OCR GATEWAY A GCSE PHYSICS J249 | P1

# MATTER

# Exam practice notebook

## FOUNDATION TIER

12 diagnostic choices + 15 topic sets
2 extended responses + 4 timed sets
138 marks | Original questions | Detailed answers at the end

P1.1 Particle model

P1.2 Changes of state

P1.3 Pressure

Name: _____

Class: _____ Date: _____

Independent practice resource. Not an official OCR examination paper. No OCR past-paper questions or mark schemes are reproduced.

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Revised edition - 13 November 2026
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ROUTE AND MARKING

# How to use this notebook

Attempt the topic sets after studying each sub-topic. Allow about 8-10 minutes per six-mark set. Complete the timed check in 32 minutes, without looking at answers. Calculator allowed; show relationships, substitutions, numerical answers and units.

> The timed check is a P1 topic assessment, not a full GCSE paper. Its timing and marks are suggested for this resource. No GCSE grade boundaries are assigned.

Use the practice equation reference if needed. For the timed check, your teacher can choose whether it is available. This reference is not a reproduction of the official exam equation sheet.

Foundation covers the common P1 outcomes, including Boyle's relationship. Higher also covers work on gases, liquid-depth pressure, floating and upthrust.

## After marking

Use the guidance at the back. Award each independent point once. Accept scientifically equivalent wording and valid alternative methods. For a calculation, allow method marks after an arithmetic slip when the method remains valid; do not award an accuracy mark for an incorrect result. No negative marks.

For the graph task, compare with the labelled reference graph and the stated plotting tolerance. Mark the extended explanations by their listed points, not by length. All answers are grouped in the final section after the score records.

## Command words

| Word | What your answer should do |
|---|---|
| State | Give a concise fact or value. |
| Calculate | Show the relationship, substitutions and result. |
| Explain | Link a cause or observation to the physics. |
| Describe | Give the relevant features or method steps. |

OPTIONAL SUPPORT

# Practice equation reference

| Relationship | Units / conditions |
|---|---|
| $\rho = m/V$ | kg/m³ with kg and m³; or g/cm³ with g and cm³ |
| $\Delta E = mc\Delta T$ | J; kg; J/(kg °C); °C temperature difference |
| $E = mL$ | J; kg; J/kg; constant-temperature state change |
| $p_1V_1 = p_2V_2$ | Fixed gas mass and temperature; absolute pressures; consistent volume units |

## Useful conversions

1 kg = 1000 g; 1 m³ = 1 000 000 cm³; 1 g/cm³ = 1000 kg/m³; 1 kPa = 1000 Pa. A temperature change of 1 °C has the same numerical value as a change of 1 K.

## Calculation checks

Use temperature change, not final temperature. Subtract the empty container mass for liquid density. Use the displaced volume for an irregular solid. Distinguish temperature change from state change. State any necessary conditions for a gas equation.

## Coverage and source

Aligned to OCR GCSE Physics A (Gateway Science), J249, specification version 5.0 (July 2026), P1 and relevant mathematical/practical skills. Checked 13 November 2026.

Official OCR J249 specification

Original text, data, diagrams and questions prepared for this collection. AI-assisted preparation. Not produced, endorsed or approved by OCR. Suggested answers and credit points are independent guidance.

**2021-2025 | ORIGINAL QUESTIONS**

# Five-series reference review

The latest five publicly linked series reviewed on the OCR assessment page are November 2021 and June 2022, 2023, 2024 and 2025. P1 is assessed within J249/01 (Foundation) and J249/03 (Higher). Both tiers and their mark schemes were consulted for skills and assessment structure.

Questions here are newly written. The contexts, datasets and combinations of tasks are original; the series below are references for assessment skills, not claimed sources of individual questions.

2021: Density methods; gas data and atmospheric reasoning; thermal energy in stages.

2022: Density data and units; state-change interpretation; gas relationships and Higher fluid pressure.

2023: Gas graphs and evidence; atmospheric pressure; multi-step thermal calculations.

2024: Thermal measurement; gas-model explanations and calculations; Higher floating and liquid pressure.

2025: Particle models; atomic-model evidence; density measurements; Higher cooling-curve reasoning.

Official assessment archive: papers and mark schemes

Full reference links appear in the companion reference record supplied with this edition. No official questions, diagrams or marking tables are reproduced. This notebook is not a prediction of a future paper.

**D1-D4 | 4 MARKS**

# Diagnostic multiple choice

D1. A sealed sample changes from liquid to solid without losing material. Which statement must be correct? [1]

A Its mass is unchanged. B Its volume must be unchanged. C Its density must decrease. D Its particles stop moving.

Answer: _____

D2. Material X has twice the mass of material Y, but both samples occupy the same volume. What is ρX / ρY? [1]

A 0.5 B 1 C 2 D 4

Answer: _____

D3. A metal warms from -12 °C to +8 °C. Which temperature change belongs in mcΔT? [1]

A -20 °C B -4 °C C 8 °C D 20 °C

Answer: _____

D4. Which unit belongs to specific latent heat? [1]

A J/kg B J/(kg °C) C kg/m³ D Pa

Answer: _____

**D5-D8 | 4 MARKS**

# Diagnostic multiple choice

D5. An accurate balance gives the mass of a stone as 48 g. Its displaced volume is 16 cm³. Which density is consistent with the measurements? [1]

A 0.33 g/cm³ B 3.0 g/cm³ C 32 g/cm³ D 768 g/cm³

Answer: _____

D6. At constant temperature, a fixed gas sample expands to three times its original volume. What is the final pressure as a fraction of its initial pressure? [1]

A 1/9 B 1/3 C 3 D 9

Answer: _____

D7. Which observation most strongly challenges a model with positive charge spread evenly throughout an atom? [1]

A The foil has a measurable mass. B Alpha particles have positive charge. C A very small fraction of alpha particles turn back. D Most alpha particles cross the foil.

Answer: _____

D8. Two samples of the same material receive equal energy and do not change state. Sample X has three times the mass of sample Y. Which temperature-rise ratio ΔTX/ΔTY is expected? [1]

A 3 B 1 C 9 D 1/3

Answer: _____

**D9-D12 | 4 MARKS**

# Diagnostic multiple choice

D9. What causes the force exerted by a gas on a container wall? [1]

A Particles becoming larger. B Particles colliding with the wall. C Particles being stationary at the wall. D Particles losing their mass.

Answer: _____

D10. A sample is melting at a steady temperature. Which statement is correct? [1]

A Its internal energy must be constant. B Its particles have zero kinetic energy. C No energy can enter the sample. D Its potential-energy contribution can increase.

Answer: _____

D11. Which change most directly reduces parallax in a measuring-cylinder reading? [1]

A Reading the meniscus at eye level. B Using a heavier liquid. C Holding the cylinder above the eyes. D Rounding every result to one significant figure.

Answer: _____

D12. A pressure sensor is carried to a higher altitude during stable weather. Which explanation best accounts for its usual decrease in reading? [1]

A Air particles lose all motion. B Gravity becomes a repulsive force. C Less weight of air lies above the sensor. D The sensor changes the mass of the air.

Answer: _____

**TOPIC PRACTICE | Q1 | 6 MARKS**

# Inside an atom

A student draws an atom with a small central nucleus and electrons around it.

Q1(a) State the charge of the nucleus and the charge of an electron. [2]

Q1(b) A typical atom has diameter 0.0000000001 m. Write this in standard form and state where almost all the atomic mass is found. [2]

Q1(c) Explain why this drawing must not show the nucleus occupying most of the atom’s volume. [2]

Score: ____ / 6 Review: secure / developing / revisit

TOPIC PRACTICE | Q2 | 6 MARKS

# Evidence changes a model

Positive alpha particles are directed at thin metal foil. Most pass straight through. A few change direction sharply and a very small number travel back towards the source.

Q2(a) Explain what most particles passing straight through suggests about atomic structure. [2]

Q2(b) Explain what the rare large deflections suggest about the nucleus. [2]

Q2(c) State one feature of Thomson’s model and one change introduced by Bohr. [2]

Score: ____ / 6 Review: secure / developing / revisit

TOPIC PRACTICE | Q3 | 6 MARKS

# Density of a building block

A rectangular solid block has mass 540 g, length 10.0 cm, width 3.0 cm and height 2.0 cm.

Q3(a) Calculate the volume of the block. Include a unit. [2]

Q3(b) Calculate its density in g/cm³. [2]

Q3(c) Convert this density to kg/m³. State why density alone cannot always identify a material uniquely. [2]

Score: ____ / 6 Review: secure / developing / revisit

TOPIC PRACTICE | Q4 | 6 MARKS

# Density of a liquid

A student measures different volumes of the same liquid in the same dry measuring cylinder. All readings are at the same temperature.

| Liquid volume / cm³ | Cylinder + liquid mass / g |
|---|---|
| 0 | 30 |
| 20 | 48 |
| 40 | 66 |

Q4(a) Use the 40 cm³ measurement to calculate the density of the liquid. [2]

Q4(b) Predict the balance reading when the cylinder contains 60 cm³ of the liquid. [2]

Q4(c) Explain why dividing 66 g by 40 cm³ gives an incorrect density. [2]

Score: ____ / 6 Review: secure / developing / revisit

TOPIC PRACTICE | Q5 | 6 MARKS

# Displacement and measurement error

An insoluble solid has mass 84 g. A measuring cylinder reads 35 $cm^3$ before submersion and 47 $cm^3$ with the solid fully submerged.

Q5(a) Calculate the solid’s density. [2]

Q5(b) An air bubble sticks to the solid. Explain the effect on the calculated density. [2]

Q5(c) Describe two measurement improvements, apart from removing bubbles. [2]

Score: ____ / 6 Review: secure / developing / revisit

TOPIC PRACTICE | Q6 | 6 MARKS

# Melting and internal energy

A sealed container holds 100 g of ice at its melting point. Energy is supplied until all the ice has become liquid water at the same temperature.

Q6(a) State the final mass of water and explain your answer. [2]

Q6(b) Explain why internal energy increases even though temperature does not. [2]

Q6(c) Explain why melting is a physical change. [2]

Score: ____ / 6 Review: secure / developing / revisit

TOPIC PRACTICE | Q7 | 6 MARKS

# Heating a metal sample

A heater transfers 7200 J to a 0.80 kg metal sample. The sample warms from 18 °C to 38 °C without changing state.

Q7(a) Calculate the temperature change. [1]

Q7(b) Calculate the sample’s specific heat capacity, using the stated energy received by the sample. [3]

Q7(c) A second sample of the same metal has twice the mass and receives the same energy. Predict its temperature rise and explain. [2]

Score: ____ / 6 Review: secure / developing / revisit

TOPIC PRACTICE | Q8 | 6 MARKS

# Energy for a change of state

A sample of 0.15 kg of ice is already at its melting point. Its specific latent heat of fusion is $3.2 \times 10^5$ J/kg.

Q8(a) Calculate the energy needed to melt the entire sample without a temperature change. [2]

Q8(b) Only 16 000 J reaches a larger ice sample at its melting point. Calculate the mass that melts. [2]

Q8(c) Explain why the equation $E = mc\Delta T$ should not be used for the melting stage. [2]

Score: ____ / 6 Review: secure / developing / revisit

**TOPIC PRACTICE | Q9 | 6 MARKS**

# Plotting a heating curve

A pure substance starts as a solid and is heated at a steady rate. It melts during the experiment but does not boil. The table gives its temperature. Plot temperature against time on the grid, label both axes with units, and join successive points with straight lines.

| Time / min | 0 | 2 | 4 | 6 | 8 | 10 |
|---|---|---|---|---|---|---|
| Temperature / °C | 20 | 40 | 40 | 40 | 60 | 80 |



Q9(a) Complete the graph described above. [3]

Q9(b) Identify the time interval in which melting takes place and explain why the temperature remains constant. [2]

Q9(c) The heater transfers 300 J each minute to the sample. Calculate the energy transferred during melting. [1]

Score: ____ / 6 Review: secure / developing / revisit

TOPIC PRACTICE | Q10 | 6 MARKS

# Pressure in a sealed container

A fixed amount of gas is held in a sealed rigid container. It is heated from room temperature. The container does not expand.

Q10(a) Explain how gas particles produce pressure. [2]

Q10(b) Explain why the pressure rises when the gas is heated. [3]

Q10(c) State one quantity, other than volume, that stays constant in this experiment. [1]

Score: ____ / 6 Review: secure / developing / revisit

TOPIC PRACTICE | Q11 | 6 MARKS

# Changing gas volume

A fixed mass of gas is held at constant temperature. Its absolute pressure is 120 kPa when its volume is 50 $cm^3$.

Q11(a) Calculate its absolute pressure when the volume is reduced to 30 $cm^3$. [3]

Q11(b) Explain the pressure change using the particle model. [2]

Q11(c) State why the gas should be allowed to return to its original temperature before a reading is taken. [1]

Score: ____ / 6 Review: secure / developing / revisit

TOPIC PRACTICE | Q12 | 6 MARKS

# Atmosphere and altitude

Two pressure sensors are placed at ground level and high on a mountain. Weather conditions are stable during the measurements.

Q12(a) Explain why the mountain sensor normally records a lower atmospheric pressure. [3]

Q12(b) A student says atmospheric pressure only pushes down. Explain why this is incorrect. [2]

Q12(c) State the SI unit of pressure. [1]

Score: ____ / 6 Review: secure / developing / revisit

TOPIC PRACTICE | Q13 | 6 MARKS

# Checking a density result

A laboratory tests one liquid. The empty bottle has mass 42.0 g. Three measurements with nominally 25.0 cm³ of liquid give bottle-plus-liquid masses of 62.1 g, 61.9 g and 62.0 g.

Q13(a) Calculate the mean mass of the liquid alone. [2]

Q13(b) Calculate density in kg/m³. [2]

Q13(c) The volume scale consistently reads 1.0 cm³ above the true liquid volume. Explain whether averaging the mass readings removes the resulting density error. [2]

Score: ____ / 6 Review: secure / developing / revisit

TOPIC PRACTICE | Q14 | 6 MARKS

# Allowing for background melting

Two identical samples of ice are already at their melting point. In 120 s, a heater supplies 2400 J to sample A and 9.0 g melts. Sample B has no heater; 1.5 g melts in the same surroundings during the same time. Assume the background energy transfer is equal for both samples.

Q14(a) Calculate the mass melted by the heater alone, in kg. [2]

Q14(b) Estimate the specific latent heat of fusion using this corrected mass. [2]

Q14(c) Explain how ignoring the unheated sample affects the calculated value. [2]

Score: ____ / 6 Review: secure / developing / revisit

TOPIC PRACTICE | Q15 | 6 MARKS

# Testing a gas relationship

A fixed mass of gas is measured after returning to room temperature at each volume. Absolute pressures are used. The sensor resolution is 1 kPa.

| Volume / cm³ | 60 | 48 | 40 |
|---|---|---|---|
| Pressure / kPa | 80 | 101 | 120 |

Q15(a) Calculate pV for the first and third readings. Include units. [2]

Q15(b) Calculate the pressure predicted by pV = constant at 48 cm³. Evaluate agreement with the observed pressure. [2]

Q15(c) Explain why plotting pressure against volume should not give a straight line through the origin. [2]

Score: ____ / 6 Review: secure / developing / revisit

P1.1d-f; working scientifically | 6 MARKS

# E1: Plan a reliable comparison

Two unlabelled liquids are supplied in separate containers. Plan how to compare their densities fairly using a balance and a measuring cylinder. Explain how the measurements lead to a valid conclusion, and address measurement quality. Do not taste the liquids.

Write one coherent response. Link measurements or evidence to the physics. Suggested time: 10 minutes.

**P1.2a-c; P1.3a-d | 6 MARKS**

# E2: Evaluate a particle explanation

A student makes three claims: (1) gas particles become larger when a sealed rigid container is heated; (2) the temperature of a pure substance must rise throughout melting at constant pressure; (3) doubling a fixed gas volume at constant temperature doubles the pressure. Evaluate all three claims using the particle model and appropriate relationships.

Write one coherent response. Link measurements or evidence to the physics. Suggested time: 10 minutes.

FRESH CONTEXTS | 24 MARKS

# Timed P1 check

Suggested time: 32 minutes. Complete all 4 sets. The following pages contain new questions on the same topic. Show your working and use units.

Start time: _____ Finish time: _____
Equation reference allowed by teacher? yes / no

Do not check answers until the whole timed section is finished. Your score helps identify what to revisit; it is not an official GCSE grade.

**TIMED CHECK | T1 | 6 MARKS**

# T1: Material testing

A small solid sample has mass 156 g. When fully immersed, it displaces 20 $cm^3$ of water.

T1(a) Calculate its density. [2]

T1(b) Explain why equal-sized samples of two materials may have different densities. [2]

T1(c) Describe how to measure the mass of a liquid sample without including its container. [2]

Score: ____ / 6 Review: secure / developing / revisit

TIMED CHECK | T2 | 6 MARKS

# T2: Heating in stages

A 0.25 kg solid starts at 10 °C. Its melting point is 30 °C, its specific heat capacity is 800 J/(kg °C), and its specific latent heat of fusion is 60 000 J/kg. Ignore losses.

T2(a) Calculate the energy needed to warm the solid to its melting point. [2]

T2(b) Calculate the total energy to warm it and then melt it completely. [2]

T2(c) State what happens to average particle kinetic energy during warming, and during melting at constant temperature. [2]

Score: ____ / 6 Review: secure / developing / revisit

TIMED CHECK | T3 | 6 MARKS

# T3: Gas in a syringe

A sealed gas syringe contains 80 $cm^3$ of gas at an absolute pressure of 100 kPa. Gas temperature remains constant as the volume changes.

T3(a) Calculate the volume when absolute pressure is 160 kPa. [3]

T3(b) Explain why the pressure increases when volume decreases at constant temperature. [2]

T3(c) State one other condition needed for this gas relationship. [1]

Score: ____ / 6 Review: secure / developing / revisit

**TIMED CHECK | T4 | 6 MARKS**

# T4: Improving a thermal experiment

An electrical heater is supplied with 6000 J while heating a 0.50 kg block. The block warms by 20 °C. A student assumes all electrical energy supplied to the heater reaches the block.

T4(a) Calculate the specific heat capacity obtained using the student’s assumption. [3]

T4(b) Explain the direction of error if some of that 6000 J heats the surroundings. [2]

T4(c) Suggest one change that reduces this energy loss. [1]

Score: ____ / 6 Review: secure / developing / revisit

COMPLETE AFTER MARKING

# Score and improvement record

| Set | Specification focus | Score / 6 |
|---|---|---|
| Q1 | P1.1a-c | |
| Q2 | P1.1a | |
| Q3 | P1.1d-f | |
| Q4 | P1.1d-f; working scientifically | |
| Q5 | P1.1d-f; working scientifically | |
| Q6 | P1.2a-c | |
| Q7 | P1.2d-e; PM1.2i | |
| Q8 | P1.2d,f; PM1.2ii | |
| Q9 | P1.2a-f; graph skills | |
| Q10 | P1.3a-c | |

Diagnostic: ____ / 12 Extended responses: ____ / 12

Topic sets: ____ / 90 Timed sets: ____ / 24

Whole notebook: ____ / 138

Question to revisit: _____ Correct physics and method:

COMPLETE AFTER MARKING

# Score and improvement record

| Set | Specification focus | Score / 6 |
|---|---|---|
| Q11 | P1.3d; PM1.3i | |
| Q12 | P1.3f-g | |
| Q13 | P1.1d-f; data evaluation | |
| Q14 | P1.2f; practical evaluation | |
| Q15 | P1.3d; PM1.3i; data analysis | |
| T1 | P1.1 | |
| T2 | P1.2 | |
| T3 | P1.3a-d; PM1.3i | |
| T4 | P1.2d-e; working scientifically | |

Diagnostic: ____ / 12 Extended responses: ____ / 12

Topic sets: ____ / 90 Timed sets: ____ / 24

Whole notebook: ____ / 138

Question to revisit: _____ Correct physics and method:

DETAILED SOLUTIONS AND MARKING GUIDANCE

# ANSWERS

Stop here until you have attempted the questions. All answers are grouped from this point to the end.

Order: diagnostic answers; topic-practice worked answers; extended-response model answers; timed-check worked answers; heating-curve reference graph.

## How to award credit

Marks in brackets beside each part are the maximum for that part. Award the independent points shown once each; accept equivalent scientific wording and valid alternative methods. A correct calculation with suitable units earns full credit unless the task specifically asks for reasoning.

If a numerical error is carried into a later calculation, award valid later method credit where the physics and units remain consistent. Do not award an accuracy mark to an incorrect number. Do not penalise the same arithmetic slip repeatedly.

Extended-response tasks use the six independent credit points supplied here. Their model paragraphs show a coherent full-credit response; they are not the only acceptable wording. This is an original point-based practice scheme, not an official OCR level-of-response grid.

Diagnostic questions earn one mark for the single correct option and zero for another option or multiple selections. Do not subtract marks for an incorrect answer.

Graph answers: allow the plotting tolerance specified in Q9 and alternative sensible scales. A clear physically correct graph can earn credit even when its appearance differs from the model.

No GCSE grade boundary or pass mark is assigned to this topic notebook. Use the score record to identify skills for further practice.

D1-D4 | REASONS INCLUDED

# Diagnostic answers

## D1: A [1]

Mass is conserved when no matter enters or leaves. Volume and density can change. Solid particles still vibrate.

## D2: C [1]

With equal volumes, density is proportional to mass: (2m/V)/(m/V) = 2.

## D3: D [1]

Final minus initial is 8 - (-12) = 20 °C. A negative starting temperature does not make the rise negative.

## D4: A [1]

Latent heat is energy per unit mass for a change of state, without a temperature change.

D5-D8 | REASONS INCLUDED

# Diagnostic answers

## D5: B [1]

Divide mass by volume: 48/16 = 3.0 g/cm³. Multiplying gives the wrong physical dimensions.

## D6: B [1]

$p_1V_1 = p_2(3V_1)$, so $p_2/p_1 = 1/3$. This depends on fixed gas mass and temperature.

## D7: C [1]

Rare large deflections require a very concentrated positive region. Transmission alone does not explain the nuclear concentration.

## D8: D [1]

$\Delta T = E/(mc)$. With E and c fixed, tripling mass divides the temperature rise by three.

D9-D12 | REASONS INCLUDED

# Diagnostic answers

## D9: B [1]

Collisions change particle momentum and exert forces on the wall. Pressure is normal force per unit area.

## D10: D [1]

Energy supplied during melting changes particle arrangements/interactions, increasing potential energy while mean kinetic energy remains constant.

## D11: A [1]

Eye-level viewing aligns the meniscus with the scale and reduces the apparent displacement caused by an angled view.

## D12: C [1]

Less overlying air means a smaller supported weight per unit area; air is also generally less dense higher up.

WORKED ANSWER | TOTAL 6 MARKS

# Q1: Inside an atom

## Part (a) / 2

Positive nucleus (1); negative electron (1).

## Part (b) / 2

$1.0 \times 10^{-10}$ m (1); in the nucleus (1).

## Part (c) / 2

The nucleus is much smaller than the atom (1); most of the atomic volume is empty space in this model (1).

## Reasoning and worked method

The atom diameter is 0.0000000001 m = $1 \times 10^{-10}$ m because the decimal point moves ten places. Mass and volume are different ideas: a nucleus can contain almost all the mass while occupying only a tiny fraction of the volume. Electrons occupy the surrounding region.

Common error to avoid: Do not label the nucleus negative or spread atomic mass uniformly throughout the atom.

WORKED ANSWER | TOTAL 6 MARKS

# Q2: Evidence changes a model

## Part (a) / 2

Most of the atom is empty space (1), so most alpha particles do not approach the small nucleus closely (1).

## Part (b) / 2

Positive charge is concentrated in a very small region (1); that region is dense/contains most atomic mass and strongly repels the positive alpha particles (1).

## Part (c) / 2

Thomson: electrons embedded in spread-out positive charge (1); Bohr: electrons occupy particular energy levels/shells (1).

## Reasoning and worked method

The observation and the inference must be linked. Easy transmission supports empty space; rare strong repulsion points to a concentrated positive centre. Evidence is used to test a model rather than merely to name a scientist. Thomson’s and Bohr’s features refer to different stages of model development.

Common error to avoid: Do not claim the scattering experiment showed electron shells. Bohr’s energy-level model is a later development.

WORKED ANSWER | TOTAL 6 MARKS

# Q3: Density of a building block

## Part (a) / 2

V = 10.0 × 3.0 × 2.0 (1); 60 $cm^3$ (1).

## Part (b) / 2

ρ = m/V = 540/60 (1); 9.0 $g/cm^3$ (1). Allow correct error carried forward from (a).

## Part (c) / 2

9000 $kg/m^3$ (1); different materials can have the same/similar density, or mixtures/measurement uncertainty can overlap (1).

## Reasoning and worked method

Volume = 10.0 cm × 3.0 cm × 2.0 cm = 60 $cm^3$. Density = 540 g / 60 $cm^3$ = 9.0 $g/cm^3$. Since 1 g = $10^{-3}$ kg and 1 $cm^3$ = $10^{-6}$ $m^3$, the conversion factor is $10^3$, giving 9000 $kg/m^3$. The unit conversion affects numerator and denominator.

Common error to avoid: Do not use surface area instead of volume. Converting $g/cm^3$ to $kg/m^3$ requires multiplication by 1000, not division.

WORKED ANSWER | TOTAL 6 MARKS

# Q4: Density of a liquid

## Part (a) / 2

Liquid mass = 66 - 30 = 36 g (1); ρ = 36/40 = 0.90 g/cm³ (1).

## Part (b) / 2

Liquid mass = 0.90 × 60 = 54 g (1); total reading = 54 + 30 = 84 g (1).

## Part (c) / 2

66 g includes the cylinder mass (1); numerator is too large, so calculated density is too high (1).

## Reasoning and worked method

The fixed 30 g intercept is the container mass. At 40 cm³ the liquid mass is 36 g, giving 0.90 g/cm³. At 60 cm³ the liquid mass is 54 g; the balance must therefore display 84 g. The density is based on the liquid, while the balance reads both liquid and cylinder.

Common error to avoid: Subtract the container mass before dividing. A larger measuring-cylinder reading does not mean the liquid’s density has increased.

WORKED ANSWER | TOTAL 6 MARKS

# Q5: Displacement and measurement error

## Part (a) / 2

Displaced volume = 47 - 35 = 12 $cm^3$ (1); $\rho = 84/12 = 7.0$ $g/cm^3$ (1).

## Part (b) / 2

Bubble increases apparent displacement/volume (1); calculated density is too low (1).

## Part (c) / 2

Any two distinct relevant improvements (1 each): read meniscus at eye level; use a finer-resolution cylinder; use a fine suspension with negligible displacement; check/zero balance; avoid splashing; ensure complete submersion. Repeats alone require explanation that random variation can be assessed/reduced by a mean.

## Reasoning and worked method

The rise from 35 to 47 $cm^3$ gives 12 $cm^3$, not 47 $cm^3$. An attached bubble occupies space as well as the solid, so the apparent displaced volume is too large. For fixed measured mass, increasing the denominator decreases the calculated density.

Common error to avoid: Do not say the bubble increases the measured mass appreciably. Name a specific measurement improvement rather than only “be careful”.

WORKED ANSWER | TOTAL 6 MARKS

# Q6: Melting and internal energy

## Part (a) / 2

100 g (1); particles/matter have not left the sealed container and mass is conserved (1).

## Part (b) / 2

Energy changes the particle arrangement/potential energy (1); average particle kinetic energy does not increase, so temperature stays constant (1).

## Part (c) / 2

The substance remains water/no new substance is formed (1); freezing can restore the original state/properties (1).

## Reasoning and worked method

A sealed system retains all the water particles, so the 100 g remains 100 g. Temperature reflects average kinetic energy, while internal energy also includes potential energy associated with particle interactions. Changing the particle arrangement can increase internal energy at a fixed temperature.

Common error to avoid: Do not say particles themselves melt or stop moving. Energy transfer continues through a constant-temperature melting stage.

WORKED ANSWER | TOTAL 6 MARKS

# Q7: Heating a metal sample

## Part (a) / 1

38 - 18 = 20 °C (1).

## Part (b) / 3

ΔE = mcΔT, so c = ΔE/(mΔT) (1); 7200/(0.80 × 20) (1); 450 J/(kg °C) (1).

## Part (c) / 2

10 °C (1); for fixed energy and specific heat capacity, temperature rise is inversely proportional to mass (1).

## Reasoning and worked method

ΔT = 38 - 18 = 20 °C. Rearranging ΔE = mcΔT gives c = 7200/(0.80 × 20) = 450 J/(kg °C). For a second sample of mass 1.60 kg, ΔT = 7200/(1.60 × 450) = 10 °C. A larger mass shares the same energy among more material.

Common error to avoid: Use the temperature difference, not 38 °C. Include the per-kilogram and per-degree parts of the specific-heat-capacity unit.

WORKED ANSWER | TOTAL 6 MARKS

# Q8: Energy for a change of state

## Part (a) / 2

E = mL = 0.15 × 3.2 × $10^5$ (1); 48 000 J (1).

## Part (b) / 2

m = E/L = 16 000/(3.2 × $10^5$) (1); 0.050 kg (1).

## Part (c) / 2

Temperature does not change in this stage (1); energy is associated with a change of state/potential energy rather than a temperature rise (1).

## Reasoning and worked method

For complete melting, E = mL = 0.15 × 320 000 = 48 000 J. For the smaller energy transfer, rearrange to m = E/L = 16 000/320 000 = 0.050 kg. The formula mcΔT describes a temperature change without a state change; it would give zero for this melting interval.

Common error to avoid: Latent heat is measured in J/kg, not J/(kg °C). The energy required for melting is not zero even though ΔT is zero.

WORKED ANSWER | TOTAL 6 MARKS

# Q9: Plotting a heating curve

## Part (a) / 3

Suitable labelled axes and consistent scales using most of the grid (1); all six points correctly plotted within half a small square (1); appropriate straight segments including horizontal 40 °C section (1).

## Part (b) / 2

2 to 6 minutes (1); supplied energy changes particle arrangement/potential energy rather than average kinetic energy (1).

## Part (c) / 1

4 × 300 = 1200 J (1).

## Reasoning and worked method

Plot (0,20), (2,40), (4,40), (6,40), (8,60) and (10,80), with time in minutes on the horizontal axis. The plateau lasts 6 - 2 = 4 min. At 300 J per minute the energy received is 4 × 300 = 1200 J. The full labelled graph appears at the end of this answer section.

Common error to avoid: The duration is four minutes, not six. Keep time units consistent with the supplied energy-per-minute rate.

WORKED ANSWER | TOTAL 6 MARKS

# Q10: Pressure in a sealed container

## Part (a) / 2

Particles collide with the walls and exert forces (1); force normal to the walls per unit area is pressure (1).

## Part (b) / 3

Average particle kinetic energy/speed increases (1); collisions with the wall become more frequent (1); greater momentum change per collision/greater overall force on a fixed area (1).

## Part (c) / 1

Gas mass/number of gas particles (1).

## Reasoning and worked method

Pressure is a macroscopic effect of microscopic collisions. At the same wall area, an increased rate of momentum transfer means greater mean force and greater pressure. Heating a fixed gas mass does not create extra particles or require the particles to become larger.

Common error to avoid: Distinguish the particle speed from the sample volume. The container is rigid, so its volume cannot increase in this question.

WORKED ANSWER | TOTAL 6 MARKS

# Q11: Changing gas volume

## Part (a) / 3

$p_1V_1 = p_2V_2$ (1); $p_2 = 120 \times 50/30$ (1); 200 kPa (1).

## Part (b) / 2

At constant temperature mean particle speed stays the same (1); smaller volume means more frequent wall collisions per unit area and hence higher pressure (1).

## Part (c) / 1

Compression may warm it; the gas relationship requires constant temperature (1).

## Reasoning and worked method

Use the same pressure and volume units in both states: $p_2 = (120\ \text{kPa} \times 50\ \text{cm}^3)/30\ \text{cm}^3 = 200\ \text{kPa}$. This is a smaller volume, so the pressure should be larger. The average particle speed is determined by temperature and does not increase in this constant-temperature comparison.

Common error to avoid: Do not assume p is proportional to V. For a fixed mass and temperature it is inversely proportional to V.

WORKED ANSWER | TOTAL 6 MARKS

# Q12: Atmosphere and altitude

## Part (a) / 3

Less air/weight of air lies above the mountain sensor (1); air is generally less dense at higher altitude (1); smaller force per unit area/less frequent particle collisions produces lower pressure (1).

## Part (b) / 2

Air particles move in all directions (1); collisions exert forces on surfaces in all orientations (1).

## Part (c) / 1

Pascal/Pa (1).

## Reasoning and worked method

Atmospheric pressure can be modelled as arising from the weight of air supported above a surface. At higher altitude there is less overlying air. The microscopic explanation uses collisions on all sides of a surface, so the pressure is not restricted to downward-facing effects.

Common error to avoid: Do not explain the change by saying there is no gravity on the mountain. Gravity still acts; the amount and density of overlying air change.

WORKED ANSWER | TOTAL 6 MARKS

# Q13: Checking a density result

## Part (a) / 2

Mean filled mass = (62.1 + 61.9 + 62.0)/3 = 62.0 g (1); mean liquid mass = 62.0 - 42.0 = 20.0 g (1).

## Part (b) / 2

ρ = 20.0/25.0 = 0.800 g/cm³ (1); 800 kg/m³ (1).

## Part (c) / 2

No; this is a systematic volume error and repetition does not remove it (1). The stated volume is too large, so the uncorrected density is too low (1).

## Reasoning and worked method

The three filled masses have mean 62.0 g; subtracting the 42.0 g empty bottle leaves 20.0 g. Using 25.0 cm³ gives 0.800 g/cm³ = 800 kg/m³. If the scale overreads by 1.0 cm³, the true volume is 24.0 cm³ and the corrected density would be about 833 kg/m³.

Common error to avoid: Averaging repeated mass readings cannot correct a consistent error in a different instrument’s volume scale.

WORKED ANSWER | TOTAL 6 MARKS

# Q14: Allowing for background melting

## Part (a) / 2

Corrected mass = 9.0 - 1.5 = 7.5 g (1); 0.0075 kg (1).

## Part (b) / 2

L = E/m = 2400/0.0075 (1); 320 000 J/kg or $3.2 \times 10^5$ J/kg (1).

## Part (c) / 2

It attributes all 9.0 g of melting to the heater, making the mass assigned to heater energy too large (1); E/m therefore gives a value that is too low (1).

## Reasoning and worked method

The unheated control estimates melting caused by the surroundings. The heater accounts for 9.0 - 1.5 = 7.5 g = 0.0075 kg. L = 2400/0.0075 = 320 000 J/kg. Without correction, the result would be 2400/0.0090 ≈ 267 000 J/kg, which is lower.

Common error to avoid: Convert grams to kilograms before using joules with latent heat in J/kg. Do not add the control mass to the heated mass.

WORKED ANSWER | TOTAL 6 MARKS

# Q15: Testing a gas relationship

## Part (a) / 2

First: 80 × 60 = 4800 kPa cm³ (1); third: 120 × 40 = 4800 kPa cm³ (1).

## Part (b) / 2

Predicted p = 4800/48 = 100 kPa (1); observed 101 kPa differs by 1 kPa/one scale step, so is close but not exact agreement (1). Resolution alone does not prove the full uncertainty.

## Part (c) / 2

Pressure is inversely proportional to volume (1); pV is approximately constant, rather than p/V, so the p-against-V graph is curved (1).

## Reasoning and worked method

The first and third readings independently give pV = 4800 kPa cm³. At 48 cm³ the prediction is therefore 100 kPa. The measured 101 kPa is close, but one resolution step is not automatically the full experimental uncertainty. The direct p-V plot is an inverse curve; a p-against-1/V plot would be straight under ideal conditions.

Common error to avoid: A decreasing graph is not necessarily a straight line. A small discrepancy should be evaluated rather than hidden.

**EXTENDED RESPONSE | 6 MARKS**

# E1: Plan a reliable comparison: model answer

Measure the mass of a clean, dry empty measuring cylinder. Add a measured volume of liquid A and read the meniscus at eye level with the cylinder level. Weigh the cylinder and liquid, and subtract the empty mass. Divide liquid mass by liquid volume using consistent units. Repeat with fresh measurements, then repeat for liquid B using a clean, dry cylinder at the same temperature. Calculate a mean density for each liquid and compare the difference with the spread/resolution of the measurements; a very small difference may be inconclusive.

## Credit points: one mark each

1. Obtain liquid mass by subtracting empty-container mass.
2. Measure liquid volume with a suitable cylinder and eye-level meniscus reading.
3. Use density = liquid mass / volume with consistent units.
4. Avoid mixing/contamination and compare at the same temperature.
5. Repeat independent measurements and use a mean/check spread.
6. Make a justified comparison, recognising a small difference may be within measurement variation.

Improvement note: Use a spill tray and eye protection where required by the supplied liquid’s risk assessment. Repeats help judge random variation; they do not fix a miscalibrated balance.

EXTENDED RESPONSE | 6 MARKS

# E2: Evaluate a particle explanation: model answer

Claim 1 is incorrect: heating raises average particle kinetic energy and speed, rather than the size of the particles. Faster particles collide with the rigid walls more frequently and with greater momentum changes, increasing pressure. Claim 2 is incorrect during melting at the melting point: the supplied energy changes arrangements/interactions and potential energy, while average kinetic energy and temperature stay constant. Claim 3 is incorrect: for a fixed gas mass at constant temperature, pV is constant. Doubling volume halves pressure because wall collisions per unit area become less frequent while mean speed remains unchanged.

## Credit points: one mark each

1. Reject claim 1 and replace particle-size change with increased mean speed/kinetic energy.
2. Connect the heating to more frequent/stronger wall collisions and higher pressure at fixed volume.
3. Reject claim 2 and state constant melting temperature at steady pressure.
4. Link melting energy to arrangement/potential-energy change rather than increased mean kinetic energy.
5. Reject claim 3 using pV = constant and predict half the original pressure.
6. Explain the expansion using unchanged mean speed and fewer wall collisions per unit area.

Improvement note: Write cause-and-effect links. Saying “the particles have more pressure” is not a useful microscopic explanation. Pressure describes the force per area on a surface.

WORKED ANSWER | TOTAL 6 MARKS

# T1: Material testing

## Part (a) / 2

ρ = m/V = 156/20 (1); 7.8 g/cm³ (1).

## Part (b) / 2

Equal volumes can contain different total particle masses (1); due to different particle masses and/or packing/spacing (1).

## Part (c) / 2

Measure empty dry container mass (1); measure container plus liquid and subtract empty mass (1).

## Reasoning and worked method

Density = 156 g/20 cm³ = 7.8 g/cm³. Equal volumes of different substances can have different total masses because of their particles and their spacing. In the liquid measurement, the tare/subtraction step isolates the mass that corresponds to the measured liquid volume.

Common error to avoid: Use the change in water volume, not the final cylinder reading, when a displaced volume must be found.

WORKED ANSWER | TOTAL 6 MARKS

# T2: Heating in stages

## Part (a) / 2

E = mcΔT = 0.25 × 800 × 20 (1); 4000 J (1).

## Part (b) / 2

Melting energy = 0.25 × 60 000 = 15 000 J (1); total = 19 000 J (1). Allow correct carried-forward warming energy.

## Part (c) / 2

Increases during warming (1); stays constant during constant-temperature melting (1).

## Reasoning and worked method

Warming: ΔT = 30 - 10 = 20 °C, so $E_1$ = 0.25 × 800 × 20 = 4000 J. Melting: $E_2$ = 0.25 × 60 000 = 15 000 J. Total = $E_1$ + $E_2$ = 19 000 J. Temperature rises in the first stage and stays fixed during the second.

Common error to avoid: Do not apply the latent heat to the warming stage or forget to include the warming energy in the total.

WORKED ANSWER | TOTAL 6 MARKS

# T3: Gas in a syringe

## Part (a) / 3

$p_1V_1 = p_2V_2$ (1); $V_2 = 100 \times 80/160$ (1); 50 $cm^3$ (1).

## Part (b) / 2

Mean particle speed remains unchanged (1); more frequent wall collisions per unit area increase pressure (1).

## Part (c) / 1

A fixed mass of gas/no leakage (1).

## Reasoning and worked method

Rearrange to $V_2 = p_1V_1/p_2 = 100 \times 80/160 = 50$ $cm^3$. The pressure has increased by a factor of 1.6, so volume should decrease by the same factor. Keeping the gas mass fixed is essential as well as maintaining temperature.

Common error to avoid: The final volume is not 128 $cm^3$; that would wrongly assume direct proportionality.

WORKED ANSWER | TOTAL 6 MARKS

# T4: Improving a thermal experiment

## Part (a) / 3

c = E/(mΔT) (1); 6000/(0.50 × 20) (1); 600 J/(kg °C) (1).

## Part (b) / 2

Energy assigned to the block is too large (1); calculated c is too high (1).

## Part (c) / 1

Insulate the block/use a suitable insulating lid or jacket (1).

## Reasoning and worked method

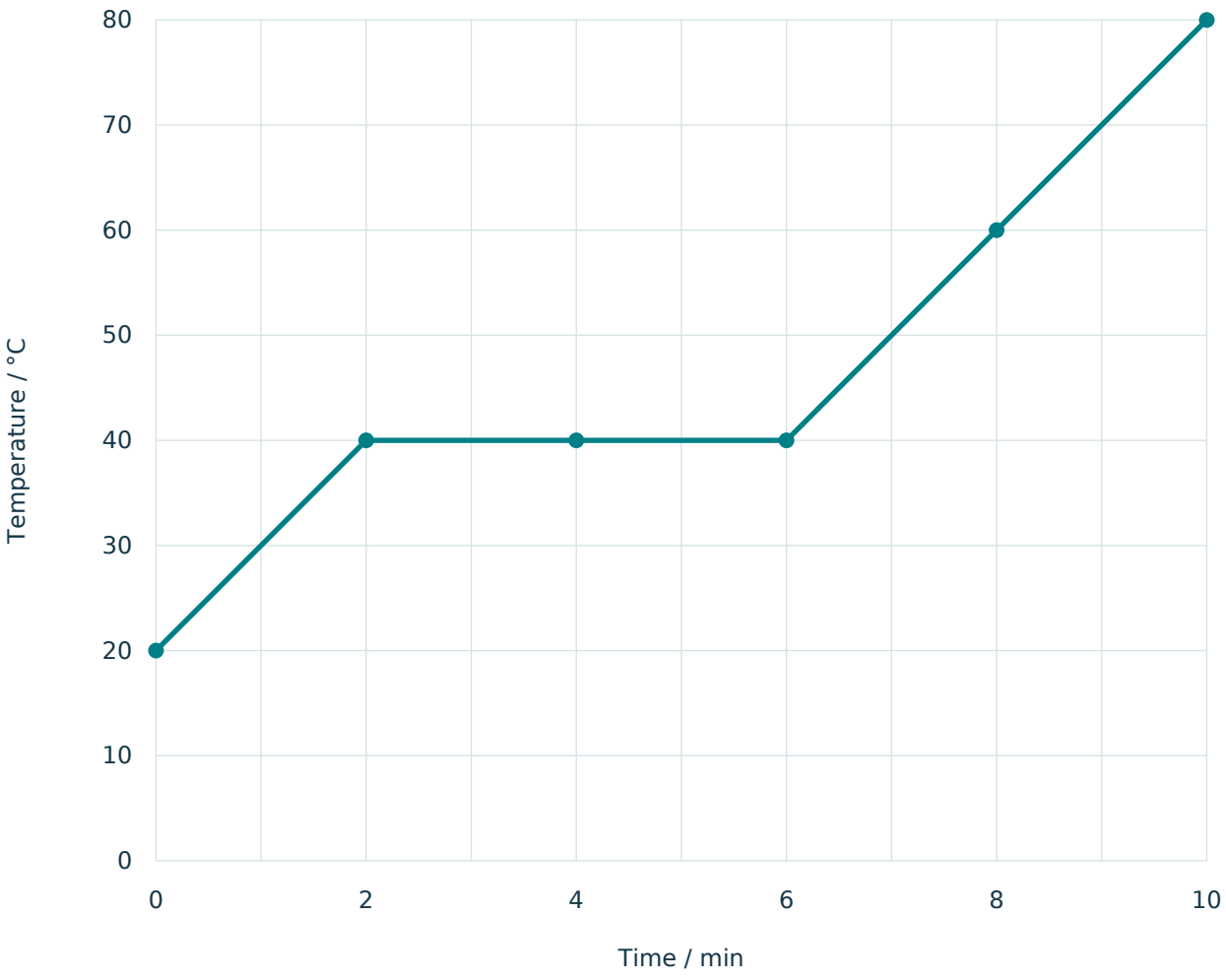
Under the assumption, c = 6000/(0.50 × 20) = 600 J/(kg °C). If some energy goes to the surroundings, the block receives less than 6000 J for the same measured rise. Its true c would therefore be smaller than the assumed result.

Common error to avoid: Avoid the vague statement “heat loss makes the answer inaccurate”. State which quantity is overestimated and why.

**Q9(a) | GRAPH CHECK**

# Heating-curve reference answer

Axes and scales may differ from this example. The coordinates and horizontal melting section must agree with the data.




Melting: 2-6 min at 40 °C. Energy received during melting: 4 min × 300 J/min = 1200 J. Constant temperature does not mean zero energy transfer.