

Cambridge OCR GCSE Combined Science A — Physics

Topic P6

Global challenges

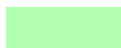
Specification J250 · Cambridge OCR

Free edition

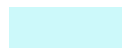
Revision notes for one topic, free to download.

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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Cambridge OCR GCSE (9–1) Combined Science A (Gateway Science) J250 · Specification reference P6 · Paper 6 (Foundation) / Paper 12 (Higher), with assumed knowledge of P1–P3

Define Thinking distance

- the distance travelled during the driver's reaction time, before braking begins.

Define Deceleration

- a negative acceleration; a rapid fall in speed.

Define National grid

- the network of transformers, cables and pylons carrying electrical power from power stations to users.

Define Transformer

- a device that changes the size of an alternating potential difference: **step-up** raises it, **step-down** lowers it.

Define Live wire

- brown, at about 230 V relative to earth; **neutral** — blue, at about 0 V; **earth** — green and yellow, a safety wire at 0 V.

Define Power

- the rate of energy transfer, in watts (W).

Define Efficiency

- useful output energy transfer ÷ input energy transfer.

Define Reaction time

- the time between a stimulus and the start of the response; typically 0.2–0.9 s.

Define Braking distance

- the distance travelled while the braking force acts.

Define Stopping distance

- thinking distance + braking distance.

Define Renewable resource

- one replenished as fast as it is used; a **non-renewable resource** has a finite supply and is used far faster than it forms.

Define Direct voltage (d.c.)

- a potential difference constant in size and direction.

Define Alternating voltage (a.c.)

- a potential difference that repeatedly reverses; UK mains is a.c. at **50 Hz** and about **230 V**.

Define Insulation

- a non-conducting covering that keeps live conductors out of reach.

P6.1 Physics on the move

This topic integrates knowledge and understanding of physical systems and processes and applies it to global challenges, so it draws together concepts from earlier topics. Here, forces and motion are used to develop ideas about how objects are affected by external factors, and how vehicles are designed to operate more safely.

Typical speeds and everyday accelerations (P6.1a, P6.1b)

Recall typical speeds encountered in everyday experience for wind and sound, and for walking, running, cycling and other transportation systems (P6.1a).

Motion	Typical speed	Motion	Typical speed
Walking	1.5 m/s	Car, town (30 mph)	13 m/s
Running	3 m/s	Car, motorway (70 mph)	31 m/s
Cycling	6 m/s	Train	55 m/s
Wind, breeze to gale	5–20 m/s	Aeroplane, cruising	250 m/s
Sound in air	330 m/s		

- **Estimate the magnitudes of everyday accelerations** (P6.1b). Free fall is about **10 m/s²**; a car reaching 13 m/s in about 6 s is roughly **2 m/s²**; emergency braking on a dry road is **6–7 m/s²**. Everyday accelerations are of order 1–10 m/s².
- These are **estimates**. Quote them to one or two significant figures and say what you assumed.

Measuring human reaction times (P6.1d)

Explain methods of measuring human reaction times and recall typical results.

- **Typical reaction times are 0.2–0.9 s** — about **0.25 s** in a ruler drop, nearer **0.7 s** for a driver, who must also recognise the hazard and decide what to do.
- **The ruler drop.** A partner drops a 1 m ruler between your open fingers without warning; the distance fallen converts to a time (about 20 cm is 0.2 s). Cheap and quick, but the fall distance must be converted, and it is easy to anticipate the drop.
- **A computer or phone reaction timer.** You click as soon as the screen changes. More **repeatable**, resolves to milliseconds and cannot be anticipated, so it is the better method.
- Both need **several trials and a mean**, discarding anomalies. **Factors that lengthen reaction time:** tiredness, alcohol, drugs including some medicines, distraction, age and illness.

Ratios, proportional reasoning and unit conversion (P6.1c)

Make calculations using ratios and proportional reasoning to convert units and to compute rates, including conversion from non-SI to SI units.

- mph → m/s: **divide by about 2.2**. km/h → m/s: **divide by 3.6**. km → m: × 1000. hours → seconds: × 3600.
- A **rate** is a quantity per unit time, so speed is a rate of change of distance and acceleration a rate of change of speed.
- **Proportional reasoning:** if a quantity is directly proportional, doubling one doubles the other; if it depends on the square, doubling one quadruples the other.

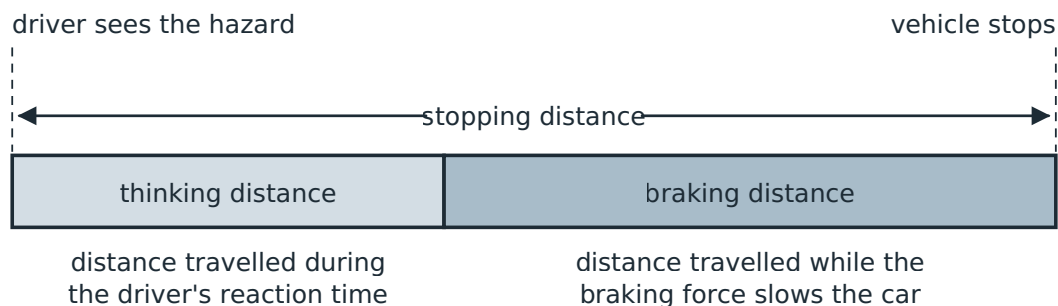
Factors affecting stopping distance (P6.1e)

Explain the factors which affect the distance required for road transport vehicles to come to rest in emergencies and the implications for safety, to include the factors affecting thinking, braking and overall stopping distance.

Factor	Affects thinking distance	Affects braking distance
Speed	Yes — in direct proportion to speed	Yes — as speed squared
Tiredness, alcohol, drugs, distraction	Yes — longer reaction time	No
Wet or icy road, mud, leaves	No	Yes — less friction at the tyre
Worn tyres or brakes	No	Yes — smaller braking force
Mass (load, passengers)	No	Yes — more kinetic energy to remove
Downhill gradient	No	Yes — weight acts down the slope

- **Thinking distance** = speed × reaction time, so it is **directly proportional to speed**. **Braking distance** depends on the kinetic energy $\frac{1}{2} m v^2$ that the brakes must remove, so it grows as **speed squared**: doubling the speed roughly **quadruples** it.
- **Implications for safety**: keep a safe separation (the two-second rule, doubled in the wet), obey speed limits, never drive when tired or after drinking, and maintain tyres and brakes. In the wet, braking distances roughly **double**; on ice they can be many times greater.

Thinking distance, braking distance and the factors that affect each.



$$\text{stopping distance} = \text{thinking distance} + \text{braking distance}$$

Factors affecting thinking distance

(= the driver's reaction time × the speed)

- the speed of the vehicle
- tiredness
- alcohol
- drugs
- distractions, eg using a phone

Typical reaction time: 0.2 s to 0.9 s.

Factors affecting braking distance

- the speed of the vehicle
- poor condition of the brakes
- poor condition of the tyres
- a wet or icy road surface
- the mass of the vehicle and its load
- a downhill gradient (slope)

Speed is the only factor affecting both.

Large decelerations are dangerous

- A greater braking force is needed to stop in a shorter distance, so the deceleration is larger.
- Work done by the friction force between the brakes and the wheel reduces the kinetic energy of the car, so the temperature of the brakes increases. Brakes may overheat and the driver may lose control.

WATCH OUT

Learners tend to **confuse the factors that affect thinking distance and braking distance**, thinking that **alcohol, drugs and tiredness will affect braking distance rather than thinking distance**. The distinction between these two terms needs to be clear, and that the combination of them gives the **stopping distance**.

Ask one question: **is the driver still reacting, or are the brakes already on?**

- Anything about the **driver** — tiredness, alcohol, drugs, distraction — affects **thinking distance only**.
- Anything about the **car or the road** — tyres, brakes, wet or icy surface, mass, slope — affects **braking distance only**.
- **Speed affects both**, and is the only factor that does.

ANALOGY

Stopping suddenly — concrete or a crash mat. You arrive with the same motion either way, and all of it has to go. On concrete you stop in milliseconds and the force is enormous; on a mat you sink in over half a second, so the same change is spread a hundred times longer and the force is a hundred times smaller. A crumple zone is a crash mat made of folding steel, and a seat belt one that stretches. Where it breaks down: the mat changes how **quickly** you stop, not how fast you were going.

HIGHER TIER

The dangers of large decelerations (P6.1f)

Explain the dangers caused by large decelerations.

- A large deceleration means, by $F = m a$, a **large force** on the vehicle and everyone in it — the cause of the injuries in a crash. Brakes and tyres overheat, and locked wheels skid so that steering is lost.
- **HT ONLY** From P2.2, the **change in momentum** ($p = m v$, PM2.2ii, Higher Tier) in a collision is fixed by the mass and speed, so **spreading that change over a longer time reduces the force**. Every safety feature works this way.
- **Safety features** — crumple zones, seat belts, air bags, helmets and crash mats — **increase the time and the distance taken to bring the occupant to rest**, so the force is smaller, and **spread the force over a larger area** so no one part of the body takes it all.

P6.2 Powering Earth

We are reliant on electricity for everyday life, and this topic explores its production: non-renewable and renewable resources, the problems of transporting electricity efficiently to homes and businesses, and safe use of electricity in the home. It is an opportunity to revisit power and efficiency.

Energy resources (P6.2a)

Describe the main energy sources available for use on Earth, compare the ways in which they are used, and distinguish between renewable and non-renewable sources. J250 names seven.

Resource, and how it is used	Renewable?	Advantages	Drawbacks
Fossil fuels (coal, oil, gas) — burned to raise steam for turbines; also transport and heating	Non-renewable	Reliable and available on demand; high output; existing infrastructure	Carbon dioxide , so global warming; sulfur dioxide and acid rain; finite; extraction damages habitats
Nuclear fuel (uranium) — fission raises steam for turbines	Non-renewable	No carbon dioxide when generating; huge output from little fuel; reliable	Radioactive waste dangerous for thousands of years; costly to build and decommission; accident risk
Biofuel — burned, or fermented to ethanol, in vehicles and power stations	Renewable	Carbon released was recently absorbed, so close to carbon neutral; grown locally	Land used for fuel not food; habitats cleared; particulates
Wind — turbines turn generators directly	Renewable	No fuel cost; no carbon dioxide when generating	Unreliable — nothing in calm or very strong winds; noise; visual impact
Hydroelectricity — reservoir water turns turbines	Renewable	Reliable; responds within seconds to peaks; long lifetime	Valleys flooded, habitats and communities lost; few suitable sites; high initial cost
Tides — an estuary barrage, water through turbines both ways	Renewable	Predictable ; large output; no carbon dioxide when generating	Damages estuary habitats; blocks shipping; very expensive; few estuaries
The Sun — photocells generate electricity, panels heat water	Renewable	No fuel or emissions when generating; good for remote sites	Varies with weather, season and time of day; nothing at night; low output per panel

- **Reliability** is the key comparison: fossil, nuclear and biofuel run on demand; wind and solar cannot; tidal is variable but **predictable**; hydroelectric responds fastest.

The national grid (P6.2c, P6.2d, P6.2e)

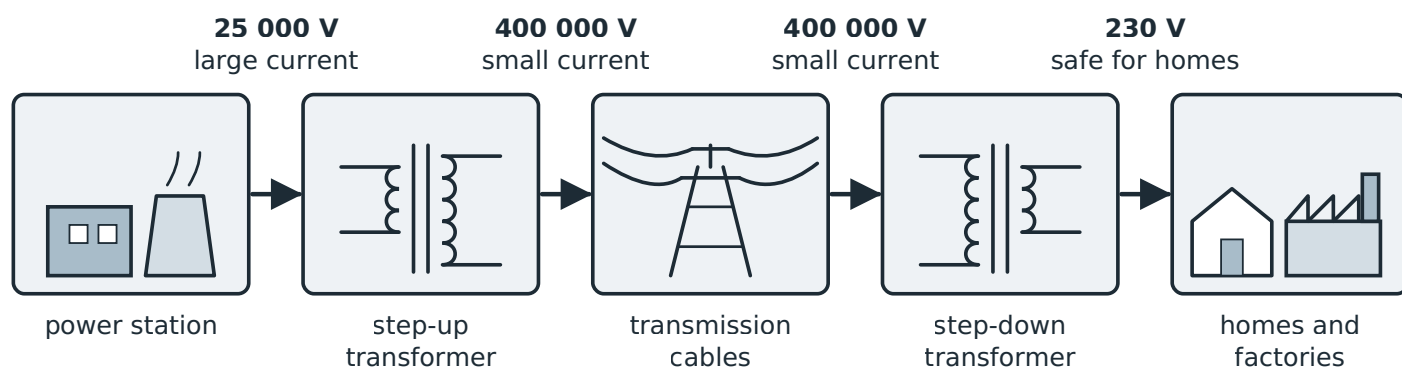
- In the national grid, electrical power is transferred at high voltages from power stations, and then transferred at lower voltages in each locality for domestic use (P6.2c) — up to 400 kV on the transmission lines, 230 V at the socket.
- Step-up and step-down transformers are used to change the potential difference as power is transferred from power stations (P6.2d): step-up at the power station, step-down at local substations. Transformers work on **a.c. only**, which is one reason the grid is a.c.
- Explain how the national grid is an efficient way to transfer energy (P6.2e). Since $P = VI$, raising the potential difference **lowers the current** for the same power. The energy dissipated by heating the cables is $P = I^2 R$, so a lower current cuts the losses **as the square**: at 400 kV rather than 25 kV the current is 16 times smaller and the heating loss about 256 times smaller. Thinner, cheaper cables then suffice, and transformers are themselves close to 100% efficient.

Patterns and trends in the use of energy resources (P6.2b)

Explain patterns and trends in the use of energy resources, to include **the changing use of different resources over time**.

- **Coal** dominated UK generation for most of the twentieth century and has almost disappeared. **Gas** rose sharply from the 1990s, being cheaper and lower in carbon dioxide.
- **Wind and solar have grown rapidly** as costs fell and governments set emissions targets; **nuclear** has held roughly steady as old stations close.
- UK demand is flat or falling as appliances become more efficient, while **world demand rises** with a growing population and development.
- The drivers are **cost, reliability, environmental impact, politics and public opinion** — the points to weigh in a six-mark evaluation.

The national grid, and why a high transmission potential difference cuts the energy wasted.



Reducing the energy dissipated in the cables

- The transmission cables have resistance, so some energy is dissipated by heating as current flows.
- A transformer does not change the power that is transferred: $P = VI$ stays the same. So if the p.d. is stepped up, the current is stepped down.
- The power wasted in the cables is $P = I^2R$, so it depends on the square of the current: halving the current cuts the wasted power to a quarter.
- A high potential difference and a low current therefore make the National Grid an efficient way of transferring energy.

$$P = I^2 R$$

P = power wasted in the cables, watts (W)

I = current in the cables, amperes (A)

R = resistance of the cables, ohms (Ω)

Stepping the potential difference up 16 times steps the current down 16 times, so the power wasted in the cables falls by $16^2 = 256$ times.

ANALOGY

Step-up transformers — a **wide, slow river**. You must deliver a fixed amount of water per second. As a narrow torrent it scours the banks away; as a wide, slow flow the same delivery does almost no damage. On the grid the "damage" is heating in the cables, which goes as the **current squared**, so a step-up transformer trades a large current at low potential difference for a small current at high potential difference. Where it breaks down: the high potential difference really is dangerous, which is why pylons are tall and their insulators long.

The domestic supply, direct and alternating voltage (P6.2f, P6.2g)

- The domestic supply in the UK is a.c. at 50 Hz and about 230 volts (P6.2f). 50 Hz means 50 complete cycles each second, so one cycle lasts 0.02 s.
- Explain the difference between direct and alternating voltage (P6.2g):

	Direct (d.c.)	Alternating (a.c.)
Direction and size	Always the same, constant	Reverses 100 times a second , rising and falling — 50 Hz means 50 complete cycles, and each cycle reverses the direction twice
Trace on an oscilloscope or data logger	A horizontal line above the zero line	A wave crossing the zero line
Source	Cells, batteries, d.c. supplies	Mains supply, generators
Use	Electronics, torches, phones	Mains distribution — only a.c. works in transformers

Mains wiring and electrical safety (P6.2h, P6.2i)

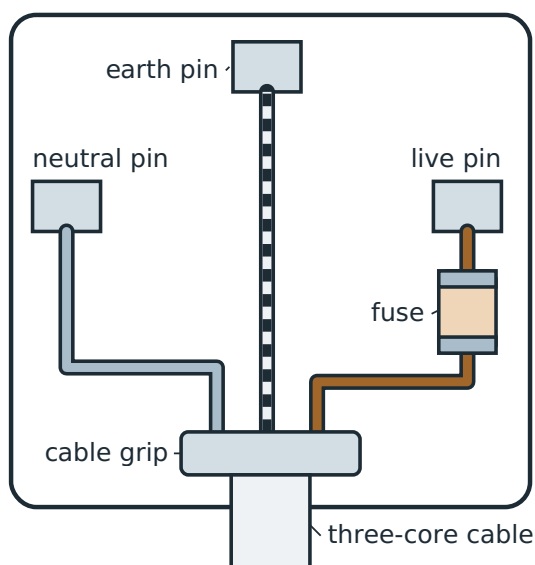
Recall the differences in function between the live, neutral and earth mains wires, and the potential differences between these wires (P6.2h).

Wire	Colour	Potential difference	Function
Live	Brown	About 230 V a.c. relative to earth	Carries the alternating potential difference in from the supply
Neutral	Blue	About 0 V	Completes the circuit back to the supply; live-to-neutral is about 230 V
Earth	Green and yellow	0 V	Safety wire carrying no current normally; earths a metal case so a fault current blows the fuse

Explain that a live wire may be dangerous even when a switch in a mains circuit is open, and explain the dangers of providing any connection between the live wire and earth, to include the protection offered by insulation of devices (P6.2i).

- The live wire sits at about 230 V relative to earth **whether the switch is open or closed**, so it is dangerous even with the appliance switched off. Isolate at the consumer unit before working on a circuit.
- **Your body conducts and the ground is at 0 V**, so any live-to-earth path — including one through a person — carries a **large current**, giving a severe or fatal shock and a fire risk.
- **Insulation** — cable sheathing, plug bodies and casings — keeps live conductors out of reach. **Double-insulated** appliances have a plastic case with no exposed metal and need **no earth wire**. The **fuse** or circuit breaker goes in the **live** wire, and its rating is chosen just above the normal current, from $I = P \div V$.

The wiring of a three-pin plug, and why the live wire is dangerous.



- live wire — brown
- neutral wire — blue
- earth wire — green and yellow stripes

Why the live wire is dangerous even when a switch is open

- A switch only breaks the circuit. It does not disconnect the live wire from the supply, so the live wire is still at about 230 V compared with earth (0 V).
- If you touch the live wire you complete a path from the live wire to earth. A current flows through your body and you get an electric shock, which can be fatal.
- Any connection between the live wire and earth causes a very large current, which can melt the fuse and can start a fire.
- The earth wire and the fuse work together: a fault current flows to earth, the fuse in the live wire melts and the appliance is cut off from the live supply.

wire	job it does	potential difference
live (brown)	carries the alternating potential difference from the supply to the appliance	about 230 V compared with earth
neutral (blue)	completes the circuit — it carries the current back to the supply	at or close to 0 V (earth potential)
earth (green and yellow stripes)	a safety wire that stops the metal case of the appliance becoming live; it carries a current only if there is a fault	0 V

WATCH OUT

Learners often **confuse the idea of energy with terms including the word power, such as solar power**. There are often difficulties in understanding that **higher voltages are applied across power lines and not along them**. Another common misconception is that **batteries and wall sockets have current inside them ready to escape**.

- **Power is the rate of energy transfer**, in watts; the Sun is an energy **resource**. Say "energy resource" and "power station", and quote power in W or kW.
- The 400 kV of a transmission line is the potential difference **between the line and earth** — across the gap, not along the wire. The p.d. **along** the cable is small, which is exactly why little energy is dissipated in it.
- Sockets and batteries store **charge** and provide a potential difference, not current. Current exists only when a **complete circuit** allows charge to flow.

NOTE

Not required by J250. Combined Science has **no** "Beyond Earth" sub-topic: no red-shift, no Big Bang or cosmic microwave background, no life cycle of a star, no solar system, satellites or orbits, and no radiation balance of the Earth — those are separate physics only. J250 also has **no** turns- ratio equation for transformers and **no** requirement to estimate stopping distances across a table of speeds. Paper 6 / Paper 12 carries **synoptic** assessment, so expect P4 and P5 ideas — waves, half- life, work, power and efficiency — inside P6 questions.