Course Companion

Pearson Edexcel · International GCSE · Physics

Every topic handout in one volume

全部专题讲义合集

exercises.lol

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Forces and motion

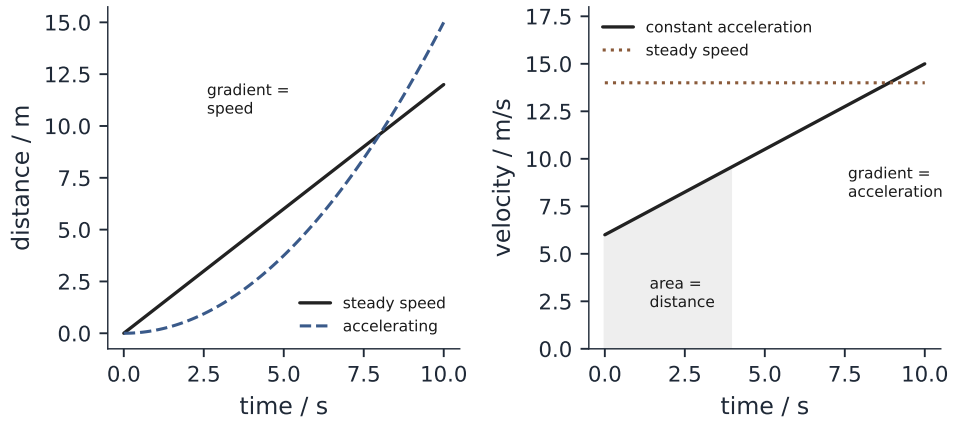
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Describing and explaining motion

Physics begins with movement. This first section builds the toolkit: graphs that describe motion, the equations that link speed, acceleration and distance, the forces that cause every change, and (P) the momentum and moments that explain crumple zones and balanced beams.

Edexcel International GCSE Physics 4PH1, Section 1 (statements 1.1–1.33P). P-suffixed statements are the separate-science extension, assessed on Paper 2P; units to learn include the newton (N) and, (P), the newton metre and kg m/s.

Movement and position



Distance-time and velocity-time graphs: gradient means speed on one, acceleration on the other.

Average speed = distance moved ÷ time taken. On a distance–time graph the **gradient** is the speed: a straight sloping line is steady speed, a curve is acceleration, a flat line is at rest. **Acceleration** 加速度 is the change of velocity per second:

$$a = \frac{v - u}{t} \qquad v^2 = u^2 + 2as$$

On a velocity–time graph the **gradient is acceleration** and the **area between the line and the time axis is the distance travelled**.

Worked check. A car accelerates from 4 m/s to 16 m/s in 6 s: $a = (16 - 4)/6 = 2$ m/s^2. Distance covered $= \frac{1}{2}(4 + 16) \times 6 = 60$ m.

Worked example ($v^2 = u^2 + 2as$). A car travelling at 20 m/s brakes with a deceleration of 5.0 m/s^2. How far does it travel before it stops?

The car stops, so $v = 0$; it slows down, so $a = -5.0$ m/s^2.

$$0 = 20^2 + 2(-5.0)s \quad \Rightarrow \quad s = \frac{400}{10} = 40 \text{ m}$$

At 40 m/s (twice the speed) the same brakes need $\frac{1600}{10} = 160$ m: four times as far, because the speed is squared.

Worked example (reading a velocity–time graph). A lift starts from rest, speeds up steadily to 3.0 m/s in 2.0 s, moves at 3.0 m/s for 6.0 s, then slows steadily to rest in 2.0 s. Distance = area under the graph = $\frac{1}{2}(2.0)(3.0) + (6.0)(3.0) + \frac{1}{2}(2.0)(3.0) = 3.0 + 18 + 3.0 = 24$ m. The acceleration at the start is $3.0 \div 2.0 = 1.5$ m/s^2.

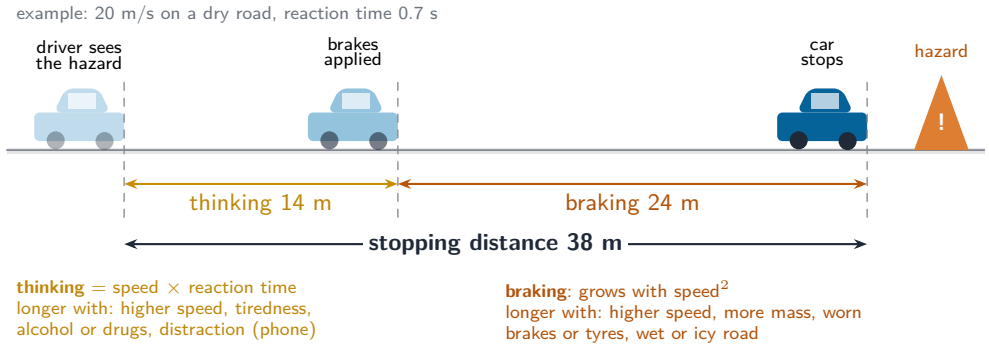
Forces and movement

Forces change a body's **speed, shape or direction**. Force is a **vector** 矢量 (size + direction); scalars like speed have only size. Along a line, forces add: two 5 N pulls against one 8 N pull give a **resultant force** 合力 of 2 N. **Friction** 摩擦 opposes relative sliding, or its tendency, between contacting surfaces. The unbalanced force causes acceleration:

$$F = m \times a \qquad W = m \times g$$

Worked check. A 1200 kg car with a driving force of 3600 N against 1200 N of drag: $F = 2400$ N; $a = 2400/1200 = 2$ m/s^2. Weight at $g = 10$ N/kg: $W = 1200 \times 10 = 12\,000$ N.

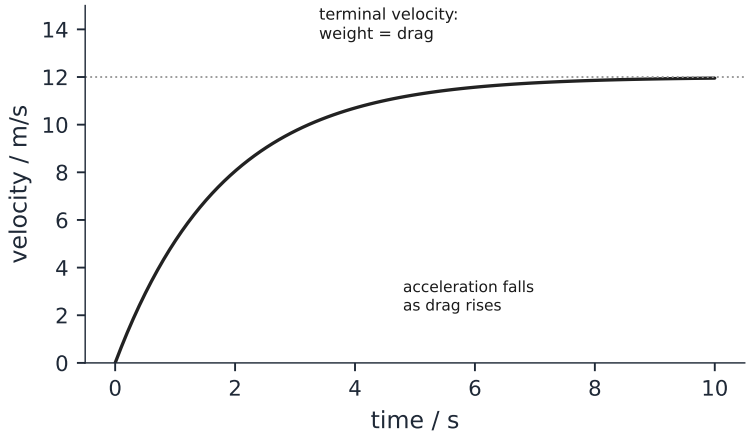
Stopping distance = thinking distance + braking distance. Thinking grows with speed and reaction time (tiredness, alcohol, phones); braking grows with speed squared, mass, weak brakes, poor grip (wet or icy roads, worn tyres).



Stopping distance splits into thinking distance and braking distance.

Worked example (thinking distance). A driver's reaction time is 0.70 s and the car moves at 25 m/s. Thinking distance = speed × reaction time = $25 \times 0.70 = 17.5$ m. If the braking distance at this speed is 48 m, the stopping distance is $17.5 + 48 = 65.5$ m, about 66 m. A tired driver with a reaction time of 1.4 s adds another 17.5 m.

Ignoring upthrust in this falling-in-air model, **falling objects** accelerate while weight exceeds drag; as speed rises, drag rises, the resultant falls, until **weight = drag** – **terminal velocity** 终末速度.



Velocity against time for a falling object levelling at terminal velocity.

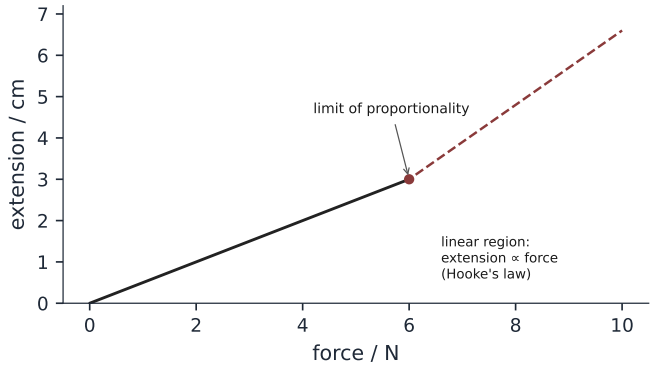
Forces and shape

A spring stretches with load. In the **initial linear region, extension is proportional to force – Hooke's law** 胡克定律; beyond the **limit of proportionality** it bends away. **Elastic behaviour** 弹性 recovers the original shape when the force is removed. Practical: hang masses on a spring (or rubber band), plot force against extension.



A spring obeys Hooke's law: up to the limit of proportionality, extension is proportional to the force

> **Worked example.** A spring is 8.0 cm long with no load. With a 2.0 N load it is 10.5 cm long. Extension $= 10.5 - 8.0 = 2.5$ cm. If it obeys Hooke's law, a 4.0 N load gives twice the extension, 5.0 cm, so the spring is $8.0 + 5.0 = 13.0$ cm long, not $2 \times 10.5 = 21$ cm.



A force-extension graph with a linear region to the limit of proportionality.

Momentum and moments (P)

$$p = m \times v \qquad F = \frac{mv - mu}{t}$$



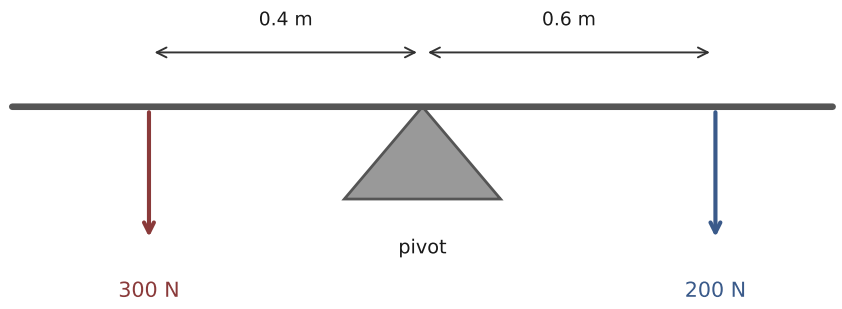
In a crash a large force acts for a short time; crumple zones lengthen that time and so reduce the force

Momentum 动量 (kg m/s) is conserved when the resultant external force on the chosen system is zero; over a short collision, negligible external impulse gives total before ≈ total after.

> **Worked example (P).** A 1200 kg car moving at 15 m/s hits a stationary 800 kg car and they move off together. Total momentum before $= 1200 \times 15 + 800 \times 0 = 18\,000$ kg m/s. After, the combined mass is 2000 kg, so $v = 18\,000 \div 2000 = 9.0$ m/s.

If the collision lasted 0.15 s, the force on the 800 kg car was $F = \dfrac{mv - mu}{t} = \dfrac{800 \times 9.0 - 0}{0.15} = 48\,000$ N. A crumple zone that stretched the time to 0.30 s would halve this force. **Safety features** work by stretching the time of a collision, so for the same momentum change the force is smaller – crumple zones, seat belts, airbags. **Newton's third law**: to every action there is an equal and opposite reaction.

Moment 力矩 = force × perpendicular distance from the pivot. A beam balances when **clockwise moments = anticlockwise moments**; the weight of a body acts through its **centre of gravity** 重心.



anticlockwise 300 N × 0.4 m = clockwise 200 N × 0.6 m = 120 N m

A loaded beam with two weights on supports: clockwise moments equal anticlockwise moments.

Worked check. Two children (300 N at 0.4 m, 200 N at 0.6 m from the pivot) on a see-saw: clockwise $200 \times 0.6 = 120$ N m; anticlockwise $300 \times 0.4 = 120$ N m – balanced.

Common mistakes

- Using $v^2 = u^2 + 2as$ with a positive when the object is slowing down. A deceleration goes in as a negative acceleration.
- Doubling the length of a spring instead of its extension when the load doubles. Only the extension is proportional to the force.
- Saying no forces act on a skydiver at terminal velocity. Weight and drag both act; they are equal, so the *resultant* force is zero.
- Forgetting that velocity has direction in momentum questions. If two objects move towards each other, give one velocity a minus sign.
- Measuring a moment's distance along the beam to a force that is not perpendicular. Use the perpendicular distance from the pivot to the line of the force.
- Thinking that alcohol or tiredness increase the braking distance. They increase the reaction time, so the *thinking* distance.

Check yourself

1. What does the gradient of a distance-time graph give, and of a velocity-time graph?
2. A cyclist covers 900 m in 3 minutes. Calculate the average speed in m/s.
3. Calculate the acceleration from 30 m/s to rest in 5 s.
4. State the equation linking unbalanced force, mass and acceleration, and its unit.
5. Name two factors that lengthen the thinking distance and two that lengthen the braking distance.
6. Explain, in terms of forces, why a skydiver reaches terminal velocity.
7. State Hooke's law.
8. (P) A 60 kg runner at 8 m/s: calculate momentum.
9. (P) Explain how a crumple zone protects passengers.
10. (P) What is the moment of a 50 N force at 0.3 m from the pivot?

Answers: 1 speed; acceleration (and the area under the velocity-time line is distance); 2 $900/180 = 5$ m/s; 3 $a = (0 - 30)/5 = -6$ m/s^2 (deceleration of 6 m/s^2); 4 F = ma, with F in newtons; 5 thinking – higher speed, longer reaction time; braking – higher speed (speed^2), mass, poor brakes/tyres, wet or icy roads; 6 drag rises with speed until it equals the weight – resultant and acceleration reach zero, so velocity is constant; 7 extension is proportional to force, up to the limit of proportionality; 8 (P) $p = 60 \times 8 = 480$ kg m/s; 9 (P) it crumples, lengthening the collision time; force = momentum change ÷ time, so a longer time means a smaller force on the passengers; 10 (P) $50 \times 0.3 = 15$ N m.

Electricity

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The energy you cannot see

Press a switch and a room lights. Between the power station and the lamp stands everything in this section: how domestic wiring keeps you safe, how voltage drives current through circuits, and – (P) – how electrons rubbed from one surface to another make charges that attract, repel and sometimes spark.

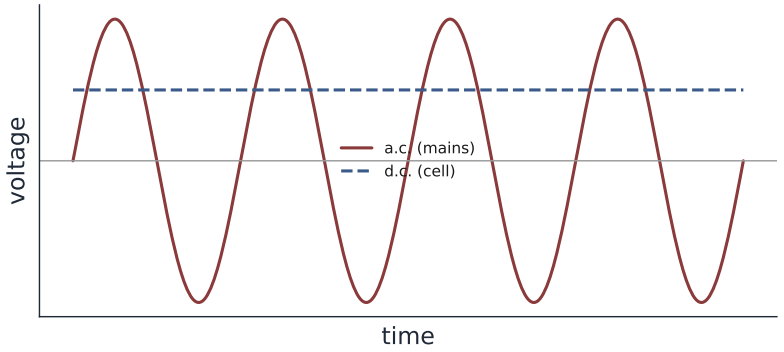
Edexcel International GCSE Physics 4PH1, Section 2 (statements 2.1–2.28P). Units: ampere (A), coulomb (C), joule (J), ohm (Ω), volt (V), watt (W). P-suffixed statements are the Physics-only extension, assessed on Paper 2P.

Mains electricity

Mains electricity is **alternating current (a.c.)** 交流电 – direction reverses many times a second; a cell gives **direct current (d.c.)** 直流电 – one direction only.



A consumer unit: circuit breakers cut the current when a fault makes it too large



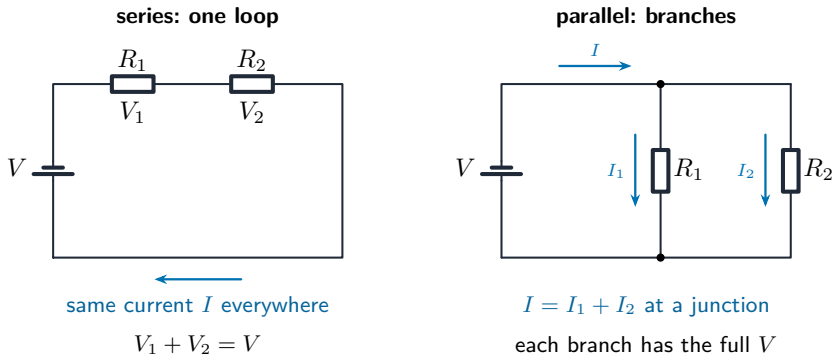
An a.c. trace oscillates about zero; a d.c. line is flat.

Safety: insulation on wires; **double insulation** (plastic casing, no earth needed); **earthing** 接地 (a low-resistance path so a fault current blows the fuse); **fuses** 保险丝 and **circuit breakers** 断路器 (melt or trip on excess current, protecting wiring and people). Current in a resistor transfers electrical energy to **thermal** energy – the point of kettles and heaters, and the reason fuse ratings matter:

$$P = I \times V \qquad E = I \times V \times t$$

Worked check (fuse choice). A 230 V, 1.15 kW heater draws $I = P/V = 1150/230 = 5$ A – fit a 13 A fuse (next standard rating above the current); a 3 A fuse would blow in normal use.

Circuits



Series: one loop, same current, voltages add. Parallel: branches share the same voltage, currents add.

Series 串联 suits chains (switches, ammeters, fairy lights) – the same current every-

where, voltages add, and one failure breaks all. **Parallel** 并联 suits domestic lighting – each lamp gets the full supply voltage, works independently, and currents add at junctions (**charge is conserved at a junction**).

$$V = I \times R \qquad Q = I \times t \qquad E = Q \times V$$

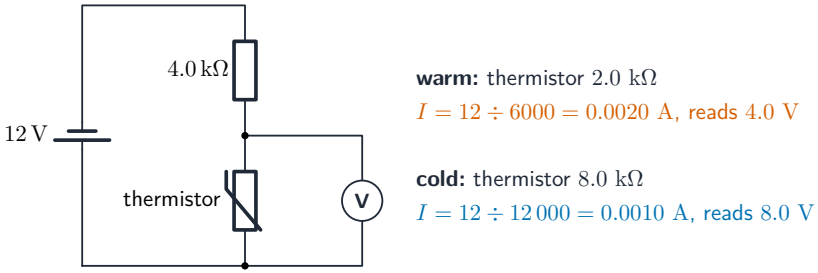
Current is a **flow of negatively charged electrons** in metals. Voltage is the **energy transferred per unit charge** (1 V = 1 J/C). Two resistors in series: $R = R_1 + R_2$; in parallel the combined resistance is less than either alone.

> **Worked example (charge and energy).** A phone charger delivers 2.0 A at 5.0 V for 30 minutes. Time in seconds: $t = 30 \times 60 = 1800$ s. Charge: $Q = It = 2.0 \times 1800 = 3600$ C. Energy: $E = QV = 3600 \times 5.0 = 18\,000$ J. The same answer comes from $E = IVt = 2.0 \times 5.0 \times 1800$.

I–V characteristics 伏安特性: an ohmic wire at constant temperature gives a straight line through the origin (constant resistance); a filament lamp curves as heating raises its resistance; a diode conducts in one direction only. **LDRs**: resistance falls as light rises. **Thermistors**: resistance falls as temperature rises (or rises as it cools – used in temperature sensors). Lamps and LEDs indicate current.

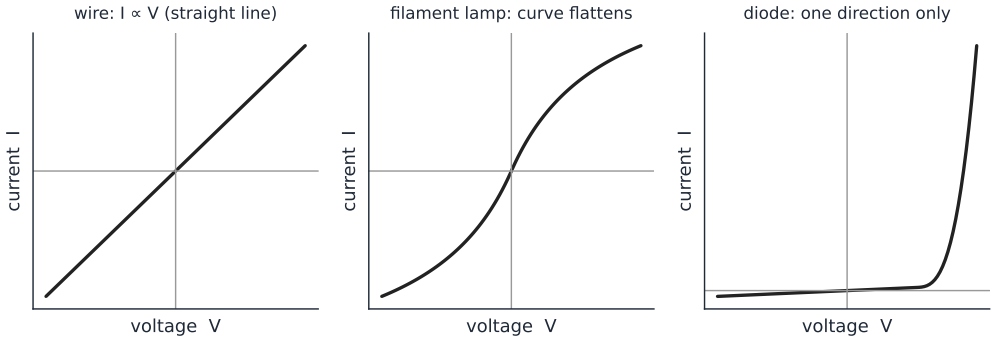
> **Worked example (a temperature sensor).** A thermistor and a fixed 4.0 kΩ resistor are in series across a 12 V supply. A voltmeter reads the voltage across the thermistor.

- Warm room, thermistor 2.0 kΩ: total $R = 6.0$ kΩ, so $I = 12 \div 6000 = 0.0020$ A. Voltage across the thermistor $= IR = 0.0020 \times 2000 = 4.0$ V.
- Cold room, thermistor 8.0 kΩ: total $R = 12$ kΩ, so $I = 0.0010$ A. Voltage across the thermistor $= 0.0010 \times 8000 = 8.0$ V.



Colder means more thermistor resistance, so the thermistor takes a bigger share of the 12 V

Colder means a higher thermistor resistance, so it takes a bigger share of the 12 V. The voltmeter reading can switch on a heater when it rises above a set value. Check: in each case the two voltages add to 12 V ($4.0 + 8.0$ and $8.0 + 4.0$).



I-V curves for a wire, a filament lamp and a diode.

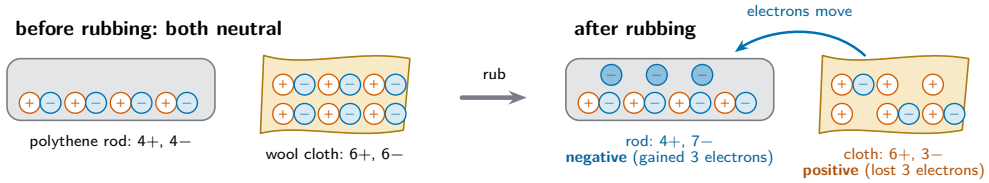
Worked check. Two resistors, 4 Ω and 6 Ω, in series across 10 V: total 10 Ω, $I = 10/10 = 1$ A; voltages 4 V and 6 V. In parallel across 10 V: each branch draws $10/4 = 2.5$ A and $10/6 \approx 1.67$ A – total ≈ 4.17 A, equivalent resistance ≈ 2.4 Ω (less than either).

Electric charge (P)

Conductors (metals) let charge flow; **insulators** (plastics) 绝缘体 do not.



Every hair gains the same charge from the dome, and like charges repel, so the hairs push apart



Rubbing transfers electrons from cloth to rod: the rod becomes negative, the cloth positive.

Rubbing an insulator transfers **electrons**: the loser becomes **positive**, the gainer **negative** – never protons moving. **Unlike charges attract; like charges repel.** A charged rod attracts tiny uncharged paper because it **induces** charge separation. Dangers: sparks while fuelling aircraft and tankers – earthed bonds drain charge safely. Uses: photocopiers and inkjet printers steer charged toner or droplets.

Common mistakes

- Leaving time in minutes or hours in $Q = It$ or $E = IVt$. Use seconds.
- Saying current is used up by a lamp. In a series circuit the current is the same everywhere; it is energy that is transferred.
- Adding resistances in parallel. The combined resistance of a parallel pair is *less* than the smaller one.
- Choosing a fuse rating equal to or just below the working current. It must be above the working current, or it melts in normal use.
- Saying an LDR's resistance rises in bright light, or a thermistor's rises when hot. Both fall: brighter or hotter means lower resistance.
- (P) Saying positive charges move when an insulator is rubbed. Only electrons are transferred.

Check yourself

1. State the difference between a.c. and d.c. and give one source of each.
2. Explain how earthing and a fuse work together to protect a user.
3. A 230 V kettle is rated 2.0 kW. Calculate the current and the best fuse.
4. State two reasons domestic lighting is wired in parallel.
5. State the I–V shapes for a wire, a filament lamp and a diode.
6. What happens to an LDR's resistance in bright light?
7. Define voltage in terms of energy and charge.
8. Calculate the charge passing when 2 A flows for 30 s.
9. (P) Explain how rubbing a polythene rod with a cloth makes it negative.
10. (P) Give one danger and one use of electrostatic charge.

Answers: 1 a.c. reverses direction repeatedly – the mains; d.c. flows one way – a cell or battery; 2 the earth wire gives a low-resistance path, so the large fault current flows to earth and melts the fuse, cutting off the supply before a user can touch the live casing; 3 $I = 2000/230 = 8.7$ A – a 13 A fuse; 4 each lamp receives the full mains voltage; one lamp failing leaves the others working (and switches control lamps independently); 5 straight line through the origin; S-shaped curve (gradient falls as it heats); zero until a forward threshold then steep (one direction); 6 it falls; 7 voltage is the energy transferred per unit charge (1 volt = 1 joule per coulomb); 8 $Q = 2 \times 30 = 60$ C; 9 (P) friction transfers electrons from the cloth to the rod – the rod gains electrons and becomes negative, the cloth positive; 10 (P) danger – sparking while fuelling aircraft/tankers; use – photocopier or inkjet printer.

Waves

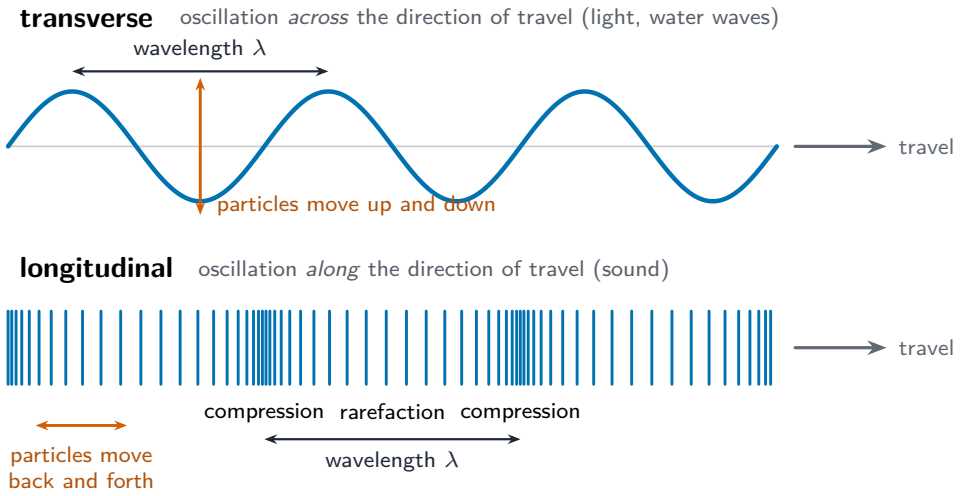
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Waves: energy that travels

Ripples cross a pond, light crosses a room, sound crosses air – waves carry **energy and information without transferring matter**. This section gives you their vocabulary and equations, the electromagnetic spectrum with its uses and dangers, and the behaviour of light and (P) sound: reflection, refraction and total internal reflection.

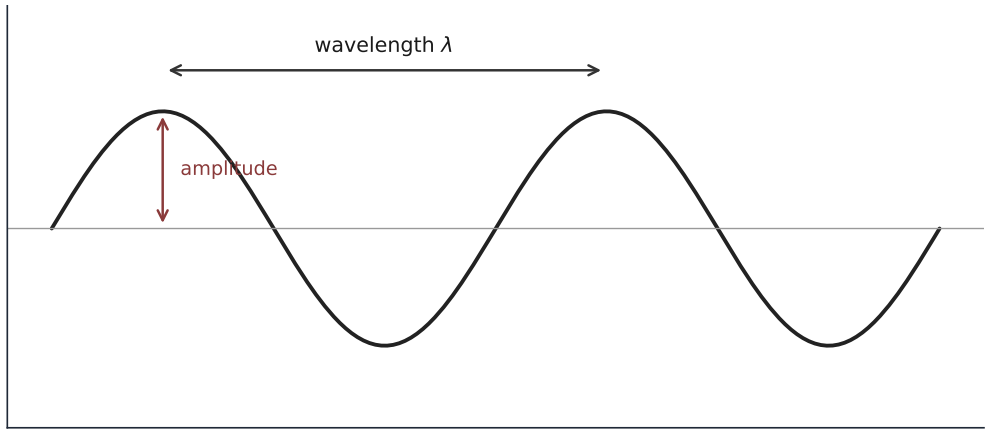
Edexcel International GCSE Physics 4PH1, Section 3 (statements 3.1–3.29P). Units: degree (°), hertz (Hz), metre (m), m/s, second (s).

Properties of waves



A transverse wave oscillates across its travel; a longitudinal wave oscillates along it, making compressions.

Transverse waves 横波 oscillate perpendicular to travel (light, water). **Longitudinal** waves 纵波 oscillate along the travel direction as compressions and rarefactions (sound). Vocabulary: **amplitude** 振幅 (maximum displacement), **wavelength** λ 波长 (one crest to the next), **frequency** f 频率 (waves per second, Hz), **period** T (time per wave), **wavefront** (a line of simultaneous crests).



A labelled wave with amplitude and wavelength marked.

$$v = f \times \lambda \qquad f = \frac{1}{T}$$

Worked check. A 340 Hz sound wave at 340 m/s: $\lambda = 340/340 = 1$ m; period $= 1/340 \approx 2.9$ ms. The **Doppler effect** 多普勒效应: a source moving towards an observer bunches wavefronts – higher observed frequency; moving away stretches them – lower.

The electromagnetic spectrum

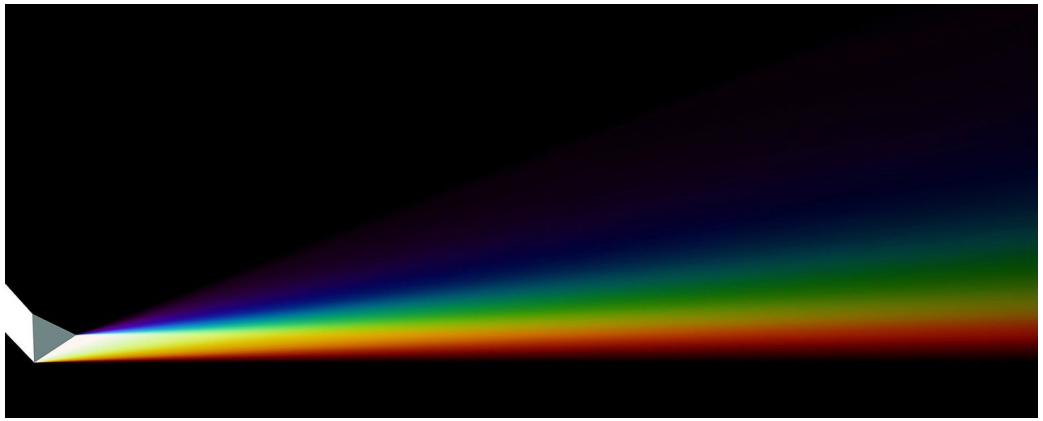
One family, same speed in free space, ordered by decreasing wavelength (increasing frequency): **radio → microwave → infrared → visible (red to violet) → ultraviolet → X-ray → gamma**.

Radiation	Use	Danger
radio	broadcasting, communications	–
microwave	cooking, satellite TV	internal heating of tissue
infrared	heaters, night vision	skin burns
visible	optical fibres, photography	–
ultraviolet	fluorescent lamps	damage to surface cells, blindness
X-ray	imaging inside objects/bodies	cancer, mutation (ionising)
gamma	sterilising food and equipment	cancer, mutation

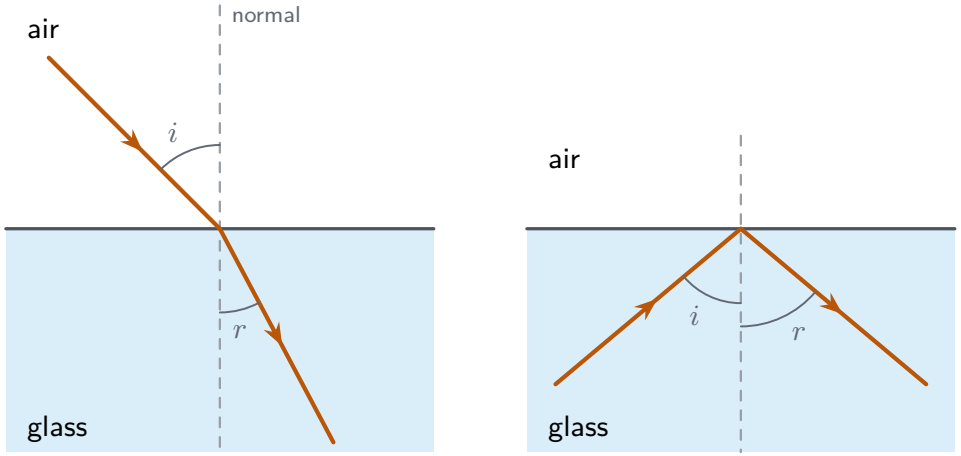
Protection: limit exposure time, shielding, sun cream (UV).

Light and sound

Light is **transverse** and reflects and refracts. **Law of reflection**: angle of incidence = angle of reflection. **Refraction** 折射: entering glass (optically denser), light slows and bends **towards the normal**; leaving, it bends away.



A glass prism refracts each colour by a different amount, splitting white light into a spectrum



entering glass the ray slows and bends *towards* the normal: $r < i$

inside the glass, i greater than the critical angle: *all* the light reflects, $r = i$

Refraction towards the normal entering glass; total internal reflection beyond the critical angle.

$$n = \frac{\sin i}{\sin r} \qquad \sin c = \frac{1}{n}$$

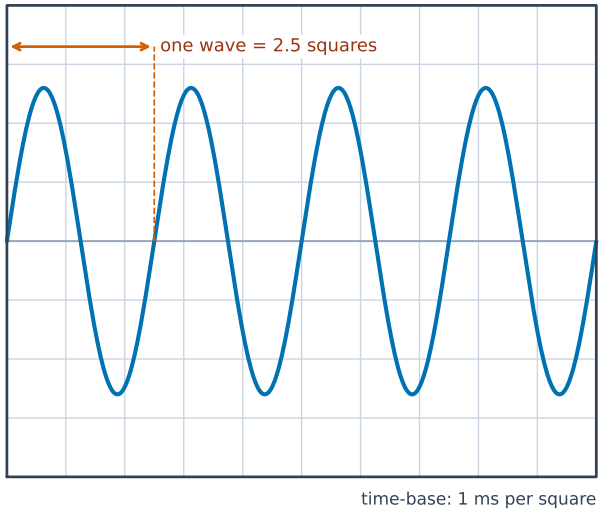
> **Worked example (Snell's law).** A ray in air meets a glass block at an angle of incidence of 50°; the angle of refraction is 30°. Refractive index $n = \dfrac{\sin 50^\circ}{\sin 30^\circ} = \dfrac{0.766}{0.500} = 1.53$. Both angles are measured from the **normal**: a ray at 50° to the *surface* has an angle of incidence of only 40°.

Total internal reflection 全内反射 happens at a boundary from higher to lower refractive index when the incidence angle, measured from the normal, exceeds the **critical angle** 临界角 – the principle of optical fibres (communications, endoscopes) and prisms in periscopes.

Worked check. Glass with $n = 1.5$: $\sin c = 1/1.5 = 0.667$, so $c \approx 41.8^\circ$. A ray inside the glass hitting the boundary at 45° exceeds 41.8° – totally internally reflected.

(P) Sound is longitudinal, 20–20 000 Hz for human hearing; pitch rises with frequency, loudness with amplitude. An oscilloscope with a microphone displays the wave; practicals time echoes or resonances to find the speed of sound in air.

> **Worked example (P) (reading an oscilloscope).** A sound wave on an oscilloscope screen shows exactly 4 complete waves across 10 squares; the time-base is set to 1 ms per square. One wave covers 2.5 squares, so the period $T = 2.5 \times 1$ ms $= 2.5$ ms $= 0.0025$ s and $f = 1/T = 400$ Hz. If the sound is made louder at the same pitch, the waves get taller (bigger amplitude) but still take 2.5 squares each.



Count squares for one complete wave, then multiply by the time-base

Worked example (P) (echo). A student claps 165 m from a wall and hears the echo 1.0 s later. The sound travels there and back, $2 \times 165 = 330$ m, so $v = 330 \div 1.0 = 330$ m/s.

Common mistakes

- Measuring angles from the surface. Angles of incidence, reflection and refraction are measured from the normal.
- Saying total internal reflection happens as light goes *into* glass. It only happens inside the denser material, at an angle bigger than the critical angle.
- Mixing up which waves are transverse. Light and all electromagnetic waves are transverse; sound is longitudinal.
- Counting oscilloscope squares for the whole screen as one period. Count the squares for *one* complete wave, then multiply by the time-base.
- Forgetting the echo travels there and back. Double the distance (or halve the time).
- Saying electromagnetic waves of higher frequency travel faster. All of them travel at the same speed in a vacuum.

Check yourself

1. Give one similarity and one difference between transverse and longitudinal waves.
2. Define amplitude, wavelength and frequency.
3. A wave of frequency 500 Hz travels at 340 m/s. Calculate its wavelength.
4. State the order of the electromagnetic spectrum by increasing frequency.
5. Give one use each of microwaves, infrared and gamma rays, and one danger of UV.
6. State the law of reflection.
7. Which way does light bend entering glass, and leaving it?
8. Glass has n = 1.5. Calculate the critical angle.
9. (P) State the human hearing frequency range, and what raises pitch and loudness.
10. (P) How does an oscilloscope trace change when a sound gets louder at the same pitch?

Answers: 1 both transfer energy without transferring matter; transverse oscillates across the travel direction (light), longitudinal along it as compressions (sound); 2 amplitude – maximum displacement from the rest position; wavelength – distance between successive identical points; frequency – number of waves passing per second; 3 $\lambda = 340/500 = 0.68$ m; 4 radio, microwave, infrared, visible, ultraviolet, X-ray, gamma; 5 microwaves – cooking/satellite; infrared – heaters/night vision; gamma – sterilising; UV damages surface cells and can blind; 6 angle of incidence = angle of reflection; 7 towards the normal entering, away from the normal leaving; 8 $\sin c = 1/1.5$, $c \approx 41.8°$; 9 (P) 20–20 000 Hz; higher frequency raises pitch, larger amplitude raises loudness; 10 (P) the trace's peaks grow taller (amplitude) while the number of cycles per second (frequency) stays the same.

Energy resources and energy transfers

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Energy: stored, transferred, wasted

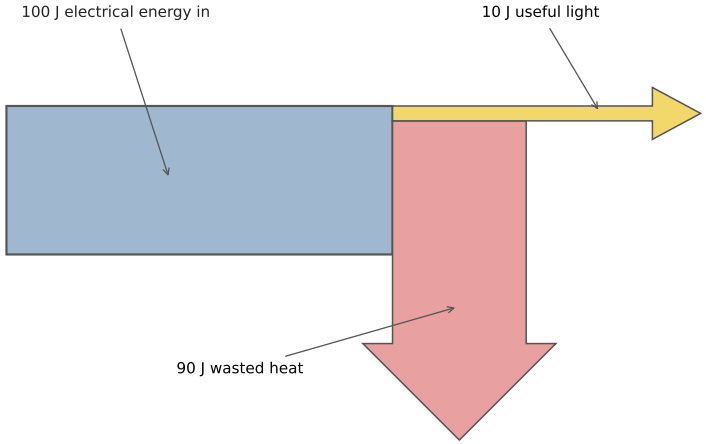
Nothing uses energy up – energy only moves between **stores** and leaks along the way. This section names the stores and transfers, measures **efficiency** 效率 with **Sankey diagrams** 桑基图, follows heat by conduction, convection and radiation, links work, GPE and kinetic energy, and (P) weighs how electricity is generated.

Edexcel International GCSE Physics 4PH1, Section 4 (statements 4.1–4.19P). Units: joule (J), watt (W), newton (N), and (P) J/kg °C.

Energy transfers

Eight **stores**: chemical, kinetic, gravitational, elastic, thermal, magnetic, electrostatic, nuclear. Four **transfer pathways**: mechanically, electrically, by heating, by radiation (light and sound). Energy is **conserved** – the total is unchanged; devices just divert part of it from the store we want to ones we do not.

$$\text{efficiency} = \frac{\text{useful energy output}}{\text{total energy output}} \times 100\%$$



A Sankey diagram: an incandescent lamp turns 100 J of electrical energy into 10 J of light and 90 J of wasted heat.

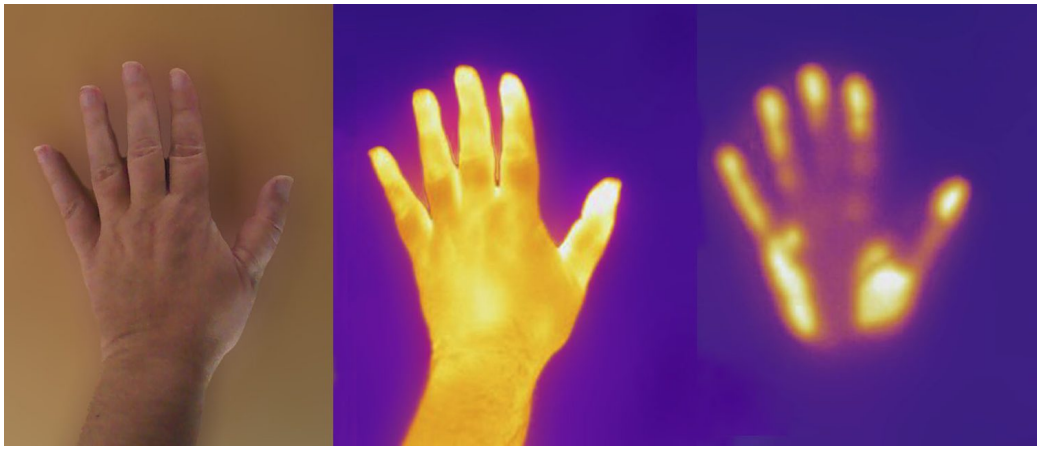
Worked check. The lamp above: efficiency $= 10/100 \times 100 = 10\%$.

> **Worked example (efficiency both ways).** A kettle takes 2000 J of electrical energy and 1800 J of it heats the water; the other 200 J heats the kettle and the air. Efficiency $= 1800/2000 \times 100 = 90\%$.

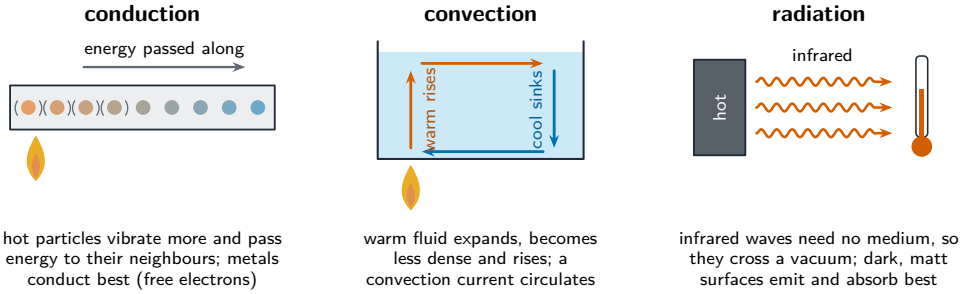
Working backwards: a lamp is 25% efficient and gives out 15 J of light each second. The input must be $15 \div 0.25 = 60$ J each second, so it is a 60 W lamp; the other 45 J each second is wasted as heat.

Thermal energy transfer

Heat moves three ways, each with its own mechanism and each beaten by a different defence.



A hand in visible light and through a thermal camera: warm objects radiate infrared



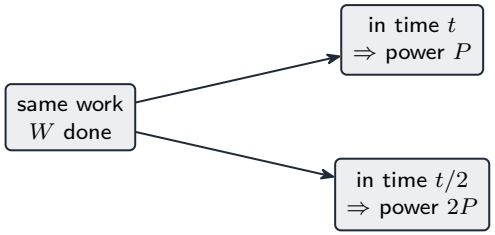
Conduction passes energy particle to particle; convection circulates a fluid; infrared radiation needs no medium.

Conduction 传导: particle vibrations pass energy along a solid – fast in metals (free electrons). **Convection** 对流: fluid warms, expands, becomes less dense and rises; cooler fluid sinks to replace it – sea breezes, radiators heating rooms. **Radiation** 辐射:

infrared waves travel through a vacuum; **dark, dull surfaces** are the best emitters and absorbers; light, shiny surfaces reflect. Reducing unwanted transfer: insulation (cavity wall, loft, double glazing cuts conduction and convection; shiny foil reflects radiation).

Work, power and the energy equations

$$W = F \times d \qquad GPE = mgh \qquad KE = \tfrac{1}{2}mv^2 \qquad P = \frac{W}{t}$$



$P = \dfrac{W}{t}$ — less time, more power

The same work done in less time means more power

Work done equals energy transferred. Falling, GPE converts to KE (minus work against drag).

Worked check. A 2 kg book lifted 1.5 m at g = 10 N/kg: $GPE = 2 \times 10 \times 1.5 = 30$ J. Dropped, at the ground $KE = 30$ J $\rightarrow v = \sqrt{2 \times 30/2} = \sqrt{30} \approx 5.5$ m/s. A 60 W lamp runs 10 s: $W = 60 \times 10 = 600$ J.

> **Worked example (KE turns into GPE).** A 0.50 kg ball is thrown straight up at 8.0 m/s. Ignore air resistance ($g = 10$ N/kg).

- Kinetic energy at the start: $KE = \frac{1}{2} \times 0.50 \times 8.0^2 = \frac{1}{2} \times 0.50 \times 64 = 16$ J. Square the speed first.
- At the top all 16 J is GPE: $h = \dfrac{GPE}{mg} = \dfrac{16}{0.50 \times 10} = 3.2$ m.

A 1.0 kg ball thrown at the same speed also reaches 3.2 m: the mass cancels.

> **Worked example (power and efficiency together).** An electric motor lifts a 20 kg load through 3.0 m in 5.0 s. Useful work = $mgh = 20 \times 10 \times 3.0 = 600$ J, so useful power = $600 \div 5.0 = 120$ W. The motor takes 1000 J of electrical energy in that time, so its efficiency is $600/1000 \times 100 = 60\%$.

Energy resources and electricity generation (P)

Every power station is an energy-transfer chain from a store to electricity; the table names the seven the specification requires.

Method	Energy transfer	Advantages	Disadvantages
wind	kinetic → electrical	renewable, no fuel cost	unreliable, visual/noise impact
hydroelectric	gravitational → electrical	renewable, instant supply	floods valleys, few sites
geothermal	thermal → electrical	renewable, steady	few suitable locations
solar heating	radiation → thermal (hot water)	renewable, no running cost	daytime/cloud dependent
solar cells	light → electrical	renewable, silent	expensive, low intensity output
fossil fuels	chemical → thermal → electrical	reliable, concentrated	CO_2 emissions, non-renewable
nuclear	nuclear → thermal → electrical	huge energy per kg, no CO_2	radioactive waste, decommissioning

Common mistakes

- Giving an efficiency above 100%, or mixing a decimal (0.6) with a percentage (60%). Check that useful output ≤ total input, and say which form you use.
- Saying energy is used up. It is transferred to other stores, mostly the thermal store of the surroundings, where it is no longer useful.
- Forgetting to square the speed in $KE = \frac{1}{2}mv^2$, or using mass in grams. Use kilograms, and square v before multiplying.
- Saying shiny surfaces are good emitters. Dark, dull surfaces are the best emitters *and* absorbers of infrared; shiny surfaces reflect it.
- Saying heat rises. Hot *fluid* rises because it expands and becomes less dense; convection cannot happen in a solid.
- Calling a renewable resource reliable. Wind and solar are renewable but depend on the weather.

Check yourself

1. Name four energy stores and two transfer pathways.
2. A motor uses 500 J and delivers 350 J of useful work. Calculate the efficiency.
3. Name the three thermal transfer methods and the one needing no medium.
4. Which surfaces emit infrared best?

5. State two ways a house reduces unwanted heat loss.
6. Calculate the work done by a 40 N force moving 3 m.
7. Calculate the KE of a 800 kg car at 20 m/s.
8. A heater transfers 12 000 J in 30 s. Calculate its power.
9. (P) Give one advantage and one disadvantage each of wind and nuclear power.
10. (P) Which two renewable methods use energy already stored, as heat deep in the ground or as gravitational energy of water held behind a dam?

Answers: 1 chemical, kinetic, gravitational, thermal (also elastic, magnetic, electrostatic, nuclear); mechanically and electrically (also heating, radiation); 2 $350/500 \times 100 = 70\%$; 3 conduction, convection, radiation – radiation needs no medium; 4 dark, dull (matt black) surfaces; 5 loft/cavity-wall insulation and double glazing (also reflective foil, draught excluders); 6 $W = 40 \times 3 = 120$ J; 7 $KE = \frac{1}{2} \times 800 \times 400 = 160\,000$ J; 8 $P = 12\,000/30 = 400$ W; 9 (P) wind – renewable with no fuel cost, but unreliable and visually intrusive; nuclear – enormous energy per kilogram with no CO_2, but radioactive waste must be stored safely for centuries; 10 (P) geothermal (ground heat) and hydroelectric (gravitational store of water).

Solids, liquids and gases

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Matter under pressure

The same substance can be solid, liquid or gas, and its molecules never stop moving. This section measures matter: density and pressure, the (P) energy needed to heat or melt things, and the ideal-gas behaviour that links pressure, volume and temperature.

Edexcel International GCSE Physics 4PH1, Section 5 (statements 5.1–5.22). Units include the pascal (Pa), kelvin (K) and (P) J/kg °C.

Density and pressure

$$\rho = \frac{m}{V} \qquad p = \frac{F}{A} \qquad p = h \times \rho \times g$$



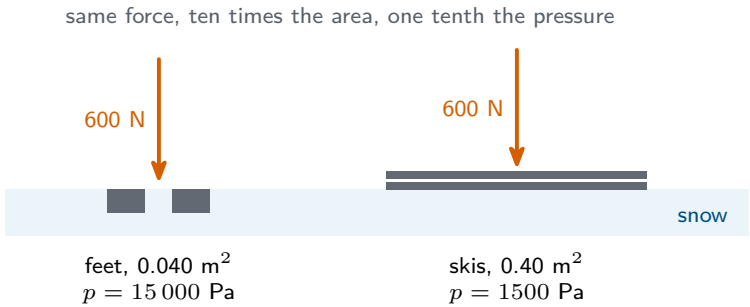
A dam is thickest at the bottom because water pressure increases with depth

Density is measured directly – mass on a balance, volume by displacement (irregular solid) or dimensions (regular shape). Pressure in a fluid at rest acts **equally in all directions**, and the pressure difference between two depths comes from the weight of fluid between them.

Worked check. A diver at 10 m in water ($\rho = 1000$ kg/m^3, $g = 10$ N/kg): pressure difference $= 10 \times 1000 \times 10 = 100\,000$ Pa on top of atmospheric pressure.

Worked example (density by displacement). A stone has a mass of 54 g. In a measuring cylinder the water level rises from 50.0 cm^3 to 70.0 cm^3. Volume $= 70.0 - 50.0 = 20.0$ cm^3, so $\rho = 54 \div 20.0 = 2.7$ $g/cm^3 = 2700$ kg/m^3 (multiply g/cm^3 by 1000 to get kg/m^3).

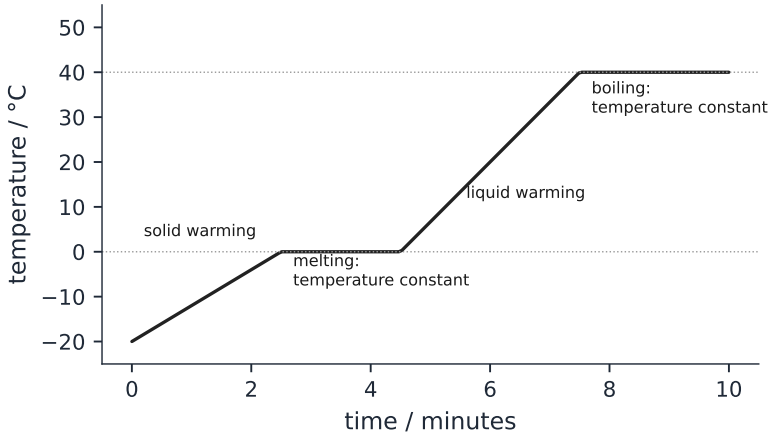
Worked example (pressure on an area). A 600 N student stands on two feet with a total area of 0.040 m^2: $p = 600 \div 0.040 = 15\,000$ Pa. On skis of total area 0.40 m^2 the same weight gives only 1500 Pa, so the student does not sink into the snow.



Ten times the area, one tenth the pressure.

Worked example (pressure difference). The pressure difference between 2.0 m and 5.0 m deep in water uses the *difference* in depth: $p = 3.0 \times 1000 \times 10 = 30\,000$ Pa.

Change of state (P)



A heating curve with constant-temperature plateaus at melting and boiling.

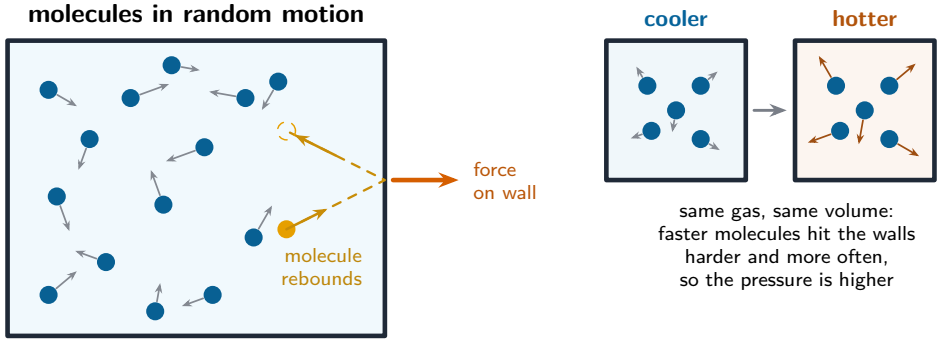
Heating raises the energy stored in a system – either its temperature rises, or at a **melting point** or **boiling point** the extra energy breaks bonds while the temperature **stays constant**. Particles: solids vibrate about fixed points; liquids move randomly but touch; gases move fast, far apart, in straight lines between collisions. **Specific heat capacity** 比热容 is the energy needed to raise 1 kg by 1 °C:

$$\Delta Q = m \times c \times \Delta T$$

Worked check. Heating 2 kg of water ($c = 4200$ J/(kg °C)) by 30 °C: $\Delta Q = 2 \times 4200 \times 30 = 252\,000$ J.

Worked example (start and end temperatures). 0.50 kg of water is heated from 20 °C to 80 °C. The temperature *change* is $\Delta T = 80 - 20 = 60$ °C, so $\Delta Q = 0.50 \times 4200 \times 60 = 126\,000$ J. Using 80 °C instead of 60 °C is the most common slip.

Ideal gas molecules



$$\text{pressure} = \frac{\text{total force of collisions}}{\text{wall area}}$$

Pressure is the total force of the molecules' collisions on a wall divided by its area; hotter, faster molecules hit harder and more often.

Gas molecules move **randomly**, exerting force – and so **pressure** – on the walls at every collision. **Absolute zero** 绝对零度 (−273 °C) is the temperature at which molecular kinetic energy is minimum: **K = °C + 273**. Higher temperature → faster average molecular speed, and the **Kelvin temperature is proportional to the average kinetic energy** of the molecules.

For a fixed mass of gas: at constant temperature, **pressure × volume is constant** (squeeze it and the molecules hit the walls more often); at constant volume, **pressure/T (K) is constant** (hotter molecules hit harder):

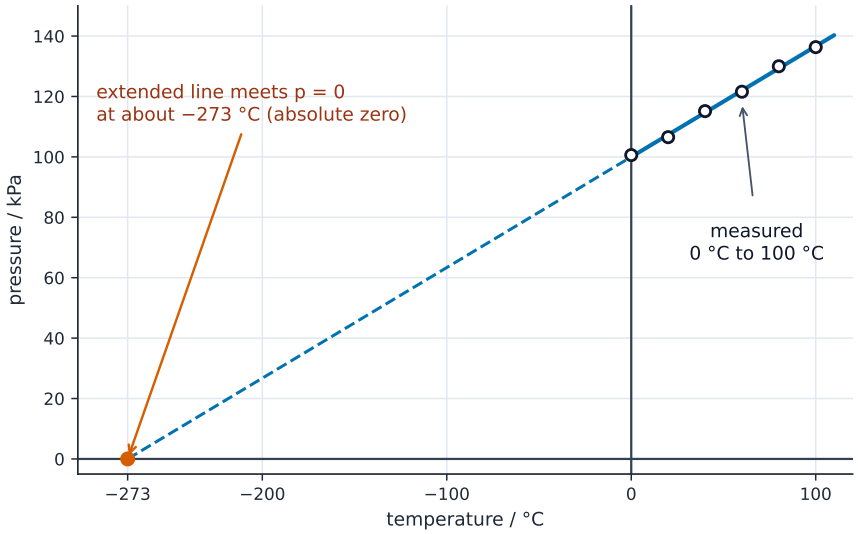
$$p_1V_1 = p_2V_2 \qquad \frac{p_1}{T_1} = \frac{p_2}{T_2}$$

Worked check. A gas at 100 kPa and 300 K is heated (constant volume) to 450 K: $p_2 = 100 \times 450/300 = 150$ kPa. Squashed from 2 dm^3 to 0.5 dm^3 at constant temperature: $p_2 = 100 \times 2/0.5 = 400$ kPa.

> **Worked example (convert to kelvin first).** A tyre is at 200 kPa when the air is 27 °C. After a long drive the air is 57 °C; the volume stays the same. $T_1 = 27 + 273 = 300$ K and $T_2 = 57 + 273 = 330$ K, so $p_2 = 200 \times 330/300 = 220$ kPa. Using °C would give $200 \times 57/27 = 422$ kPa: more than double the pressure for a 30 °C rise, which is clearly wrong.

> **Worked example (reading a pressure–temperature graph).** A student heats a sealed flask of air in a water bath and records the pressure from 0 °C to 100 °C. The points lie on a straight line through (0 °C, 100 kPa) and (100 °C, 137 kPa).

- Gradient $= \dfrac{137 - 100}{100 - 0} = 0.37$ kPa per °C.
- To fall from 100 kPa to zero, the temperature must drop by $100 \div 0.37 \approx 270$ °C, so the line reaches $p = 0$ at about −270 °C, close to absolute zero (−273 °C).
- The line does **not** pass through the origin of this graph, so p is not proportional to the Celsius temperature. Plot the same data against temperature in kelvin and the line passes through (0 K, 0): $p \propto T$ only in kelvin.



Extend the straight line back to zero pressure: it meets the temperature axis near −273 °C

Common mistakes

- Mixing units in density. 1 g/cm^3 = 1000 kg/m^3; for $p = h\rho g$ the density must be in kg/m^3.
- Using an area in cm^2 in $p = F/A$. 1 m^2 = 10 000 cm^2, so 50 cm^2 = 0.0050 m^2.
- Putting °C into the gas equations. Always change to kelvin: K = °C + 273.
- Using the final temperature as ΔT in $\Delta Q = mc\Delta T$. Subtract the start temperature.
- Saying the temperature rises while a substance melts or boils. It stays constant; the energy breaks bonds between particles.
- Saying gas pressure rises when heated because molecules get bigger. They move faster, so they hit the walls harder and more often.

Check yourself

1. A 240 g block has volume 40 cm^3. Calculate its density in kg/m^3.
2. State the pressure equation and its unit.
3. Calculate the pressure under a 500 N boot heel of area 0.01 m^2.
4. (P) What stays constant while a substance melts?
5. (P) Calculate the energy to heat 0.5 kg of aluminium (c = 900 J/(kg °C)) by 40 °C.
6. Convert 27 °C to kelvin, and 373 K to °C.
7. Why does a gas exert pressure on its container?
8. What happens to average molecular speed as temperature rises?
9. A gas at 120 kPa in 3 dm^3 is compressed to 1 dm^3 at constant temperature. Find the new pressure.
10. State two conditions that make a gas's pressure double.

Answers: 1 $m = 0.24$ kg, $V = 4.0 \times 10^{-5}$ m^3; $\rho = 0.24/4.0 \times 10^{-5} = 6000$ kg/m^3; 2 $p = F/A$, in pascals (N/m^2); 3 $p = 500/0.01 = 50\,000$ Pa; 4 (P) temperature – the energy goes to breaking intermolecular bonds, not to faster molecules; 5 (P) $\Delta Q = 0.5 \times 900 \times 40 = 18\,000$ J; 6 300 K; 100 °C; 7 its molecules collide with the walls, each collision exerting a force; the total force per unit area is the pressure; 8 it increases; 9 $p_2 = 120 \times 3/1 = 360$ kPa; 10 doubling the Kelvin temperature at constant volume, or halving the volume at constant temperature.

Magnetism and electromagnetism

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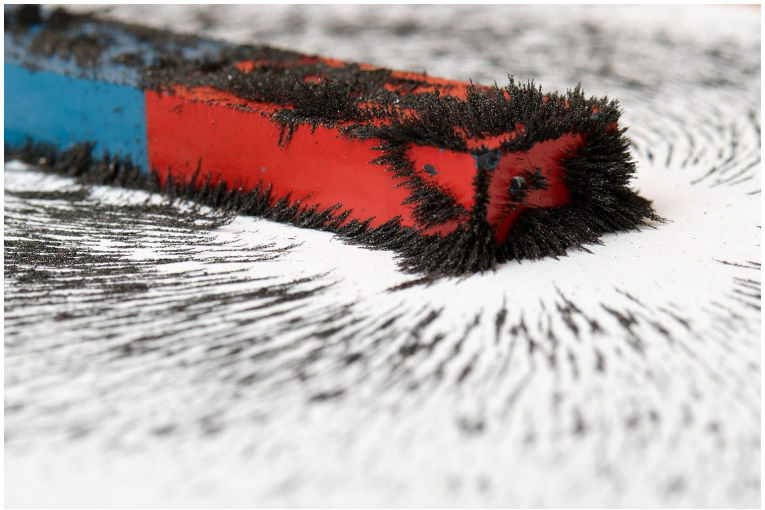
Magnetism to mains

A magnet moves, and current appears in a wire kilometres away. This section builds that chain: permanent magnets and field patterns, the magnetic effect of a current, the motor force with its left-hand rule, induction in coils and generators, and (P) the transformers that move electrical energy across a country.

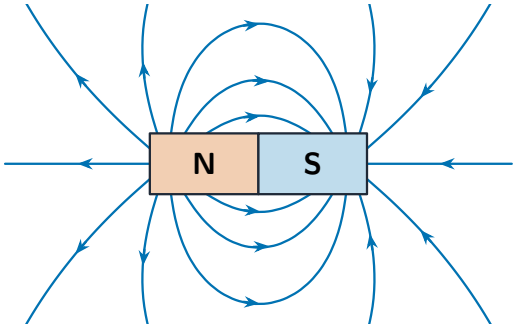
Edexcel International GCSE Physics 4PH1, Section 6 (statements 6.1–6.20P). P-suffixed statements are the Physics-only extension.

Magnetism

Magnets repel like poles and attract unlike ones, and attract **magnetic materials** (iron, steel, nickel, cobalt). **Magnetically hard** materials (steel) keep their magnetism – permanent magnets; **soft** materials (iron) magnetise and demagnetise easily – electromagnet cores. **Field lines** 磁感线 point from N to S outside a magnet (never cross); magnetism is **induced** in a magnetic material placed in a field. Between broad, flat **unlike** pole faces, the central gap has an approximately **uniform field** 匀强磁场; ignore edge effects there.



Iron filings line up along the magnetic field lines of a bar magnet



field lines leave N and enter S; they never cross,
and they are closest together at the poles, where the field is strongest

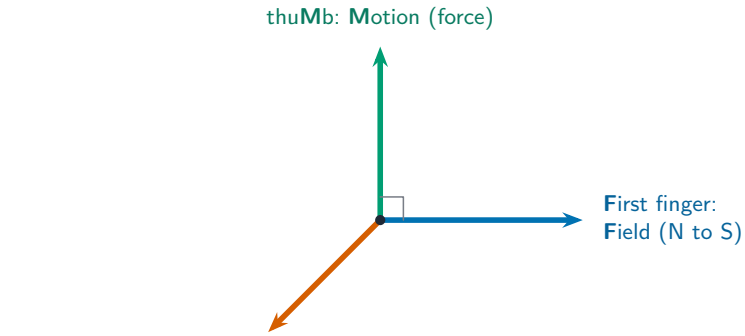
A bar magnet field lines run N to S outside, never crossing.

Electromagnetism and the motor effect

A **current in a conductor creates a magnetic field around it** – concentric circles, right-hand grip rule. (P) Electromagnets: a coil (solenoid) 螺线管 around a soft-iron core, switchable and adjustable. (P) Field patterns for a straight wire, flat coil and solenoid.

A wire carrying current **across** a magnetic field feels a force – the **motor effect**, used in d.c. motors (rotating coil + commutator) and loudspeakers. Predict the direction with the **left-hand rule** 左手定则: first finger Field, seCond finger Current, thuMb Motion. The force grows with stronger field and larger current, and reverses if either reverses.

> **Worked example (using the left-hand rule).** A wire sits between a N pole on the left and a S pole on the right, so the field points to the right. The current flows into the page. Point your first finger to the right and your second finger into the page: your thumb points **down**, so the wire is pushed downwards. Reverse the current and the force is up; reverse the current *and* swap the poles and it is down again.



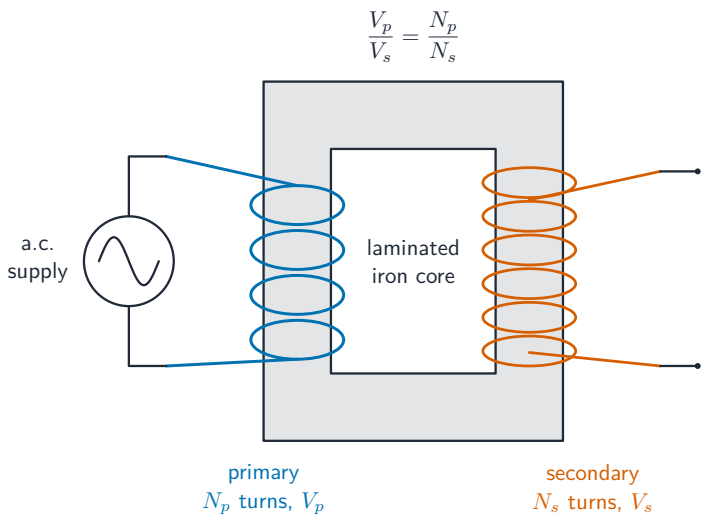
The left-hand rule: field, current and force at right angles.

Electromagnetic induction

A voltage is **induced** 感生 in a conductor or coil when it **moves through** a magnetic field or when the **field through it changes**. The induced voltage is larger with faster movement, a stronger field, more turns and (for generators) faster rotation. **Generators** rotate a magnet inside a coil (or a coil inside a magnet) – the size and frequency of the induced a.c. follow the rotation.

(P) **Transformers** change an alternating voltage using two coils on an iron core:

$$\frac{V_p}{V_s} = \frac{N_p}{N_s} \qquad V_p I_p = V_s I_s \text{ (100\% efficient)}$$



A transformer: primary and secondary coils on a laminated iron core.

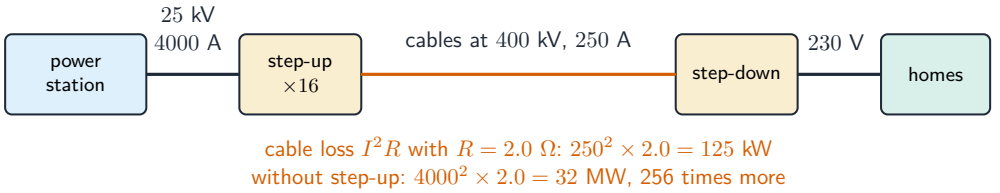
Step-up transformers raise the voltage (and cut the current) for transmission – high voltage means low current, so far less energy lost as heat in the cables; **step-down** transformers bring it back to safe levels for use.

Worked check. A transformer has 200 primary turns and 50 secondary turns; the primary is 230 V. $V_s = 230 \times 50/200 = 57.5$ V – a step-down. If the primary current is 0.5 A: $I_s = 230 \times 0.5/57.5 = 2.0$ A.

Worked example (P) (transmission). A power station makes 100 MW at 25 kV. A step-up transformer raises this to 400 kV.

- Turns ratio: $N_s/N_p = 400/25 = 16$, so a primary of 500 turns needs a secondary of $500 \times 16 = 8000$ turns.
- Current (100% efficient): at 25 kV, $I = P/V = 100\,000\,000/25\,000 = 4000$ A; at 400 kV, $I = 100\,000\,000/400\,000 = 250$ A.
- Cable loss: the heating power in the cables is $P = I^2R$. For cables of total resistance 2.0 Ω: at 400 kV, $P = 250^2 \times 2.0 = 125\,000$ W $= 125$ kW; at 25 kV it would be $4000^2 \times 2.0 = 32\,000\,000$ W $= 32$ MW, almost a third of the power station's output.

The current in the cables is 16 times smaller, so the heating loss is $16^2 = 256$ times smaller: far less energy is wasted.



Stepping up to 400 kV cuts the cable current 16 times and the heating loss 256 times

Common mistakes

- Using the right hand for the motor effect. The left-hand rule gives the force on a current; the right-hand grip rule gives the field *around* a wire.
- Saying the motor force is biggest when the wire is parallel to the field. There is no force then; the force is biggest when the wire is at right angles to the field.
- Saying a voltage is induced in a still coil next to a still magnet. Something must move or the field must change.
- (P) Saying a transformer works on d.c. It needs a.c., because only a changing current gives a changing field in the core.
- (P) Saying step-up transformers increase power. They raise the voltage and lower the current; at best the power stays the same.
- (P) Turning the turns ratio upside down. Check: more secondary turns means a *higher* secondary voltage.

Check yourself

1. State two differences between magnetically hard and soft materials.
2. In which direction do field lines point outside a magnet?
3. Describe how to produce a uniform magnetic field with two bar magnets.
4. What does a current in a wire create around it?
5. State the left-hand rule's three fingers.
6. Name two factors that increase the force on a current-carrying wire in a field.
7. State two ways to induce a voltage in a coil.
8. Name two factors that increase the size of an induced voltage.
9. (P) A step-down transformer has 1000 primary and 100 secondary turns; input 230 V. Calculate the output.
10. (P) Why is electricity transmitted at high voltage?

Answers: 1 hard keeps its magnetism (permanent magnets, steel); soft loses it easily (temporary, iron – electromagnet cores); 2 from N to S; 3 face broad, flat N and S poles across a small gap; the central field is approximately uniform away from the edges; 4 a magnetic field of concentric circles (grip rule); 5 first finger Field, second

finger Current, thumb Motion; 6 stronger field; larger current.
Answers continued: 7 move the coil or magnet so the coil cuts field lines, or change the field through a stationary coil; 8 faster movement; stronger magnet; more turns; 9 (P) $V_s = 230 \times 100/1000 = 23$ V; 10 (P) high voltage gives low current for the same power; cable heating is I^2R, so losses fall sharply over long distances.

Radioactivity and particles

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The nucleus at work

Some nuclei are unstable: they throw out radiation at random, decay by half-lives, and – in reactors and stars – release energy by splitting or joining. This section covers atomic notation, the three ionising radiations with their penetrating powers, half-life calculations, the fission chain reaction, and why fusion lights the stars but not our power stations.

Edexcel International GCSE Physics 4PH1, Section 7 (statements 7.1–7.26). Units: becquerel (Bq), with time in s, min or h.

Radioactivity

An atom holds protons and neutrons in a nucleus; notation ${}^{A}_{Z}X$ gives **mass (nucleon) number** A and **atomic (proton) number** Z. **Isotopes** share Z but differ in neutrons.



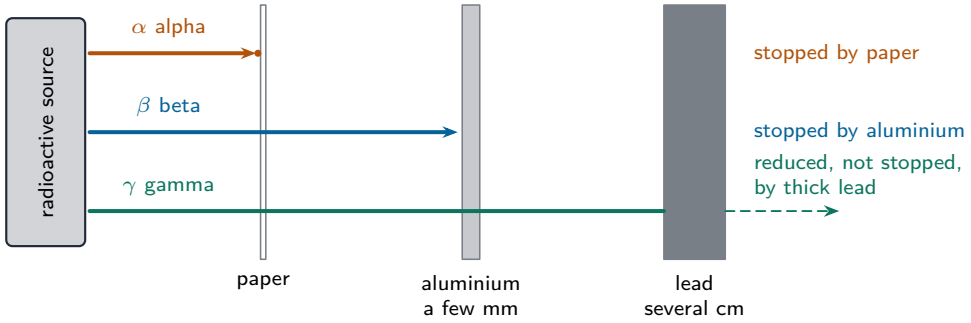
A Geiger counter detects ionising radiation and shows the count rate

Unstable nuclei emit – randomly – **alpha** α (helium nucleus, ${}^{4}_{2}\mathrm{He}$), **beta-minus** β^- (an electron, created as a neutron turns proton) and **gamma** γ (high-energy electromagnetic wave, no particles). Balancing: both **mass number and charge are**

conserved.

Worked check. Carbon-14: ${}^{14}_{6}C \rightarrow {}^{14}_{7}N + {}^{0}_{-1}e$ – A stays 14; charge $6 = 7 + (-1)$ ✓. Radon: ${}^{222}_{86}Rn \rightarrow {}^{218}_{84}Po + {}^{4}_{2}He$.

> **Worked example (filling the gaps).** Strontium-90 decays by beta emission: ${}^{90}_{38}\mathrm{Sr} \rightarrow {}^{90}_{39}\mathrm{Y} + {}^{0}_{-1}e$. The mass number stays 90 and the atomic number goes **up** by 1, because a neutron has turned into a proton. Uranium-238 decays by alpha emission: ${}^{238}_{92}\mathrm{U} \rightarrow {}^{234}_{90}\mathrm{Th} + {}^{4}_{2}\mathrm{He}$; the mass number falls by 4 and the atomic number by 2. Gamma emission changes neither number.



Alpha stopped by paper, beta by a few mm of aluminium, gamma attenuated by thick lead.

Radiation	Nature	Ionising	Range in air
alpha	2p + 2n	strongest	a few cm
beta	fast electron	medium	tens of cm
gamma	EM wave	weakest	metres

Detection: photographic film (badge) or a **Geiger–Müller tube**. **Background radiation** comes from rocks and cosmic rays (space), food, medical uses and fallout.

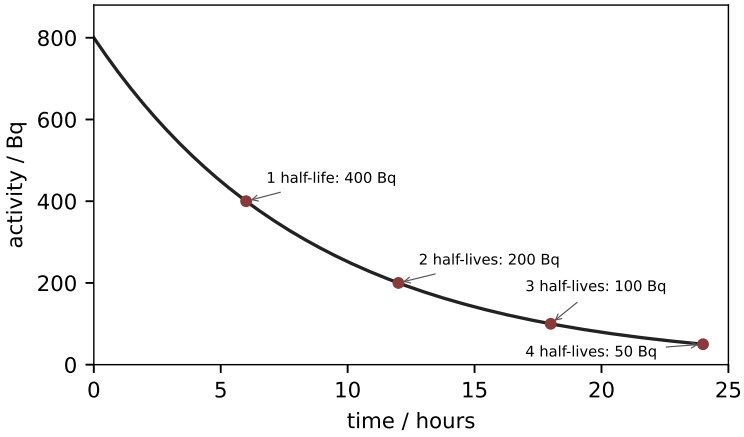
Activity 活度 (in becquerels; 1 Bq = 1 decay/s) falls steadily: the **half-life** 半衰期 is the time for half the undecayed nuclei to decay. **Worked check.** 800 Bq with half-life 6 h: after 24 h (4 half-lives) activity $= 800/2^4 = 50$ Bq.

> **Worked example (half-life from counts, with background).** A Geiger–Müller tube records 680 counts per minute from a sample; the background count is 40 counts per minute. Twelve days later it records 120 counts per minute.

- Corrected counts: $680 - 40 = 640$ at the start and $120 - 40 = 80$ at the end.
- $640 \rightarrow 320 \rightarrow 160 \rightarrow 80$ is three half-lives in 12 days, so the half-life is $12 \div 3 = 4.0$ days.

Halving 680 three times gives 85, not 120: forgetting the background gives the wrong

answer.

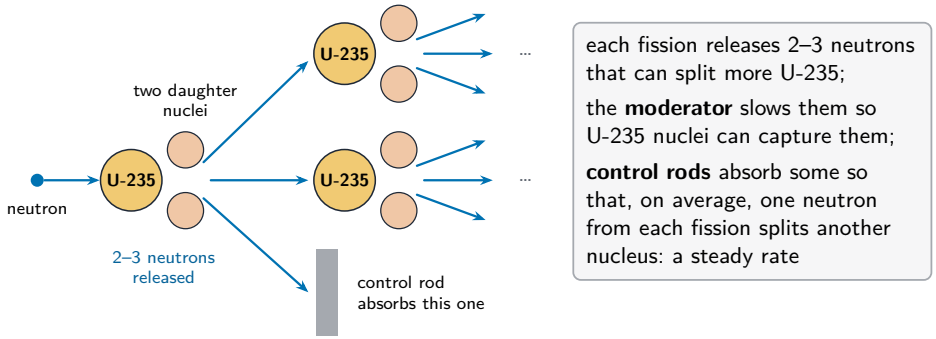


A decay curve halving every half-life, annotated at each halving.

Uses: medical tracers (short half-life, gamma), cancer treatment, sterilising, thickness control (beta through paper). **Contamination** (radioactive material on you – must be removed) differs from **irradiation** (exposure to radiation – stops when the source leaves). Dangers: mutation of DNA, cell and tissue damage; radioactive waste must be stored safely for its long half-lives.

Fission and fusion

Split a big nucleus or join two small ones – both release energy, and each powers a different machine.



Each fission's neutrons can split further U-235 nuclei; control rods absorb some, and the moderator slows them.

Fission 裂变: a neutron strikes **U-235**, splitting it into **two radioactive daughter nuclei**, 2–3 neutrons and **kinetic energy** – and if those neutrons strike more U-235, a **chain reaction** runs. The **moderator** 慢化剂 slows neutrons so they split nuclei efficiently; **control rods** 控制棒 absorb neutrons to hold the rate steady; **shielding** protects workers. **Fusion** 聚变 joins small nuclei into a larger one, converting mass to energy – the Sun's source. Fusion needs enormous temperature and pressure because **positively charged protons electrostatically repel** – the nuclei must collide fast enough to overcome that repulsion.

Common mistakes

- Saying a beta particle comes from the electron shells. It is made in the nucleus when a neutron turns into a proton.
- Lowering the atomic number in beta decay. Beta-minus decay *raises* it by 1; alpha decay lowers it by 2 and the mass number by 4.
- Thinking two half-lives remove the whole sample. After two half-lives a quarter is left; after three, an eighth.
- Forgetting to subtract the background count before halving.
- Calling gamma the most dangerous because it is the most penetrating. Inside the body, alpha does the most damage because it is the most ionising.
- Mixing up contamination and irradiation. An irradiated object does not become radioactive.
- (P) Saying control rods slow the neutrons. The moderator slows them; the control rods absorb them.

Check yourself

1. In ${}^{19}_{9}F$, state the numbers of protons, neutrons and electrons in the neutral atom.
2. Name the three ionising radiations and their natures.
3. Write the full equation for alpha decay of ${}^{226}_{88}Ra$.
4. Which radiation is stopped by paper, and which passes through aluminium?
5. Give two sources of background radiation.
6. Define half-life.
7. A source of 3200 Bq has half-life 8 days. Find its activity after 32 days.
8. State the difference between contamination and irradiation.
9. Name the roles of the moderator, control rods and shielding in a reactor.
10. Why does fusion need such high temperatures?

Answers: 1 9 protons, 10 neutrons, 9 electrons; 2 alpha – helium nucleus (2p+2n); beta-minus – fast electron; gamma – high-energy electromagnetic wave; 3 ${}^{226}_{88}Ra \rightarrow {}^{222}_{86}Rn + {}^{4}_{2}He$; 4 alpha stopped by paper; gamma passes aluminium (needs thick lead); 5 any two: rocks/building materials, cosmic rays, food/drink, medical, radon gas, nuclear fallout; 6 the time for the expected undecayed population or source activity to halve; 7 32 days = 4 half-lives: 3200 → 1600 → 800 → 400 → 200 Bq;

8 contamination – radioactive material stuck to you, hazard remains until removed; irradiation – exposure to radiation from a source, ends when the source is removed; 9 moderator slows neutrons for efficient fission; control rods absorb neutrons to control the rate; shielding absorbs escaping radiation to protect workers; 10 the positively charged protons of two nuclei repel electrostatically, so nuclei must collide at enormous speed – only reached at very high temperature and pressure – to get close enough to fuse.

Astrophysics

Pearson Edexcel · International GCSE · Physics

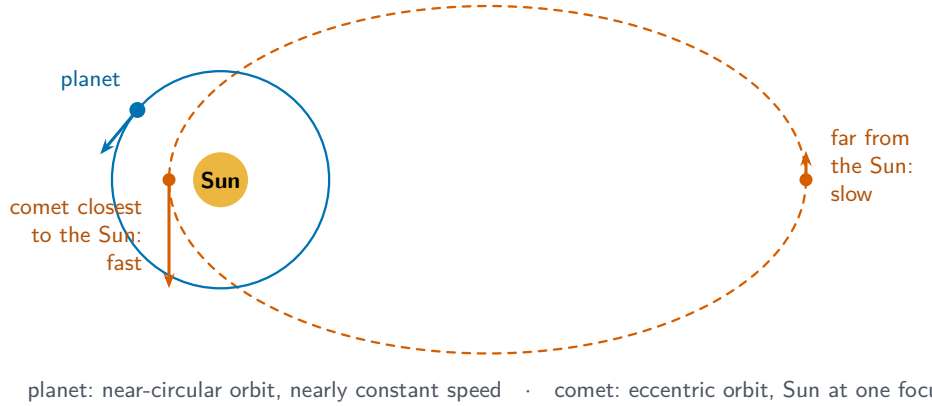
The universe and its history

The universe is billions of galaxies; each galaxy is billions of stars; the Sun is one star in the Milky Way. Gravity shapes every orbit in it, stars are born and die in patterns set by their mass, and the red-shift of distant galaxies tells us the whole universe is expanding – evidence for a beginning: the Big Bang.

Edexcel International GCSE Physics 4PH1, Section 8 (statements 8.1–8.18P). P-suffixed statements are the Physics-only extension (Paper 2P).

Motion in the universe

Universe 宇宙 → billions of **galaxies** 星系 → each billions of **stars** → our solar system lies in the **Milky Way**. **Gravitational field strength** g varies with mass and size – weaker on the Moon, stronger on Jupiter. Gravity holds every orbit: moons orbit planets, planets and comets orbit the Sun, artificial satellites orbit the Earth.



A planet's near-circular orbit beside a comet's eccentric orbit with the Sun at one focus: fast close in, slow far out.

Planetary orbits are **nearly circular**; comet orbits are highly **eccentric** – fast near the Sun, slow far away. Orbital speed comes from circumference ÷ period:

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

Worked check. A satellite at orbital radius 7000 km (r measured from Earth's centre) with period 5800 s: $v = 2\pi \times 7.0 \times 10^6 / 5800 \approx 7580$ m/s ≈ 7.6 km/s.

Worked example (the Moon's orbit). The Moon orbits 3.84×10^8 m from the Earth's centre once every 27.3 days. First change the period to seconds: $T = 27.3 \times 24 \times 3600 = 2.36 \times 10^6$ s. Then $v = \dfrac{2 \times \pi \times 3.84 \times 10^8}{2.36 \times 10^6} \approx 1.0 \times 10^3$ m/s, about 1.0 km/s, much slower than a low satellite.

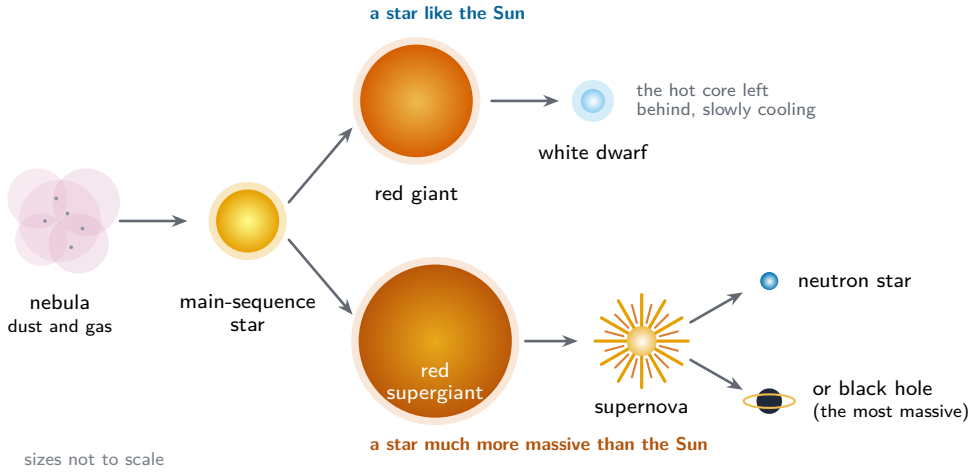
Worked example (weight on another world). A 70 kg astronaut weighs $70 \times 10 = 700$ N on Earth and $70 \times 1.6 = 112$ N on the Moon ($g = 1.6$ N/kg). The mass is 70 kg in both places.

Stellar evolution

Stars are classified by **colour**, which follows **surface temperature**: blue hottest → red coolest. A Sun-like star runs nebula → main sequence (fusion balances gravity for billions of years) → red giant → white dwarf; a star **much more massive than the Sun** (roughly eight or more times its mass) runs nebula → main sequence → red supergiant → supernova → **neutron star or black hole**.



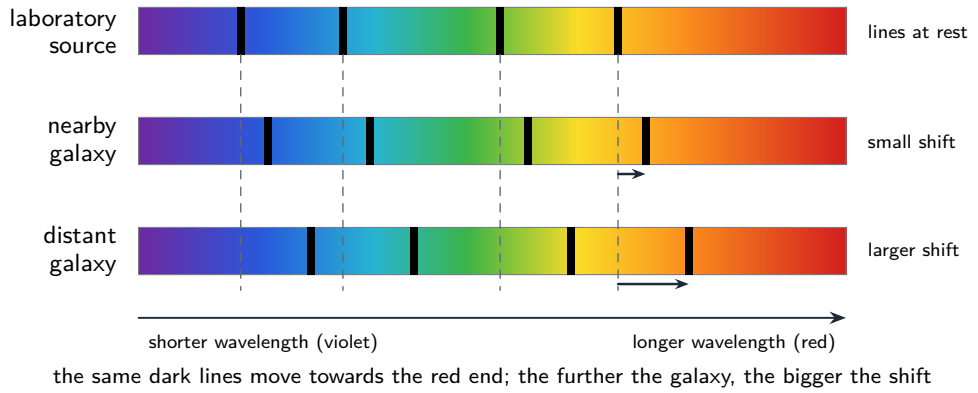
The Pillars of Creation: a nebula where gravity is pulling dust and gas together into new stars



Two life cycles: Sun-like stars end as white dwarfs; massive stars end in supernovae, neutron stars or black holes.

(P) A star's brightness is compared using **absolute magnitude** at a standard distance; the **Hertzsprung–Russell diagram** plots absolute magnitude against temperature, with the main sequence, giants and white dwarfs as its main bands.

Cosmology (P)



Spectral lines shift to the red as a galaxy recedes faster; further galaxies shift more.

A moving wave source changes the observed wavelength (**red-shift** 红移 for recession). Galaxy red-shift grows with distance, and the relationship is quantified as:

$$\frac{\Delta\lambda}{\lambda_0} = \frac{v}{c}$$

Worked check. A spectral line at 500 nm appears at 505 nm in a distant galaxy: $\Delta\lambda/\lambda_0 = 5/500 = 0.01$, so $v = 0.01c = 3000$ km/s.

Worked example (P) (predicting the shift). A galaxy moves away at 6000 km/s. A hydrogen line emitted at 656 nm is shifted by $\Delta\lambda = \lambda_0 \times \frac{v}{c} = 656 \times \frac{6000}{300\,000} = 13$ nm, so it is seen at about 669 nm. Use the same unit for v and c (here km/s).

Red-shift increasing with distance means the galaxies are receding faster the further they are – the universe is **expanding**, which points back to a hot, dense beginning: the **Big Bang** 大爆炸. The **cosmic microwave background (CMB)** – faint microwaves from every direction – is the cooled remnant of that early radiation, the second pillar of evidence.

Common mistakes

- Measuring the orbital radius from the planet's surface. r is from the centre; add the planet's radius to the height.
- Leaving the period in hours or days in $v = 2\pi r/T$. Change it to seconds for m/s.
- Saying an astronaut on the Moon has less mass. The mass is the same; the weight is smaller because g is smaller.
- (P) Saying red-shifted galaxies look red. Every line in the spectrum moves to a longer wavelength; the galaxy's colour hardly changes.
- (P) Dividing by the observed wavelength. λ_0 in $\Delta\lambda/\lambda_0$ is the wavelength measured in the laboratory.
- Saying every star ends as a black hole. A Sun-like star ends as a white dwarf; only much more massive stars become neutron stars or black holes.

Check yourself

1. Put in order of size: galaxy, solar system, universe, star.
2. Why does g differ between the Earth and the Moon?
3. Name the two orbit shapes of comets and planets.
4. Calculate the orbital speed of a satellite at r = 42 000 km with T = 24 hours.
5. State the two stages after the main sequence for a Sun-like star.
6. What does a star's colour tell you?
7. (P) Which two quantities does the HR diagram plot?
8. (P) A line at 400 nm shifts to 404 nm. Calculate v/c.
9. (P) State the two pieces of evidence for the Big Bang.
10. (P) Why does red-shift increase with distance?

Answers: 1 star (smallest) → solar system → galaxy → universe (largest); 2 g depends on the body's mass and radius – the Moon is smaller and less massive, so its g is about 1.6 N/kg; 3 planets – nearly circular; comets – highly eccentric ellipses; 4 $r = 4.2 \times 10^7$ m, $T = 86\,400$ s; $v = 2\pi \times 4.2 \times 10^7/86\,400 \approx 3060$ m/s ≈ 3.1 km/s; 5 red giant, then white dwarf; 6 its surface temperature – blue hottest, red coolest; 7 (P) absolute magnitude against temperature (or colour); 8 (P) $\Delta\lambda/\lambda_0 = 4/400 = 0.01 = v/c$; 9 (P) the red-shift of galaxies increasing with distance, and the cosmic microwave background radiation; 10 (P) the further the galaxy, the faster it recedes – space itself expands, so recession speed grows with distance, shifting the light further to the red.