** caused by the Earth getting closer to the Sun: the orbit is almost a circle, and the two hemispheres have opposite seasons at the same moment.

The Moon and its phases

The Moon orbits the Earth in about **one month** (about 28 days). It gives out no light of its own; we see it because it reflects sunlight. The half of the Moon facing the Sun is always lit. What changes is **how much of that lit half faces us**.



Moon's orbit: about one month · not to scale

- **New Moon:** the Moon is between the Earth and the Sun. Its lit half faces away from us, so we see almost nothing.
- **Quarter Moon:** the Moon is a quarter of the way round (at right angles to the Sun–Earth line). We see half of the disc lit.
- **Full Moon:** the Moon is on the far side of the Earth from the Sun. Its whole lit half faces us.

One orbit takes about a month, so the cycle new → quarter → full → quarter → new repeats every month.

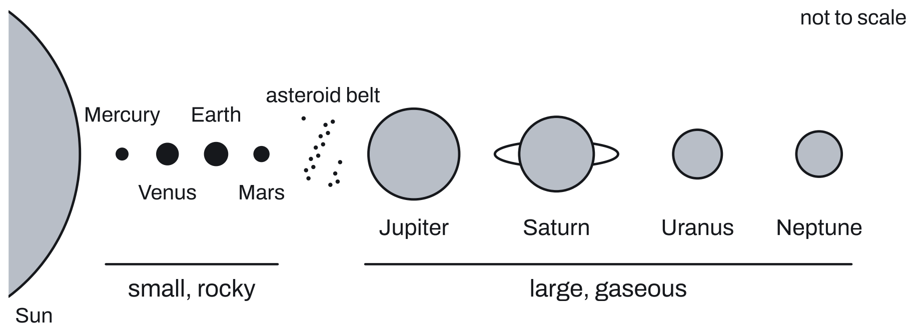
What is in the Solar System

The Solar System contains:

- **one star**, the Sun, which holds most of the Solar System's mass;
- **eight planets**, which orbit the Sun: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune (a way to remember the order: **M**y **V**ery **E**asy **M**ethod **J**ust **S**peeds **U**p **N**aming);

- **minor planets** that orbit the Sun, including **dwarf planets** such as Pluto and the **asteroids** in the **asteroid belt** between Mars and Jupiter;
- **moons**, which orbit planets (a moon is a natural satellite: the Moon orbits the Earth);
- smaller bodies, such as **comets** (balls of ice and dust) and other natural satellites.

A **star** is orbited by **planets**, and a planet is orbited by **moons**.



Compared with each other, the **four inner planets** (Mercury to Mars) are **small and rocky**, and the **four outer planets** (Jupiter to Neptune) are **large and gaseous**.

How the Solar System formed: the accretion model

1. The Solar System began as a huge **interstellar cloud of gas and dust**. The cloud contained many different elements.
2. **Gravity** pulled the material together, so the cloud collapsed.
3. The cloud was **rotating**. As it collapsed it spun faster and flattened into a spinning disc, the **accretion disc**.
4. Most of the material fell to the centre and formed the **Sun**.
5. In the disc, particles stuck together into larger and larger lumps, which pulled in more material by gravity and became the **planets**.

Close to the young Sun it was very hot, and gases were driven away, so only rocky material (rock and metal) was left to build planets: the inner planets are **rocky and small**. Far from the Sun it was cold, so gases stayed and collected in great amounts: the outer planets are **gaseous and large**.

Gravity holds it together

Every mass attracts every other mass. **Gravitational field strength** g is the gravitational **force per unit mass** (the force on each kilogram), in N/kg (from Mass and weight: $g = W \div m$).

- At a planet's **surface**, g depends on the planet's **mass**: a planet with more mass has a stronger field. The Earth's is about 9.8 N/kg; Mars has much less mass, so its surface g is smaller.
- **Around** a planet, g gets **weaker the further you go** from it. A space probe approaching a planet measures bigger and bigger values. An object's mass stays the same, but its weight falls as it moves away.

The Sun contains most of the mass of the Solar System, so it has by far the strongest gravitational field. That is why everything orbits the Sun: the **gravitational attraction of the Sun** is the force that keeps each planet in orbit. In the same way, the Earth's gravity keeps the Moon in orbit.

Light takes time to cross space

Light (and every electromagnetic wave, such as radio waves) travels through space at 3.0×10^8 m/s. Solar System distances are so large that even light takes minutes or hours:

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

For example, Uranus is about 2.9×10^{12} m from the Sun, so sunlight takes $2.9 \times 10^{12} \div 3.0 \times 10^8 \approx 9700$ s (about 2.7 hours) to reach it.

Extended only: orbital speed

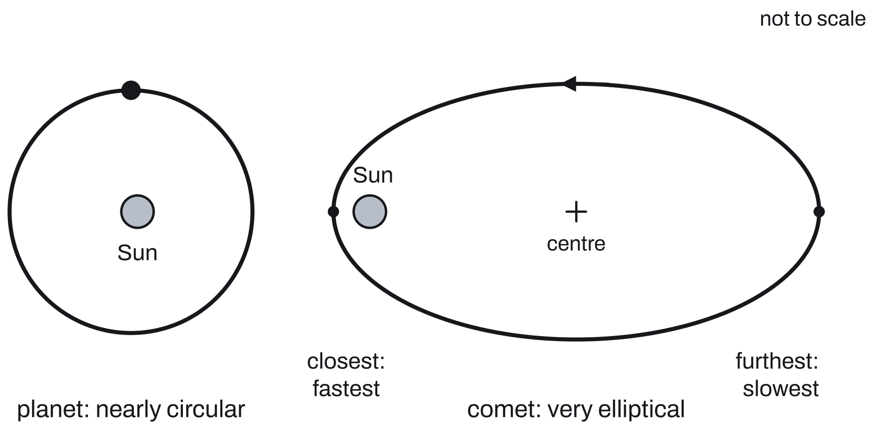
A body in a (nearly) circular orbit travels once round a circle of circumference $2\pi r$ in one orbital period T, so its average orbital speed is

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

r is measured from the **centre** of the body being orbited, and T is the time for **one** orbit. The units follow the numbers: r in m and T in s give m/s; r in km and T in hours give km/h.

Extended only: elliptical orbits

Planets, minor planets and comets move in **ellipses** (stretched circles). The Sun is **not at the centre** of an ellipse: it sits at a point off to one side, called a focus. Planets' orbits are almost circles, so for them the Sun is nearly at the centre; a comet's orbit is very stretched.



Because the orbit is an ellipse, the distance from the Sun keeps changing, so a planet's "distance from the Sun" in a data table is an **average**.

Extended only: why a comet speeds up near the Sun

A comet's total energy, **gravitational potential energy (GPE) + kinetic energy (KE)**, stays the same (conservation of energy), because space is a vacuum and nothing takes energy away.

- As the comet moves **towards** the Sun, the Sun's gravity pulls it along its path. Its GPE **decreases** and its KE **increases**, so it speeds up.
- As it moves **away** from the Sun, KE is transferred back to GPE, so it slows down.

So an object in an elliptical orbit is **fastest at its closest point** to the Sun (GPE least, KE most) and **slowest at its furthest point** (GPE most, KE least).

Extended only: speed and field strength with distance

The Sun's gravitational field gets **weaker** further from the Sun. A planet further out is pulled less strongly and moves more slowly in its orbit, so **orbital speed decreases as distance from the Sun increases**: Mercury is the fastest planet and Neptune the slowest. (Don't try to argue this from $v = \frac{2\pi r}{T}$ alone: a bigger r comes with a much bigger T.)

Extended only: reading planetary data

Tables give orbital distance, orbital period, density, surface temperature and surface gravitational field strength. The patterns to look for:

As distance from the Sun increases…	Why
orbital period increases	a longer path at a lower speed
orbital speed decreases	the Sun's field is weaker further out
surface temperature generally decreases	less of the Sun's radiation reaches each square metre

- **Surface** g follows the planet's **mass**, not its density or size alone: Jupiter has a low density (it is mostly gas) but a huge mass, so its surface g is larger than the Earth's.
- **Density** is low for the gaseous outer planets and high for the rocky inner ones.
- Venus is the exception to the temperature pattern: its thick atmosphere traps heat, so it is hotter than Mercury.

Key facts and formulas

There is no formula sheet in the IGCSE Physics exam, so you must learn all of these.

Formula	Status
Time for light to travel a distance: $t = \frac{d}{c}$, with $c = 3.0 \times 10^8$ m/s	Learn it
Speed of light in km/s: 3.0×10^5 km/s $= 0.30 \times 10^6$ km/s	Learn it

Formula	Status
Average orbital speed $v = \frac{2\pi r}{T}$, r = average orbit radius, T = orbital period (Extended)	Learn it
Rearranged: $T = \frac{2\pi r}{v}$, $r = \frac{vT}{2\pi}$ (Extended)	Learn it
Gravitational field strength $g = \frac{W}{m}$ (force per unit mass, N/kg)	Learn it
Density $\rho = \frac{m}{V}$, so $m = \rho V$ (Extended, planetary data)	Learn it
Temperature: θ in °C $=$ T in K -273	Learn it
Fraction of an orbit completed $= \frac{\text{time}}{\text{orbital period}}$; angle turned $= \text{fraction} \times 360^\circ$	Learn it

Facts to learn: Earth spins once in about 24 hours (1 day); Moon orbits the Earth in about 1 month (about 28 days); Earth orbits the Sun in about 365 days (1 year). Time conversions: 1 day $= 24$ h $= 86\,400$ s; 1 year $= 365 \times 24 = 8760$ h. Distance conversions: 1 km $= 10^3$ m, 1 km³ $= 10^9$ m³.

How to do it

We have tagged 98 questions on this topic (89 different; 2021 and 2023–2025; Papers 1–4). 35 of them mix more than one type, so the counts add up to more than 98.

Question type	Questions
Name or order the planets	20
Calculate light or radio travel time or distance	19
State the periods of the Earth's and Moon's motions	16
Calculate orbital speed with $v = 2\pi r/T$	15
Explain day and night, the Sun's daily motion, seasons and Moon phases	14
State what gravity does: holds orbits, g depends on mass and falls with distance	13
Describe rocky inner and gaseous outer planets	10
State the shape of orbits (elliptical, Sun not at the centre)	9
Name other Solar System bodies and how they are arranged	9
Interpret planetary data tables	8
Explain the speed change in an elliptical orbit with energy	7
Describe the accretion model of Solar System formation	7
State what the Sun is made of and what radiation it gives out	6
Relate orbital speed and the Sun's field strength to distance	3
Use orbital periods to find positions or times for part of an orbit	3

1. Name or order the planets (20 questions)

1. Write out the order first: **Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune** (My Very Easy Method Just Speeds Up Naming).
2. Check which way the question counts: "increasing distance from the Sun" starts at Mercury; "decreasing distance" or "starting with the furthest" starts at Neptune.
3. On a diagram, count the orbits outwards from the Sun and match each blank label to its position. Spell the names correctly.

Variations you will meet:

- **Fill in the missing names** on a not-to-scale diagram, where some planets are already labelled. Use the labelled ones to anchor your count.
- **Only some planets**: the four inner ones, the three closest, the four gaseous ones in order (Jupiter, Saturn, Uranus, Neptune).
- **"Name one planet further from (or closer to) the Sun than Venus"**: any planet from Earth outwards; closer means Mercury.
- **"Which planet orbits between Mars and Saturn?"**: Jupiter.

2. Calculate light or radio travel time or distance (19 questions)

1. Write $\text{speed} = \dfrac{\text{distance}}{\text{time}}$, so $t = \dfrac{d}{c}$ or $d = c \times t$. Light, radio waves and all electromagnetic waves travel at $c = 3.0 \times 10^8$ m/s; Paper 4 may expect you to know this.
2. Decide how far the signal really travels (see the variations), and put the distance in metres.
3. Substitute and give the answer with its unit, usually to 2 significant figures.

Variations you will meet:

- **Given the time, find the distance**, for example the Sun–planet distance from the time sunlight takes to arrive: $d = c \times t$.
- **A reflected signal (echo):** the time measured is for the trip **there and back**, so halve it to get the one-way time, or double the one-way distance. A radar pulse to an asteroid 6.0×10^9 m away returns after $2 \times 6.0 \times 10^9 \div 3.0 \times 10^8 = 40$ s.
- **Message and reply** (a vehicle on another planet signals Earth, and Earth signals back): the shortest possible time is two one-way trips.
- **Distance between two planets** when they are closest: the difference of their orbit radii (they are in line on the same side of the Sun).
- **Units:** if distances are in km, use $c = 3.0 \times 10^5$ km/s (0.30×10^6 km/s). If the distance is in light-years (the distance light travels in one year), light takes 1 year for each light-year: 0.0020 light-years takes 0.0020 years one way.

3. State the periods of the Earth's and Moon's motions (16 questions)

1. Learn the three facts as pairs of *motion* → *time*:
   - the Earth **spins once on its axis** → about **24 hours** (one day);
   - the Moon **orbits the Earth** → about **one month** (about 28 days);
   - the Earth **orbits the Sun** → about **365 days** (one year).
2. Give the **unit** with the number when the question says "include the unit": "365 days", not "365".

Variations you will meet:

- **Matching boxes** of descriptions to "one day / one month / one year": watch the distractor "one week", which matches nothing.
- **Put the three periods in order** of size: spin (day) < Moon's orbit (month) < Earth's orbit (year).
- **Spot the correct statement** in a list: wrong ones swap the motions ("the Earth orbits the Sun in 24 hours") or the bodies ("the Sun orbits the Earth", "the Earth orbits the Moon").
- **Complete a sentence with a unit**: "The Moon orbits the Earth in approximately 1 ..." → month.
- **Convert a rotation time to Earth days**: divide hours by 24. A planet that spins once in 1416 hours takes $1416 \div 24 = 59$ Earth days.

4. Extended only: Calculate orbital speed with $v = 2\pi r/T$ (15 questions)

1. Write the equation $v = \dfrac{2\pi r}{T}$.
2. **Convert** T to the time unit of the answer: days $\times 24$ for hours, days $\times 24 \times 3600$ (that is, $\times 86\,400$) for seconds; years $\times 365$ for days.
3. Check r is the **radius** (from the centre of the body orbited), not the diameter and not the circumference, and in the right length unit.
4. Substitute and give the answer to 2 or 3 significant figures, with the unit asked for.

Variations you will meet:

- **"State the equation and the meaning of the symbols"**: v = average orbital speed, r = average radius of the orbit, T = orbital period (time for one orbit).
- **Pick the right expression** ($\frac{2\pi r}{T}$) or **pick the data needed**: the radius of the orbit (the distance of the satellite from the planet's centre) and the time for one orbit, **not** the planet's own radius or rotation period.
- **Rearrange for T or r.** A satellite with $r = 6.8 \times 10^6$ m and $v = 7.7 \times 10^3$ m/s has $T = \frac{2\pi r}{v} = 5549$ s ≈ 92 minutes. Convert seconds to minutes ($\div 60$) or hours and minutes if the options are given that way.
- **The period is given as a count**, such as "12 orbits every 24 hours": $T = 24 \div 12 = 2$ hours.
- **The period is in Earth years**: multiply by 365×24 to get hours.
- **"Show that"**: write every step and give your answer to one more significant figure than the printed value.

5. Explain day and night, the Sun's daily motion, seasons and Moon phases (14 questions)

Match each cycle to the motion that causes it:

Cycle	Caused by	Period
Day and night; the Sun's apparent path from east to west	the Earth spinning on its axis	about 24 hours
Seasons	the Earth orbiting the Sun **with its axis tilted**	about 365 days
Phases of the Moon	the Moon orbiting the Earth	about 1 month

1. For a written explanation, **name the motion and its time**: "The Earth spins on its axis once every 24 hours, so a place turns to face the Sun (day) and then away from it (night)."
2. For the seasons, name the **tilt** and the **orbit**, and say which hemisphere leans towards the Sun: that one has summer (the Sun is higher, its rays are more concentrated and days are longer).

Variations you will meet:

- **Seasons on an orbit diagram**: find where the northern end of the axis leans towards the Sun (northern summer) or away from it (northern winter). For a place in the southern hemisphere it is the other way round.
- **Countries far from the Equator** have big temperature changes through the year: because of the tilt, the Sun's height in the sky and the length of the day change a lot there during the orbit.
- **Moon positions on an orbit diagram** with sunlight from one side: full Moon on the far side of the Earth from the Sun, new Moon between the Earth and the Sun, quarter Moons at right angles.
- **Multiple choice**: "What causes the phases of the Moon?" → the Moon orbiting the Earth. "What causes the seasons?" → the tilt of the axis, never "the Earth is closer to the Sun".

6. State what gravity does: holds orbits, g depends on mass and falls with distance (13 questions)

1. **The force keeping a planet (or the Moon) in orbit** is gravity: the **gravitational attraction** of the Sun (or of the Earth for the Moon). Write "gravitational force", not "gravitational potential energy".
2. **Why one planet has a bigger surface g**: it has a **greater mass** (or the other has a smaller mass).
3. **How g changes with distance**: it **decreases** as the distance from the planet increases.

Variations you will meet:

- **Suggest a value**: a planet of similar size with a bit less mass than the Earth has a surface g a bit below 9.8 N/kg (for example about 9 N/kg), with the reason "smaller mass".

- **Order readings**: a probe moving towards a planet measures values that **increase**; moving away, they **decrease**.
- **Mass and weight moving away from a planet**: mass unchanged, weight decreases (because g decreases).
- **"On which planet does an object fall a height in the shortest time?"** The one with the **largest** g, because the acceleration of free fall is greatest there (so is the gravitational force on the object).
- **Why the planets orbit the Sun**: the Sun has most of the Solar System's mass.

7. Describe rocky inner and gaseous outer planets (10 questions)

1. The **four inner** planets (Mercury, Venus, Earth, Mars) are **small** and **rocky**.
2. The **four outer** planets (Jupiter, Saturn, Uranus, Neptune) are **large** and **gaseous**.

Variations you will meet:

- **"State two ways the inner planets differ from the outer ones"**: size and composition. If the question has already told you they are nearer the Sun, distance doesn't count as one of your two.
- **Choose words from a list**: small, rocky / large, gaseous.
- **Pick the rocky planet(s)**: from names (only Mercury, Venus, Earth and Mars are rocky), or from a table of distances (the two with the smallest distances are rocky).
- **Explain the difference**: see type 12, the accretion model.

8. Extended only: State the shape of orbits (9 questions)

1. Planets, minor planets and comets have **elliptical** orbits.
2. The Sun is **not at the centre** of the ellipse (it is at a focus). Only for a nearly circular orbit is the Sun close to the centre.

Variations you will meet:

- **"State the shape of the orbits of the planets"**: "elliptical" (or "approximately circular"). "Circular" alone does not score.
- **Pick the comet's orbit** on a diagram: the very stretched one, with the Sun far from its centre.
- **Sketch a comet's orbit** and mark the Sun S: draw a clear ellipse and put S well off-centre, near one end (at a focus). Mark the slowest point furthest from S and the fastest point nearest S.
- **Why is "distance from the Sun" an average?** Because the orbit is elliptical, so the distance keeps changing.

9. Name other Solar System bodies and how they are arranged (9 questions)

1. Bodies other than planets that **orbit the Sun**: dwarf planets (such as Pluto), asteroids, comets.
2. Bodies that **orbit planets**: moons (natural satellites).

3. Give exactly as many answers as asked; don't name a planet, a star or a galaxy when the question asks for other objects.

Variations you will meet:

- **Star, planet, moon diagrams**: the body at the centre is the star; a body orbiting it is a planet; a body orbiting a planet is a moon.
- **Order by size**: asteroids < the Moon < planets < the Sun.
- **Draw a moon of Jupiter**: a small cross near Jupiter with a closed loop round Jupiter (not round the Sun).
- **True statements**: the Solar System has **one** star; Pluto is a dwarf planet; not all planets are rocky; many planets have moons, not only the Earth.

10. Extended only: Interpret planetary data tables (8 questions)

1. Find the trend the question asks about, and describe it with both quantities: "as the distance from the Sun increases, the surface temperature decreases".
2. Use a trend to identify a planet or estimate a missing value: the hottest planet is the closest (except Venus, whose atmosphere traps heat); a planet's period lies between those of its neighbours.

Variations you will meet:

- **Name a planet from its data**: compare distance, period or g with the Earth's (a period of about 225 days and distance a bit less than the Earth's means Venus).
- **Mass and** g: a bigger mass gives a bigger surface g. Check claims carefully: density does **not** rise with mass, and g is **not** proportional to density.
- **Temperatures in kelvin**: subtract 273. 110 K $= 110 - 273 = -163$ °C.
- **Low density but high** g (Jupiter): low density because it is mostly gas; high g because its total mass is huge.
- **A planet's surface colour and its temperature** (uses Transfer of thermal energy): a white or light surface is a poor absorber (a good reflector) and a poor emitter of infrared radiation. So as the planet rotates, its temperature rises less while that side faces the Sun and falls less while it faces away: the temperature changes less than for a dark surface.
- **Mass from density and volume**: $m = \rho V$, converting km³ to m³ first ($\times 10^9$). A planet of density 5500 kg/m³ and volume 1.08×10^{12} km³ has $m = 5500 \times 1.08 \times 10^{21} = 5.9 \times 10^{24}$ kg.

11. Extended only: Explain the speed change in an elliptical orbit with energy (7 questions)

1. **Describe**: the object is **fastest when closest** to the Sun and **slowest when furthest** away. Describe the whole trip: from closest to furthest the speed decreases; on the way back it increases.
2. **Explain**: the **total energy** (GPE + KE) is **conserved**. Moving towards the Sun, **GPE decreases and KE increases**, so the speed increases. Moving away, KE is transferred to GPE, so it slows down.
3. Say that energy is transferred **between** the two stores, not just that each changes.

Variations you will meet:

- **Mark the slowest (or fastest) point** on a sketch: furthest from (or nearest to) the Sun.
- **State the energy transfer from the closest point to the furthest point**: kinetic to gravitational potential.
- **Multiple choice at the closest point**: GPE at its minimum, orbital speed at its maximum.

12. Describe the accretion model of Solar System formation (7 questions)

Key words the mark schemes look for, in order:

1. an interstellar **cloud of gas and dust** (containing many elements);
2. pulled together by **gravity**;
3. the **rotating** material forms an **accretion disc**;
4. the Sun forms at the centre, and material in the disc clumps together into **planets**;
5. near the hot Sun only **rocky** material stayed (small rocky planets); further out, **gases** collected (large gaseous planets).

Variations you will meet:

- **Fill in the gaps**: "gas and **dust**", "the force of **gravity**", "an accretion **disc**", inner planets "**rocky**", outer planets "**gaseous**".
- **Describe in your own words** (usually 3 marks): give three of the points above. Don't describe the life cycle of a star; that is a different model.

13. State what the Sun is made of and what radiation it gives out (6 questions)

1. The Sun is a star made mostly of **hydrogen** and **helium** (one mark each).
2. It gives out most of its energy as **infrared**, **visible light** and **ultraviolet** radiation. If the question names one, give the other two.

14. Extended only: Relate orbital speed and the Sun's field strength to distance (3 questions)

1. **Statement**: the planet further from the Sun has the **lower** orbital speed (Jupiter is slower than the Earth; Mercury is faster than the Earth).
2. **Reason**: it is further from the Sun.
3. **Explanation**: the Sun's gravitational field (strength) **decreases** with distance from the Sun.

For multiple choice: closer to the Sun means a **greater** field strength of the Sun **and** a **faster** orbit.

15. Extended only: Use orbital periods to find positions or times for part of an orbit (3 questions)

1. Fraction of the orbit completed $= \dfrac{\text{time}}{\text{orbital period}}$.
2. Angle turned round the Sun $= \text{fraction} \times 360^\circ$, in the direction of motion shown. Mark the new position on the orbit and show this working.
3. For several planets, do each separately; a planet that has completed whole orbits is back where it started.

Variations you will meet:

- **Time for part of the Earth's orbit**: the Earth takes 365 days for 360°, so moving 60° takes $365 \div 6 \approx 61$ days, because a full orbit is 365 days.
- **Periods given as multiples**: if Y takes 3 times as long as X, then when X has done one full orbit, Y has done $\frac{1}{3}$ of an orbit (120°).
- **Are the planets lined up again?** Work out each planet's angle, subtract 360° for each full orbit, and compare. If the angles are equal, the planets are in line again, so from the Earth one is seen in front of the other. Neither needs to have made a whole number of orbits. For example, planets with periods of 10 years and 6 years start in line. After 15 years the first has turned $\frac{15}{10} \times 360^\circ = 540^\circ$, that is $540^\circ - 360^\circ = 180^\circ$, and the second $\frac{15}{6} \times 360^\circ = 900^\circ$, that is $900^\circ - 720^\circ = 180^\circ$. Both are at 180°, so they are lined up again, on the other side of the star.

Worked examples

The bold codes show where marks are earned, as in Cambridge mark schemes. The number is how many marks.

- **A1** accuracy mark: for a correct answer; it needs the M mark before it.
- **B1** mark for a correct result on its own, with no method needed.

Example 1

A radar station on the Earth sends a radio pulse towards an asteroid. The asteroid is 6.0×10^9 m from the Earth. The pulse reflects from the asteroid and returns to the station.

(a) State the region of the Solar System where most asteroids are found. **[1]**

(b) Calculate the time between the pulse leaving the station and the echo arriving back. **[3]**

(a) The asteroid belt, between Mars and Jupiter. **B1**

(b) The pulse travels to the asteroid and back, so the distance is $2 \times 6.0 \times 10^9 = 1.2 \times 10^{10}$ m. **C1** for doubling the distance (or doubling the time at the end).

$t = \frac{d}{c} = \frac{1.2 \times 10^{10}}{3.0 \times 10^{8}}$ **C1** for the equation with the numbers in.

$t = 40$ s **A1**

Example 2

(a) It is December. Explain why it is summer in Australia, in the southern hemisphere of the Earth, while it is winter in Canada, in the northern hemisphere. **[3]**

(b) Explain why the Moon's phases repeat about once a month. **[2]**

(a) The Earth's axis is tilted. **B1** In December the southern hemisphere is tilted towards the Sun, so the Sun is higher in the sky, its rays are more concentrated and the days are longer there, while the northern hemisphere is tilted away from the Sun. **B1** As the Earth orbits the Sun (once in 365 days), which hemisphere leans towards the Sun changes, so the seasons repeat every year. **B1**

(b) The Moon orbits the Earth once in about one month. **B1** During the orbit we see different amounts of the half of the Moon lit by the Sun, from none (new Moon) to all of it (full Moon). **B1**

Example 3 (Extended)

Neptune orbits the Sun in an almost circular orbit of average radius 4.5×10^{9} km. One orbit takes 165 Earth years.

(a) Calculate the average orbital speed of Neptune. Give your answer in km/h. **[3]**

(b) The average orbital speed of the Earth is about 1.1×10^{5} km/h. State and explain why Neptune's orbital speed is much less than the Earth's. **[2]**

(a) $v = \frac{2\pi r}{T}$ **C1**

$T = 165 \times 365 \times 24 = 1\,445\,400$ h **C1** for converting the period to hours.

$v = \frac{2\pi \times 4.5 \times 10^{9}}{1\,445\,400} = 19\,561$ km/h $= 2.0 \times 10^{4}$ km/h **A1**

(b) Neptune is much further from the Sun than the Earth is. **B1** The Sun's gravitational field is weaker further from the Sun, so the orbital speed is lower. **B1**

Example 4 (Extended)

A comet orbits the Sun. At its closest point P it is 9.0×10^{10} m from the Sun. At its furthest point Q it is 5.3×10^{12} m from the Sun.

(a) Describe the shape of the comet's orbit and state where the Sun is. **[2]**

(b) The comet moves from Q to P. Describe and explain, in terms of energy, how its speed changes. **[3]**

(c) Calculate the time taken for light from the Sun to reach the comet when it is at Q. **[2]**

(a) The orbit is an ellipse (elliptical). **B1** The Sun is not at the centre of the ellipse; it is off-centre, at a focus, near the P end. **B1**

(b) The speed increases from Q to P. **B1** The total energy of the comet (GPE + KE) is conserved. **B1** As it moves closer to the Sun its gravitational potential energy decreases and is transferred to kinetic energy, so its speed increases. **B1**

(c) $t = \frac{d}{c} = \frac{5.3 \times 10^{12}}{3.0 \times 10^{8}}$ **C1**

$t = 17\,667$ s $= 1.8 \times 10^{4}$ s (about 4.9 hours) **A1**

Common mistakes

- **Blaming the seasons on distance.** "Winter is when the Earth is further from the Sun" is wrong, and it is the most common error examiners report on this topic. Say the axis is **tilted**, name the hemisphere tilted towards the Sun, and mention the 365-day orbit.
- **Saying the Sun moves round the Earth.** The Sun's daily path is **apparent**: it comes from the Earth spinning on its axis once every 24 hours. Weaker answers just describe sunrise and sunset; say what the Earth does and how long it takes.
- **Mixing up the three periods.** The Earth's **spin** is 24 hours; the **Moon's orbit** is about a month; the Earth's **orbit** is about 365 days. Read which motion is asked, and write the unit.
- **Putting the Sun at the centre of a comet's orbit.** Many candidates know comet orbits are elliptical but still place the Sun in the middle. It is off-centre, at a focus.
- **Writing "circular" for the planets' orbits.** The answer is "elliptical" (or "approximately circular"). Writing both "elliptical" and "circular" as if they were the same thing contradicts itself.
- **Using the radius as the distance travelled.** In one orbit a satellite travels $2\pi r$, not r. Using 7000 km for the distance round a 7000 km orbit was a common wrong choice in one multiple-choice question.
- **Forgetting to convert units.** If the answer is asked in km/h, the period must be in hours; for m/s, the radius in m and the period in s. Answers in other units lose the final mark.
- **Rearranging speed = distance ÷ time wrongly**, for example $t = d \times c$. Write the equation first, then rearrange.
- **Ignoring the round trip.** For an echo or a message and reply, the signal travels the distance twice.
- **Calling a light-year a time.** It is a **distance**: the distance light travels in one year.
- **Explaining a big g by a big size.** Jupiter's large surface g comes from its large **mass**; its density is low.
- **Arguing that Jupiter is faster** because $v = \frac{2\pi r}{T}$ has a bigger r. It is slower, because the Sun's field is weaker out there.
- **Vague energy answers.** "GPE and KE change" is not enough. Say GPE **decreases** and KE **increases** as the object gets closer, so energy moves from one store to the other, and the total stays the same. Describe the speed change for the whole path (decreasing from closest to furthest, increasing on the way back).

- **Describing a star's life cycle** when asked about the accretion model. Use the words cloud of gas and dust, gravity, rotation, accretion disc.
- **Naming the wrong kind of object.** Asked for "other types of object in the Solar System", don't name a planet, a star or a galaxy, and don't write extra answers that contradict your correct ones.

How to get the marks

- **"State"** needs only the fact, but the exact one: "gravitational force", "elliptical", "hydrogen" and "helium". One mark per separate fact.
- **"Explain"** needs the cause: for seasons, the tilt plus the orbit; for phases, the Moon's orbit; for speed changes, the energy transfer between GPE and KE with the total conserved.
- **"Describe"** a change (such as the comet's speed) needs the direction of the change for each part of the path.
- **"Calculate"** is usually 3 marks: the equation (or rearranged equation), the numbers substituted, the answer. The first two marks can be earned even if the final answer goes wrong, so always show them.
- **Units**: give the unit the answer line asks for and convert before substituting. A time with no unit ("365") can lose the mark when the question says "include the unit".
- **Significant figures**: 2 or 3 significant figures, matching the data. For "show that", give one more figure than the printed value.
- **"Suggest"** (for example a value of g for Venus) wants a sensible value **with** a reason (smaller mass).
- **Diagrams and sketches**: draw a clear ellipse; mark the Sun and the points asked for with the letters the question gives.
- **"ORA" (or reverse argument)** in mark schemes means the comparison can be made either way round ("Mars has less mass" = "the Earth has more mass"), but it must be a comparison.

Quick check

1. List the four gaseous planets in order of **decreasing** distance from the Sun.
2. A space probe is 1.8×10^{11} m from the Earth. Engineers send it a command and it replies at once. Calculate the shortest time between sending the command and receiving the reply. Give your answer in minutes.
3. **(Extended)** A satellite orbits the Earth once every 24 hours at an orbital radius of 4.2×10^{7} m. Calculate its average orbital speed in m/s.
4. **(Extended)** The table gives data for four planets P, Q, R and S of a star like the Sun.

Planet	Average distance from the star / 10^6 km	Orbital period / days	Surface temperature / K
P	40	58	520
Q	75	150	390

Planet	Average distance from the star / 10^6 km	Orbital period / days	Surface temperature / K
R	190	?	250
S	410	1900	70

(a) State the relationship between distance from the star and surface temperature. (b) Which is the most likely orbital period of R: 90 days, 120 days, 600 days or 2500 days? (c) Give the surface temperature of S in °C.

5. **(Extended)** Two planets orbit a star in the same direction and start in a line with it. Planet A takes 4 years to orbit and planet B takes 10 years. Through what angle has each moved round the star after 3 years?

Answers

1. Neptune, Uranus, Saturn, Jupiter.
2. Two trips: $d = 2 \times 1.8 \times 10^{11} = 3.6 \times 10^{11}$ m. $t = \dfrac{3.6 \times 10^{11}}{3.0 \times 10^{8}} = 1200$ s $= 20$ minutes.
3. $T = 24 \times 3600 = 86\,400$ s. $v = \dfrac{2\pi \times 4.2 \times 10^{7}}{86\,400} = 3054$ m/s $\approx 3.1 \times 10^{3}$ m/s.
4. (a) As the distance from the star increases, the surface temperature decreases. (b) 600 days: R is between Q and S, so its period is between 150 and 1900 days, and further out than Q means longer than 150 days. (c) $70 - 273 = -203$ °C.
5. A: $\frac{3}{4}$ of an orbit, $\frac{3}{4} \times 360^{\circ} = 270^{\circ}$. B: $\frac{3}{10}$ of an orbit, $\frac{3}{10} \times 360^{\circ} = 108^{\circ}$.

Past questions to try

- **0625/42/F/M/25 Q10**: days for part of the Earth's orbit, seasons on an orbit diagram, and orbital speed.
- **0625/41/M/J/23 Q10**: how Pluto's speed changes round its elliptical orbit, explained with energy.
- **0625/11/M/J/24 Q38**: light travel time between Venus and the Earth, in km.
- **0625/43/M/J/23 Q9**: positions of Saturn and Jupiter after a number of years, and planetary data.