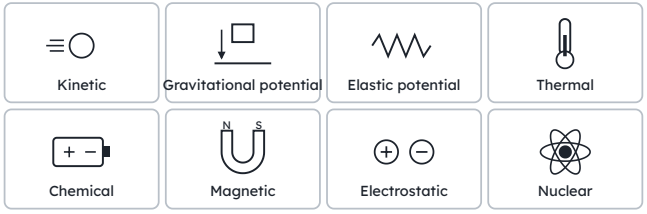
4.1 Energy

ENERGY STORES AND SYSTEMS

- A **system** is an object or group of objects. When a system changes, energy is transferred between stores.
- Energy is transferred by heating, by waves, by an electric current, or by a force doing work.
- **Conservation of energy:** energy can be transferred usefully, stored or dissipated, but cannot be created or destroyed.
- In a **closed system** there is no net change to the total energy.
- Wasted energy is **dissipated**, usually to the thermal store of the surroundings.

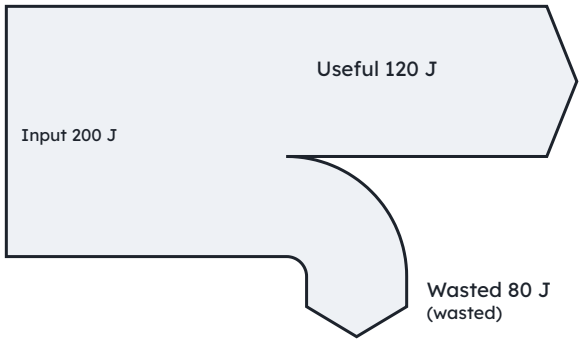
THE EIGHT STORES



POWER AND EFFICIENCY

- **Power** is the rate at which energy is transferred, or the rate at which work is done. 1 W = 1 J/s.
- Two motors lifting the same load: the more powerful one does it faster.
- **Efficiency** = useful output ÷ total input (energy or power). Never more than 1 (100%).
- Reduce waste: **lubrication** (less friction), **thermal insulation**, streamlining.
- Higher **thermal conductivity** → higher rate of energy transfer by conduction. Thick walls with low thermal conductivity slow the rate of cooling of a building.

SANKEY DIAGRAMS



Arrow widths are drawn to scale. Efficiency here = 120 ÷ 200 = 0.6 (60%).

SPECIFIC HEAT CAPACITY

The amount of energy required to raise the temperature of 1 kg of a substance by 1 °C. Water has a high specific heat capacity.

ENERGY RESOURCES

Type	Examples
Renewable	wind, solar, hydro-electricity, tides, water waves, geothermal, bio-fuel (replenished as used)
Non-renewable	coal, oil, gas (fossil fuels), nuclear fuel: reliable but will run out; fossil fuels release CO_2
Reliability	wind and solar depend on weather; tides are predictable; fossil fuels and nuclear meet demand at any time

EXAM TIPS

- Say energy is **dissipated** or **wasted**, never 'lost' or 'used up'.
- Square the speed in Ek before multiplying.
- Convert kW → W and minutes → s first.

MODEL EXPLANATIONS (GRADE 7+ ANSWERS)

Why does a car's brakes get hot when it stops?
The car's kinetic energy store decreases because friction between the brakes and wheels does work, transferring energy to the thermal store of the brakes. The energy is dissipated to the surroundings by heating, so it's less useful, but the total energy stays the same (conservation of energy).

How does loft insulation keep a house warm for longer?
Insulation has a low thermal conductivity, so the rate of energy transfer by conduction is lower. Less energy is transferred out of the house per second. The rate of cooling depends on the thickness and thermal conductivity of the walls and roof: thicker insulation with lower conductivity means slower cooling.

Why is it impossible for any device to be 100% efficient?
Some energy is always dissipated (wasted), usually by heating the surroundings. So the useful output is always less than the total input. e.g. a motor: friction in the bearings and current in the wires heat the motor and surroundings, so energy ends up stored in less useful ways.

RP2: THERMAL INSULATION (PO)

Aim: Investigate the effectiveness of different materials as thermal insulators, and the factors that may affect the thermal insulation properties of a material (such as its thickness).

Change	Type of material (or number of layers)
Measure	Temperature drop over a fixed time
Control	Starting temperature, volume of water, beaker size, time, lid

Must include:

- Investigate a factor such as thickness (number of layers)
- Control the volume and starting temperature of water
- Measure temperature at regular intervals for a fixed time
- Use a lid
- Compare the temperature change for each material

Common mistake: Starting the timer at different temperatures.

4.1 Energy

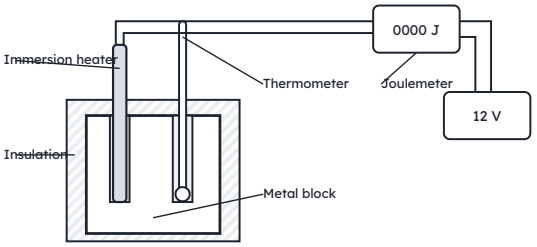
KEY EQUATIONS (ALL ON THE PHYSICS EQUATIONS SHEET)

Equation	Quantities (units)	Watch out
$E_k = \frac{1}{2} m v^2$	kinetic energy (J), mass (kg), speed (m/s)	Square the speed first
$E_p = m g h$	gravitational potential energy (J), mass (kg), g (N/kg), height (m)	g = 9.8 N/kg is given in the question
$E_e = \frac{1}{2} k e^2$	elastic potential energy (J), spring constant (N/m), extension (m)	Extension in metres
$\Delta E = m c \Delta\theta$	change in thermal energy (J), mass (kg), specific heat capacity (J/kg °C), temperature change (°C)	$\Delta\theta$ = final – start temperature
P = E ÷ t	power (W), energy transferred (J), time (s)	kW → W, minutes → s
P = W ÷ t	power (W), work done (J), time (s)	Work done = energy transferred
efficiency = useful output energy transfer ÷ total input energy transfer	no unit (or %); also works with power	Never more than 1 (100%)

KEY WORDS

System: an object or group of objects.
Conservation of energy: energy can be transferred usefully, stored or dissipated, but cannot be created or destroyed.
Dissipated: energy transferred to the surroundings so it is stored in less useful ways; often called 'wasted'.
Specific heat capacity: the amount of energy required to raise the temperature of 1 kg of a substance by 1 °C.
Power: the rate at which energy is transferred, or the rate at which work is done.
Thermal conductivity: the higher it is, the higher the rate of energy transfer by conduction across a material.
Efficiency: useful output energy transfer ÷ total input energy transfer.
Renewable resource: one that is being (or can be) replenished as it is used.

RP1: SPECIFIC HEAT CAPACITY



Aim: Determine the specific heat capacity of one or more materials, such as aluminium and copper blocks, by linking the energy transferred by the heater (work done) to the increase in temperature and thermal energy stored.

Change	Energy transferred (J)
Measure	Temperature (°C)
Control	Mass of block, insulation, power of heater

Must include:

- Measure mass with a balance
- Insulate the block
- Measure energy with a joulemeter or E = VIt
- Record temperature at regular intervals
- Calculate c = ΔE ÷ (mΔθ) or from the gradient

Common mistake: Forgetting to convert mass to kg or time to seconds.

MISCONCEPTIONS

× **Energy gets used up.**	✓ Energy is never used up; it's transferred to other stores, often dissipated.
× **Heat and temperature are the same.**	✓ Temperature is a measure of hotness; energy is transferred by heating.
× **A machine can be 100% efficient.**	✓ Some energy is always dissipated, so efficiency is less than 1.

AIM FOR GRADE 7+

- Combine equations: Ep lost = Ek gained → v = √(2gh).
- Explain why measured specific heat capacity is too high (energy dissipated → smaller Δθ).
- Evaluate energy resources: give both sides and a justified conclusion.

COMMAND WORDS

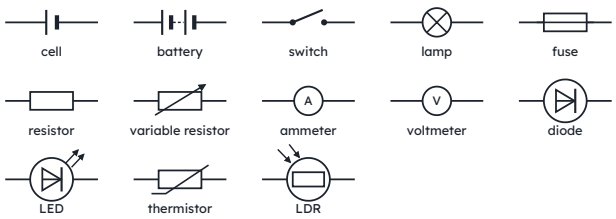
State	a short answer, no explanation
Describe	say what happens, in order
Explain	say what and why: use "because" and "so"
Calculate	equation, substitution, answer, unit
Evaluate	both sides, then a justified conclusion

QUICK-FIRE QUIZ: COVER THE ANSWERS

Unit of specific heat capacity?	**J/kg °C**
Unit of power?	**Watt (W)**
Store that increases when a spring is stretched?	**Elastic potential**
Value of g on Earth?	**9.8 N/kg**
Way to reduce friction?	**Lubrication**
A reliable renewable resource?	**Tidal, hydroelectric or geothermal**

4.2 Electricity

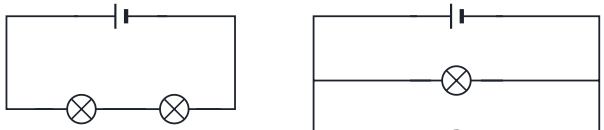
CIRCUIT SYMBOLS



CURRENT, P.D. AND RESISTANCE

- **Current** is the rate of flow of electrical charge. In a single closed loop the current is the same at every point.
- A current needs a closed circuit and a source of potential difference.
- The greater the **resistance**, the smaller the current for a given p.d.
- **Ohmic conductor:** current is directly proportional to p.d. at constant temperature.
- **Thermistor:** resistance decreases as temperature increases. **LDR:** resistance decreases as light intensity increases.
- Ammeter in **series**; voltmeter in **parallel**.

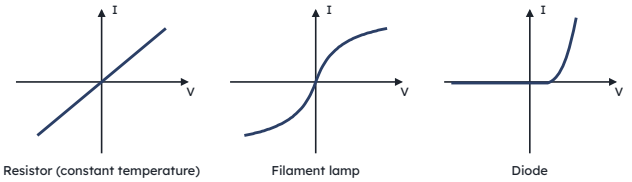
SERIES AND PARALLEL



Series: one loop
same current everywhere
p.d. shared; R total = $R_1 + R_2$

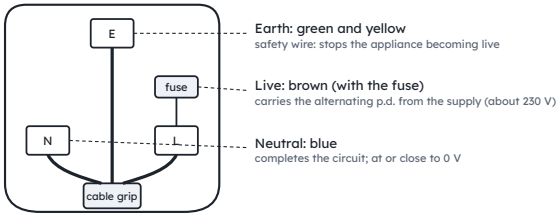
Parallel: separate branches
same p.d. across each branch; currents add
total R less than the smallest resistor

I–V CHARACTERISTICS



Filament lamp: resistance increases as temperature increases. Diode: current flows in one direction only; very high resistance in reverse.

MAINS ELECTRICITY



- UK mains: a.c., about 230 V, 50 Hz. Batteries give d.c.
- Touching the live wire: your body is at 0 V, so a large p.d. drives a current through you.

THE NATIONAL GRID



Step-up transformers increase the p.d. and reduce the current, so less energy is wasted heating the cables. Step-down transformers make it safe for homes.

STATIC ELECTRICITY (PO)

- Rubbing insulators transfers **electrons**: one gains negative charge, the other is left positive.
- Like charges repel; unlike charges attract.
- A charged object creates an **electric field**; field is strongest closest to the object. Sparks jump when the p.d. is high enough.

EXAM TIPS

- Series: current same, p.d. shared. Parallel: p.d. same, currents add.
- Brown = live, blue = neutral, green and yellow = earth.

MODEL EXPLANATIONS (GRADE 7+ ANSWERS)

Explain why the resistance of a filament lamp increases as the current increases.

As the current increases, the filament gets hotter. Its resistance increases as its temperature increases. The ions in the metal vibrate more, so the electrons collide with them more often and their flow is reduced.

Explain how an LDR can switch on a street lamp at night.

When it gets dark, the resistance of the LDR increases. So the p.d. across the LDR increases. In series, the p.d. is shared in proportion to resistance; the bigger p.d. across the LDR can be used to switch on the lamp circuit.

Explain why a person can get an electric shock from a faulty appliance.

The live wire is at 230 V and the person is at 0 V, so a large p.d. drives a current through the person. If the appliance is earthed, a large current flows down the earth wire instead, which melts the fuse and cuts off the live wire.

UNITS AND PREFIXES

giga (G)	$\times 10^9$
mega (M)	$\times 10^6$
kilo (k)	$\times 10^3$
centi (c)	$\times 10^{-2}$
milli (m)	$\times 10^{-3}$
micro (μ)	$\times 10^{-6}$
nano (n)	$\times 10^{-9}$

Convert to the base unit (m, kg, s, J, W) before you calculate.

4.2 Electricity

AQA GCSE Physics 8463
Paper 1 · Physics only content marked (PO)
All equations are on the Physics Equations Sheet

KEY EQUATIONS (ALL ON THE PHYSICS EQUATIONS SHEET)

Equation	Quantities (units)	Watch out
Q = I t	charge flow (C), current (A), time (s)	Time in seconds
V = I R	potential difference (V), current (A), resistance (Ω)	Rearrange: R = V ÷ I
P = V I	power (W), potential difference (V), current (A)	Mains p.d. ≈ 230 V
P = I² R	power (W), current (A), resistance (Ω)	Square the current first
E = P t	energy transferred (J), power (W), time (s)	kW → W, minutes → s
E = Q V	energy transferred (J), charge flow (C), potential difference (V)	p.d. = energy per unit charge

KEY WORDS

Current: the rate of flow of electrical charge. Same at every point in a single closed loop.
Potential difference: the energy transferred per unit charge passed (E = QV).
Resistance: the greater it is, the smaller the current for a given p.d.
Ohmic conductor: current is directly proportional to p.d. at constant temperature.
Thermistor: resistance decreases as temperature increases.
LDR: resistance decreases as light intensity increases.
Direct current (d.c.): flows in one direction only (cells and batteries).
Alternating current (a.c.): keeps changing direction; UK mains is 230 V, 50 Hz.

RP3: RESISTANCE

Aim: Investigate how wire length affects resistance, and how resistors combine in series and parallel.

Change	Length of wire
Measure	Resistance (from V and I)
Control	Material and thickness of wire, temperature, current

Must include:
- Draw and use a correct circuit diagram
- Test resistors in series and in parallel and compare total resistance
- Ammeter in series, voltmeter in parallel
- Calculate R = V ÷ I
- Range of at least five lengths

Common mistake: Connecting the voltmeter in series or the ammeter in parallel.

RP4: I–V CHARACTERISTICS

Aim: Plot I–V graphs for a filament lamp, a resistor at constant temperature and a diode.

Change	Potential difference
Measure	Current
Control	Component being tested, temperature (for the resistor)

Must include:
- Correct circuit with a variable resistor
- Record pairs of V and I readings
- Reverse the connections for negative values
- Plot I against V for each component
- Describe the shape of each graph and explain the lamp's curve

Common mistake: Plotting the axes the wrong way round (AQA uses current on the y-axis).

MISCONCEPTIONS

× **Current gets used up round a circuit.**	✓ Current is the same at every point in a series loop; energy is transferred, not charge.
× **Adding resistors in parallel increases resistance.**	✓ It decreases the total resistance: more paths for the charge.
× **The fuse is in the neutral wire.**	✓ The fuse is in the live wire, so a fault disconnects the dangerous supply.

AIM FOR GRADE 7+

- Two-step calculations: I = P ÷ V, then R = V ÷ I.
- Explain the filament lamp's I–V curve using temperature and resistance.
- Explain why the National Grid uses high p.d.: P = I²R, so a lower current wastes less power.

COMMAND WORDS

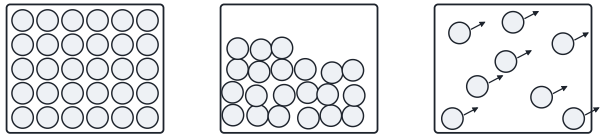
State	a short answer, no explanation
Describe	say what happens, in order
Explain	say what and why: use "because" and "so"
Calculate	equation, substitution, answer, unit
Evaluate	both sides, then a justified conclusion

QUICK-FIRE QUIZ: COVER THE ANSWERS

Unit of charge?	**Coulomb (C)**
Unit of resistance?	**Ohm (Ω)**
UK mains p.d. and frequency?	**230 V, 50 Hz**
Colour of the neutral wire?	**Blue**
Series: what's the same everywhere?	**Current**
Parallel: what's the same across each branch?	**p.d.**

4.3 Particle model of matter

STATES OF MATTER



Solid
close together, regular pattern, vibrate about fixed positions

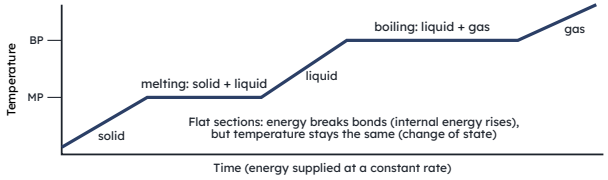
Liquid
close together, random arrangement, move past each other

Gas
far apart, random, move quickly in all directions

DENSITY

- ρ = m ÷ V. Units: kg/m³ (1 g/cm³ = 1000 kg/m³).
- Solids and liquids are dense because the particles are close together; gases are much less dense.
- Changes of state are **physical** changes: the material recovers its properties if the change is reversed, and **mass is conserved**.

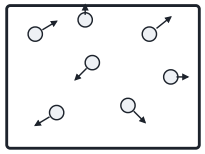
HEATING AND COOLING CURVES



INTERNAL ENERGY AND LATENT HEAT

- **Internal energy** is the total kinetic energy and potential energy of all the particles in a system.
- Heating increases internal energy: either the temperature rises or the state changes.
- **Specific heat capacity:** energy to raise 1 kg by 1 °C.
- **Specific latent heat:** energy to change the state of 1 kg with no change in temperature. Fusion: solid ↔ liquid. Vaporisation: liquid ↔ gas.

GAS PRESSURE



Particles collide with the walls, xerting a force at right angles: pressure

Higher temperature → particles move faster → hit the walls more often and harder → higher pressure

Smaller volume (constant temperature) → particles hit the walls more often → higher pressure: pV = constant (Physics only)

PARTICLE MOTION IN GASES

- Gas molecules are in constant random motion.
- The temperature of a gas is related to the **average kinetic energy** of its molecules.
- Increasing the temperature at constant volume increases the pressure.
- (PO) Increasing the volume at constant temperature decreases the pressure.
- (PO, Higher) Doing work on a gas (e.g. a bike pump) increases its internal energy and can increase its temperature.

EXAM TIPS

- Flat section on a heating curve = change of state: temperature constant, internal energy increasing.
- Temperature ≠ internal energy.
- Evaporation and boiling both turn liquid into gas; sublimation: solid → gas.

MODEL EXPLANATIONS (GRADE 7+ ANSWERS)

Explain why a gas exerts more pressure when it is heated in a sealed container.

Heating increases the kinetic energy of the particles, so they move faster. They collide with the walls more often and with more force, so the total force on each unit of area (pressure) increases.

Explain why sweating cools you down.

Sweat evaporates from the skin, which needs energy (latent heat of vaporisation) taken from the skin, so the skin cools. The fastest-moving particles with the most energy escape, so the average kinetic energy of the particles left behind falls.

Explain why pumping up a bike tyre makes the pump warm. (Physics only, Higher)

Pushing the piston does work on the gas. This transfers energy to the gas. The internal energy of the gas increases, so the particles move faster and the temperature rises.

PRACTICAL LANGUAGE

Accurate: close to the true value. **Precise:** measurements close to each other. **Repeatable:** same person, same method, similar results. **Reproducible:** similar results by another person or method. **Resolution:** smallest change an instrument can show. **Random error:** unpredictable scatter; reduce by repeating and averaging. **Systematic error:** every reading out by the same amount, e.g. a **zero error**.

SIX-MARK ANSWERS

- Plan: jot 6 key points first.
- Write in a logical order, using AQA key words.
- Methods: equipment, what you change, what you measure, what you keep the same, repeats, safety.
- Explanations: link each step with "so" or "because".

MATHS SKILLS

- Standard form: $3.2 \times 10^4 = 32\,000$; $5 \times 10^{-3} = 0.005$.
- Give answers to the same number of significant figures as the data (usually 2 or 3).
- Rearrange before substituting; show every step.
- Mean = total ÷ number of readings (leave out anomalies).

4.3 Particle model of matter

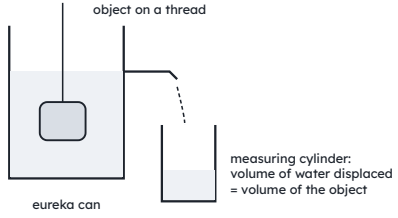
KEY EQUATIONS (ALL ON THE PHYSICS EQUATIONS SHEET)

Equation	Quantities (units)	Watch out
ρ = m ÷ V	density (kg/m³), mass (kg), volume (m³)	1 g/cm³ = 1000 kg/m³
ΔE = m c Δθ	change in thermal energy (J), mass (kg), specific heat capacity (J/kg °C), temperature change (°C)	Used when the temperature changes
E = m L	energy for a change of state (J), mass (kg), specific latent heat (J/kg)	Used when the state changes (no temperature change)
p V = constant	pressure (Pa), volume (m³); fixed mass of gas at constant temperature (Physics only)	$p_1V_1 = p_2V_2$

KEY WORDS

Density: mass per unit volume (ρ = m ÷ V).
Internal energy: the total kinetic energy and potential energy of all the particles that make up a system.
Specific latent heat: the amount of energy required to change the state of 1 kg of a substance with no change in temperature.
Latent heat of fusion: solid ↔ liquid. Latent heat of vaporisation: liquid ↔ gas.
Physical change: the material recovers its original properties if the change is reversed; mass is conserved.
Gas pressure: particles colliding with the walls exert a net force at right angles to the surface.
Temperature of a gas: related to the average kinetic energy of its molecules.

RP5: DENSITY



Aim: Determine the density of regular and irregular solids and of a liquid.

Change	Object or material
Measure	Mass and volume
Control	Balance and measuring equipment used

Must include:

- Measure mass with a balance
- Measure volume correctly for regular and irregular objects
- Use a eureka can for irregular objects
- Calculate ρ = m ÷ V with units
- Read the meniscus at eye level

Common mistake: Forgetting units, or mixing g with m³.

MISCONCEPTIONS

× **Particles expand when heated.**	✓ Particles move faster and further apart; they don't get bigger.
× **Temperature rises while ice melts.**	✓ Temperature stays constant during a change of state.
× **Mass changes when a substance melts.**	✓ Mass is conserved in a change of state.

AIM FOR GRADE 7+

- Heating then melting: add mcΔθ and mL for the total energy.
- Explain flat sections of heating curves using internal energy (potential, not kinetic, increases).
- (PO) pV = constant: compressing a gas at constant temperature increases its pressure.

COMMAND WORDS

State	a short answer, no explanation
Describe	say what happens, in order
Explain	say what and why: use "because" and "so"
Calculate	equation, substitution, answer, unit
Evaluate	both sides, then a justified conclusion

QUICK-FIRE QUIZ: COVER THE ANSWERS

Unit of specific latent heat?	**J/kg**
Water's density?	**1000 kg/m³**
Solid → gas directly?	**Sublimation**
Flat section on a heating curve?	**Change of state**
What increases in a gas when it's heated?	**Particles' kinetic energy**
Is a change of state physical or chemical?	**Physical**

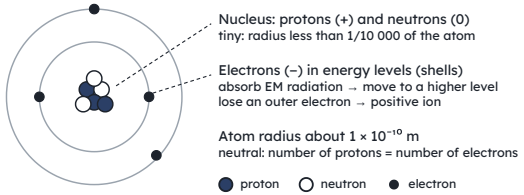
UNITS AND PREFIXES

giga (G)	× 10^9
mega (M)	× 10^6
kilo (k)	× 10^3
centi (c)	× 10^{-2}
milli (m)	× 10^{-3}
micro (μ)	× 10^{-6}
nano (n)	× 10^{-9}

Convert to the base unit (m, kg, s, J, W) before you calculate.

4.4 Atomic structure

THE ATOM



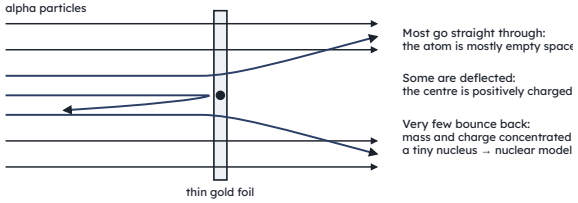
ISOTOPES AND IONS

- Atoms of the same element have the same number of protons (**atomic number**).
- **Mass number** = protons + neutrons.
- **Isotopes:** atoms of the same element with different numbers of neutrons.
- Atoms that lose outer electrons become **positive ions**.

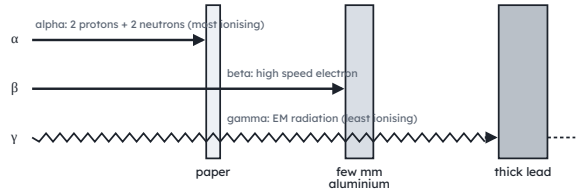
DEVELOPING THE MODEL OF THE ATOM

- Tiny indivisible spheres → **plum pudding** (ball of positive charge with electrons embedded) after the electron was discovered.
- Alpha scattering → **nuclear model** (mass concentrated in a small positive nucleus).
- Bohr: electrons orbit at specific distances. Later: protons, then Chadwick's neutron.
- New evidence changes models.

ALPHA SCATTERING



NUCLEAR RADIATION

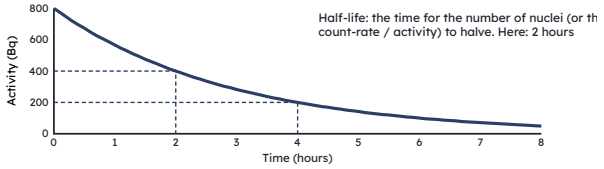


Type	What it is · range in air · ionising
α **alpha**	2 protons + 2 neutrons (helium nucleus) · a few cm · strongly
β **beta**	high speed electron from the nucleus (neutron → proton) · about 1 m · moderately
γ **gamma**	EM radiation from the nucleus · large distances · weakly

NUCLEAR EQUATIONS

- Alpha: $^{219}_{86}Rn \rightarrow {}^{215}_{84}Po + {}^{4}_{2}He$ (mass −4, atomic number −2)
- Beta: $^{14}_{6}C \rightarrow {}^{14}_{7}N + {}^{0}_{-1}e$ (mass same, atomic number +1)
- Gamma: no change to mass or charge. A neutron can also be emitted.

HALF-LIFE

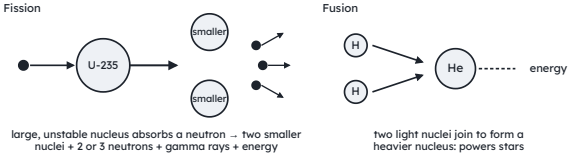


- Decay is **random**. **Activity**: rate of decay, in becquerel (Bq). **Count-rate**: decays recorded each second by a detector (e.g. Geiger-Muller tube).
- (Higher) Net decline: after n half-lives, $(½)^n$ of the original remains.

HAZARDS

- **Contamination:** unwanted presence of materials containing radioactive atoms on other materials. **Irradiation:** exposure to radiation; the object does not become radioactive.
- Results about radiation risks should be shared and **peer reviewed**.
- (PO) **Background radiation**: rocks, cosmic rays, fallout from weapons tests and nuclear accidents. Dose measured in **sieverts (Sv)**.
- (PO) Uses: tracers (short half-life, gamma), radiotherapy; weigh benefits against risks.

FISSION AND FUSION (PO)



- **Fission:** splitting of a large and unstable nucleus (e.g. uranium or plutonium) into two smaller nuclei, roughly equal in size, emitting 2–3 neutrons and gamma rays. A chain reaction is controlled in a reactor.
- **Fusion:** joining of two light nuclei to form a heavier nucleus; some mass may be converted into the energy of radiation.

EXAM TIPS

- Alpha is most ionising but least penetrating; gamma the opposite.
- Short half-life for medical tracers; gamma passes out of the body.

MODEL EXPLANATIONS (GRADE 7+ ANSWERS)

Explain why the plum pudding model was replaced.
A few alpha particles were deflected through large angles or bounced back. This showed the mass and positive charge are concentrated in a tiny nucleus. The plum pudding model has positive charge spread out, so it predicted that all the alpha particles would pass straight through.

Explain why gamma sources are used as medical tracers rather than alpha sources. (Physics only)
Gamma passes out of the body to the detector; alpha would be absorbed inside the body. Gamma is weakly ionising, so it causes less damage to cells; a short half-life means the activity falls quickly after the scan.

Explain the difference between contamination and irradiation.
Contamination is the unwanted presence of materials containing radioactive atoms on or in other materials. Irradiation is exposing an object to nuclear radiation; it does not become radioactive. Contamination is more dangerous because the source stays with you and keeps decaying; irradiation stops when you move away from the source.

4.4 Atomic structure

NUCLEAR EQUATIONS

- Alpha: $^{219}_{86}Rn \rightarrow {}^{215}_{84}Po + {}^{4}_{2}He$ (mass number −4, atomic number −2)
- Beta: $^{14}_{6}C \rightarrow {}^{14}_{7}N + {}^{0}_{-1}e$ (mass number same, atomic number +1)
- Gamma: no change to mass or charge.
- Mass numbers and atomic numbers must balance on both sides.

KEY WORDS

Isotopes: atoms of the same element with the same number of protons but different numbers of neutrons.
Atomic number: the number of protons. Mass number: protons + neutrons.
Activity: the rate at which a source of unstable nuclei decays, in becquerel (Bq).
Count-rate: the number of decays recorded each second by a detector (e.g. Geiger-Muller tube).
Half-life: the time for the number of nuclei of the isotope in a sample to halve, or for the count-rate (or activity) to fall to half its initial level.
Contamination: the unwanted presence of materials containing radioactive atoms on other materials.
Irradiation: exposing an object to nuclear radiation; the object does not become radioactive.
Nuclear fission (PO): the splitting of a large and unstable nucleus into two smaller nuclei, roughly equal in size.
Nuclear fusion (PO): the joining of two light nuclei to form a heavier nucleus.

WORKING SCIENTIFICALLY

- Radioactive decay is random: measure count-rate over a longer time and subtract background radiation.
- Half-life from a graph: read the time for the activity to fall to half; repeat from another starting value.
- Peer review checks findings on radiation risk before they're accepted.

MISCONCEPTIONS

× **Irradiated food becomes radioactive.**	✓ Irradiation doesn't make things radioactive; contamination is the problem.
× **Gamma is the most dangerous everywhere.**	✓ Inside the body, alpha is most dangerous because it's most ionising.
× **Half-life is half the time a sample lasts.**	✓ It's the time for the activity (or number of nuclei) to halve.

AIM FOR GRADE 7+

- Balance nuclear equations: mass and atomic numbers must add up on both sides.
- Choose a medical isotope: type of radiation and half-life, with reasons.
- Explain how the model of the atom changed with new evidence.

COMMAND WORDS

State	a short answer, no explanation
Describe	say what happens, in order
Explain	say what and why: use "because" and "so"
Calculate	equation, substitution, answer, unit
Evaluate	both sides, then a justified conclusion

QUICK-FIRE QUIZ: COVER THE ANSWERS

Radius of an atom?	**About 1×10^{-10} m**
Most penetrating radiation?	**Gamma**
Most ionising radiation?	**Alpha**
Who discovered the neutron?	**James Chadwick**
Fusion joins what?	**Two light nuclei → a heavier nucleus**
Half-life of a sample: random or predictable?	**Each decay is random; half-life is predictable**

UNITS AND PREFIXES

giga (G)	$\times 10^{9}$
mega (M)	$\times 10^{6}$
kilo (k)	$\times 10^{3}$
centi (c)	$\times 10^{-2}$
milli (m)	$\times 10^{-3}$
micro (μ)	$\times 10^{-6}$
nano (n)	$\times 10^{-9}$

Convert to the base unit (m, kg, s, J, W) before you calculate.

PRACTICAL LANGUAGE

Accurate: close to the true value. **Precise:** measurements close to each other. **Repeatable:** same person, same method, similar results. **Reproducible:** similar results by another person or method.
Resolution: smallest change an instrument can show.
Random error: unpredictable scatter; reduce by repeating and averaging. **Systematic error:** every reading out by the same amount, e.g. a **zero error**.

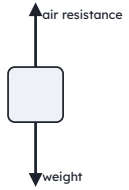
4.5 Forces

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All equations are on the Physics Equations Sheet

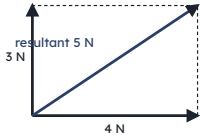
FORCES

- **Scalar:** size only (speed, distance, mass, energy). **Vector:** size and direction (velocity, displacement, force, acceleration, momentum).
- **Contact forces:** friction, air resistance, tension, normal contact force. **Non-contact:** gravitational, electrostatic, magnetic.
- **Weight** is the force acting on an object due to gravity; it acts at the centre of mass. g = 9.8 N/kg.
- **Resultant force:** a single force with the same effect as all the forces acting. Work done = energy transferred.

FREE BODY AND VECTOR DIAGRAMS

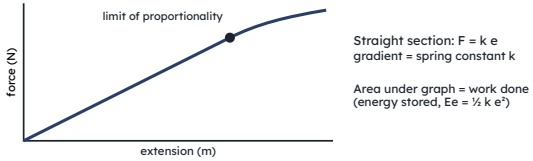


Free body diagram: skydiver



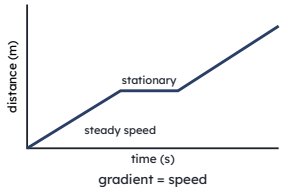
Vector diagram: forces added tip-to-tail (Higher)

ELASTICITY (RP6)

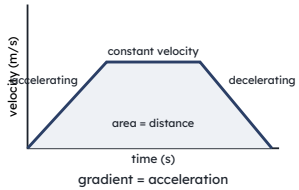


- Elastic deformation: returns to original shape. Extension ∝ force up to the limit of proportionality.
- Measure extension with a pointer, reading at eye level.

MOTION



gradient = speed



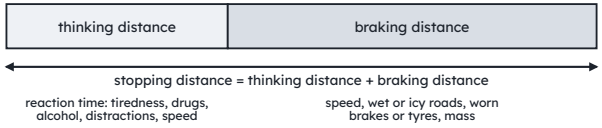
gradient = acceleration

- Speed of sound ≈ 330 m/s; walking ≈ 1.5 m/s; running ≈ 3 m/s; cycling ≈ 6 m/s.
- Acceleration in free fall near Earth's surface ≈ 9.8 m/s².

NEWTON'S LAWS

- **First:** if the resultant force is zero, a stationary object stays still and a moving object keeps the same velocity.
- **Second:** acceleration ∝ resultant force and inversely ∝ mass (F = ma). (HT) Inertial mass = force ÷ acceleration.
- **Third:** whenever two objects interact, the forces they exert on each other are equal and opposite.
- **Terminal velocity:** air resistance increases with speed until it equals weight; resultant force zero.
- **RP7:** vary force at constant mass (move masses from trolley to hanger), and mass at constant force; light gates.

STOPPING DISTANCE



Reaction time 0.2–0.9 s. Large decelerations can overheat brakes or cause loss of control.

MOMENTUM (HT) · MOMENTS AND PRESSURE (PO)

- In a closed system, total momentum before = total momentum after.
- Airbags, seat belts and crumple zones increase the time to stop, reducing the force.
- Balanced when clockwise moments = anticlockwise moments. Gears and levers transmit rotational effects.
- Pressure in a fluid increases with depth and density; upthrust causes floating.

MODEL EXPLANATIONS (GRADE 7+ ANSWERS)

Explain how a skydiver reaches terminal velocity.
At first weight is bigger than air resistance, so there is a resultant force downwards and the skydiver accelerates. As speed increases, air resistance increases, so the resultant force and acceleration decrease; when air resistance = weight, resultant force is zero: terminal velocity.

Explain why an airbag reduces injury in a crash. (Higher)
The airbag increases the time taken for the driver to stop. So the force on the driver is smaller. Force = change in momentum ÷ time; the same change in momentum over a longer time gives a smaller force.

Explain why driving faster makes the braking distance much longer.
Kinetic energy depends on speed squared, so doubling the speed gives four times the kinetic energy. The brakes must transfer more energy. Work done by brakes = braking force × distance; with the same maximum braking force, the distance must be about four times longer.

RP7: ACCELERATION

Aim: Investigate how force and mass affect the acceleration of an object.

Change	Force (or mass)
Measure	Acceleration
Control	Mass (when changing force), force (when changing mass), surface

Must include:

- Investigate both effects: varying force at constant mass, and varying mass at constant force
- Identify which variable is changed and which is kept constant
- Keep the total mass constant when changing force
- Measure acceleration with light gates or timings
- Repeat and average

Common mistake: Adding masses to the hanger without removing them from the trolley.

4.5 Forces

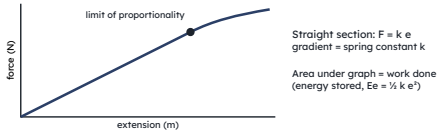
KEY EQUATIONS (ALL ON THE PHYSICS EQUATIONS SHEET)

Equation	Quantities (units)	Watch out
W = m g	weight (N), mass (kg), gravitational field strength (N/kg)	g = 9.8 N/kg on Earth
W = F s	work done (J), force (N), distance moved along the line of the force (m)	1 J = 1 N m
F = k e	force (N), spring constant (N/m), extension (m)	Only up to the limit of proportionality
M = F d	moment (N m), force (N), perpendicular distance from the pivot (m) (Physics only)	Perpendicular distance
p = F ÷ A	pressure (Pa), force normal to the surface (N), area (m^2) (Physics only)	1 Pa = 1 N/m^2
p = h ρ g	pressure (Pa), height of column (m), density (kg/m^3), g (N/kg) (Physics only, Higher)	Pressure increases with depth
s = v t	distance (m), speed (m/s), time (s)	km → m, minutes → s
a = Δv ÷ t	acceleration (m/s^2), change in velocity (m/s), time (s)	Negative a = deceleration
$v^2 - u^2 = 2as$	final velocity (m/s), initial velocity (m/s), acceleration (m/s^2), distance (m)	Square the velocities
F = m a	resultant force (N), mass (kg), acceleration (m/s^2)	Use the resultant force
p = m v	momentum (kg m/s), mass (kg), velocity (m/s) (Higher)	Momentum has a direction
F = m Δv ÷ Δt	force (N) = rate of change of momentum (Higher)	Longer time → smaller force

KEY WORDS

Scalar: size only (speed, distance, mass, energy, time).
Vector: size and direction (velocity, displacement, force, acceleration, momentum).
Weight: the force acting on an object due to gravity; acts at the centre of mass.
Resultant force: a single force that has the same effect as all the original forces acting together.
Work done: energy transferred when a force moves an object through a distance.
Limit of proportionality: the point beyond which extension is no longer proportional to force.
Terminal velocity: the constant velocity reached when the resultant force on a falling object is zero.
Newton's First Law: if the resultant force is zero, a stationary object stays still and a moving object continues at the same velocity.
Newton's Second Law: acceleration is proportional to the resultant force and inversely proportional to the mass (F = ma).
Newton's Third Law: whenever two objects interact, the forces they exert on each other are equal and opposite.
Inertia (Higher): the tendency of objects to continue in their state of rest or of uniform motion.
Stopping distance: thinking distance (during reaction time) + braking distance (under the braking force).

RP6: FORCE AND EXTENSION



Aim: Investigate how adding weights affects the extension of a spring.

Change	Force (weight added)
Measure	Extension
Control	Same spring

Must include:
- Measure the original length
- Calculate extension, not just length
- Add equal force steps
- Plot force against extension
- Determine k from the gradient

Common mistake: Plotting length instead of extension.

MISCONCEPTIONS

× A moving object needs a resultant force.	✓ Constant velocity means zero resultant force (Newton's First Law).
× Mass and weight are the same.	✓ Mass (kg) doesn't change; weight (N) depends on g.
× Third Law pairs cancel out.	✓ They act on different objects, so they can't cancel.

AIM FOR GRADE 7+

- $v^2 - u^2 = 2as$ for braking distances; F = mΔv ÷ Δt for collisions (Higher).
- Explain terminal velocity in steps: forces → resultant → acceleration.
- Describe RP7 with how to keep the investigation valid (constant total mass).

COMMAND WORDS

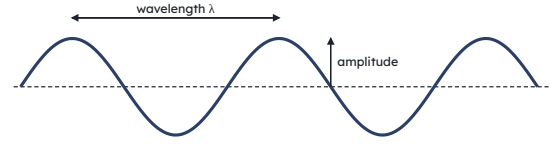
State	a short answer, no explanation
Describe	say what happens, in order
Explain	say what and why: use "because" and "so"
Calculate	equation, substitution, answer, unit
Evaluate	both sides, then a justified conclusion

QUICK-FIRE QUIZ: COVER THE ANSWERS

Unit of momentum?	**kg m/s**
Gradient of a distance–time graph?	**Speed**
Area under a v–t graph? (Higher)	**Distance travelled**
g on Earth?	**9.8 N/kg**
Typical reaction time?	**0.2–0.9 s**
Newton's First Law, in a few words?	**Zero resultant force: velocity doesn't change**

4.6 Waves

TRANSVERSE AND LONGITUDINAL



Transverse: oscillations perpendicular to the direction of energy transfer (e.g. light, water ripples)

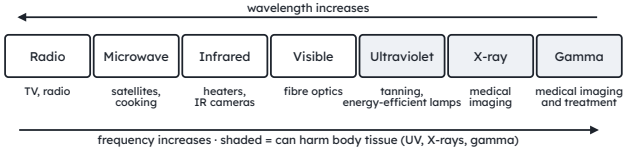


Longitudinal: oscillations parallel to the direction of energy transfer (e.g. sound)

WAVE PROPERTIES

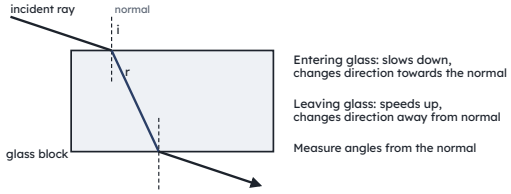
- **Amplitude:** maximum displacement of a point on a wave from its undisturbed position.
- **Wavelength:** distance from a point on one wave to the equivalent point on the adjacent wave.
- **Frequency:** number of waves passing a point each second (Hz). **Period** T = 1 ÷ f.
- Waves transfer energy, not matter (ripples move but the water doesn't travel).

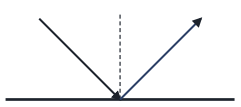
ELECTROMAGNETIC SPECTRUM



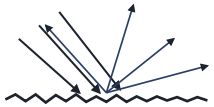
- Transverse; all travel at the same speed in a vacuum (3×10^8 m/s); transfer energy from source to absorber.
- UV: skin ageing and skin cancer risk. X-rays and gamma: ionising, can cause gene mutation and cancer. Dose in sieverts.
- (HT) Radio waves can induce an alternating current in a circuit (aerial).

REFRACTION AND REFLECTION



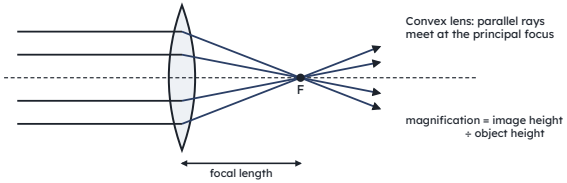


Specular: smooth surface, angle i = angle r



Diffuse: rough surface, light scattered in many directions

LENSES AND LIGHT (PO)

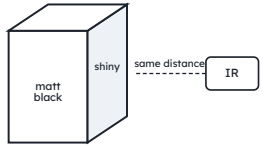


- Convex lens: real or virtual image. Concave lens: always virtual.
- An object's colour depends on which wavelengths it reflects most; filters transmit some colours and absorb the rest.

SOUND, ULTRASOUND, SEISMIC (PO, HT)

- Human hearing: 20 Hz to 20 kHz. Ultrasound is above 20 kHz: partially reflected at boundaries; echo timing gives depth (distance = speed × time ÷ 2).
- P-waves: longitudinal, through solids and liquids. S-waves: transverse, can't pass through liquids → evidence for a liquid outer core.

BLACK BODY RADIATION (RP10)



Leslie cube full of hot water: matt black emits most infrared, shiny silver emits least

Good emitters are good absorbers. Perfect black body absorbs all incident radiation (Physics only)

- All bodies emit and absorb infrared; the hotter, the more it emits.
- (PO) A perfect black body absorbs all radiation incident on it; it is the best emitter.

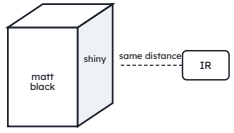
MODEL EXPLANATIONS (GRADE 7+ ANSWERS)

Explain why a ray of light changes direction when it enters a glass block at an angle.
Light slows down when it enters glass, so it changes direction, towards the normal. One side of each wavefront enters the glass first and slows down while the rest is still faster, so the wavefront changes direction.

Explain why a red object looks black in blue light. (Physics only)
A red object reflects red light and absorbs other colours, including blue. Blue light is all absorbed, so no light is reflected to the eye, so the object appears black.

Explain why the Earth's temperature stays roughly constant. (Higher)
The Earth absorbs radiation from the Sun and emits radiation into space. When the rate of absorption equals the rate of emission, the temperature stays constant (it also depends on the atmosphere).

RP10: RADIATION AND ABSORPTION



Leslie cube full of hot water: matt black emits most infrared, shiny silver emits least

Good emitters are good absorbers. Perfect black body absorbs all incident radiation (Physics only)

Aim: Investigate how the amount of infrared radiation absorbed or radiated by a surface depends on the nature of that surface.

Change	Type of surface
Measure	Infrared emitted (detector reading)
Control	Water temperature, distance from detector

Must include:

- Investigate absorption as well as emission
- Same water temperature for all faces
- Same distance from the detector
- Record a reading for each surface
- Conclude which surface emits most and least

Common mistake: Drawing a line graph for categoric data.

4.6 Waves

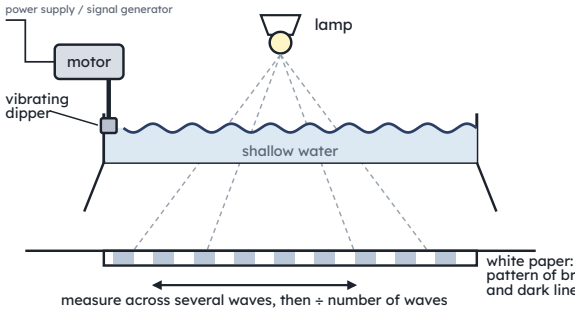
KEY EQUATIONS (ALL ON THE PHYSICS EQUATIONS SHEET)

Equation	Quantities (units)	Watch out
v = f λ	wave speed (m/s), frequency (Hz), wavelength (m)	MHz → Hz: × 10^6
T = 1 ÷ f	period (s), frequency (Hz)	Period: time for one wave
magnification = image height ÷ object height	no units (Physics only)	Same units top and bottom

KEY WORDS

Transverse: oscillations are perpendicular to the direction of energy transfer.
Longitudinal: oscillations are parallel to the direction of energy transfer; compressions and rarefactions.
Amplitude: the maximum displacement of a point on a wave away from its undisturbed position.
Wavelength: the distance from a point on one wave to the equivalent point on the adjacent wave.
Frequency: the number of waves passing a point each second (Hz).
Refraction: a change in direction when a wave changes speed crossing a boundary.
Perfect black body (PO): an object that absorbs all of the radiation incident on it; the best possible emitter.

RP8: WAVES



Aim: Make observations to identify suitable apparatus to measure the frequency, wavelength and speed of waves in a ripple tank and waves in a solid (a stretched string), and take appropriate measurements.

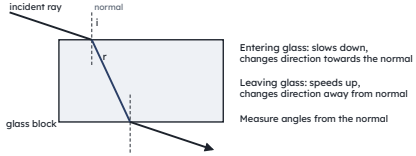
Change	Frequency (string)
Measure	Wavelength
Control	Water depth (ripple tank), tension and string length

Must include:

- Take measurements for both the ripple tank and waves in a solid (string)
- Justify why the apparatus is suitable
- Measure across several wavelengths and divide
- Determine frequency by counting over a set time or from the signal generator
- Calculate v = fλ

Common mistake: Measuring one wavelength only.

RP9: LIGHT (REFLECTION AND REFRACTION) (PO)



Aim: Investigate the reflection of light by different types of surface and the refraction of light by different substances.

Change	Angle of incidence
Measure	Angle of reflection or refraction
Control	Ray box, block material, width of ray

Must include:

- Test reflection from different types of surface
- Test refraction in different substances
- Draw a normal
- Measure angles from the normal with a protractor
- Use a thin ray

Common mistake: Measuring angles from the surface instead of the normal.

MISCONCEPTIONS

× **Water travels along with the wave.**	✓ Waves transfer energy, not matter.
× **Sound travels through a vacuum.**	✓ Sound needs particles to vibrate.
× **All EM waves are dangerous.**	✓ Only UV, X-rays and gamma rays harm body tissue; X-rays and gamma rays are ionising.
× **Light bends when it goes into glass.**	✓ Light travels in straight lines. It changes direction at the boundary because its speed changes.

AIM FOR GRADE 7+

- Standard form and unit prefixes in v = fλ (MHz, kHz, 3 × 10^8 m/s).
- Explain refraction using wavefronts (Higher).
- Echo questions: halve the total distance (Physics only, Higher).

COMMAND WORDS

State	a short answer, no explanation
Describe	say what happens, in order
Explain	say what and why: use "because" and "so"
Calculate	equation, substitution, answer, unit
Evaluate	both sides, then a justified conclusion

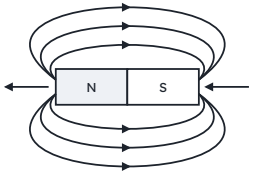
QUICK-FIRE QUIZ: COVER THE ANSWERS

Unit of frequency?	**Hertz (Hz)**
Fastest EM wave?	**All the same speed in a vacuum**
Human hearing range?	**20 Hz – 20 kHz**
Best emitter of infrared?	**Matt black surface**
EM wave used in fibre optics?	**Visible light**
Waves that can't pass through liquids?	**S-waves**

4.7 Magnetism and electromagnetism

AQA GCSE Physics 8463
Paper 2 · Physics only (PO) · Higher (HT)
All equations are on the Physics Equations Sheet

MAGNETS AND FIELDS

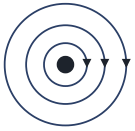


Field lines: N → S
closest at the poles,
where the field is strongest

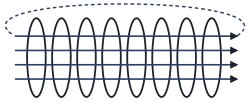
Like poles repel,
unlike poles attract

- Like poles repel; unlike poles attract.
- **Permanent magnet:** produces its own field. **Induced magnet:** becomes a magnet when placed in a magnetic field; always attracts; loses most magnetism when removed.
- Magnetic materials: iron, steel, cobalt, nickel.
- Plot field lines with a compass. A compass points north: evidence that the Earth's core is magnetic.

ELECTROMAGNETISM



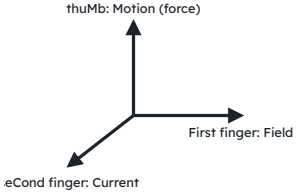
Wire (current into page):
circular field; stronger near the wire



Solenoid: strong, uniform field inside;
add an iron core → electromagnet

- Current in a wire produces a magnetic field around it; stronger with more current and closer to the wire.
- Solenoid: strong, uniform field inside. Stronger with more turns, more current, iron core (electromagnet).

MOTOR EFFECT (HT)



Fleming's left-hand rule (Higher)

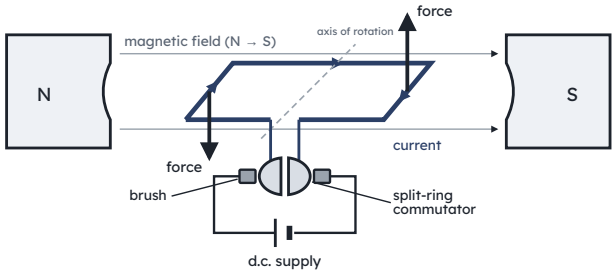
$F = B\,I\,l$

F = force (N)
B = magnetic flux density (T)
I = current (A); l = length (m)

Reverse the current or the field
→ the force reverses

- A current-carrying wire in a magnetic field experiences a force.
- Magnetic flux density B is measured in tesla (T).

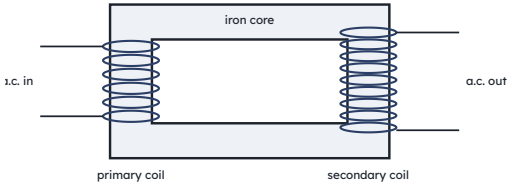
ELECTRIC MOTOR (HT)



GENERATOR EFFECT (PO, HT)

- A p.d. is induced when a conductor moves relative to a magnetic field, or the field around it changes. In a complete circuit, a current flows.
- The induced current's field opposes the original change.
- Bigger p.d.: move faster, stronger magnet, more turns.
- **Alternator:** generates a.c. **Dynamo:** generates d.c.
- **Microphone:** sound vibrates a coil in a magnetic field → induced p.d. (generator effect). **Loudspeaker:** a.c. in a coil → force → cone vibrates (motor effect).

TRANSFORMERS (PO, HT)



$V_p \div V_s = n_p \div n_s$
$V_s \times I_s = V_p \times I_p$
(Physics only, Higher)

- Primary and secondary coils on an iron core (easily magnetised).
- a.c. in the primary → changing field in the core → induced p.d. in the secondary. Doesn't work with d.c.
- Step-up: more secondary turns, higher p.d., lower current (National Grid).

EXAM TIPS

- Fleming's left-hand rule: First finger Field, seCond finger Current, thuMb Motion.
- Reverse the current or the field to reverse the force.

MODEL EXPLANATIONS (GRADE 7+ ANSWERS)

Explain how a loudspeaker produces sound. (Physics only, Higher)
An alternating current flows through a coil in a magnetic field, so the coil feels a force (motor effect) that keeps changing direction. The coil and cone vibrate in and out, creating pressure variations in the air: a sound wave.

Explain why a compass needle points north.
A compass contains a small bar magnet, which lines up with the Earth's magnetic field. So the Earth has a magnetic field, which is evidence that the Earth's core is magnetic.

Explain how a moving-coil microphone works. (Physics only, Higher)
Sound waves make the diaphragm and coil vibrate in the field of a permanent magnet. The coil moves relative to the field, inducing a p.d. (generator effect); the p.d. varies in the same pattern as the sound wave.

UNITS AND PREFIXES

giga (G)	$\times 10^{9}$
mega (M)	$\times 10^{6}$
kilo (k)	$\times 10^{3}$
centi (c)	$\times 10^{-2}$
milli (m)	$\times 10^{-3}$
micro (μ)	$\times 10^{-6}$
nano (n)	$\times 10^{-9}$

Convert to the base unit (m, kg, s, J, W) before you calculate.

4.7 Magnetism and electromagnetism

AQA GCSE Physics 8463
Paper 2 · Physics only (PO) · Higher (HT)
All equations are on the Physics Equations Sheet

KEY EQUATIONS (ALL ON THE PHYSICS EQUATIONS SHEET)

Equation	Quantities (units)	Watch out
F = B I l	force (N), magnetic flux density (T), current (A), length (m) (Higher)	Wire at right angles to the field
Vp ÷ Vs = np ÷ ns	p.d. (V) and number of turns on the primary and secondary coils (Physics only, Higher)	Same ratio both sides
Vs × Is = Vp × Ip	for a 100% efficient transformer: power in = power out (Physics only, Higher)	Step up p.d. → current down

KEY WORDS

Permanent magnet: produces its own magnetic field.
Induced magnet: becomes a magnet when placed in a magnetic field; induced magnetism always causes attraction.
Magnetic field: the region around a magnet where a force acts on another magnet or magnetic material.
Solenoid: a coil of wire; the field inside is strong and uniform. With an iron core: an electromagnet.
Motor effect (Higher): a force on a current-carrying conductor in a magnetic field.
Generator effect (PO, Higher): a p.d. is induced when a conductor moves relative to a magnetic field, or the field changes.
Magnetic flux density: the strength of a magnetic field, in tesla (T).

PRACTICAL SKILLS

- Plot field lines with a compass: mark where the needle points, move the compass along, join the marks.
- Electromagnet investigation: independent = turns (or current); dependent = paper clips picked up; control = core, clip size.
- Repeat readings and calculate a mean to reduce random error.

MISCONCEPTIONS

× **All metals are magnetic.**	✓ Only iron, steel, cobalt and nickel.
× **Field lines can cross.**	✓ Field lines never cross.
× **Transformers work with d.c.**	✓ They need a changing (a.c.) field to induce a p.d.

AIM FOR GRADE 7+

- Rearrange F = BIl; convert cm to m.
- Two-step transformer questions: p.d. from turns ratio, then current from power in = power out.
- Explain motors, loudspeakers and microphones as chains of cause and effect.

COMMAND WORDS

State	a short answer, no explanation
Describe	say what happens, in order
Explain	say what and why: use "because" and "so"
Calculate	equation, substitution, answer, unit
Evaluate	both sides, then a justified conclusion

QUICK-FIRE QUIZ: COVER THE ANSWERS

Unit of magnetic flux density?	**Tesla (T)**
Field direction outside a magnet?	**North to south**
Rule for the motor effect?	**Fleming's left-hand rule**
Generator that makes a.c.?	**Alternator**
Why an iron core?	**Easily magnetised**
Does an induced magnet attract or repel?	**Always attracts**

PRACTICAL LANGUAGE

Accurate: close to the true value. **Precise:** measurements close to each other. **Repeatable:** same person, same method, similar results. **Reproducible:** similar results by another person or method. **Resolution:** smallest change an instrument can show. **Random error:** unpredictable scatter; reduce by repeating and averaging. **Systematic error:** every reading out by the same amount, e.g. a **zero error**.

GRAPH SKILLS

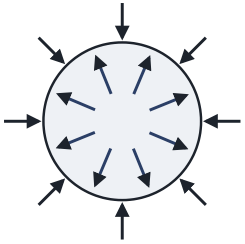
- Label both axes with quantity and unit; use more than half the grid.
- Draw a line (or smooth curve) of best fit; circle and ignore anomalous results.
- Straight line through the origin = directly proportional.
- Gradient = change in y ÷ change in x; use a big triangle.

4.8 Space physics

OUR SOLAR SYSTEM

- One star (the Sun), eight planets, dwarf planets (e.g. Pluto) and natural satellites (moons) that orbit planets.
- Our solar system is a small part of the **Milky Way** galaxy.
- The Sun formed from a **nebula** (cloud of dust and gas) pulled together by gravity.

MAIN SEQUENCE STARS



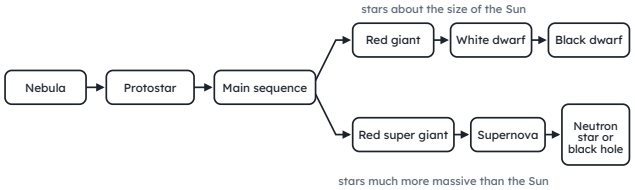
Main sequence star is stable: inward gravity balances the outward force from fusion energy (equilibrium)

- Gravity pulls the nebula together → protostar → hot enough for fusion of hydrogen → main sequence star.
- Stable for billions of years: forces in equilibrium.

WHERE THE ELEMENTS COME FROM

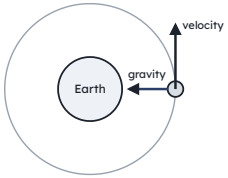
- Fusion in stars produces all the naturally occurring elements up to iron.
- Elements heavier than iron are produced in a **supernova**.
- The supernova explosion distributes the elements throughout the universe.

LIFE CYCLE OF STARS



The life cycle depends on the size (mass) of the star.

ORBITS

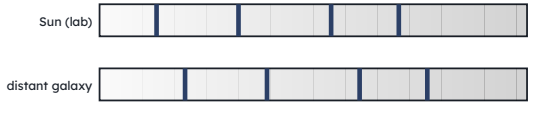


Gravity provides the force towards the centre, so speed stays the same but direction (velocity) changes: the satellite is accelerating (Higher)

Smaller orbit → must move faster to stay in orbit (stable orbit: if speed changes, radius changes)

- Gravity provides the force that keeps planets and satellites (natural and artificial) in orbit.
- (HT) In a circular orbit, gravity changes the velocity but not the speed: the object is accelerating.
- (HT) For a stable orbit, if the speed changes the radius must change: faster → smaller orbit.

RED-SHIFT



Red-shift: lines move to longer wavelengths → galaxy moving away. Further away = bigger red-shift → universe is expanding → evidence for the Big Bang

- **Red-shift:** an observed increase in the wavelength of light from most distant galaxies.
- The further away the galaxy, the faster it is moving away and the bigger the red-shift.

THE BIG BANG

- Red-shift shows the universe is expanding: evidence for the **Big Bang**.
- The universe began from a very small region that was extremely hot and dense.
- Since 1998, observations of supernovae suggest distant galaxies are receding ever faster.
- **Dark mass** and **dark energy** are proposed to explain observations, but are not understood: there is still much to learn.

EXAM TIPS

- The Sun will not become a black hole: it isn't massive enough.
- 'Red-shift' is about wavelength increasing, not the galaxy turning red.
- Use 'equilibrium' or 'balanced' for main sequence stars.

MODEL EXPLANATIONS (GRADE 7+ ANSWERS)

Explain how the elements found on Earth were made.
Fusion in stars joins light nuclei to make heavier elements, up to iron. Elements heavier than iron are made in supernovas, which distribute them through the universe, where they form new stars and planets.

Explain why a satellite in a lower orbit must travel faster. (Higher)
Closer to the Earth, the gravitational force is stronger, so the satellite must move faster to stay in orbit. For a stable orbit, if the speed changes the radius must change; a smaller orbit needs a higher speed.

Explain why scientists accept the Big Bang theory.
It explains why light from most distant galaxies is red-shifted, showing the universe is expanding. Theories are accepted when they explain the evidence; they can be changed if new evidence (e.g. dark energy) is found.

4.8 Space physics

AQA GCSE Physics 8463
Paper 2 · All Physics only · Higher (HT)
All equations are on the Physics Equations Sheet

SEQUENCES TO LEARN

- Sun-sized: nebula → protostar → main sequence → red giant → white dwarf → black dwarf
- Much more massive: nebula → protostar → main sequence → red super giant → supernova → neutron star or black hole
- Evidence chain: red-shift → galaxies receding → expanding universe → Big Bang

KEY WORDS

Nebula: a cloud of dust and gas where stars form.
Main sequence star: a stable star: inward gravity balances the outward force from fusion energy.
Supernova: the explosion of a massive star; produces elements heavier than iron and distributes them through the universe.
Satellite: an object that orbits a larger body; moons are natural, others artificial.
Red-shift: an observed increase in the wavelength of light from most distant galaxies.
Big Bang theory: the universe began from a very small region that was extremely hot and dense.
Dark mass and dark energy: proposed to explain observations; not yet understood.

DATA AND EVIDENCE SKILLS

- Plot speed of recession against distance: a straight line through the origin shows proportionality.
- Evidence → conclusion: red-shift → galaxies moving away → universe expanding → Big Bang.
- Theories change when new evidence appears (e.g. dark energy since 1998).

MISCONCEPTIONS

× **The Sun will become a black hole.**	✓ It isn't massive enough: it becomes a white dwarf, then a black dwarf.
× **Red-shift means the galaxy looks red.**	✓ It means the wavelength of its light has increased.
× **Satellites at constant speed aren't accelerating.**	✓ Their direction changes, so velocity changes: they accelerate (Higher).

AIM FOR GRADE 7+

- Explain the life cycle of a star as a sequence of linked steps.
- Link red-shift to distance and speed, then to an expanding universe.
- Explain why orbiting objects accelerate at constant speed (Higher).

COMMAND WORDS

State	a short answer, no explanation
Describe	say what happens, in order
Explain	say what and why: use "because" and "so"
Calculate	equation, substitution, answer, unit
Evaluate	both sides, then a justified conclusion

QUICK-FIRE QUIZ: COVER THE ANSWERS

Number of planets in our solar system?	**Eight**
Where do stars form?	**Nebula**
Elements made in normal stars?	**Up to iron**
What keeps planets in orbit?	**Gravity**
Evidence universe is expanding?	**Red-shift of distant galaxies**
Unknowns in cosmology?	**Dark mass and dark energy**

PRACTICAL LANGUAGE

Accurate: close to the true value. **Precise:** measurements close to each other. **Repeatable:** same person, same method, similar results. **Reproducible:** similar results by another person or method.
Resolution: smallest change an instrument can show.
Random error: unpredictable scatter; reduce by repeating and averaging. **Systematic error:** every reading out by the same amount, e.g. a **zero error**.

SIX-MARK ANSWERS

- Plan: jot 6 key points first.
- Write in a logical order, using AQA key words.
- Methods: equipment, what you change, what you measure, what you keep the same, repeats, safety.
- Explanations: link each step with "so" or "because".

MATHS SKILLS

- Standard form: $3.2 \times 10^4 = 32\,000$; $5 \times 10^{-3} = 0.005$.
- Give answers to the same number of significant figures as the data (usually 2 or 3).
- Rearrange before substituting; show every step.
- Mean = total ÷ number of readings (leave out anomalies).