Topics 4.1–4.4
Full edition:
Topics 1–4

Paper 1 Revision Booklet

ANSWERS AQA GCSE Physics 8463 · Foundation & Higher



Name _____ Class _____ Target grade _____

4.1 Energy	**4.2** Electricity	**4.3** Particle model of matter	**4.4** Atomic structure

Work through a topic, then come back to it on the dates in your planner. Little and often beats one long cram.

Revise like a scientist

This booklet uses six revision techniques that research shows work best. Every activity is labelled with the technique it uses and the grade it targets.

Retrieval practice
Pulling ideas out of your memory makes them stick far better than re-reading. Brain dumps, quizzes and cover-and-recall tasks.

Spaced practice
Revisit each topic after 2 days, 1 week and 3 weeks. Forgetting a little, then remembering again, strengthens memory.

Interleaving
Mixed-topic questions train you to spot which idea a question needs, just like the real exam.

Dual coding
Words plus diagrams: graphs, ray diagrams and labelled apparatus give your memory two routes in.

Elaboration
Asking 'why?' and 'how?' and linking ideas together turns facts into understanding.

Worked examples
I do → We do → You do: study a full solution, finish a half-done one, then do one alone.

KEY

Grade pathways

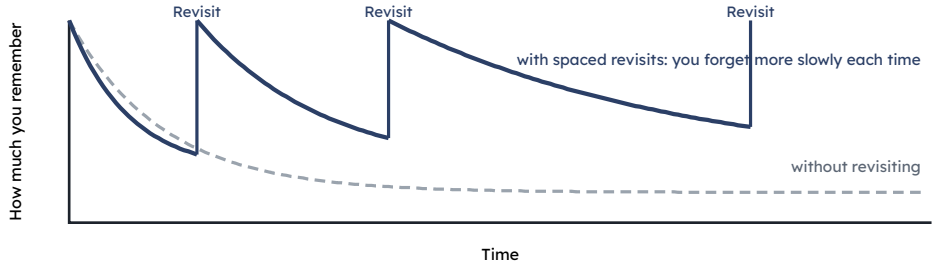
GRADE 4
Secure the basics: recall definitions and units, pick the right equation from the equation sheet, and do one-step calculations.

GRADE 5
Rearrange equations, convert units, describe practicals and explain in two linked steps.

GRADE 7+
Multi-step calculations, evaluate methods and data, and write logical 6-mark answers.

SPACED PRACTICE DUAL CODING

Why spacing works



SPACED PRACTICE

My spaced revision planner

Write the date you'll do each session. Tick it off when it's done.

Topic	First go	+2 days	+1 week	+3 weeks	Before the mock
4.1 Energy					
4.2 Electricity					
4.3 Particle model of matter					
4.4 Atomic structure					
Paper 1 mixed quiz					

What's inside

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ROUTINE

The routine for every page

1. Try it cold. Answer from memory first, without notes. Struggling a bit is good: it's what makes learning stick.

2. Check and correct. Mark it with the answer booklet in a different colour pen. Fix every mistake.

3. Come back later. Redo anything you got wrong on your next spaced session.

ONLINE

Use it with mrsullyphysics.com

Flashcards for retrieval practice: cards you get wrong come back until you get them right.

Quizzes and Aim higher for extra Grade 5+ and 7+ questions with mark schemes.

Animations to see the physics move (dual coding).

Brain dump and checklist

RETRIEVAL PRACTICE · GRADE 4 · GRADE 5 · GRADE 7

Brain dump

Set a timer for 5 minutes. Write or draw everything you remember about energy: stores, equations, units, practicals. No notes! Afterwards, add anything you missed in a different colour.

Prompts if you get stuck: stores? · pathways? · Ek, Ep, Ee? · specific heat capacity? · power? · efficiency? · renewables?

METACOGNITION

How confident am I?

Rate each statement now (before) by shading R, A or G. Rate again at the end of the topic (after).

I can...	Before			After		
	R	A	G	R	A	G
Name the eight energy stores and describe how energy is transferred between them	◯	◯	◯	◯	◯	◯
Calculate kinetic, gravitational potential and elastic potential energy	◯	◯	◯	◯	◯	◯
Use $\Delta E = mc\Delta\theta$ and describe the specific heat capacity practical	◯	◯	◯	◯	◯	◯
Define power and use $P = E \div t$ and $P = W \div t$	◯	◯	◯	◯	◯	◯
State the principle of conservation of energy and describe dissipation	◯	◯	◯	◯	◯	◯
Explain how lubrication and thermal insulation reduce wasted energy	◯	◯	◯	◯	◯	◯
Explain how thermal conductivity and wall thickness affect the rate of cooling	◯	◯	◯	◯	◯	◯
Calculate efficiency and rearrange the equation	◯	◯	◯	◯	◯	◯
Describe the thermal insulation practical (Physics only)	◯	◯	◯	◯	◯	◯
Compare renewable and non-renewable energy resources	◯	◯	◯	◯	◯	◯

Extra practice

Retrieval · answers in the answer booklet

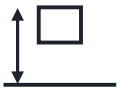
1 Fill the gap: Power is the _____ at which energy is transferred. [1]

rate. Power = energy ÷ time: a rate.

DUAL CODING | GRADE 4 | GRADE 5 | GRADE 7

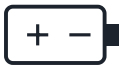
THE EIGHT ENERGY STORES


Kinetic


Gravitational potential


Elastic potential


Thermal


Chemical



Magnetic


Electrostatic


Nuclear

HOW ENERGY IS TRANSFERRED

- **Mechanically:** by a force doing work
- **Electrically:** by an electric current doing work
- **By heating:** because of a temperature difference
- **By radiation:** by waves, e.g. light and sound

BIG IDEAS

- Energy can be transferred usefully, stored or **dissipated**, but can't be created or destroyed.
- In a **closed system** there is no net change to the total energy.
- Wasted energy is usually dissipated to the surroundings by heating.

KEY EQUATIONS: ALL GIVEN ON THE PHYSICS EQUATIONS SHEET IN THE EXAM

Equation (on your equation sheet)	Quantities and 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)	Δθ = final – start temperature
$P = E \div t$	power (W), energy transferred (J), time (s)	kW → W, minutes → s
$P = W \div t$	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%)

TURN OVER

Key words, misconceptions and Grade 7+ links are on the next page.

Knowledge organiser: key words, misconceptions, practicals

ELABORATION | GRADE 4 | GRADE 5 | GRADE 7

KEY WORDS: LEARN THESE WORD FOR WORD (SAME AS SIDE 2 OF YOUR KNOWLEDGE ORGANISER)

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.

MISCONCEPTIONS: SPOT THE MISTAKE

× Common mistake	✓ What's actually true
× 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.

REDUCE WASTED ENERGY

Lubrication: reduces friction.
Thermal insulation: reduces energy transfer by heating.
Streamlining: reduces air resistance.
Thicker walls with low thermal conductivity slow the rate of cooling of a building.

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

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.
Common mistake: Starting the timer at different temperatures.

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.

RETRIEVAL PRACTICE | SPACED PRACTICE | GRADE 4 | GRADE 5

Equation sheet skills: which equation, which unit?

You get every equation on the Physics Equations Sheet, but it won't tell you which one a question needs or what unit the answer has. Cover the knowledge organiser and fill in the table. Redo it on another day (spaced!).

Situation	Which equation?	Unit of the answer	Redo 1 ✓/×	Redo 2 ✓/×
A 2 kg trolley is moving at 3 m/s. How much energy is in its kinetic store?	**$E_k = \frac{1}{2} m v^2$**	**J (joules)**		
A crate is lifted onto a shelf. How much energy does it gain?	**$E_p = m g h$**	**J**		
A spring is stretched by 5 cm. How much energy does it store?	**$E_e = \frac{1}{2} k e^2$**	**J (convert cm → m)**		
A block of copper warms up by 20 °C. How much energy did it take in?	**$\Delta E = m c \Delta\theta$**	**J**		
A motor lifts a load in 4 s. How quickly is it transferring energy?	**P = E ÷ t (or W ÷ t)**	**W (watts)**		
How much of a lamp's input ends up as light?	**efficiency = useful ÷ total**	**no unit (or %)**		

RETRIEVAL PRACTICE | GRADE 4 | GRADE 5

Fill the gaps

Use the AQA key words. No word bank: that's the point.

1. Energy can be transferred usefully, stored or **dissipated**, but cannot be created or destroyed.
2. The amount of energy needed to raise the temperature of 1 kg of a substance by 1 °C is its **specific heat capacity**.
3. Power is the **rate** at which energy is transferred.
4. One watt is equal to one **joule** per second.
5. Wasted energy is usually transferred to the **thermal** store of the surroundings.

ELABORATION | GRADE 5

Odd one out

Circle the odd one out in each row and explain why.

1. kinetic · thermal · heating · nuclear

Heating: it is a way energy is transferred, not a store.

2. watt · joule per second · joule

Joule: it is a unit of energy; the others are units of power.

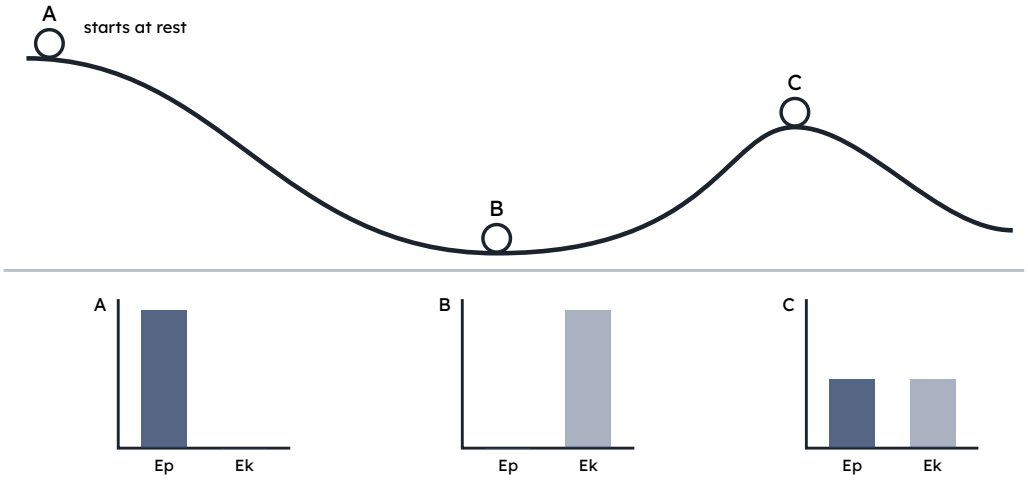
3. wind · tidal · nuclear · solar

Nuclear: nuclear fuel is non-renewable; the others are renewable.

DUAL CODING GRADE 4 GRADE 5

Roller coaster energy

A car starts at rest at A. Ignore friction. Draw bars to show the gravitational potential (Ep) and kinetic (Ek) energy at A, B and C.



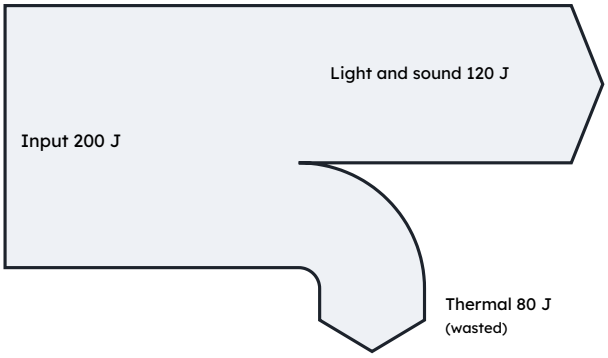
At A all the energy is in the gravitational potential store. At B (lowest point) it has all been transferred to the kinetic store.

At C some is back in the gravitational store; the total stays the same (conservation of energy).

DUAL CODING GRADE 4 GRADE 5

Reading a Sankey diagram

Sankey diagrams show energy transfers to scale. The width of each arrow shows the amount of energy.



a How much energy is wasted? [1]

80 J

b Calculate the efficiency of the TV. [2]

120 ÷ 200

= 0.6 (60%)

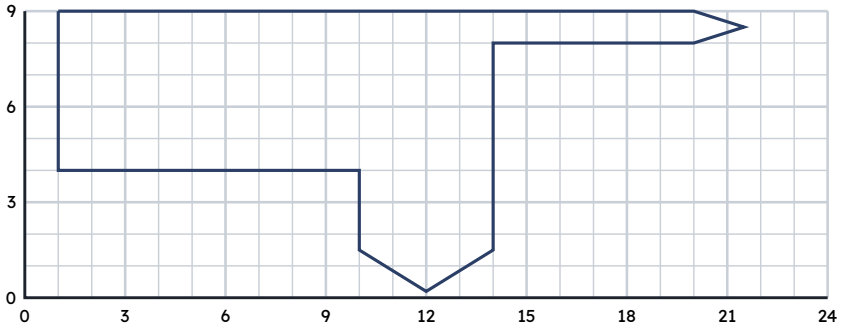
c Where does the wasted energy go? [1]

Thermal store of the surroundings (dissipated by heating).

DUAL CODING GRADE 5

Draw your own Sankey diagram

An energy-saving lamp is supplied with 100 J. It transfers 20 J usefully by light. Draw a Sankey diagram to scale on the grid (1 square = 20 J).



Answer: input arrow 5 squares wide (100 J); useful arrow 1 square wide (20 J light) continues straight; wasted arrow 4 squares wide (80 J thermal) turns downwards. Efficiency = 20 ÷ 100 = 0.2.

WORKED EXAMPLES | GRADE 4 | GRADE 5

Kinetic energy

I do (worked example)

A 2 kg ball moves at 3 m/s. Calculate Ek.

1. Write the equation: Ek = ½mv²
2. Substitute: Ek = ½ × 2 × 3²
3. Square first: 3² = 9
4. Ek = ½ × 2 × 9 = **9 J**

We do (finish it)

A 60 kg runner moves at 5 m/s.

1. Ek = ½mv²
2. Ek = ½ × 60 × ___ **5²**
3. 5² = ___ **25**
4. Ek = ___ J **750**

You do

A 900 kg car moves at 20 m/s.

Ek = ½mv²

= ½ × 900 × 20²

= ½ × 900 × 400

= 180 000 J

WORKED EXAMPLES | GRADE 4 | GRADE 5

Gravitational potential energy

I do (worked example)

A 3 kg box is lifted 2 m. Calculate Ep. (g = 9.8 N/kg)

1. Ep = mgh
2. Ep = 3 × 9.8 × 2
3. **Ep = 58.8 J**

Units: kg, N/kg, m → J

We do (finish it)

A 50 kg student climbs 4 m.

1. Ep = mgh
2. Ep = 50 × 9.8 × ___ **4**
3. Ep = ___ J **1960**

You do

A 0.5 kg book is lifted 1.2 m.

Ep = mgh

= 0.5 × 9.8 × 1.2

= 5.88 J

WORKED EXAMPLES | GRADE 7

Rearranging: the next step

Grade 7+ questions often ask you to rearrange. Use the triangle-free method: write the equation, substitute, then solve.

1 A 0.2 kg ball is dropped from 1.8 m. Calculate its speed just before it hits the ground (ignore air resistance). [4]

Ep lost = mgh = 0.2 × 9.8 × 1.8 = 3.528 J

Ek gained = Ep lost, so ½ × 0.2 × v² = 3.528

v² = 3.528 ÷ 0.1 = 35.28

v = √35.28 = 5.9 m/s

2 A spring (k = 40 N/m) stores 0.2 J. Calculate its extension. [3]

Ee = ½ke², so e² = 2Ee ÷ k

e² = 2 × 0.2 ÷ 40 = 0.01

e = 0.1 m

WORKED EXAMPLES GRADE 4 GRADE 5

Specific heat capacity

I do (worked example)

Heat 0.5 kg of water by 20 °C (c = 4200 J/kg °C).

1. ΔE = mcΔθ
2. ΔE = 0.5 × 4200 × 20
3. **ΔE = 42 000 J**

Δθ = change in temperature

We do (finish it)

Heat 2 kg of oil by 15 °C (c = 2000).

1. ΔE = mcΔθ
2. ΔE = 2 × ___ × 15 **2000**
3. ΔE = ___ J **60 000**

You do

Heat 0.25 kg of water from 20 °C to 80 °C.

Δθ = 80 − 20 = 60 °C

ΔE = 0.25 × 4200 × 60

= 63 000 J

WORKED EXAMPLES GRADE 4 GRADE 5

Power and efficiency

I do (worked example)

A 2 kW kettle runs for 2 minutes. Calculate E.

1. Convert: 2 kW = 2000 W, 2 min = 120 s
2. E = Pt
3. E = 2000 × 120
4. **E = 240 000 J**

We do (finish it)

A motor: 500 J in, 400 J useful.

1. efficiency = useful ÷ total
2. = ___ ÷ 500 **400**
3. = ___ **0.8**
4. As a %: ___ **80%**

You do

A 1.5 kW heater runs for 10 min.

1500 W, 600 s

E = Pt = 1500 × 600

= 900 000 J

ELABORATION GRADE 5

Spot the mistake

Each student has made one mistake. Find it and correct it.

1 Ali: "A 2 kg ball at 4 m/s has Ek = ½ × 2 × 4 = 4 J." [2]

Speed wasn't squared: Ek = ½ × 2 × 4² = 16 J

2 Bea: "A 60 W lamp on for 2 minutes transfers 60 × 2 = 120 J." [2]

Time must be in seconds: 60 × 120 = 7200 J

3 Cal: "A machine with an efficiency of 1.2 is very good." [1]

Efficiency can't be more than 1 (100%): energy can't be created.

Extra practice

Retrieval · answers in the answer booklet

1 True or false? Energy can be created in a power station. Explain. [2]

False. Energy can't be created or destroyed, only transferred.

ELABORATION GRADE 4 GRADE 5 GRADE 7

Build an explanation

Answer each question in two steps. Use the starter, then push yourself with the Grade 7+ extension.

1 Why does a car's brakes get hot when it stops?

Grade 4–5 starter: "The car's kinetic energy store decreases because…"

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.

Grade 7+ extension: "This means the energy is… so the total energy…"

The energy is dissipated to the surroundings by heating, so it's less useful,

but the total energy stays the same (conservation of energy).

2 How does loft insulation keep a house warm for longer?

Grade 4–5 starter: "Insulation has a low thermal conductivity, so…"

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.

Grade 7+ extension: "Link to the rate of cooling: the rate depends on…"

The rate of cooling depends on the thickness and thermal conductivity of the walls and roof:

thicker insulation with lower conductivity means slower cooling.

3 Why is it impossible for any device to be 100% efficient?

Grade 4–5 starter: "Some energy is always…"

Some energy is always dissipated (wasted), usually by heating the surroundings.

So the useful output is always less than the total input.

Grade 7+ extension: "Use an example and explain where the energy goes."

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.

ELABORATION GRADE 5

True or false? Justify it.

Saying why is worth more marks than saying true or false.

4 "Energy is used up when a battery goes flat." [2]

False: energy isn't used up; the chemical store has been transferred

to other stores, e.g. dissipated by heating.

5 "A more powerful kettle transfers more energy per second." [1]

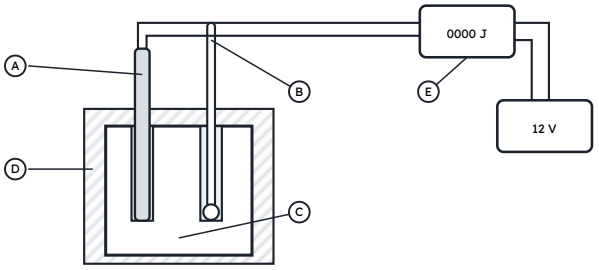
True: power is the rate of energy transfer.

Required practical 1: specific heat capacity

DUAL CODING GRADE 4

Label the apparatus

Write the name of each labelled part, A to E.



A Immersion heater

B Thermometer

C Aluminium block

D Insulation

E Joulemeter

RETRIEVAL PRACTICE GRADE 4 GRADE 5

Put the method in order

Write the letters in the right order.

A. Switch on the heater and start the stopwatch.
B. Measure the mass of the aluminium block.
C. Record the temperature and energy every minute for 10 minutes.
D. Wrap the block in insulation and insert the heater and thermometer.
E. Plot temperature against energy and find the gradient.
F. Record the starting temperature.

B, D, F, A, C, E

ELABORATION GRADE 5 GRADE 7

Why do we...?

1 ...wrap the block in insulation? [1]

To reduce energy transferred to the surroundings by heating.

2 ...put a drop of water in the thermometer hole? [1]

To improve thermal contact between the thermometer and the block.

3 ...usually get a value of c that is higher than the true value? [2]

Some energy is dissipated to the surroundings, so $\Delta\theta$ is smaller than expected;

$c = \Delta E \div (m\Delta\theta)$, so a smaller $\Delta\theta$ gives a larger c.

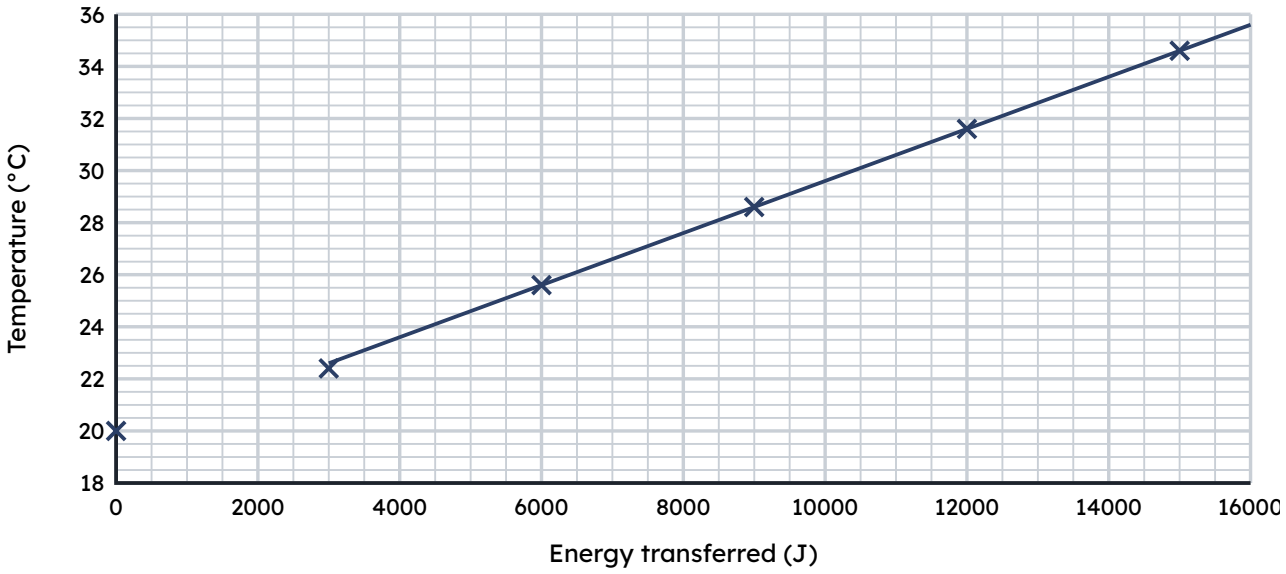
RP1: analyse the results

DUAL CODING | WORKED EXAMPLES | GRADE 5 | GRADE 7

Plot and analyse

A 1.0 kg aluminium block was heated. Plot the results and draw a line of best fit through the straight section.

Energy (J)	0	3000	6000	9000	12 000	15 000
Temperature (°C)	20.0	22.4	25.6	28.6	31.6	34.6



a Explain why the first point is below the line. [1]

The block takes time to heat up evenly (the thermometer lags).

b Calculate the gradient of the straight section. [2]

Gradient = (34.6 – 25.6) ÷ (15 000 – 6000)

= 9.0 ÷ 9000 = 0.0010 °C/J

c Use c = 1 ÷ (gradient × mass) to calculate the specific heat capacity. [2]

c = 1 ÷ (0.0010 × 1.0) = 1000 J/kg °C

d The accepted value is 900 J/kg °C. Suggest one improvement. [1]

Better insulation / a lid / oil in the thermometer hole.

Extra practice

Retrieval · answers in the answer booklet

1 Grade 7+ A 0.06 kg tennis ball is hit straight up at 30 m/s. Assuming all its kinetic energy becomes gravitational potential energy, calculate the maximum height it reaches. (g = 9.8 N/kg) [3]

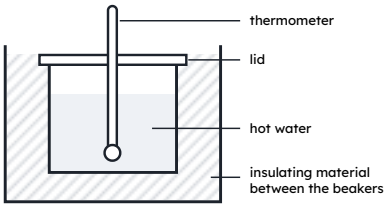
Ek = ½ × 0.06 × 30² = 27 J

At the top, Ep = Ek, so mgh = 27

h = 27 ÷ (0.06 × 9.8) = 46 m

RETRIEVAL PRACTICE GRADE 4 GRADE 5

Required practical 2: thermal insulation



a Independent variable: [1]

Type of material (or thickness)

b Dependent variable: [1]

Temperature drop in a fixed time

c Two control variables: [2]

Volume and starting temperature of water;

same beakers, lid and time

d Which result shows the best insulator? [1]

The smallest temperature drop in the same time.

RETRIEVAL PRACTICE GRADE 4 GRADE 5

Compare energy resources

Complete the table from memory, then check.

Resource	Renewable?	Reliable?	Environmental impact
Coal	No	Yes	CO_2 (climate change), SO_2 (acid rain)
Nuclear	No	Yes	Radioactive waste
Wind	Yes	No: depends on weather	Visual impact, noise
Solar	Yes	No: not at night	Uses land
Hydroelectric	Yes	Yes	Floods valleys, habitats
Tidal	Yes	Yes: tides are predictable	Few sites, affects habitats

ELABORATION GRADE 7

Evaluate

Grade 7+: weigh up both sides and reach a conclusion.

1 A town council wants to replace its coal power station. Evaluate replacing it with a wind farm. [6]

For: wind is renewable, so it won't run out; no CO_2 is released while generating, reducing climate change.

Against: output depends on the wind, so it's unreliable; it can't respond to sudden demand.

Many turbines are needed to match a coal station; some people object to noise and appearance.

Coal is reliable but releases CO_2 and SO_2 and will run out.

Conclusion: wind is better for the environment, but needs back-up (e.g. gas, storage or other renewables)

to keep supply reliable, so a mix of resources is the best solution.

RETRIEVAL PRACTICE SPACED PRACTICE GRADE 4

Quick-fire retrieval: Topic 1 so far

Cover the topic pages. Answer in under 3 minutes.

1 Unit of specific heat capacity?

J/kg °C

2 Unit of power?

Watt (W)

3 Store that increases when a spring is stretched?

Elastic potential

4 Value of g on Earth?

9.8 N/kg

5 Way to reduce friction?

Lubrication

6 A reliable renewable resource?

Tidal, hydroelectric or geothermal

Exam practice

GRADE RADE 4

Secure the basics

1 Which of these is an energy store? Tick one. [1]

☐ heating ☐ chemical ☐ radiation ☐ electrically

Chemical

2 A kettle has a power of 2000 W. It is switched on for 60 s. Calculate the energy transferred. [2]

E = Pt = 2000 × 60

= 120 000 J

3 Give one way to reduce unwanted energy transfers in a machine with moving parts. [1]

Lubrication (reduces friction).

4 A lamp is supplied with 50 J of energy and transfers 10 J usefully. Calculate its efficiency. [2]

Efficiency = 10 ÷ 50

= 0.2 (20%)

5 Name the energy store that decreases when a ball falls. [1]

Gravitational potential energy store

GRADE RADE 5

Apply and rearrange

6 A 1200 kg car travels at 15 m/s. Calculate its kinetic energy. [2]

Ek = ½ × 1200 × 15²

= 135 000 J

7 A motor has an efficiency of 0.6 and a useful output of 300 W. Calculate the input power. [3]

Input = useful ÷ efficiency = 300 ÷ 0.6

= 500 W

8 Calculate the energy needed to heat 2.0 kg of water from 15 °C to 65 °C. (c = 4200 J/kg °C) [3]

Δθ = 50 °C; ΔE = 2.0 × 4200 × 50

= 420 000 J

9 Explain why a house with thick walls made of a material with a low thermal conductivity cools more slowly. [2]

Low thermal conductivity means a lower rate of energy transfer by conduction;

thicker walls reduce the rate further, so the house cools more slowly.

Exam practice (continued)

GRADE RADE 7+

Stretch

10 A 2.0 kW heater warms 3.0 kg of liquid from 20 °C to 70 °C in 5 minutes. Calculate the specific heat capacity, assuming no energy is wasted. [4]

E = Pt = 2000 × 300 = 600 000 J

c = ΔE ÷ (mΔθ) = 600 000 ÷ (3.0 × 50)

c = 4000 J/kg °C

11 Describe how a student could find the specific heat capacity of a metal block. Include how to make the result as accurate as possible. [6]

Measure the mass of the block with a balance.

Insulate the block; put the heater and thermometer in the holes (drop of water for contact).

Record the start temperature; switch on; record energy (joulemeter) and temperature every minute.

Plot temperature against energy; use the gradient of the straight section.

c = 1 ÷ (gradient × mass), or c = ΔE ÷ (mΔθ).

Accuracy: insulation reduces energy transfer to the surroundings; digital thermometer (better resolution);

repeat and take a mean. Hazard: heater gets hot.

Total: _____ / 27

EXAM TECHNIQUE

Command words

Command word	What to do
State / Give / Name	A short answer; no explanation needed.
Describe	Say what happens, in order. No need to say why.
Explain	Say what happens *and why*: use “because” and “so”.
Calculate	Show the equation, substitution, answer and unit.
Evaluate	Give points for and against, then a justified conclusion.

Extra practice

Retrieval · answers in the answer booklet

1 Grade 5 0.25 kg of water is heated from 20 °C to 80 °C. Calculate the energy transferred. (c = 4200 J/kg °C) [2]

Δθ = 60 °C; ΔE = mcΔθ = 0.25 × 4200 × 60

ΔE = 63 000 J

METACOGNITION

Re-rate yourself

Go back to the checklist on the first page of this topic and fill in the 'After' column.

METACOGNITION GRADE 4 GRADE 5 GRADE 7

Exam wrapper: why did I drop marks?

After marking the exam practice, write the question numbers you got wrong in the right row. This tells you what kind of revision you need.

Reason I lost marks	Question numbers	What to do next
I didn't know or remember it (knowledge gap)		Flashcards and brain dumps
I knew it but misread the question or command word		Underline command words
Maths slip: units, rearranging, squaring		Redo the "we do / you do" pages
I ran out of time or didn't finish		Timed practice: 1 mark per minute

METACOGNITION GRADE 4 GRADE 5 GRADE 7

Two things I'm now confident about

METACOGNITION

One thing I still need to work on, and how I'll fix it

e.g. 'Rearranging Ek = ½mv² → redo the Grade 7+ questions in section 1.9 and use the website's Aim higher section.'

SPACED PRACTICE

Book my next spaced sessions

Write the dates in the planner on page 2: +2 days, +1 week, +3 weeks.

Brain dump and checklist

RETRIEVAL PRACTICE · GRADE 4 · GRADE 5 · GRADE 7

Brain dump

Set a timer for 5 minutes. Write or draw everything you remember about electricity. No notes! Afterwards, add anything you missed in a different colour.

Prompts if you get stuck: circuit symbols? · Q = It? · V = IR? · series vs parallel? · I–V graphs? · thermistor and LDR? · a.c. and d.c.? · plug wires? · National Grid? · static?

METACOGNITION

How confident am I?

Rate each statement now (before) by shading R, A or G. Rate again at the end of the topic (after).

I can...	Before			After		
	R	A	G	R	A	G
Draw and recognise circuit symbols	○	○	○	○	○	○
Use Q = It and define current as the rate of flow of charge	○	○	○	○	○	○
Use V = IR and describe the resistance practical (RP3)	○	○	○	○	○	○
Sketch and explain I–V graphs for a resistor, filament lamp and diode (RP4)	○	○	○	○	○	○
Describe how thermistors and LDRs respond to temperature and light	○	○	○	○	○	○
State the rules for current, p.d. and resistance in series and parallel	○	○	○	○	○	○
Describe a.c. and d.c. and UK mains (230 V, 50 Hz)	○	○	○	○	○	○
Name the three wires in a plug and explain why the live wire is dangerous	○	○	○	○	○	○
Use P = VI, P = I^2R, E = Pt and E = QV	○	○	○	○	○	○
Explain how the National Grid uses transformers to reduce the energy wasted in the cables	○	○	○	○	○	○
Explain static charge and electric fields (Physics only)	○	○	○	○	○	○

Extra practice

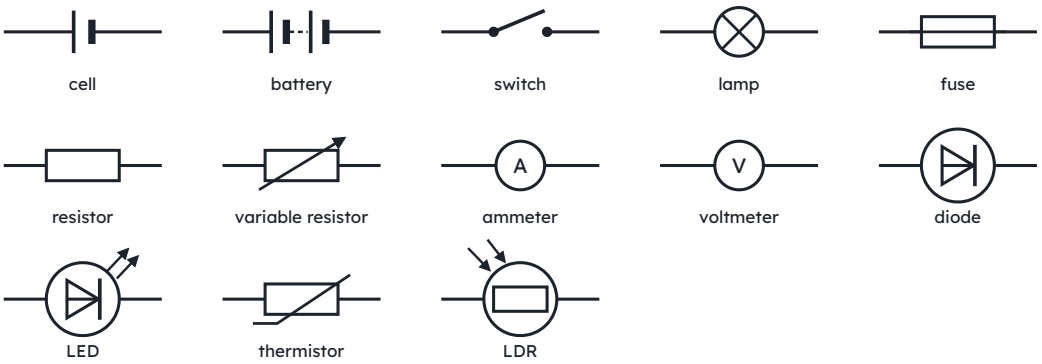
Retrieval · answers in the answer booklet

1 Fill the gap: Mains electricity in the UK has a frequency of _____ Hz. [1]

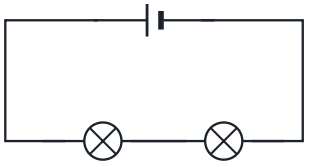
50. UK mains: about 230 V and 50 Hz.

DUAL CODING | GRADE 4 | GRADE 5 | GRADE 7

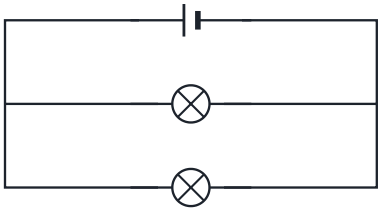
CIRCUIT SYMBOLS



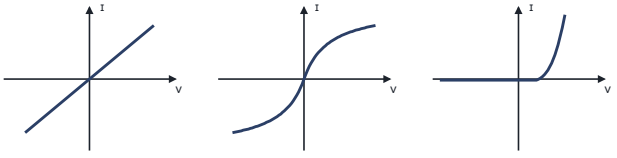
SERIES AND PARALLEL · I–V GRAPHS



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



Resistor (constant temperature) | Filament lamp | Diode

KEY EQUATIONS: ALL GIVEN ON THE PHYSICS EQUATIONS SHEET IN THE EXAM

Equation	Quantities and 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 = I^2 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

SERIES AND PARALLEL RULES

Series: same current everywhere; p.d. is shared; $R_{total} = R_1 + R_2$.

Parallel: same p.d. across each branch; branch currents add up to the total; total resistance is less than the smallest resistor.

MAINS ELECTRICITY

UK mains is a.c. at 230 V, 50 Hz.
Live (brown) 230 V · **neutral** (blue) about 0 V · **earth** (green and yellow stripes) safety wire, only carries current if there is a fault.

TURN OVER

Key words, misconceptions, required practicals and Grade 7+ links are on the next page.

Knowledge organiser: key words, misconceptions, practicals

ELABORATION GRADE 4 GRADE 5 GRADE 7

KEY WORDS: LEARN THESE WORD FOR WORD (SAME AS SIDE 2 OF YOUR KNOWLEDGE ORGANISER)

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.

MISCONCEPTIONS: SPOT THE MISTAKE

× Common mistake	✓ What's actually true
× 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.

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

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 = I^2R, so a lower current wastes less power.

Extra practice

Retrieval · answers in the answer booklet

1 Grade 7+ A 60 W lamp runs on 230 V mains for 5 minutes. Calculate the charge that flows through it. [4]

I = P ÷ V = 60 ÷ 230 = 0.26 A

t = 5 × 60 = 300 s

Q = It = 0.26 × 300

Q = 78 C

RETRIEVAL PRACTICE | SPACED PRACTICE | GRADE 4 | GRADE 5

Equation sheet skills: which equation, which unit?

Every equation is on the Physics Equations Sheet, but it won't tell you which one a question needs or what unit the answer has. Cover the knowledge organiser and fill in the table. Redo it on another day.

Situation	Which equation?	Unit of the answer	Redo 1 ✓/×	Redo 2 ✓/×
A charge flows through a lamp in 2 minutes. How much charge?	**Q = I t**	**C (coulombs), time in s**		
What p.d. drives 0.5 A through a 20 Ω resistor?	**V = I R**	**V (volts)**		
A kettle runs on mains and draws 9 A. What is its power?	**P = V I**	**W (watts)**		
Power wasted in a cable carrying a large current?	**P = I^2 R**	**W**		
A 2 kW heater is on for 30 minutes. How much energy?	**E = P t**	**J (kW → W, min → s)**		
Energy transferred when 50 C moves through 12 V?	**E = Q V**	**J**		

RETRIEVAL PRACTICE | GRADE 4 | GRADE 5

Fill the gaps

Use the AQA key words. No word bank: that's the point.

1. Current is the rate of flow of electrical **charge**.
2. In a series circuit the **current** is the same at every point.
3. The resistance of a thermistor decreases as the **temperature** increases.
4. The earth wire is green and yellow; the neutral wire is **blue**.
5. Step-up transformers increase the p.d. so the **current** in the cables is smaller and less energy is wasted.

ELABORATION | GRADE 5

Odd one out

Circle the odd one out in each row and explain why.

1. ammeter · voltmeter · thermistor · fuse

Thermistor: its resistance changes with temperature; the others measure or protect.

2. Q = It · V = IR · ρ = m ÷ V · P = VI

ρ = m ÷ V: it's a particle model (density) equation; the others are electricity equations.

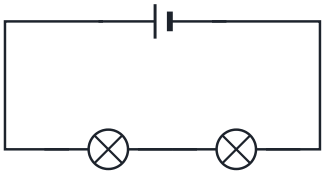
3. live · neutral · earth · fuse

Fuse: it's a safety device, not one of the three wires in the cable.

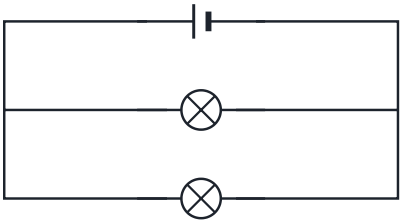
DUAL CODING GRADE 4 GRADE 5

Read the circuit

Use the circuits to answer.



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

a In the series circuit, the cell is 6 V and one lamp has 2 V across it. What is the p.d. across the other lamp? [2]

6 – 2 = 4 V (p.d. is shared in series)

b In the parallel circuit, the branch currents are 0.2 A and 0.3 A. What does the ammeter by the cell read? [1]

0.5 A (branch currents add)

c Which circuit has the lower total resistance? Explain. [2]

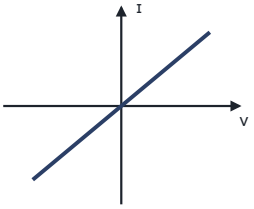
Parallel:

there are more paths for the current, so total resistance is less than either resistor.

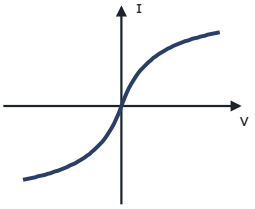
DUAL CODING GRADE 5 GRADE 7

I–V graphs

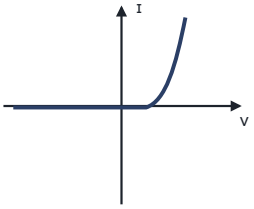
Match each graph to the component and explain its shape.



Resistor (constant temperature)



Filament lamp



Diode

a Which graph shows a resistor at constant temperature? How do you know? [2]

The straight line through the origin:

current is directly proportional to p.d. (ohmic conductor).

b Explain why the filament lamp graph curves. [3]

As the current increases, the filament gets hotter;

the resistance increases as the temperature increases,

so the current increases less for each extra volt.

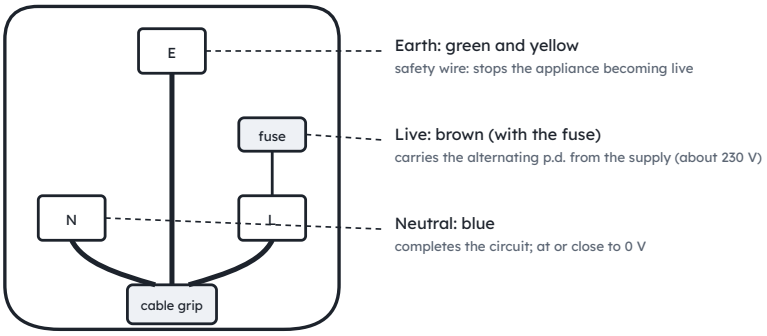
c What is special about the diode? [1]

Current flows in one direction only (very high resistance in reverse).

Picture it (continued)

DUAL CODING GRADE 4 GRADE 5 GRADE 7

Plugs and the National Grid



a Why is the live wire dangerous even when a switch is open? [2]

It is still at 230 V;

touching it makes a current flow through you to earth.

b Explain why the National Grid transmits at a very high p.d. [3]

Step-up transformers increase the p.d.,

which reduces the current for the same power,

so less energy is wasted by heating the cables ($P = I^2R$).

Extra practice

Retrieval · answers in the answer booklet

1 Grade 5 Explain why touching the live wire can give you an electric shock. [2]

Your body is at (or near) 0 V / earth potential

So there is a large potential difference across your body and a current flows through you

2 Grade 7+ Explain why a person who touches the live wire can get an electric shock, even if the appliance's switch is off. [4]

The live wire can still be at a high p.d. (about 230 V) even when the switch is open

The person's body is at about 0 V (earth potential)

So there is a large p.d. across the body

A current flows through the person to earth

3 Grade 7+ Fuel flowing through a pipe into an aircraft can produce a spark. Explain why, and how the risk is reduced. [3]

Friction between the fuel and the pipe transfers electrons, so charge builds up

A large enough charge produces a high p.d. which can cause a spark and ignite fuel vapour

The aircraft and tanker are earthed / connected with a conducting cable so charge flows away

WORKED EXAMPLES GRADE 4 GRADE 5

Charge and current

I do (worked example)

A current of 0.4 A flows for 2 minutes. Calculate the charge.

1. Q = It
2. t = 2 × 60 = 120 s
3. Q = 0.4 × 120
4. **Q = 48 C**

We do (finish it)

3 A for 5 minutes.

1. t = ___ s **300**
2. Q = 3 × ___ **300**
3. Q = ___ C **900**

You do

1.5 A for 40 s.

Q = It

= 1.5 × 40

= 60 C

WORKED EXAMPLES GRADE 4 GRADE 5

V = IR

I do (worked example)

A 12 V supply drives 0.3 A through a resistor. Calculate R.

1. V = IR, so R = V ÷ I
2. R = 12 ÷ 0.3
3. **R = 40 Ω**

Check the units: V ÷ A = Ω

We do (finish it)

0.25 A through a 48 Ω resistor. Calculate V.

1. V = IR
2. V = 0.25 × ___ **48**
3. V = ___ V **12**

You do

6 V across 30 Ω. Calculate I.

I = V ÷ R

= 6 ÷ 30

= 0.2 A

WORKED EXAMPLES GRADE 5 GRADE 7

Series circuits: two steps

Grade 7+ questions often need the series rules and V = IR together.

1 A 4 Ω and an 8 Ω resistor are in series with a 6 V battery. Calculate the current and the p.d. across the 8 Ω resistor. [4]

R total = 4 + 8 = 12 Ω

I = V ÷ R = 6 ÷ 12 = 0.5 A

V = IR = 0.5 × 8 = 4 V

Extra practice

Retrieval · answers in the answer booklet

1 Grade 5 State the colour of the neutral wire in a three-core cable and describe what it does. [2]

Blue

It completes the circuit, and is at or close to 0 V

WORKED EXAMPLES GRADE 4 GRADE 5

Power and energy

I do (worked example)

A 230 V toaster draws 4 A for 3 minutes. Calculate the energy.

1. P = VI = 230 × 4 = 920 W
2. t = 3 × 60 = 180 s
3. E = Pt = 920 × 180
4. **E = 165 600 J**

We do (finish it)

A 60 W lamp on for 10 s.

1. E = Pt
2. E = 60 × ___ **10**
3. E = ___ J **600**

You do

2 A through 15 Ω. Calculate P.

P = I^2R

= 2^2 × 15

= 60 W

WORKED EXAMPLES GRADE 5 GRADE 7

E = QV

I do (worked example)

20 C passes through a 9 V battery. Calculate the energy.

1. E = QV
2. E = 20 × 9
3. **E = 180 J**

p.d. = energy per coulomb

We do (finish it)

500 J transferred by 50 C.

1. V = E ÷ Q
2. V = 500 ÷ ___ **50**
3. V = ___ V **10**

You do

230 V mains, 2 A for 1 s.

Q = It = 2 C

E = QV = 2 × 230

= 460 J

ELABORATION GRADE 5

Spot the mistake

Each student has made one mistake. Find it and correct it.

1 Ana: "A 2 kW heater on for 10 minutes transfers 2 × 10 = 20 J." [2]

Convert: 2000 W × 600 s = 1 200 000 J.

2 Ben: "In parallel, adding another resistor makes the total resistance bigger." [1]

It makes the total resistance smaller: there are more paths.

3 Cara: "P = I^2R, so 3 A through 10 Ω gives 3 × 2 × 10 = 60 W." [2]

Square the current: 3^2 × 10 = 90 W.

Extra practice

Retrieval · answers in the answer booklet

1 Which wire is brown in a UK plug? [1]

A Live **B** Neutral **C** Earth **D** Fuse

A: Live. Brown is live, blue is neutral, green and yellow is earth.

ELABORATION GRADE 4 GRADE 5 GRADE 7

Build an explanation

Answer each question in two steps. Use the starter, then push yourself with the Grade 7+ extension.

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

Grade 4–5 starter: "As the current increases, the filament…"

As the current increases, the filament gets hotter.

Its resistance increases as its temperature increases.

Grade 7+ extension: "Link to the ions in the metal and the electrons:…"

The ions in the metal vibrate more,

so the electrons collide with them more often and their flow is reduced.

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

Grade 4–5 starter: "When it gets dark, the resistance of the LDR…"

When it gets dark, the resistance of the LDR increases.

So the p.d. across the LDR increases.

Grade 7+ extension: "Link to how the p.d. is shared in a series circuit:…"

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.

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

Grade 4–5 starter: "The live wire is at a high p.d., and the person is at…"

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.

Grade 7+ extension: "Link to the earth wire and the fuse:…"

If the appliance is earthed, a large current flows down the earth wire instead,

which melts the fuse and cuts off the live wire.

ELABORATION GRADE 5

True or false? Justify it.

Saying why is worth more marks than saying true or false.

4 "Current is used up as it flows round a circuit." [2]

False: current is the same at every point in a series loop;

energy is transferred, not charge.

5 "The earth wire normally carries a current." [1]

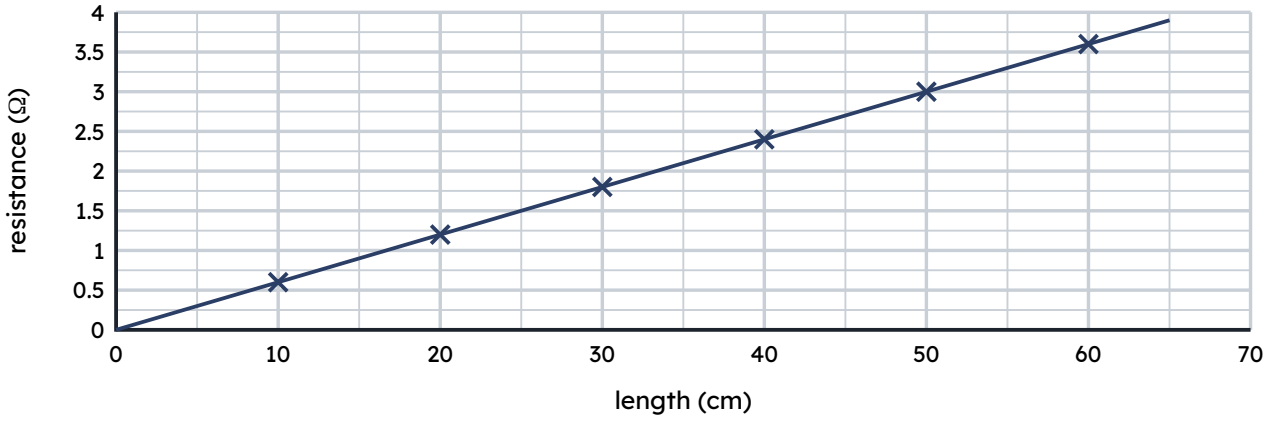
False: it only carries a current if there is a fault.

DUAL CODING | WORKED EXAMPLES | GRADE 4 | GRADE 5 | GRADE 7

RP3: resistance of a wire

A student measures the resistance of different lengths of wire using an ammeter and a voltmeter.

Length (cm)	10	20	30	40	50	60
p.d. (V)	0.30	0.60	0.90	1.20	1.50	1.80
Current (A)	0.50	0.50	0.50	0.50	0.50	0.50
Resistance (Ω)	**0.6**	**1.2**	**1.8**	**2.4**	**3.0**	**3.6**



a Complete the resistance row (R = V ÷ I) and plot the graph. [3]

0.6, 1.2, 1.8, 2.4, 3.0, 3.6 Ω; straight line through the origin.

b Describe the relationship. [1]

Resistance is directly proportional to length.

c Why should the current be kept small? [2]

So the wire doesn't heat up;

a temperature rise would increase its resistance (control variable).

d The line doesn't quite pass through (0, 0) on a real graph. Suggest why. [1]

Zero error / resistance of the crocodile clips and contacts (systematic error).

Extra practice

Retrieval · answers in the answer booklet

1 Grade 7+ Two identical 6 Ω resistors are connected in parallel to a 12 V supply. Calculate the total current from the supply and explain why the total resistance is less than 6 Ω. [4]

Each branch has 12 V across it, so I = 12 ÷ 6 = 2 A in each

Total current = 2 + 2 = 4 A

Adding a branch gives the charge another path

So the total current increases for the same p.d., meaning total resistance decreases (12 ÷ 4 = 3 Ω)

RP4: I–V characteristics

RETRIEVAL PRACTICE | ELABORATION | GRADE 4 | GRADE 5 | GRADE 7

RP4: I–V characteristics

A student uses a variable resistor to change the p.d. across a filament lamp, then reverses the supply.

a Draw the circuit she should use. [3]

Cell, variable resistor, lamp in series; ammeter in series; voltmeter in parallel with the lamp.

p.d. (V)	−6	−4	−2	0	2	4	6
Current (A)	−0.30	−0.26	−0.18	0	0.18	0.26	0.30

b Describe the shape of the I–V graph for these results. [2]

An S-shaped curve through the origin;

the same shape for negative values (the gradient decreases as p.d. increases).

c Calculate the resistance of the lamp at 2 V and at 6 V. [3]

2 ÷ 0.18 = 11 Ω

6 ÷ 0.30 = 20 Ω

d Explain the difference in your answers to (c). [2]

At 6 V the filament is hotter,

so its resistance is higher.

e How would the graph be different for a diode? [2]

Almost no current for negative p.d. (very high resistance in reverse);

current rises steeply once the forward p.d. passes about 0.6 V.

Extra practice

Retrieval · answers in the answer booklet

1 Grade 7+ A current of 3 A flows through a cable with a resistance of 5 Ω for 10 minutes. Calculate the energy transferred by heating in the cable. [4]

$P = I^2R = 3^2 \times 5 = 45$ W

$t = 10 \times 60 = 600$ s

$E = Pt = 45 \times 600$

$E = 27\,000$ J

2 Grade 7+ A phone charger transfers 18 000 J to a phone in 1 hour at a p.d. of 5 V. Calculate the charge that flows, then the average current. [4]

$Q = E \div V = 18\,000 \div 5$

$Q = 3600$ C

$t = 3600$ s, so $I = Q \div t = 3600 \div 3600$

$I = 1$ A

Exam practice

GRADE RADE 4

Secure the basics

1 Draw the circuit symbol for a thermistor. [1]

Rectangle with a diagonal line and a short horizontal flick at the end

2 State the frequency and p.d. of the UK mains supply. [2]

50 Hz

230 V

3 Calculate the charge that flows when a current of 2 A flows for 30 s. [2]

Q = It = 2 × 30

= 60 C

4 Name the colour of the live wire in a UK plug. [1]

Brown

5 A resistor has 6 V across it and a current of 0.2 A. Calculate its resistance. [2]

R = V ÷ I = 6 ÷ 0.2

= 30 Ω

GRADE RADE 5

Apply and rearrange

6 A 1.5 kW hairdryer is used for 4 minutes. Calculate the energy transferred. [3]

E = Pt = 1500 × 240

= 360 000 J

7 Explain how the resistance of a thermistor changes as it is heated, and give one use. [2]

Resistance decreases as temperature increases.

Use: thermostat / fire alarm / temperature sensor.

8 A current of 0.5 A flows through a 40 Ω resistor. Calculate the power transferred. [2]

$P = I^2R = 0.5^2 \times 40$

= 10 W

9 Explain why a lamp in parallel stays on when another branch is switched off. [2]

Each branch is connected directly across the supply,

so it has its own path and the full p.d.

Extra practice

Retrieval · answers in the answer booklet

1 True or false? The resistance of an LDR decreases as light intensity increases. Explain. [2]

True. Brighter light → lower resistance.

GRADE RADE 7+

Stretch

10 A 6 V battery is connected to a 10 Ω and a 20 Ω resistor in parallel. Calculate the current from the battery. [4]

Each resistor has 6 V across it.

$I_1 = 6 \div 10 = 0.6$ A; $I_2 = 6 \div 20 = 0.3$ A

Total current = 0.6 + 0.3

= 0.9 A

11 Describe how to investigate how the resistance of a wire depends on its length. Include how you would make the results valid. [6]

Connect the wire to a battery with an ammeter in series and a voltmeter in parallel with the wire.

Attach crocodile clips at 0 cm and at a set length on a metre ruler.

Record the current and p.d.; calculate R = V ÷ I.

Repeat for at least five lengths (e.g. 10 cm steps), repeating and averaging each.

Keep the current low / switch off between readings so the wire doesn't heat up; use the same wire (material and thickness).

Plot R against length: straight line through the origin shows R ∝ length.

Total: _____ / 27

RETRIEVAL PRACTICE SPACED PRACTICE GRADE 4

Quick-fire retrieval: Electricity

Cover everything. Answer in under 3 minutes. Redo it on your next spaced session.

1 Unit of charge?

Coulomb (C)

2 Unit of resistance?

Ohm (Ω)

3 UK mains p.d. and frequency?

230 V, 50 Hz

4 Colour of the neutral wire?

Blue

5 Series: what's the same everywhere?

Current

6 Parallel: what's the same across each branch?

p.d.

Extra practice

Retrieval · answers in the answer booklet

1 Grade 5 A current of 0.4 A flows for 3 minutes. Calculate the charge that flows. [2]

t = 180 s

Q = It = 0.4 × 180 = 72 C

Reflect and plan

METACOGNITION

Re-rate yourself

Go back to the checklist at the start of this topic and fill in the 'After' column.

METACOGNITION GRADE 4 GRADE 5 GRADE 7

Exam wrapper: why did I drop marks?

After marking the exam practice, write the question numbers you got wrong in the right row.

Reason I lost marks	Question numbers	What to do next
I didn't know or remember it (knowledge gap)		Flashcards and brain dumps
I knew it but misread the question or command word		Underline command words
Maths slip: units, rearranging, standard form		Redo the "we do / you do" pages
I ran out of time or didn't finish		Timed practice: 1 mark per minute

METACOGNITION

Two things I'm now confident about

METACOGNITION

One thing I still need to work on, and how I'll fix it

e.g. 'Rearranging equations → redo the Grade 7+ questions and use the website's Aim higher section.'

SPACED PRACTICE

Book my next spaced sessions

Write the dates in the planner at the front: +2 days, +1 week, +3 weeks.

Extra practice

Retrieval · answers in the answer booklet

1 True or false? A fuse is connected in the neutral wire. Explain. [2]

False. The fuse goes in the live wire so it can cut off the dangerous supply.

Brain dump and checklist

RETRIEVAL PRACTICE · GRADE 4 · GRADE 5 · GRADE 7

Brain dump

Set a timer for 5 minutes. Write or draw everything you remember about particle model of matter. No notes! Afterwards, add anything you missed in a different colour.

Prompts if you get stuck: density? · ρ = m ÷ V? · solid, liquid, gas? · internal energy? · specific heat capacity? · latent heat? · heating curves? · gas pressure? · pV = constant?

METACOGNITION

How confident am I?

Rate each statement now (before) by shading R, A or G. Rate again at the end of the topic (after).

I can...	Before			After		
	R	A	G	R	A	G
Use the particle model to explain differences in density of solids, liquids and gases	○	○	○	○	○	○
Use ρ = m ÷ V and describe the density practical (RP5)	○	○	○	○	○	○
Describe changes of state and explain why mass is conserved	○	○	○	○	○	○
Define internal energy as the total kinetic and potential energy of the particles	○	○	○	○	○	○
Use ΔE = mcΔθ for temperature changes	○	○	○	○	○	○
Define specific latent heat of fusion and vaporisation and use E = mL	○	○	○	○	○	○
Interpret heating and cooling graphs	○	○	○	○	○	○
Explain gas pressure using particle motion	○	○	○	○	○	○
Explain how temperature affects the pressure of a gas at constant volume	○	○	○	○	○	○
Use pV = constant for a fixed mass of gas at constant temperature (Physics only)	○	○	○	○	○	○
Explain why doing work on a gas increases its temperature (Physics only, Higher)	○	○	○	○	○	○

Extra practice

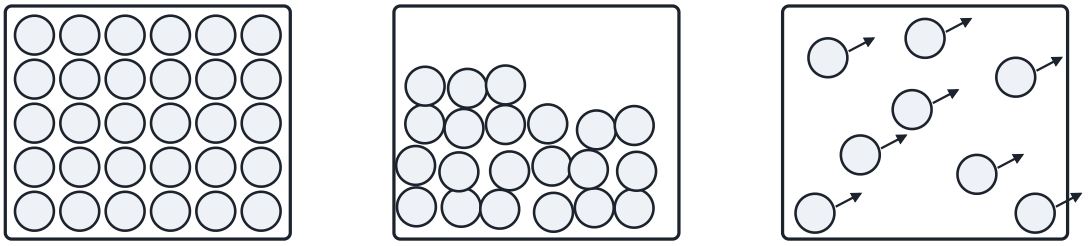
Retrieval · answers in the answer booklet

1 True or false? When a substance melts, its mass increases. Explain. [2]

False. Mass is conserved in a change of state.

DUAL CODING | GRADE 4 | GRADE 5 | GRADE 7

STATES OF MATTER

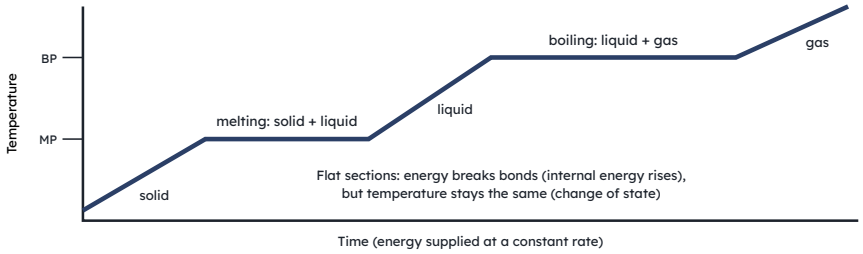


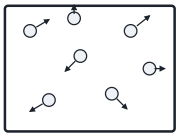
Solid
close together, regular pattern,
vibrate about fixed positions

Liquid
close together, random arrangement,
move past each other

Gas
far apart, random,
move quickly in all directions

HEATING CURVE · GAS PRESSURE





Particles collide with the walls,
exerting 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)

KEY EQUATIONS: ALL GIVEN ON THE PHYSICS EQUATIONS SHEET IN THE EXAM

Equation	Quantities and 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)	$p_1V_1 = p_2V_2$

INTERNAL ENERGY

Internal energy is the total kinetic energy and potential energy of all the particles in a system.
Heating either raises the temperature (more kinetic energy) or changes the state (more potential energy), not both at once.

CHANGES OF STATE

Melting, freezing, boiling, evaporating, condensing and sublimating are **physical changes**: the material recovers its original properties if the change is reversed. Mass is conserved.

TURN OVER

Key words, misconceptions, required practicals and Grade 7+ links are on the next page.

Knowledge organiser: key words, misconceptions, practicals

ELABORATION GRADE 4 GRADE 5 GRADE 7

KEY WORDS: LEARN THESE WORD FOR WORD (SAME AS SIDE 2 OF YOUR KNOWLEDGE ORGANISER)

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.

MISCONCEPTIONS: SPOT THE MISTAKE

× Common mistake	✓ What's actually true
× 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.

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.
Common mistake: Forgetting units, or mixing g with m^3.

AIM FOR GRADE 7+

- Heating then melting: add $mc\Delta\theta$ 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.

Extra practice

Retrieval · answers in the answer booklet

1 Grade 7+ 0.5 kg of water at 20 °C is heated to 100 °C, and then 0.1 kg of it boils away. Calculate the total energy supplied. (c = 4200 J/kg °C, L = 2 260 000 J/kg) [4]

Heating: ΔE = 0.5 × 4200 × 80 = 168 000 J

Boiling: E = mL = 0.1 × 2 260 000 = 226 000 J

Add the two energies

Total = 394 000 J

2 Grade 5 Name the change of state when (a) a gas turns into a liquid, (b) a solid turns straight into a gas. [2]

(a) Condensing

(b) Sublimation

RETRIEVAL PRACTICE | SPACED PRACTICE | GRADE 4 | GRADE 5

Equation sheet skills: which equation, which unit?

Every equation is on the Physics Equations Sheet, but it won't tell you which one a question needs or what unit the answer has. Cover the knowledge organiser and fill in the table. Redo it on another day.

Situation	Which equation?	Unit of the answer	Redo 1 ✓/×	Redo 2 ✓/×
A block of metal has a mass and a measured volume. How dense is it?	$\rho = m \div V$	kg/m³		
Energy to warm 2 kg of water by 30 °C?	$\Delta E = m\,c\,\Delta\theta$	J		
Energy to melt 0.5 kg of ice at 0 °C?	$E = m\,L$	J (L in J/kg)		
Gas compressed slowly at constant temperature: new pressure?	$p\,V = \text{constant}$	Pa		
Calculate the mass of air in a room from its volume and density.	$m = \rho\,V$	kg		
Energy given out as steam condenses.	$E = m\,L$	J		

RETRIEVAL PRACTICE | GRADE 4 | GRADE 5

Fill the gaps

Use the AQA key words. No word bank: that's the point.

1. Density is mass per unit ___volume___.
2. Internal energy is the total kinetic and ___potential___ energy of the particles.
3. The energy needed to change the state of 1 kg of a substance with no change in temperature is its specific ___latent___ heat.
4. In a change of state, mass is ___conserved___.
5. Gas particles colliding with the walls of a container exert a ___force___ at right angles to the wall.

ELABORATION | GRADE 5

Odd one out

Circle the odd one out in each row and explain why.

1. melting · boiling · burning · condensing

Burning: it's a chemical change; the others are physical changes of state.

2. fusion · vaporisation · evaporation · density

Density: the others are linked to latent heat and changes of state.

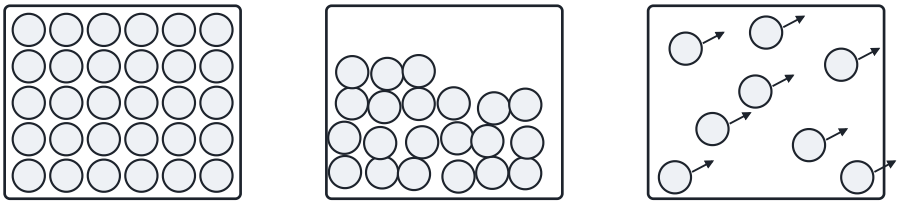
3. kg/m³ · J/kg · J/kg °C · N/kg

N/kg: it's gravitational field strength; the others are particle model units.

DUAL CODING GRADE 4 GRADE 5

Particles and density

Use the diagram to answer.



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

a Describe the arrangement and motion of particles in a solid. [2]

Close together in a regular pattern;

vibrate about fixed positions.

b Explain why a gas is much less dense than its solid. [2]

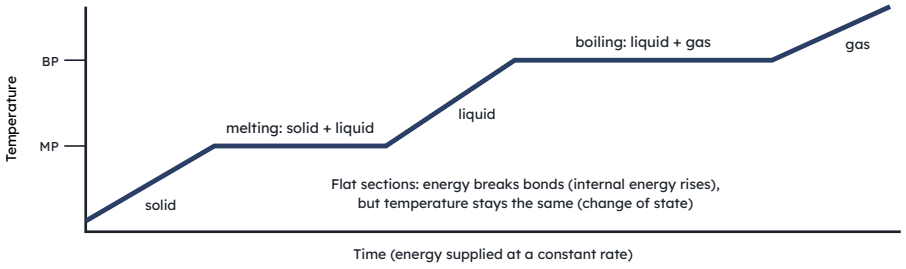
The particles in a gas are much further apart,

so there is less mass in each unit of volume.

DUAL CODING GRADE 5 GRADE 7

Read the heating curve

Ice is heated steadily from −20 °C until it has all turned to steam.



a What is happening at the first flat section? [1]

Melting (solid → liquid) at 0 °C

b Explain why the temperature doesn't rise while it is melting. [3]

The energy is used to break the bonds between particles;

this increases the potential energy, not the kinetic energy,

so the temperature stays the same.

c Why is the second flat section longer than the first? [2]

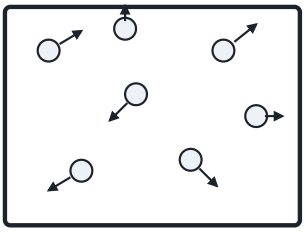
The specific latent heat of vaporisation is greater than that of fusion,

so more energy is needed to boil it.

Picture it (continued)

DUAL CODING GRADE 4 GRADE 5 GRADE 7

Gas pressure



Particles collide with the walls, exerting 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)

a Explain how gas particles exert a pressure on the walls of a container. [2]

Particles move randomly and collide with the walls;

each collision exerts a force at right angles to the wall.

b The gas is heated at constant volume. Explain why the pressure increases. [3]

The particles gain kinetic energy and move faster,

so they hit the walls more often and with more force,

so the pressure increases.

Extra practice

Retrieval · answers in the answer booklet

1 Grade 7+ Explain why the temperature of a liquid stays constant while it freezes, even though energy is being transferred away from it. [3]

As it freezes, bonds form between the particles, releasing energy

The potential energy of the particles decreases, not their kinetic energy

Temperature depends on the average kinetic energy, so it stays the same

2 Grade 5 A block measures 2 cm × 3 cm × 5 cm and has a mass of 81 g. Calculate its density. [3]

Volume = 2 × 3 × 5 = 30 cm^3

$\rho = m \div V = 81 \div 30$

$\rho = 2.7\ g/cm^3$

3 Grade 5 A 0.5 kg object has a volume of 2.0×10^{-4} m^3. Calculate its density. [2]

$\rho = m \div V = 0.5 \div 2.0 \times 10^{-4}$

$\rho = 2500\ kg/m^3$

4 Fill the gap: Changing straight from a solid to a gas is called _____. [1]

sublimation. Dry ice (solid carbon dioxide) sublimes.

WORKED EXAMPLES GRADE 4 GRADE 5

Density

I do (worked example)	We do (finish it)	You do
A 0.54 kg block has a volume of 0.0002 m³. Calculate ρ.	**2 kg of oil, volume 0.0025 m³.**	**Mass of 3 m³ of water (ρ = 1000 kg/m³).**
1. ρ = m ÷ V	1. ρ = m ÷ V	**m = ρ V**
2. ρ = 0.54 ÷ 0.0002	2. ρ = 2 ÷ ___ **0.0025**	**= 1000 × 3**
3. **ρ = 2700 kg/m³**	3. ρ = ___ kg/m³ **800**	**= 3000 kg**
(aluminium)		

WORKED EXAMPLES GRADE 4 GRADE 5

Specific latent heat

I do (worked example)	We do (finish it)	You do
Energy to melt 2 kg of ice. (L = 334 000 J/kg)	**Boil away 0.3 kg of water. (L = 2 260 000 J/kg)**	**50 000 J melts 0.2 kg of wax. Calculate L.**
1. E = mL	1. E = mL	**L = E ÷ m**
2. E = 2 × 334 000	2. E = 0.3 × ___ **2 260 000**	**= 50 000 ÷ 0.2**
3. **E = 668 000 J**	3. E = ___ J **678 000**	**= 250 000 J/kg**
No temperature change		

WORKED EXAMPLES GRADE 5 GRADE 7

Units: the next step

Density questions often give g and cm³. Convert first, or work in g/cm³ and convert at the end.

1 A stone has a mass of 150 g and a volume of 60 cm³. Calculate its density in kg/m³. [3]

ρ = 150 ÷ 60 = 2.5 g/cm³

1 g/cm³ = 1000 kg/m³

ρ = 2500 kg/m³

Extra practice

Retrieval · answers in the answer booklet

1 Grade 5 Explain why the temperature of ice stays at 0 °C while it is melting, even though it is being heated. [3]

Energy is still being transferred to the ice

It is used to break the bonds between particles / increases their potential energy

The kinetic energy of the particles doesn't increase, so the temperature stays the same

WORKED EXAMPLES GRADE 5 GRADE 7

Heating then melting (two steps)

I do (worked example)

Energy to warm 1 kg of ice from –10 °C to 0 °C, then melt it.

1. $\Delta E = mc\Delta\theta = 1 \times 2100 \times 10 = 21\,000$ J
2. $E = mL = 1 \times 334\,000 = 334\,000$ J
3. Total = 21 000 + 334 000
4. **355 000 J**

We do (finish it)

0.5 kg of water from 20 °C to 100 °C (c = 4200).

1. $\Delta E = mc\Delta\theta$
2. $= 0.5 \times 4200 \times$ ___ **80**
3. $=$ ___ J **168 000**

You do

Then boil it all away (L = 2 260 000 J/kg).

$E = mL = 0.5 \times 2\,260\,000$

$= 1\,130\,000$ J

Total = 1 298 000 J

WORKED EXAMPLES GRADE 5 GRADE 7

pV = constant (Physics only)

I do (worked example)

Gas at 100 kPa, 0.03 m³ is squashed to 0.01 m³.

1. $p_1V_1 = p_2V_2$
2. $100\,000 \times 0.03 = p_2 \times 0.01$
3. $p_2 = 3000 \div 0.01$
4. **p_2 = 300 000 Pa**

We do (finish it)

200 kPa, 2 m³ expands to 4 m³.

1. $p_1V_1 = p_2V_2$
2. $200\,000 \times 2 = p_2 \times$ ___ **4**
3. $p_2 =$ ___ Pa **100 000**

You do

50 kPa, 6 m³ compressed to 1.5 m³.

$p_2 = p_1V_1 \div V_2$

$= 50\,000 \times 6 \div 1.5$

$= 200\,000$ Pa

ELABORATION GRADE 5

Spot the mistake

Each student has made one mistake. Find it and correct it.

1 Dan: "Ice at 0 °C melting into water at 0 °C has gained no energy, because the temperature didn't change." [2]

It gained energy (latent heat); it increased the potential energy of the particles.

2 Eve: "When water boils away, the mass is destroyed." [1]

Mass is conserved: the particles are still there as steam.

3 Fay: "ρ = 400 g ÷ 0.0005 m³ = 800 000 kg/m³." [2]

Convert to kg first: 0.4 ÷ 0.0005 = 800 kg/m³.

Extra practice

Retrieval · answers in the answer booklet

1 Grade 7+ A gas in a 0.002 m³ cylinder is at a pressure of 100 kPa. It is slowly compressed to 0.0005 m³ at constant temperature. Calculate the new pressure and explain the change in terms of particles. [4]

pV = constant: $p_2 = 100 \times 0.002 \div 0.0005$

$p_2 = 400$ kPa

The same particles are in a smaller volume, so they hit the walls more often

More collisions per second on each unit area means a higher pressure

2 Grade 7+ A sealed aerosol can is left in strong sunlight. Explain, in terms of particles, why the pressure inside increases and why the can could burst. [3]

The gas gets hotter, so the particles move faster

They hit the walls more often and with more force, so the pressure increases

If the force on the walls becomes too great, the can could burst

Why? How? Explaining particle model of matter

ELABORATION GRADE 4 GRADE 5 GRADE 7

Build an explanation

Answer each question in two steps. Use the starter, then push yourself with the Grade 7+ extension.

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

Grade 4–5 starter: "Heating the gas increases the kinetic energy of the particles, so…"

Heating increases the kinetic energy of the particles,

so they move faster.

Grade 7+ extension: "Link to collisions with the walls, force and area:…"

They collide with the walls more often and with more force,

so the total force on each unit of area (pressure) increases.

2 Explain why sweating cools you down.

Grade 4–5 starter: "The sweat evaporates, which needs…"

Sweat evaporates from the skin, which needs energy (latent heat of vaporisation)

taken from the skin, so the skin cools.

Grade 7+ extension: "Link to which particles leave the liquid:…"

The fastest-moving particles with the most energy escape,

so the average kinetic energy of the particles left behind falls.

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

Grade 4–5 starter: "Pushing the piston does work on the gas…"

Pushing the piston does work on the gas.

This transfers energy to the gas.

Grade 7+ extension: "Link work done to internal energy and temperature:…"

The internal energy of the gas increases,

so the particles move faster and the temperature rises.

ELABORATION GRADE 5

True or false? Justify it.

Saying why is worth more marks than saying true or false.

4 "The temperature of a substance always increases when you heat it." [2]

False: during a change of state, energy increases the potential energy of the particles

and the temperature stays the same.

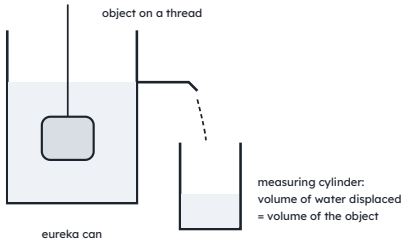
5 "Gas particles in a container all move at the same speed." [1]

False: they move randomly with a range of speeds.

DUAL CODING | WORKED EXAMPLES | GRADE 4 | GRADE 5 | GRADE 7

RP5: density of regular and irregular objects

Part 1: a regular block. Part 2: an irregular stone, using a eureka can.



	Block	Stone
Mass (g)	216	130
Dimensions / water displaced	3 cm × 4 cm × 6 .75 cm	52 cm³ displaced
Volume (cm³)	**81**	**52**
Density (g/cm³)	**2.67**	**2.5**

a Complete the table. [4]

Block V = 3 × 4 × 6.75 = 81 cm³, ρ = 216 ÷ 81 = 2.67 g/cm³; stone V = 52 cm³, ρ = 130 ÷ 52 = 2.5 g/cm³

b Describe how to measure the volume of the stone using a eureka can. [3]

Fill the eureka can until water flows out of the spout; wait until it stops.

Lower the stone in gently and collect the water that overflows in a measuring cylinder.

The volume of water collected = the volume of the stone.

c Convert the density of the stone to kg/m³. [1]

2.5 × 1000 = 2500 kg/m³

d Suggest one source of error and how to reduce it. [2]

Water left in the spout or splashing, or reading the meniscus wrongly;

lower the stone gently with thread and read the meniscus at eye level.

e How would you find the density of a liquid? [2]

Measure the mass of an empty measuring cylinder, then add a known volume of liquid and measure again;

ρ = (mass of liquid) ÷ volume.

	Trial 1	Trial 2	Trial 3	Mean
Mass of empty cylinder (g)	84.2	84.2	84.2	
Mass of cylinder + 50 cm³ oil (g)	130.1	130.4	129.9	
Mass of oil (g)	**45.9**	**46.2**	**45.7**	**45.9**

f Complete the table and calculate the density of the oil in kg/m³. [3]

Mean mass = 45.9 g; ρ = 45.9 ÷ 50 = 0.92 g/cm³

= 920 kg/m³

g Why does repeating and calculating a mean improve the result? [1]

It reduces the effect of random errors.

h Will the oil float on water (1000 kg/m³)? Explain. [1]

Yes: its density is less than that of water.

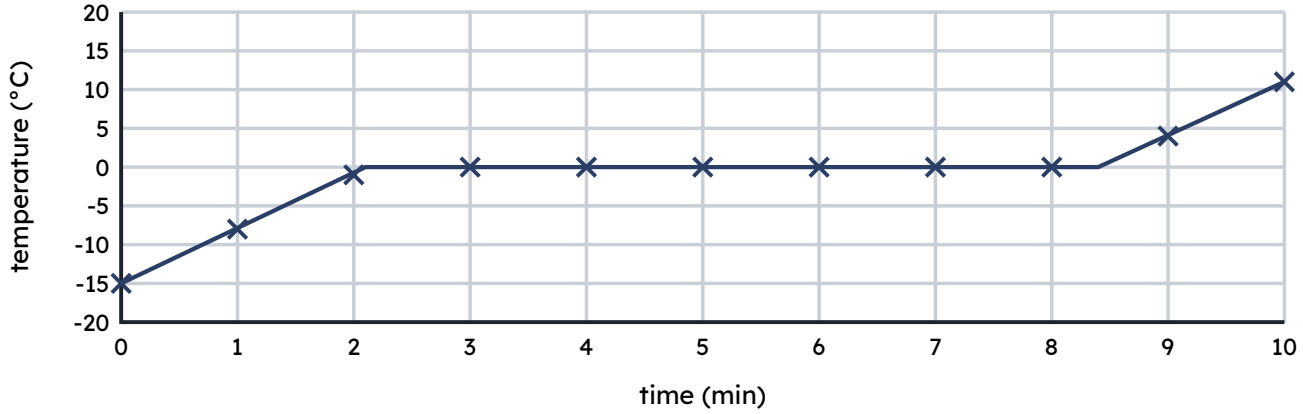
Required practical 5 and heating data (continued)

DUAL CODING | ELABORATION | GRADE 5 | GRADE 7

Specific heat capacity and latent heat: data skills

A student heats 0.2 kg of ice with a 50 W immersion heater and records the temperature every minute.

Time (min)	0	1	2	3	4	5	6	7	8	9	10
Temperature (°C)	−15	−8	−1	0	0	0	0	0	0	4	11



a Plot the graph. Mark where the ice is melting. [3]

Points plotted; flat section at 0 °C from about 2 to 8 minutes = melting.

b Use the time for melting to estimate the specific latent heat of fusion of ice. [3]

Melting takes about 6 min = 360 s; E = Pt = 50 × 360 = 18 000 J

L = E ÷ m = 18 000 ÷ 0.2

= 90 000 J/kg

c The accepted value is 334 000 J/kg. Suggest why the estimate is so different. [2]

Energy is transferred to the ice from the warm surroundings / not all the ice melts at the heater;

the timings of the start and end of melting are hard to judge.

Extra practice

Retrieval · answers in the answer booklet

1 Grade 7+ A 2 kW kettle, already at 100 °C, boils away 0.25 kg of water in 5 minutes. Use this to estimate the specific latent heat of vaporisation of water, and explain why the estimate is too high. [4]

E = Pt = 2000 × 300 = 600 000 J

L = E ÷ m = 600 000 ÷ 0.25 = 2 400 000 J/kg

Some energy is transferred to the surroundings, not to the water

So less energy was actually used to boil the water than was supplied, making the calculated

L too high

Exam practice

GRADE RADE 4

Secure the basics

1 Name the change of state from gas to liquid. [1]

Condensing (condensation)

2 State the unit of density. [1]

kg/m³

3 A block has a mass of 6 kg and a volume of 0.002 m³. Calculate its density. [2]

ρ = m ÷ V = 6 ÷ 0.002

= 3000 kg/m³

4 Describe the arrangement of particles in a liquid. [2]

Close together

in a random arrangement (they can move past each other)

5 What happens to the mass of a substance when it melts? [1]

It stays the same (mass is conserved).

GRADE RADE 5

Apply and rearrange

6 Calculate the energy needed to boil away 0.4 kg of water at 100 °C. (L = 2 260 000 J/kg) [2]

E = mL = 0.4 × 2 260 000

= 904 000 J

7 Define internal energy. [2]

The total kinetic energy and potential energy

of all the particles that make up a system.

8 Explain why a balloon left in the sun gets bigger. [3]

The air particles gain kinetic energy and move faster,

so they hit the inside of the balloon harder and more often,

the pressure increases and pushes the rubber outwards.

Extra practice

Retrieval · answers in the answer booklet

1 Grade 5 Oil has a density of 900 kg/m³. Calculate the mass of 0.03 m³ of oil. [2]

m = ρV = 900 × 0.03

m = 27 kg

GRADE RADE 7+

Stretch

9 A gas has a volume of 0.6 m³ at a pressure of 120 kPa. It is compressed at constant temperature to 0.2 m³. Calculate the new pressure. (Physics only) [3]

$p_1V_1 = p_2V_2$

$120\,000 \times 0.6 = p_2 \times 0.2$

$p_2 = 360\,000$ Pa (360 kPa)

10 Describe how to find the density of an irregular object and of a liquid. Include the measurements you would take and how you would calculate density. [6]

Measure the mass of the object on a top-pan balance.

Fill a eureka can to the spout; lower the object in and collect the displaced water in a measuring cylinder.

The volume of water displaced = the volume of the object; $\rho = m \div V$.

For a liquid: zero a balance with an empty measuring cylinder on it.

Pour in a known volume (e.g. 50 cm³), read at eye level at the bottom of the meniscus, and record the mass.

$\rho = m \div V$; repeat and calculate a mean; convert g/cm³ to kg/m³ (× 1000).

Total: _____ / 23

RETRIEVAL PRACTICE | SPACED PRACTICE | GRADE 4

Quick-fire retrieval: Particle model of matter

Cover everything. Answer in under 3 minutes. Redo it on your next spaced session.

1 Unit of specific latent heat?

J/kg

2 Water's density?

1000 kg/m³

3 Solid → gas directly?

Sublimation

4 Flat section on a heating curve?

Change of state

5 What increases in a gas when it's heated?

Particles' kinetic energy

6 Is a change of state physical or chemical?

Physical

Extra practice

Retrieval · answers in the answer booklet

1 Grade 5 Explain why gases are much less dense than solids. [3]

Gas particles are much further apart

So the same mass takes up a much larger volume

Density = mass ÷ volume, so the density is much lower

Reflect and plan

METACOGNITION

Re-rate yourself

Go back to the checklist at the start of this topic and fill in the 'After' column.

METACOGNITION GRADE 4 GRADE 5 GRADE 7

Exam wrapper: why did I drop marks?

After marking the exam practice, write the question numbers you got wrong in the right row.

Reason I lost marks	Question numbers	What to do next
I didn't know or remember it (knowledge gap)		Flashcards and brain dumps
I knew it but misread the question or command word		Underline command words
Maths slip: units, rearranging, standard form		Redo the "we do / you do" pages
I ran out of time or didn't finish		Timed practice: 1 mark per minute

METACOGNITION

Two things I'm now confident about

METACOGNITION

One thing I still need to work on, and how I'll fix it

e.g. 'Rearranging equations → redo the Grade 7+ questions and use the website's Aim higher section.'

SPACED PRACTICE

Book my next spaced sessions

Write the dates in the planner at the front: +2 days, +1 week, +3 weeks.

Extra practice

Retrieval · answers in the answer booklet

1 True or false? Heating ice while it melts increases its internal energy. Explain. [2]

True. The potential energy of the particles increases, even though the temperature doesn't.

Brain dump and checklist

RETRIEVAL PRACTICE · GRADE 4 · GRADE 5 · GRADE 7

Brain dump

Set a timer for 5 minutes. Write or draw everything you remember about atomic structure. No notes! Afterwards, add anything you missed in a different colour.

Prompts if you get stuck: protons, neutrons, electrons? · isotopes? · plum pudding? · alpha scattering? · alpha, beta, gamma? · nuclear equations? · half-life? · contamination? · fission and fusion?

METACOGNITION

How confident am I?

Rate each statement now (before) by shading R, A or G. Rate again at the end of the topic (after).

I can...	Before			After		
	R	A	G	R	A	G
Describe the structure of the atom and its size (about 1×10^{-10} m)	○	○	○	○	○	○
Explain how electrons change energy levels by absorbing or emitting EM radiation	○	○	○	○	○	○
Use mass number and atomic number; define isotopes	○	○	○	○	○	○
Describe how the model of the atom changed: plum pudding, alpha scattering, Bohr, Chadwick	○	○	○	○	○	○
Describe alpha, beta and gamma: what they are, how penetrating and how ionising	○	○	○	○	○	○
Write balanced nuclear equations for alpha and beta decay	○	○	○	○	○	○
Define half-life and find it from a graph	○	○	○	○	○	○
Calculate the net decline as a ratio after a number of half-lives (Higher)	○	○	○	○	○	○
Explain the difference between contamination and irradiation	○	○	○	○	○	○
Describe uses and dangers of nuclear radiation (Physics only)	○	○	○	○	○	○
Describe nuclear fission and fusion and chain reactions (Physics only)	○	○	○	○	○	○

Extra practice

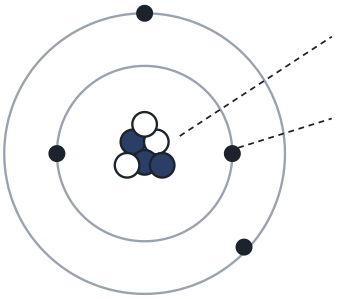
Retrieval · answers in the answer booklet

1 True or false? You can predict exactly when a particular nucleus will decay. Explain. [2]

False. Radioactive decay is random.

DUAL CODING | GRADE 4 | GRADE 5 | GRADE 7

THE ATOM · ALPHA SCATTERING

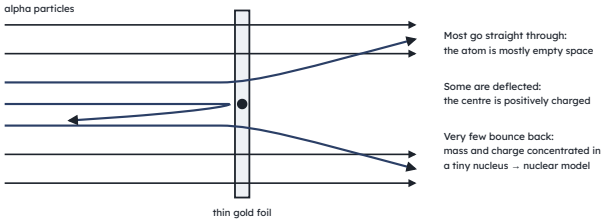


Nucleus: protons (+) and neutrons (0)
tiny: radius less than 1/10 000 of the atom

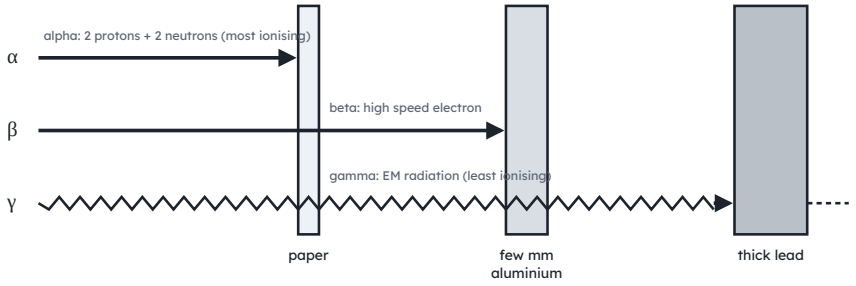
Electrons (–) in energy levels (shells)
absorb EM radiation → move to a higher level
lose an outer electron → positive ion

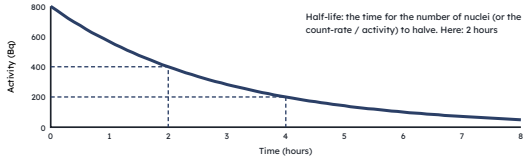
Atom radius about 1×10^{-10} m
neutral: number of protons = number of electrons

proton neutron electron



PENETRATION · HALF-LIFE





NUCLEAR RADIATION

Alpha (α): two neutrons and two protons (a helium nucleus). Most ionising; stopped by paper or a few cm of air.
Beta (β): a high speed electron ejected from the nucleus as a neutron turns into a proton. Stopped by a few mm of aluminium.
Gamma (γ): electromagnetic radiation from the nucleus. Least ionising; reduced by thick lead or concrete.

NUCLEAR EQUATIONS

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

TURN OVER

Key words, misconceptions, required practicals and Grade 7+ links are on the next page.

Knowledge organiser: key words, misconceptions, practicals

ELABORATION GRADE 4 GRADE 5 GRADE 7

KEY WORDS: LEARN THESE WORD FOR WORD (SAME AS SIDE 2 OF YOUR KNOWLEDGE ORGANISER)

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.

MISCONCEPTIONS: SPOT THE MISTAKE

× Common mistake	✓ What's actually true
× 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.

Extra practice

Retrieval · answers in the answer booklet

1 Grade 5 Give two natural sources of background radiation. [2]

Rocks (e.g. radon gas from rocks)

Cosmic rays from space

2 Grade 7+ A sample contains 1600 unstable nuclei and has a half-life of 5 days. After 15 days, what is the net decline, as a ratio of the original number? [3]

15 days = 3 half-lives

Nuclei left = 1600 → 800 → 400 → 200

Net decline = 1400 ÷ 1600 = 7/8 (0.875)

3 Grade 7+ Carbon-14 (atomic number 6) decays by beta emission. Write the products and explain what happens inside the nucleus. [3]

A neutron turns into a proton, and a high speed electron (beta particle) is emitted

Mass number stays 14; atomic number increases by 1 to 7

The new nucleus is nitrogen-14

RETRIEVAL PRACTICE GRADE 4 GRADE 5

Order it: how the model of the atom developed

Number the models in the order they were proposed and say what evidence led to each change.

Bohr's electrons in shells · tiny solid spheres · Chadwick's neutron · plum pudding model · nuclear model from alpha scattering

Tiny solid spheres → plum pudding (electron discovered) → nuclear model (alpha scattering)

→ Bohr's electrons at specific distances → protons → Chadwick's neutron (about 20 years later)

RETRIEVAL PRACTICE GRADE 4 GRADE 5

Fill the gaps

Use the AQA key words. No word bank: that's the point.

1. Atoms of the same element with different numbers of neutrons are called **isotopes**.
2. The time it takes for the count-rate from a sample to fall to half is the **half-life**.
3. A beta particle is a high speed **electron** ejected from the nucleus.
4. Exposing an object to nuclear radiation without it becoming radioactive is called **irradiation**.
5. The rate at which a source of unstable nuclei decays is its activity, measured in **becquerels** (Bq).

ELABORATION GRADE 5

Odd one out

Circle the odd one out in each row and explain why.

1. alpha · beta · gamma · neutron

Gamma: it's electromagnetic radiation, not a particle.

2. proton · neutron · electron · nucleus

Electron: it's outside the nucleus (or nucleus: it's not a particle).

3. fission · fusion · chain reaction · red-shift

Red-shift: it's space physics; the others are nuclear processes.

Extra practice

Retrieval · answers in the answer booklet

1 Grade 7+ Explain how the results of the alpha scattering experiment led to the nuclear model of the atom. [4]

Most alpha particles went straight through, so the atom is mostly empty space

Some were deflected, so the centre must be positively charged

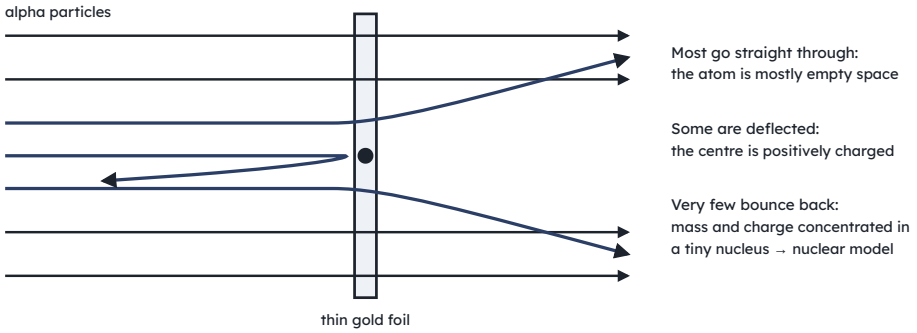
A very few bounced back, so the mass is concentrated in a tiny nucleus

The plum pudding model couldn't explain these results, so it was replaced

DUAL CODING GRADE 4 GRADE 5 GRADE 7

The alpha scattering experiment

Alpha particles were fired at thin gold foil.



a Most alpha particles went straight through. What does this show? [1]

Most of the atom is empty space.

b A few were deflected back. What does this show? [2]

The mass is concentrated in a tiny nucleus at the centre,

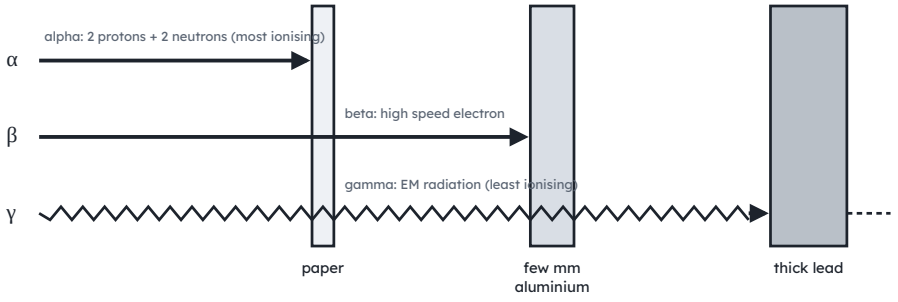
which is positively charged (it repels the alpha particles).

c Which model did this experiment replace? [1]

The plum pudding model

DUAL CODING GRADE 4 GRADE 5

Penetrating power



a Which radiation is stopped by paper? [1]

Alpha

b Which radiation passes through aluminium but is reduced by thick lead? [1]

Gamma

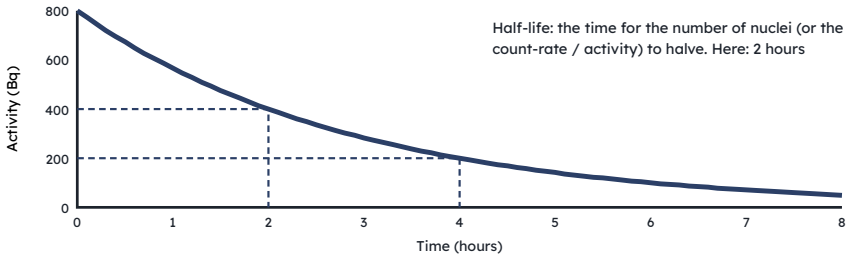
c Explain why an alpha source is most dangerous inside the body. [2]

Alpha is the most ionising,

and inside the body it can't be stopped before reaching cells, so it damages them.

DUAL CODING GRADE 5 GRADE 7

Read the half-life graph



a Use the graph to find the half-life. [2]

Read off the time for the count-rate to fall from 80 to 40 (draw lines on the graph).

b What fraction of the original count-rate is left after 3 half-lives? [1]

⅛

c Why is the graph a smooth curve even though decay is random? [2]

There are a huge number of nuclei,

so the overall pattern is predictable even though each decay is random.

Extra practice

Retrieval · answers in the answer booklet

1 Grade 7+ Compare nuclear fission and nuclear fusion. [4]

Fission splits a large and unstable nucleus into two smaller nuclei, roughly equal in size

Fusion joins two light nuclei to form a heavier nucleus

Fission usually needs the nucleus to absorb a neutron first, and releases neutrons that can cause a chain reaction

Both release energy; fission is used in nuclear reactors, and fusion powers stars

2 Grade 7+ Explain how a nuclear chain reaction happens and how it is controlled in a nuclear reactor. [4]

A uranium-235 nucleus absorbs a neutron, becomes unstable and splits into two smaller nuclei

Two or three neutrons are released, plus gamma rays and energy

These neutrons can be absorbed by other nuclei, causing further fission: a chain reaction

In a reactor, control rods absorb some neutrons so energy is released at a steady rate

3 Grade 5 What is meant by the half-life of a radioactive isotope? [2]

The time it takes for the number of nuclei of the isotope in a sample to halve

OR the time for the count-rate (activity) to fall to half

WORKED EXAMPLES GRADE 4 GRADE 5

Balancing nuclear equations

I do (worked example)

Polonium-210 decays by alpha emission.

1. Alpha = $^{4}_{2}He$
2. Mass number: 210 − 4 = 206
3. Atomic number: 84 − 2 = 82 (lead)
4. $^{210}_{84}Po \rightarrow {}^{206}_{82}Pb + {}^{4}_{2}He$

We do (finish it)

Carbon-14 (atomic number 6) decays by beta.

1. Beta = $^{0}_{-1}e$
2. Mass number stays ___ **14**
3. Atomic number becomes ___ **7 (nitrogen)**

You do

Uranium-238 (92) decays by alpha.

238 − 4 = 234

92 − 2 = 90

$^{234}_{90}Th + {}^{4}_{2}He$

WORKED EXAMPLES GRADE 5 GRADE 7

Half-life

I do (worked example)

Activity 800 Bq, half-life 2 days. Activity after 6 days?

1. 6 ÷ 2 = 3 half-lives
2. 800 → 400 → 200 → 100
3. **100 Bq**

Halve once per half-life

We do (finish it)

Count-rate 120 cpm, half-life 5 min. After 15 min?

1. Number of half-lives = ___ **3**
2. 120 → 60 → ___ → ___ **30 → 15**
3. ___ cpm **15**

You do

Determine the half-life: 640 Bq falls to 40 Bq in 12 hours.

640 → 320 → 160 → 80 → 40

4 half-lives in 12 h

half-life = 3 h

WORKED EXAMPLES GRADE 7

Net decline as a ratio (Higher)

1 A sample has a half-life of 4 years. What fraction of the original unstable nuclei is left after 12 years? Express the net decline as a ratio. [3]

12 ÷ 4 = 3 half-lives

fraction left = $(½)^3 = ⅛$

net decline = 7/8 of the original (ratio of decline to initial = 7 : 8)

Extra practice

Retrieval · answers in the answer booklet

1 Grade 7+ Explain why a medical tracer injected into the body should emit gamma radiation rather than alpha radiation. [4]

Gamma is very penetrating, so it passes out of the body to the detector

Gamma is weakly ionising, so it does less damage to cells

Alpha would be absorbed inside the body and not reach the detector

Alpha is highly ionising, so it would damage the surrounding cells

2 Grade 7+ A food company says 'Our irradiated food is not radioactive, but contaminated food can be dangerous.' Explain why the company is correct. [4]

Irradiation exposes food to radiation from outside

The food does not become radioactive

Contamination means radioactive atoms are on or in the food

If eaten, they keep emitting radiation inside the body, damaging cells (especially alpha)

Why? How? Explaining atomic structure

ELABORATION GRADE 4 GRADE 5 GRADE 7

Build an explanation

Answer each question in two steps. Use the starter, then push yourself with the Grade 7+ extension.

1 Explain why the plum pudding model was replaced.

Grade 4–5 starter: "In the alpha scattering experiment, a few alpha particles…"

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.

Grade 7+ extension: "Explain what the plum pudding model predicted instead:…"

The plum pudding model has positive charge spread out,

so it predicted that all the alpha particles would pass straight through.

2 Explain why gamma sources are used as medical tracers rather than alpha sources. (Physics only)

Grade 4–5 starter: "The radiation must get out of the body to be detected, so…"

Gamma passes out of the body to the detector;

alpha would be absorbed inside the body.

Grade 7+ extension: "Compare ionisation and choose a suitable half-life:…"

Gamma is weakly ionising, so it causes less damage to cells;

a short half-life means the activity falls quickly after the scan.

3 Explain the difference between contamination and irradiation.

Grade 4–5 starter: "Contamination is when radioactive atoms…"

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.

Grade 7+ extension: "Say which is more dangerous and why:…"

Contamination is more dangerous because the source stays with you

and keeps decaying; irradiation stops when you move away from the source.

ELABORATION GRADE 5

True or false? Justify it.

Saying why is worth more marks than saying true or false.

4 "A sample with a half-life of 2 hours will have completely decayed after 4 hours." [2]

False: after 4 hours (2 half-lives) one quarter is still left;

it halves each time and never reaches exactly zero.

5 "Isotopes of an element have different numbers of protons." [1]

False: same number of protons, different numbers of neutrons.

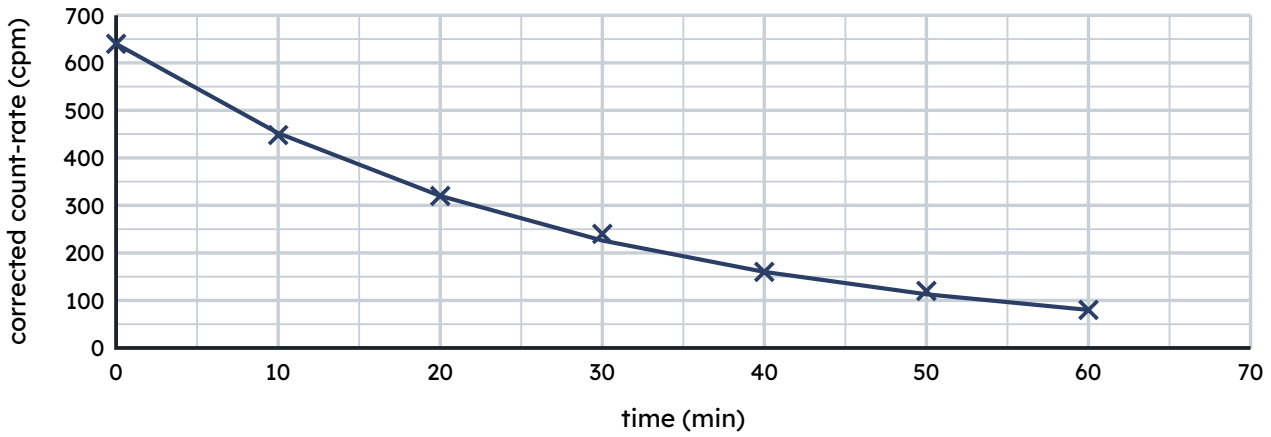
Data skills: half-life

DUAL CODING | ELABORATION | GRADE 5 | GRADE 7

Analyse decay data

A student measures the count-rate from a radioactive source every 10 minutes. Background radiation is 20 counts per minute.

Time (min)	0	10	20	30	40	50	60
Measured count-rate (cpm)	660	468	340	260	180	140	100
Corrected count-rate (cpm)	**640**	**448**	**320**	**240**	**160**	**120**	**80**



a Complete the corrected row by subtracting background radiation, then plot the graph. [3]

640, 448, 320, 240, 160, 120, 80; smooth curve.

b Use your graph to find the half-life. [2]

640 → 320 takes 20 min; 320 → 160 takes 20 min: half-life = 20 min

c Why does the student need to subtract background radiation? [1]

Background radiation is always present, so it would add to every reading.

d Some points are off the curve. Explain why. [2]

Radioactive decay is random,

so each count-rate varies; counting over a longer time reduces this.

e Give two ways the student should protect herself. [2]

Handle the source with tongs at arm's length;

keep it in a lead-lined box when not in use / minimise time of exposure.

Extra practice

Retrieval · answers in the answer booklet

1 Grade 5 The activity of a sample falls from 800 Bq to 100 Bq. The half-life is 5 days. How long did this take? [2]

800 → 400 → 200 → 100: 3 half-lives

3 × 5 = 15 days

Exam practice

GRADE RADE 4

Secure the basics

1 Name the particle with no charge in the nucleus. [1]

Neutron

2 What is the charge on an alpha particle? [1]

+2

3 Which type of radiation is an electromagnetic wave? [1]

Gamma

4 State the unit of activity. [1]

Becquerel (Bq)

5 An atom has 6 protons and 8 neutrons. What is its mass number? [1]

14

6 Give one source of background radiation. [1]

Rocks / cosmic rays / medical / nuclear weapons testing and accidents

GRADE RADE 5

Apply and rearrange

7 Describe what happens to an electron when an atom absorbs electromagnetic radiation. [2]

The electron moves to a higher energy level

(further from the nucleus).

8 A sample has an activity of 1200 Bq and a half-life of 3 hours. Calculate its activity after 9 hours. [2]

9 ÷ 3 = 3 half-lives

1200 → 600 → 300 → 150 Bq

9 Describe nuclear fission. (Physics only) [3]

A neutron is absorbed by a large and unstable nucleus (e.g. uranium-235).

It splits into two smaller nuclei, roughly equal in size,

and emits two or three neutrons plus gamma rays, releasing energy.

Extra practice

Retrieval · answers in the answer booklet

1 Which radiation is most dangerous inside the body? [1]

A Alpha **B** Beta **C** Gamma **D** They're all the same

A: Alpha. Alpha is the most ionising, so it does the most damage to nearby cells.

GRADE RADE 7+

Stretch

10 Write the nuclear equation for the beta decay of iodine-131 (atomic number 53) to xenon (Xe). [2]

$^{131}_{53}I \rightarrow {}^{131}_{54}Xe + {}^{0}_{-1}e$

(mass number unchanged; atomic number +1)

11 Describe how scientists' model of the atom has changed over time and explain why it changed. [6]

Atoms were first thought to be tiny spheres that could not be divided.

The discovery of the electron led to the plum pudding model: a ball of positive charge with electrons in it.

Alpha scattering: most passed straight through, a few deflected; so mass is concentrated in a small, positive nucleus (nuclear model).

Bohr suggested electrons orbit at specific distances, which agreed with experiments.

Later experiments showed the positive charge is made of protons.

About 20 years later Chadwick showed neutrons exist in the nucleus. Models change when new evidence can't be explained.

Total: _____ / 21

RETRIEVAL PRACTICE SPACED PRACTICE GRADE 4

Quick-fire retrieval: Atomic structure

Cover everything. Answer in under 3 minutes. Redo it on your next spaced session.

1 Radius of an atom?

About 1×10^{-10} m

2 Most penetrating radiation?

Gamma

3 Most ionising radiation?

Alpha

4 Who discovered the neutron?

James Chadwick

5 Fusion joins what?

Two light nuclei → a heavier nucleus

6 Half-life of a sample: random or predictable?

Each decay is random; half-life is predictable

Extra practice

Retrieval · answers in the answer booklet

1 Grade 5 Compare alpha, beta and gamma radiation in terms of penetration and ionising power. [3]

Alpha: stopped by paper/skin; most ionising

Beta: stopped by a few mm of aluminium; moderately ionising

Gamma: reduced by thick lead/concrete; least ionising

Reflect and plan

METACOGNITION

Re-rate yourself

Go back to the checklist at the start of this topic and fill in the 'After' column.

METACOGNITION GRADE 4 GRADE 5 GRADE 7

Exam wrapper: why did I drop marks?

After marking the exam practice, write the question numbers you got wrong in the right row.

Reason I lost marks	Question numbers	What to do next
I didn't know or remember it (knowledge gap)		Flashcards and brain dumps
I knew it but misread the question or command word		Underline command words
Maths slip: units, rearranging, standard form		Redo the "we do / you do" pages
I ran out of time or didn't finish		Timed practice: 1 mark per minute

METACOGNITION

Two things I'm now confident about

METACOGNITION

One thing I still need to work on, and how I'll fix it

e.g. 'Rearranging equations → redo the Grade 7+ questions and use the website's Aim higher section.'

SPACED PRACTICE

Book my next spaced sessions

Write the dates in the planner at the front: +2 days, +1 week, +3 weeks.

Extra practice

Retrieval · answers in the answer booklet

1 Fill the gap: Radiation dose is measured in _____. [1]

sieverts. A measure of the risk of harm (Physics only).

Interleaved retrieval quiz

Do this a week after finishing a topic

INTERLEAVING · RETRIEVAL PRACTICE · GRADE 4 · GRADE 5 · GRADE 7

Mixed Paper 1 questions

The questions are mixed up on purpose. First decide which topic each one is from, then answer it. Some questions link two topics, just like the real exam.

1 (?) Calculate the resistance of a lamp with 12 V across it and 0.4 A through it. [2]

R = V ÷ I = 12 ÷ 0.4 = 30 Ω

2 (?) A 2 kg ball moves at 3 m/s. Calculate its kinetic energy. [2]

Ek = ½ × 2 × 3² = 9 J

3 (?) What is the difference between two isotopes of the same element? [1]

Different numbers of neutrons

4 (?) Name the change of state from liquid to gas. [1]

Boiling / evaporating

5 (?) Give two ways to reduce unwanted energy transfers in a machine. [2]

Lubrication; thermal insulation

6 (?) Why does the National Grid use step-up transformers? [2]

To increase the p.d. and reduce the current, so less energy is wasted in the cables.

7 (?) Calculate the density of a 4 kg object with a volume of 0.002 m³. [2]

ρ = 4 ÷ 0.002 = 2000 kg/m³

8 (?) A source's count-rate falls from 400 to 100 cpm in 6 hours. Determine the half-life. [2]

400 → 200 → 100 is 2 half-lives, so 3 hours

9 (?) Calculate the energy to warm 0.5 kg of water by 10 °C. (c = 4200 J/kg °C) [2]

ΔE = 0.5 × 4200 × 10 = 21 000 J

10 (?) A 60 W lamp is on for 1 hour. How much energy does it transfer? [2]

E = Pt = 60 × 3600 = 216 000 J

Q	1	2	3	4	5	6	7	8	9	10
Topic	Electricity	Energy	Atomic	Particles	Energy	Electricity	Particles	Atomic	Energy + particles	Electricity + energy

Extra practice

Retrieval · answers in the answer booklet

1 Define **hydroelectricity**. [1]

Renewable and reliable; water stored high up flows down through turbines. Floods valleys.