Pure Physics 6091/02 2026

Model answers aligned to **Physics Matters 5th ed.** · Physics Matters GCE 'O' Level, 5th edition (Marshall Cavendish Education, 2023). Printed page numbers of the textbook (read from the page images); chapter and section given for each quote; pdf_page is the page index inside that chapter's PDF/Markdown file (printed page = pdf_page + a fixed chapter offset), not the printed page.

Unofficial suggested solutions written by chermistry.com. This is NOT the Cambridge / SEAB mark scheme: Cambridge has not released one, so every mark point and accept/reject note here is our own. Where the official scheme differs, the official scheme wins.

Suggested solutions for the real Oct/Nov 2026 Physics (Pure) Paper 2 (6091/02, 80 marks: Section A 70 + one Section B option of 10). No official mark scheme exists yet and the teacher-supplied ChatGPT key is unofficial, so these are teacher-grade model answers: each part was solved independently from the scan, compared with the key, and built from the exact words of Physics Matters (5th ed.). Each part shows the mark points (one per mark), working with units and sig figs, accept/reject notes and the verbatim textbook quotation with printed page.

Concepts not (fully) covered by the textbook

Parts by status: In the textbook **38** · Partly in the textbook **12** · NOT in the textbook **0** · Data skill (answered from the question) **1**

Part	Concept	Status	What to do
1(a)(ii)	Work is a scalar quantity (classifying work as scalar/vector)	Partly in the textbook	Add to Chapter 1 / Chapter 7 teaching: Table 1.5 lists energy, not work, as a scalar; tell students work (like energy) is a scalar measured in J.
2(d)(ii)	Ice below 0 °C must warm to 0 °C before it melts (cold-ice energy balance)	Partly in the textbook	Teach a mixing example with ice below 0 °C (Q = m c Δθ for the ice, then m l_f); the book only has this as an end-of-chapter exercise (p. 185).
3(b)(iii)	Energy shared between two moving masses (falling load pulls glider)	Partly in the textbook	Use a load-and-trolley example in the energy chapter: gravitational potential energy lost = kinetic energy of the trolley + kinetic energy of the load.
4(b)(ii)	Partial reflection with a fixed percentage of energy at each reflection; tan geometry in a rod	Partly in the textbook	Reflection energy fractions are not taught (law of reflection only, p. 236); treat as an unseen data/geometry question: count the reflections (10%, 1%, 0.10%) and the crossings of the rod, distance = n × diameter × tan 35°.
5(c)	Speed of a moving object from the change in round-trip time of successive light pulses (speed gun)	Partly in the textbook	Extend the echo idea (Chapter 12, p. 211) to light: extra round trip = c Δt, so the car moved c Δt / 2 between pulses; then v = distance/time.
7(a)	Factors that change the deflection of a charged beam: particle speed and screen distance	Partly in the textbook	Tell students that a faster particle is deflected less and that a longer straight path after the field increases the displacement; the book only gives field strength.
7(c)	Effect of particle mass on the size of the deflection (electron vs proton, same speed)	Partly in the textbook	Combine F = qvB-type ideas (the book: force is same size) with F = ma: smaller mass gives larger acceleration, so larger deflection.

8(a)	Short circuit between live and neutral wires blows the fuse	Partly in the textbook	The phrase 'short circuit' is absent from the textbook; teach: live touches neutral, very low resistance, very large current, fuse melts.
8(d)	Advantages of a circuit breaker over a fuse (faster, more sensitive)	Partly in the textbook	The book gives only 'can be turned on again'; add that a circuit breaker trips faster and is more sensitive.
9(b)(iv)	Why the primary coil of a step-up transformer uses thicker wire	Partly in the textbook	Combine $V_p I_p = V_s I_s$ (primary carries the larger current) with 'thicker wire, lower resistance, less I^2R heating' (p. 391).
10(a)(ii)	Compressibility of gases and liquids explained by particle spacing	Partly in the textbook	The book states 'gases are compressible' but only asks the explanation as a practice question (p. 146); give the answer: much empty space in a gas, almost none in a liquid.
10(b)(ii)(B)	Force balance on a cylinder held in a liquid by a string (tension, weight, upward force on the base)	Partly in the textbook	Draw the free-body diagram: $T + p A = W$; the book has the principle (Ch 4) and the liquid-pressure force (Ch 6) but never combines them.

Question 1 — Scalars, vectors and base quantities [7]

1(a)(i) **[1]**

State the difference between a scalar quantity and a vector quantity.

- A scalar quantity has magnitude (size) only; a vector quantity has both magnitude and direction [1]

Both halves are needed (scalar: magnitude only / vector: magnitude and direction). Accept 'a vector has direction as well as magnitude'. Reject 'a vector has direction' alone, or 'scalar has no direction' alone if vector is not also described.

> **Ch 1 Physical Quantities, Units and Measurements › 1.4 What Are Scalars and Vectors? › p. 12 (PDF p. 12)**
> *"Scalar quantities are physical quantities that have only magnitude. Vector quantities are physical quantities that have both magnitude and direction. Some scalar and vector quantities are shown in Table 1.5."*

In the textbook

LO: 1(f)

1(a)(ii) **[3]**

Classify mass, weight, energy and work as vector or scalar, and tick the base quantities (Table 1.1).

- mass: tick scalar AND tick base quantity (no tick under vector) [1]
- weight: tick vector only (weight is a force; it is not a base quantity) [1]
- energy AND work: tick scalar only, no tick under vector and none under base quantity [1]

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Mark allocation is assumed (no scheme): one mark per row for mass and weight, one for the
energy/work rows. A row with an extra tick loses its mark.
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Mass is the only base quantity in the table (the SI base quantities are length, mass, time, current, temperature, amount of substance). Weight is a force (N), so vector. Energy and work are both measured in J and have no direction, so scalar. Reject a tick for energy or work under 'base quantity' (the joule is a derived unit).

> **Ch 1 Physical Quantities, Units and Measurements › 1.4 What Are Scalars and Vectors? (Table 1.5 Common scalar and vector quantities) › p. 12 (PDF p. 12)**
> *"Scalar: distance, speed, mass, energy, time. Vector: displacement, velocity, acceleration, force, weight."*

> **Ch 1 Physical Quantities, Units and Measurements › 1.4 What Are Scalars and Vectors? › p. 12 (PDF p. 12)**
> *"Scalar quantities are physical quantities that have only magnitude. Vector quantities are physical quantities that have both magnitude and direction. Some scalar and vector quantities are shown in Table 1.5."*

Ch 3 Dynamics I: Mass and Weight › 3.2 Is Mass the Same as Weight? (Mass) › p. 46 (PDF p. 4)

"Mass is a property of a body that does not change with its location or shape. The mass of a body depends on the number and composition of atoms and molecules that make up the body. It is a scalar quantity."

Ch 3 Dynamics I: Mass and Weight › 3.2 Is Mass the Same as Weight? (Weight) › p. 46 (PDF p. 4)

"Weight is the gravitational force acting on an object that has mass. Its SI unit is the newton (N). Since weight is a force, it is a vector quantity with both magnitude and direction."

Ch 1 Physical Quantities, Units and Measurements › 1.2 What Are Physical Quantities? (Table 1.1 Base quantities and their SI units) › p. 3 (PDF p. 3)

"Base quantity / SI unit / symbol: length, metre, m; mass, kilogram, kg; time, second, s; electric current, ampere, A; thermodynamic temperature, kelvin, K; amount of substance, mole, mol."

Partly in the textbook

Gap: The book lists mass and energy as scalars and weight as a vector (Table 1.5, p. 12) and mass as the base quantity (Table 1.1, p. 3), but it never classifies WORK as a scalar quantity (searched Ch 1, Ch 7 'Work Done by a Force').
LO: 1(f), 1(b)

1(a)(iii) **[1]**

State the SI base unit for temperature.

- kelvin (K) [1]

Accept 'K' or 'kelvin'. Reject degree Celsius / °C / 'Kelvins degrees' (Celsius is not an SI base unit).

Ch 1 Physical Quantities, Units and Measurements › 1.2 What Are Physical Quantities? (Table 1.1 Base quantities and their SI units) › p. 3 (PDF p. 3)

"Base quantity / SI unit / symbol: length, metre, m; mass, kilogram, kg; time, second, s; electric current, ampere, A; thermodynamic temperature, kelvin, K; amount of substance, mole, mol."

Ch 1 Physical Quantities, Units and Measurements › 1.2 What Are Physical Quantities? › p. 4 (PDF p. 4)

"A common unit of temperature is the degree Celsius. Temperatures in degree Celsius can be expressed in kelvin using this relationship: Temperature in kelvin = temperature in degree Celsius + 273"

In the textbook

LO: 1(b)

1(b) **[2]**

By drawing on Figure 1.1, construct and label the vector P + Q.

- Redraw one vector so that the two are joined head-to-tail: from the head (right-hand end, where the arrowheads point) of P draw a line parallel to Q and the same length as Q (or equivalently translate P to the head of Q, or complete a parallelogram with a construction line parallel to each vector) [1]
- Draw the resultant from the tail (left-hand end) of P to the free end of the redrawn Q, with an arrowhead pointing away from the start, and label it P + Q [1]

```
In the scan P and Q both point to the right and share their HEAD (the right-hand end), so they
cannot be added as drawn: one must be moved parallel to itself. Measured from the scan with P =
(right 267, up 31) and Q = (right 267, up 99) pixel units, P + Q = (534, 130): about 2.06 times
the length of P, about 14 degrees above the line of P's direction (horizontal). Tolerance for a
correct drawing: parallel lines within 1 mm / 2 degrees, equal lengths within 1 mm.
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Either order is acceptable (Q from the head of P, ending above and to the right; or P from the head of Q, giving the same vector displaced). The resultant must start at the tail of the first vector (tail of P in the first method, tail of Q in the second) and carry an arrowhead and the label P + Q ('R' alone is not enough). Reject the diagonal of a parallelogram drawn from the common HEAD, and a resultant with no arrowhead.

Ch 1 Physical Quantities, Units and Measurements › 1.4 What Are Scalars and Vectors? (Adding Two Vectors by the Graphical Method) › p. 13 (PDF p. 13)

"We can use a vector diagram to add up two vectors. In a vector diagram, a vector quantity is represented by an arrow."

Ch 1 Physical Quantities, Units and Measurements › 1.4 What Are Scalars and Vectors? (Adding Two Vectors by the Graphical Method) › p. 13 (PDF p. 13)

"The single vector, called the resultant vector, must be equivalent to the individual vectors combined in terms of magnitude and direction."

Ch 1 Physical Quantities, Units and Measurements › 1.4 What Are Scalars and Vectors? (Adding Two Non-Parallel Vectors, Figure 1.19) › p. 14 (PDF p. 14)

"Step 2: From A, draw an arrow AB to represent the 4 N force. The head of the arrow OA is joined to the tail of arrow AB."

Ch 1 Physical Quantities, Units and Measurements › 1.4 What Are Scalars and Vectors? (Adding Two Non-Parallel Vectors, Figure 1.19) › p. 14 (PDF p. 14)

"Step 3: Join O (the tail of the 6 N force) to B (the head of the 4 N force). This forms the triangle OAB. The resultant force is represented by the arrow OB."

Ch 1 Physical Quantities, Units and Measurements › 1.4 What Are Scalars and Vectors? (Adding Two Non-Parallel Vectors) › p. 14 (PDF p. 14)

"Figure 1.19 shows how we can obtain the resultant force by the head-to-tail method."

In the textbook

LO: 1(g)

Question 2 — Ice in water: convection, heat capacity and internal energy [9]

2(a) **[1]**

Describe how convection is involved in decreasing the temperature of the water.

- Water cooled by the ice becomes denser and sinks, while warmer (less dense) water rises to take its place, so convection currents carry warm water to the ice and the whole glass cools [1]

Accept: cold (denser) water sinks and warm (less dense) water rises forming convection currents. Reject 'cold water rises', 'heat rises' with no density idea, or conduction/radiation explanations.

Ch 9 Thermal Processes › 9.2 How Is Energy Transferred by Heating? (Convection) › p. 153 (PDF p. 7)

"Convection is a process of energy transfer by means of convection currents of a fluid (liquid or gas), due to a difference in density. When a liquid is heated, it expands and increases in volume. As volume increases, density decreases. The warm liquid, being less dense than its surroundings, will rise. The cold liquid, being denser, will sink. This difference in density results in convection currents"

Ch 9 Thermal Processes › 9.2 How Is Energy Transferred by Heating? (Convection) › p. 153 (PDF p. 7)

"The circulating convection currents carry warmer liquid away from the heat source and cooler liquid towards it."

In the textbook

LO: 8(c)

2(b) **[2]**

Define specific heat capacity.

- the change in internal energy (energy transferred by heating) [1]
- per unit mass for each unit change in temperature (per kg per K or per °C) [1]

Book wording: 'the change of its internal energy per unit mass for each unit change in its temperature'. Accept the equivalent 'the energy required to raise the temperature of 1 kg of the substance by 1 K (1 °C)'. Reject 'heat per unit

mass' with no temperature change, and 'energy to raise the temperature of an object by 1 °C' (that is heat capacity, no mass).

> **Ch 10 Thermal Properties of Matter › 10.1 How Is Internal Energy Related to Heat Capacity? (Heat Capacity and Specific Heat Capacity) › p. 169 (PDF p. 3)**
> *"Specific heat capacity c of a material is the change of its internal energy per unit mass for each unit change in its temperature. c = C/m = Q/(mΔθ) where C = heat capacity (J/K or J/°C), Q = change in internal energy (J) by energy transfer, m = mass of substance (kg), Δθ = change in temperature (K or °C)"*

> **Ch 10 Thermal Properties of Matter › 10.1 How Is Internal Energy Related to Heat Capacity? (Table 10.1) › p. 170 (PDF p. 4)**
> *"The specific heat capacity of water is 4200 J/(kg K). This means that 4200 J of energy is required to raise the temperature of 1 kg of water by 1 K."*

In the textbook
LO: 9(b)

2(c) **[2]**

Explain what is meant by the term internal energy.

- it is an energy store made up of the total kinetic energy of the particles due to their random motion [1]
- plus the total potential energy between the particles (due to the forces between them) [1]

Both 'total' (sum over all the particles) and the two kinds (kinetic of random motion, potential between particles) are expected. Reject 'heat energy' / 'thermal energy of the substance' with no kinetic and potential parts, and 'kinetic energy of the particles' alone (1 mark).

> **Ch 10 Thermal Properties of Matter › 10.1 How Is Internal Energy Related to Heat Capacity? (Internal Energy) › p. 168 (PDF p. 2)**
> *"In the kinetic particle model, the particles have kinetic energy due to their random motion. The particles also have potential energy due to the forces between them. Internal energy is an energy store that is made up of the total kinetic energy associated with the random motion of the particles and the total potential energy between the particles in the system."*

In the textbook
LO: 9(a)

2(d)(i) **[3]**

Calculate the smallest mass of ice, initially at 0 °C, that must be added to cool 0.20 kg of water at 20 °C to 0 °C (c = 4200 J/(kg °C); specific latent heat of fusion 330 000 J/kg).

- energy lost by the water = mcΔθ = 0.20 × 4200 × 20 = 16 800 J [1]
- this energy only melts the ice (ice already at 0 °C, final temperature 0 °C): m × 330 000 = 16 800 [1]
- m = 16 800 ÷ 330 000 = 0.051 kg (0.0509 kg) [1]

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Q = mcΔθ = 0.20 kg × 4200 J/(kg °C) × (20 – 0) °C = 16 800 J.  Q = m l_f ⇒ m = 16 800 J ÷ 330 000 J/kg = 0.0509 kg = 0.051 kg (2 s.f.).
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Accept 0.0509 or 0.051 kg; 0.05 kg only with working. Full ecf for a wrong energy in line 1. Unit kg required. Reject using a temperature rise of the melted ice (the ice-water finishes at 0 °C, so none is needed) or adding a 'warming ice' term.

> **Ch 10 Thermal Properties of Matter › 10.1 How Is Internal Energy Related to Heat Capacity? (Heat Capacity and Specific Heat Capacity) › p. 169 (PDF p. 3)**
> *"Specific heat capacity c of a material is the change of its internal energy per unit mass for each unit change in its temperature. c = C/m = Q/(mΔθ) where C = heat capacity (J/K or J/°C), Q = change in internal energy (J) by energy transfer, m = mass of substance (kg), Δθ = change in temperature (K or °C)"*

> **Ch 10 Thermal Properties of Matter › 10.3 What Is Latent Heat? (Specific Latent Heat of Fusion) › p. 179 (PDF p. 13)**
> *"Specific latent heat of fusion lf is the amount of energy transferred per unit mass of a substance to change between the solid and liquid states, at constant temperature. Lf = lf m where Lf = latent heat of fusion (J), lf = specific latent heat of fusion (J/kg), m = mass of substance (kg)"*

> **Ch 10 Thermal Properties of Matter › 10.2 What Are the Processes that Involve a Change of State? › p. 175 (PDF p. 9)**
> *"During the process that involves a change of state, the temperature of a pure substance remains constant."*

In the textbook
LO: 9(c), 9(g)

2(d)(ii) **[1]**

Explain how your answer in 2(d)(i) is different if the ice added has a temperature lower than 0 °C.

- A smaller mass of ice is needed (less than 0.051 kg), because the colder ice must first warm up to 0 °C, absorbing extra energy m c_ice Δθ before it melts, so each kilogram of ice absorbs more than 330 000 J; the same 16 800 J is absorbed by a smaller mass [1]

```
The same 16 800 J must be absorbed by the ice: m [c_ice Δθ_ice + l_f] = 16 800 J, with c_ice Δθ_ice > 0, so m < 16 800 / 330 000 = 0.051 kg. (Not needed here: with c_ice about 2100 J/(kg °C) and ice at −10 °C, m would be 16 800 / 351 000 = 0.048 kg.)
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Both 'less/smaller mass' AND the reason (ice has to be warmed to 0 °C first / absorbs more energy per kg) are needed for the mark. Reject 'more ice', 'the same mass', 'it takes longer to melt' and 'the water ends up colder than 0 °C' (the question keeps the final temperature at 0 °C).

> **Ch 10 Thermal Properties of Matter › 10.1 How Is Internal Energy Related to Heat Capacity? (Heat Capacity and Specific Heat Capacity) › p. 169 (PDF p. 3)**
> *"Specific heat capacity c of a material is the change of its internal energy per unit mass for each unit change in its temperature. c = C/m = Q/(mΔθ) where C = heat capacity (J/K or J/°C), Q = change in internal energy (J) by energy transfer, m = mass of substance (kg), Δθ = change in temperature (K or °C)"*

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> *"Specific latent heat of fusion lf is the amount of energy transferred per unit mass of a substance to change between the solid and liquid states, at constant temperature. Lf = lf m where Lf = latent heat of fusion (J), lf = specific latent heat of fusion (J/kg), m = mass of substance (kg)"*

> **Ch 10 Thermal Properties of Matter › 10.2 What Are the Processes that Involve a Change of State? › p. 175 (PDF p. 9)**
> *"During the process that involves a change of state, the temperature of a pure substance remains constant."*

Partly in the textbook
Gap: The book gives c = Q/(mΔθ), the latent-heat equation and 'the temperature stays constant during a change of state', but it never works an example in which cold ice is warmed to its melting point before melting. The reasoning must be assembled by the candidate (a −10 °C ice question appears only in the end-of-chapter exercises, p. 185).
LO: 9(c), 9(g)

Question 3 — Glider and falling load **[10]**

3(a) **[2]**

State what is meant by uniform acceleration.

- the acceleration is constant (a constant rate of change of velocity) [1]
- the velocity changes by the same amount in every equal interval of time (e.g. the same number of m/s every second) [1]

Accept 'constant acceleration', 'constant increase in velocity each second', 'velocity changes at a constant rate'. Reject 'constant velocity', 'constant speed' and 'speed increases' with no 'constant/equal amounts'.

> **Ch 2 Kinematics › 2.1 What Are Speed, Velocity and Acceleration? (Uniform Acceleration) › p. 22 (PDF p. 6)**
> *"When the change (increase or decrease) in the velocity of an object for every unit of time is the same, the object undergoes constant or uniform acceleration"*

> **Ch 2 Kinematics › 2.1 What Are Speed, Velocity and Acceleration? (Uniform Acceleration) › p. 23 (PDF p. 7)**
> *"Uniform acceleration is a constant rate of change of velocity. The following equation can be used to determine the uniform acceleration a of an object: a = Δv/Δt = (v − u)/(tv − tu)"*

In the textbook
LO: 2(c)

3(b)(i) **[3]**

Calculate the energy in the kinetic store of the 0.50 kg glider 3.0 s after release (a = 0.30 m/s²).

- v = u + at = 0 + 0.30 × 3.0 = 0.90 m/s [1]
- Ek = ½mv² = ½ × 0.50 × 0.90² [1]
- = 0.20 J (0.2025 J) [1]

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v = 0.30 × 3.0 = 0.90 m/s.  Ek = ½ × 0.50 kg × (0.90 m/s)² = 0.2025 J = 0.20 J (2 s.f.).  Check by another route: s = ½at² = 1.35 m, F = ma = 0.15 N, work done = Fs = 0.2025 J.
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Accept 0.2 J, 0.20 J, 0.2025 J. The work-done route (F = ma, s = ½at², Ek = Fs) also earns all 3. Unit J required. ecf from a wrong v. Reject using 1.4 m or the load's mass.

> **Ch 2 Kinematics › 2.1 What Are Speed, Velocity and Acceleration? (Uniform Acceleration) › p. 23 (PDF p. 7)**
> *"Uniform acceleration is a constant rate of change of velocity. The following equation can be used to determine the uniform acceleration a of an object: a = Δv/Δt = (v − u)/(tv − tu)"*

> **Ch 7 Energy › 7.1 What Are Energy Stores and Transfers? (Calculating the Size of an Energy Store) › p. 119 (PDF p. 9)**
> *"To calculate the amount of energy in the kinetic store of a body moving at speed v, we use the following equation: Ek = ½mv²"*

In the textbook
LO: 6(b), 2(c)

3(b)(ii) **[2]**

Calculate the energy transferred from the gravitational potential store of load X (0.016 kg) as it falls 1.4 m (g = 10 m/s²).

- ΔEp = mgh = 0.016 × 10 × 1.4 [1]
- = 0.22 J (0.224 J) [1]

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ΔEp = 0.016 kg × 10 N/kg × 1.4 m = 0.224 J = 0.22 J (2 s.f.).
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Accept 0.22 or 0.224 J. Unit J required.

> **Ch 7 Energy › 7.1 What Are Energy Stores and Transfers? (Calculating the Size of an Energy Store) › p. 119 (PDF p. 9)**
> *"To calculate the amount of energy in the gravitational potential store of a body near the Earth's surface at a height h above the ground, we use the following equation: Ep = mgh"*

In the textbook
LO: 6(b)

3(b)(iii) **[1]**

Air resistance and friction are negligible. Suggest why the answers to 3(b)(i) and 3(b)(ii) are different.

- The energy lost from the gravitational potential store of X (0.22 J) is shared between the kinetic store of the glider and the kinetic store of load X (X is also moving, at the same speed as the glider) [1]

```
Load X moves at the same speed as the glider, so its own kinetic energy is ½ × 0.016 × 0.90² = 0.0065 J; 0.2025 J + 0.0065 J = 0.209 J, close to 0.224 J (the numbers in the question are not perfectly self-consistent: after 3.0 s X has fallen only 1.35 m, and 0.016 × 10 × 1.35 = 0.216 J).
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Accept: 'load X also gains kinetic energy' / 'both glider and X are moving'. Reject energy lost to friction, air resistance, sound or heat (the question says they are negligible), and 'the string stretches'.

> **Ch 7 Energy › 7.1 What Are Energy Stores and Transfers? (Principle of Conservation of Energy) › p. 120 (PDF p. 10)**
> *"The principle of conservation of energy states that energy cannot be created or destroyed. Energy can be transferred from one store to another. The total energy of an isolated system is constant."*

> **Ch 7 Energy › 7.1 What Are Energy Stores and Transfers? (Principle of Conservation of Energy) › p. 120 (PDF p. 10)**
> *"Since energy cannot be created or destroyed, the energy increase in the gravitational potential store from B to C as the pendulum gains height is equal to energy decrease in the kinetic store from B to C."*

Partly in the textbook

Gap: The principle of conservation of energy and energy 'stores' are taught (p. 119-120), but the book has no example of one falling load pulling a trolley/glider where the lost gravitational energy is shared between two kinetic stores.

LO: 6(c), 6(a)

3(c) **[2]**

Load X hits the floor before the glider reaches the end of the track. Use Newton's laws to explain the motion of the glider after X lands.

- After X lands the string goes slack (tension becomes zero), so there is no resultant (horizontal) force on the glider: the track is frictionless and air resistance is negligible [1]
- By Newton's first law (or by Newton's second law, a = F/m = 0) the glider continues to move at constant velocity (the speed it had when X landed, in a straight line) [1]

Accept either law for the second mark provided the conclusion 'constant velocity / zero acceleration' is stated. Reject 'the glider slows down and stops', 'the glider keeps accelerating', and 'forces are balanced by weight and normal reaction' used as the only reason for no horizontal force.

> **Ch 4 Dynamics II: Forces › 4.1 What Are Newton's Laws of Motion? (Balanced Forces and Newton's First Law) › p. 55 (PDF p. 3)**
> *"Newton's First Law of Motion states that every object will continue in its state of rest or uniform motion in a straight line unless a resultant force acts on it."*

> **Ch 4 Dynamics II: Forces › 4.1 What Are Newton's Laws of Motion? › p. 55 (PDF p. 3)**
> *"Based on Newton's First Law of Motion, when the resultant force acting on a body is zero, the body is at rest or is moving at a constant velocity."*

> **Ch 4 Dynamics II: Forces › 4.1 What Are Newton's Laws of Motion? (Unbalanced Forces and Newton's Second Law) › p. 57 (PDF p. 5)**
> *"Newton's Second Law of Motion states that when a resultant force acts on an object of a constant mass, the object will accelerate in the direction of the resultant force."*

> **Ch 4 Dynamics II: Forces › 4.1 What Are Newton's Laws of Motion? › p. 55 (PDF p. 3)**
> *"Zero acceleration implies that the object can be stationary or moving with constant velocity (Figure 4.2). However, even though acceleration is zero, it does not mean there are no forces acting on it. It means that the resultant of these forces is zero."*

In the textbook

LO: 3(g), 3(j)

Question 4 — Refraction and total internal reflection in a glass rod [7]

4(a) **[1]**

Define refractive index.

- the ratio of the speed of light in a vacuum to the speed of light in the medium (n = c/v) [1]

Accept n = sin i / sin r only if i (in vacuum/air) and r (in the medium) are identified, as the book gives it for light entering a medium from a vacuum. Reject 'how much the light bends' and a ratio the wrong way round.

> **Ch 14 Light › 14.2 How Is Light Refracted? (Refractive Index) › p. 244 (PDF p. 12)**
> *"The refractive index n of a medium is defined as the ratio of the speed of light in a vacuum to the speed of light in that medium."*

> **Ch 14 Light › 14.2 How Is Light Refracted? (Refractive Index) › p. 244 (PDF p. 12)**
> *"For a light ray passing from a vacuum into a given medium, the refractive index n of the medium is also given by the ratio, sin i/sin r (Figure 14.23). n = sin i/sin r where i = angle of incidence in a vacuum, r = angle of refraction in the medium"*

In the textbook

LO: 12(e)

4(b)(i) **[2]**

The angle of incidence of the ray at P (in the glass) is 35°; n = 1.5. Calculate q.

- by the principle of reversibility n = sin(angle in air)/sin(angle in glass): sin q / sin 35° = 1.5 [1]
- q = $\sin^{-1}(1.5 \times \sin 35°)$ = 59° (59.4°) [1]

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sin q = 1.5 × sin 35° = 1.5 × 0.5736 = 0.8604 ⇒ q = 59.4° = 59° (2 s.f.).
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Accept 59 to 60°. Reject sin 35° = 1.5 sin q (ratio inverted, gives q = 22.5°).

> **Ch 14 Light › 14.2 How Is Light Refracted? (Refractive Index) › p. 244 (PDF p. 12)**
> *"For a light ray passing from a vacuum into a given medium, the refractive index n of the medium is also given by the ratio, sin i/sin r (Figure 14.23). n = sin i/sin r where i = angle of incidence in a vacuum, r = angle of refraction in the medium"*

> **Ch 14 Light › 14.2 How Is Light Refracted? (Principle of Reversibility of Rays) › p. 246 (PDF p. 14)**
> *"Due to the principle of reversibility of rays, the refractive index of the material is always given by n = sin x/sin y regardless of whether the ray goes from A to B or B to A."*

In the textbook

LO: 12(d), 12(c)

4(b)(ii) **[2]**

At P and after each further reflection the reflected ray carries 10% of the incident energy. Rod diameter 1.6 cm. Calculate the horizontal distance from P where, after reflection, the energy of the reflected ray is 0.10% of the energy of the ray incident on P.

- reflected energies: at P 10%, at the bottom surface 1% (10% of 10%), at the top surface 0.10%: the 0.10% reflection is the third, and it occurs after the ray has crossed the rod twice (P to bottom, bottom to top) [1]
- distance = 2 × 1.6 × tan 35° = 2.2 cm (2.24 cm) [1]

```
Horizontal distance for one crossing = 1.6 cm × tan 35° = 1.12 cm (the ray makes 35° with the normal, which is perpendicular to the rod axis). Two crossings: 2 × 1.12 = 2.24 cm = 2.2 cm (2 s.f.). Energy check: 0.1 × 0.1 × 0.1 = 0.001 = 0.10%.
```

Accept 2.2 to 2.24 cm. Common wrong answers: 1.1 cm (one crossing) or 3.4 cm (three crossings, from not counting P as the first reflection); either may earn the second mark by ecf only if the reflection counting is shown. Reject using sin or cos instead of tan.

> **Ch 14 Light › 14.1 How Does Light Enable Us to See? (Laws of Reflection) › p. 236 (PDF p. 4)**
> *"The second law of reflection states that the angle of incidence θ is equal to the angle of reflection θ."*

Partly in the textbook

Gap: The book teaches the law of reflection (p. 236) and refraction, but never partial reflection (a fixed fraction of the energy reflected at each surface) or the geometry of a ray bouncing between the sides of a rod (tan of the angle to the normal); the 10% figure is supplied in the question, so the rest is a data/geometry skill.
LO: 12(b), 12(d)

4(c) **[2]**

The angle of incidence at P increases to 45°. Explain why all the light now passes through the rod.

- critical angle c: sin c = 1/n = 1/1.5, c = 42° (41.8°); the angle of incidence 45° is greater than the critical angle [1]
- the light travels from glass (optically denser) to air (less dense) at an angle of incidence greater than the critical angle, so total internal reflection occurs: all the light is reflected and none is refracted out; the angle at each later surface is again 45° so the light stays in the rod [1]

```
sin θc = 1/n = 1/1.5 = 0.667 ⇒ θc = 41.8°.  45° > 41.8°. (Equivalent check: 1.5 × sin 45° =
1.06 > 1, so sin q cannot be found, no refracted ray exists.)
```

Accept 'complete reflection / 100% reflected / no refraction' for TIR. Both conditions (denser to less dense; angle of incidence greater than critical angle) are expected for the second mark. Reject 'the light is refracted along the surface' (that is at exactly the critical angle) and 'the rod is a mirror'.

> **Ch 14 Light › 14.3 What Is Total Internal Reflection? › p. 250 (PDF p. 18)**
> *"Critical angle θc is defined as the angle of incidence in an optically denser medium for which the angle of refraction in the less dense medium is 90 °. Total internal reflection is the complete reflection of a light ray in an optically denser medium at the boundary with an optically less dense medium. The two conditions for total internal reflection to occur: The incident ray must travel from an optically denser medium to an optically less dense medium. The angle of incidence must be greater than the critical angle."*

> **Ch 14 Light › 14.3 What Is Total Internal Reflection? › p. 251 (PDF p. 19)**
> *"For a glass block surrounded by air, the formula for its refractive index n in terms of the critical angle θc can be derived as follows: Recall that the formula for refractive index is n = sin i/sin r. The angle of refraction is 90 ° when the angle of incidence in the glass block is θc. Applying the principle of reversibility: n = sin i/sin r = 1/sin θc"*

> **Ch 14 Light › 14.3 What Is Total Internal Reflection? (Optical Fibres) › p. 251 (PDF p. 19)**
> *"The fibres rely on total internal reflection of light to transmit signals."*

In the textbook
LO: 12(f), 12(g)

Question 5 — Speed gun (infrared) [6]

5(a) **[1]**

State one other use of infrared radiation.

- any one of: remote controls (TV/air-con); thermal imaging / infrared thermometers; camera auto-focusing; intruder (security) alarms; cooking or heating (ovens, grills, heaters); data transfer / fibre-optic communication [1]

Reject the speed gun itself (given), and uses of other waves (X-ray imaging, sterilising with UV, microwave ovens, radio broadcasts).

> **Ch 13 Electromagnetic Waves › 13.2 What Are the Uses and Dangers of Electromagnetic Waves? (Infrared) › p. 225 (PDF p. 7)**
> *"Other common uses of infrared are in remote controls, camera auto- focusing and thermometers that measure body temperature by sensing the emitted infrared radiation to produce a thermal image."*

Ch 13 Electromagnetic Waves › 13.2 What Are the Uses and Dangers of Electromagnetic Waves? (Infrared) › p. 225 (PDF p. 7)

"Electrically heated rods in ovens give out infrared waves or radiation to cook food (Figure 13.10)."

In the textbook

LO: 11(c)

5(b) **[2]**

Complete: the wavelength / frequency / speed of infrared compared with microwaves, in a vacuum.

- wavelength of infrared is shorter than the wavelength of microwaves; frequency of infrared is higher than the frequency of microwaves; speed of infrared is the same as the speed of microwaves (3.0×10^8 m/s in a vacuum) [2: all three correct = 2, two correct = 1]

```
In the spectrum radio, microwave, infrared, visible, ultraviolet, X-ray, gamma, wavelength decreases and frequency increases; all travel at c in a vacuum.
```

Accept 'smaller than' / 'less than' for shorter, 'greater/larger than' for higher, 'equal to' for the same. Marking assumption: three correct = 2 marks, two correct = 1 mark.

Ch 13 Electromagnetic Waves › 13.1 What Are Electromagnetic Waves? (Nature of Electromagnetic Waves) › p. 220 (PDF p. 2)

"Figure 13.1 shows the arrangement of electromagnetic (EM) waves in order of frequency and wavelength."

Ch 13 Electromagnetic Waves › 13.1 What Are Electromagnetic Waves? (Figure 13.1 The electromagnetic spectrum and its components) › p. 220 (PDF p. 2)

"Figure 13.1 (read left to right): wavelength axis runs from "longer" to "shorter", frequency axis from "lower" to "higher"; microwaves e.g. λ = 3 cm, f = 1010 Hz; infrared e.g. λ = 10–4 m, f = 1012 Hz; infrared lies to the right of microwaves."

Ch 13 Electromagnetic Waves › 13.1 What Are Electromagnetic Waves? (Nature of Electromagnetic Waves) › p. 221 (PDF p. 3)

"All electromagnetic waves can travel without a medium, with the same speed of 3 × 108 m/s in a vacuum."

In the textbook

LO: 11(a), 11(b)

5(c) **[3]**

One pulse is received 350 ns after emission, the next 370 ns after emission (pulses every 0.15 s, speed of infrared 3.0×10^8 m/s). Calculate the speed of the car.

- difference in return times = 370 − 350 = 20 ns [1]
- distance moved by the car between pulses = $c\,\Delta t \div 2 = 3.0 \times 10^8 \times 20 \times 10^{-9} \div 2 = 3.0$ m (÷ 2 because the pulse travels to the car and back) [1]
- speed = distance ÷ time = 3.0 ÷ 0.15 = 20 m/s [1]

```
Extra path (there and back) = 3.0 × 10⁸ m/s × 20 × 10⁻⁹ s = 6.0 m, so the car moved 6.0 m ÷ 2 = 3.0 m (it is moving away, since the later pulse takes longer). v = 3.0 m ÷ 0.15 s = 20 m/s.
```

Accept 20 m/s (72 km/h). If the ÷ 2 is omitted: 6.0 m and 40 m/s earn 2 of the 3 marks (ecf). Reject dividing the distance by 350 ns or 370 ns, or using a speed of 3.0×10^8 for the car.

Ch 1 Physical Quantities, Units and Measurements › 1.4 What Are Scalars and Vectors? (Speed and Velocity) › p. 13 (PDF p. 13)

"Speed is the distance moved per unit time. Speed is a scalar quantity."

Ch 12 General Wave Properties II: Sound › 12.3 How Is Sound Useful? (Echolocation) › p. 211 (PDF p. 7)

"With the speed of sound, a computer-controlled sound emitter and sound sensor, the distance from the emitter to the reflecting surface can be easily calculated. This is called echolocation."

Ch 13 Electromagnetic Waves › 13.1 What Are Electromagnetic Waves? (Nature of Electromagnetic Waves) › p. 221 (PDF p. 3)

"All electromagnetic waves can travel without a medium, with the same speed of 3 × 108 m/s in a vacuum."

Partly in the textbook

Gap: The book teaches speed = distance/time and the 'there-and-back' idea only for sound echoes (p. 211), not for timing light pulses, and never uses the CHANGE in the round-trip time of successive pulses to find the speed of a moving target.
LO: 2(b), 11(a)

Question 6 — Rechargeable battery and resistors [8]

6(a) **[1]**

State what is meant by electromotive force.

- the work done by the source (battery) in driving a unit charge around a complete circuit [1]

Accept 'energy transferred by the source per unit charge'. Reject 'the voltage of the battery' or 'force', and 'p.d. across the battery' (a definition must mention work/energy per unit charge).

Ch 16 Current of Electricity › 16.1 ... (Electromotive Force and Potential Difference) › p. 289 (PDF p. 5)

"The electromotive force (e.m.f.) of an electrical source is the work done by the source in driving a unit charge around a complete circuit."

In the textbook
LO: 14(d)

6(b) **[2]**

Calculate the charge that passes through the battery when it is recharged at 0.60 A for 5.0 hours.

- Q = It [1]
- = 0.60 × (5.0 × 3600) = 1.1 × 10⁴ C (10 800 C) [1]

```
t = 5.0 h × 3600 s/h = 18 000 s.  Q = 0.60 A × 18 000 s = 10 800 C = 1.1 × 10⁴ C (2 s.f.).
```

Accept 10 800, 1.1 × 10⁴ or 11 000 C. Unit C (or A s) required. Reject 3.0 C (hours not converted to seconds).

Ch 16 Current of Electricity › 16.1 How Do We Describe the Energy Transfer by an Electric Current in an Electric Circuit? › p. 287 (PDF p. 3)

"Electric current is the rate of flow of electric charge. Mathematically, we write: I = Q/t where I = current (A), Q = charge (C), t = time taken (s)"

Ch 16 Current of Electricity › 16.1 ... (Worked Example 16A) › p. 288 (PDF p. 4)

"Since current is a flow of charges per unit time, and current has been flowing for 0.5 hours, then the amount of charge must be given by the product of current and time. We need to be mindful and convert all units to SI units."

Ch 16 Current of Electricity › 16.1 ... (Worked Example 16A) › p. 288 (PDF p. 4)

"Total electric charge is given by Q = I × t = 0.1 A × (0.5 × 60 × 60 s) = 180 C"

In the textbook
LO: 14(c)

6(c)(i) **[2]**

Calculate the current in the circuit (12 V battery, 200 Ω and 350 Ω resistors in series).

- total resistance = 200 + 350 = 550 Ω [1]
- I = V/R = 12 ÷ 550 = 0.022 A (0.0218 A) [1]

```
R = 200 Ω + 350 Ω = 550 Ω.  I = 12 V ÷ 550 Ω = 0.02182 A = 0.022 A (2 s.f.).
```

Accept 0.022 A or 0.0218 A (21.8 mA). Unit required. Reject 12 ÷ 200 or 12 ÷ 350 (single resistor).

Ch 17 D.C. Circuits › 17.1 How Are Current, Potential Difference and Resistance Related in a Series Circuit? › p. 306 (PDF p. 4)

"In a series circuit, the effective resistance R is equal to the sum of the individual resistances."

Ch 16 Current of Electricity › 16.2 Why Does the Electrical Resistance of Metals Increase with Temperature? (Resistance) › p. 293 (PDF p. 9)

"The resistance R of a component is the ratio of the potential difference V across it to the current I flowing through it."

In the textbook

LO: 15(f), 14(h)

6(c)(ii) **[1]**

Calculate the p.d. across the 200 Ω resistor.

- V = IR = 0.0218 × 200 = 4.4 V (4.36 V) [1]

```
V = 0.02182 A × 200 Ω = 4.36 V = 4.4 V (alternatively 12 × 200/550).
```

Accept 4.4 V or 4.36 V; ecf from 6(c)(i) (0.022 × 200 = 4.4 V). Unit V required.

Ch 16 Current of Electricity › 16.2 Why Does the Electrical Resistance of Metals Increase with Temperature? (Resistance) › p. 293 (PDF p. 9)

"The resistance R of a component is the ratio of the potential difference V across it to the current I flowing through it."

Ch 17 D.C. Circuits › 17.1 How Are Current, Potential Difference and Resistance Related in a Series Circuit? (Series Circuits) › p. 305 (PDF p. 3)

"In a series circuit, the current at every point is the same."

Ch 17 D.C. Circuits › 17.1 How Are Current, Potential Difference and Resistance Related in a Series Circuit? › p. 306 (PDF p. 4)

"In a series circuit, the total potential difference supplied to the circuit E is equal to the sum of the individual potential differences across the resistors."

In the textbook

LO: 14(h), 15(g)

6(c)(iii) **[2]**

Calculate the time for the battery to fully discharge in this circuit (constant current).

- the battery can deliver the charge it received, Q = 10 800 C, so t = Q ÷ I [1]
- t = 10 800 ÷ 0.0218 = 4.95 × 10^5 s (≈ 5.0 × 10^5 s = 137.5 h ≈ 1.4 × 10^2 h) [1]

```
t = Q/I = 10 800 C ÷ 0.021818 A = 495 000 s = 137.5 h (about 5.7 days).
```

Accept 4.9 to 5.0 × 10^5 s or 137 to 138 h (1.4 × 10^2 h); ecf from 6(b) and 6(c)(i) (10 800 ÷ 0.022 = 4.9 × 10^5 s). Unit required. Reject 12 V × 5.0 h or 5.0 h (the charging time).

Ch 16 Current of Electricity › 16.1 How Do We Describe the Energy Transfer by an Electric Current in an Electric Circuit? › p. 287 (PDF p. 3)

"Electric current is the rate of flow of electric charge. Mathematically, we write: I = Q/t where I = current (A), Q = charge (C), t = time taken (s)"

Ch 16 Current of Electricity › 16.1 ... (Worked Example 16A) › p. 288 (PDF p. 4)

"Total electric charge is given by Q = I × t = 0.1 A × (0.5 × 60 × 60 s) = 180 C"

In the textbook

LO: 14(c), 14(h)

Question 7 — Protons deflected by an electromagnet [7]

7(a) **[2]**

State two other ways in which the distance moved by the spot can be increased.

- any two, one mark each: increase the number of turns of the coil (more turns per unit length) [1]
- decrease the speed of the protons (a slower proton is deflected more) [1]
- move the screen further from the electromagnet (more distance for the deflected beam to travel in a straight line) [1]
- make the field stronger or bigger in another way: bring the poles closer together, or use a longer pole region [1]

Max 2. Reject 'increase the current' (given in the question) and 'increase the voltage' (same idea), 'use heavier particles' and 'increase the speed of the protons' (the deflection would decrease).

> **Ch 20 Electromagnetism › 20.1 What Are the Magnetic Effects of a Current? (Magnetic Field Patterns: solenoid) › p. 365 (PDF p. 5)**
>
> *"The strength of magnetic field in a solenoid can be increased by: increasing the current flowing through the solenoid; increasing the number of turns per unit length of the solenoid; and placing a soft iron core within the solenoid."*

> **Ch 20 Electromagnetism › 20.1 What Are the Magnetic Effects of a Current? (Figure 20.19) › p. 371 (PDF p. 11)**
>
> *"Oppositely charged particles move in opposite directions in the same magnetic field. Similar to the current-carrying conductor, the force acting on a charged particle: increases when the charge on the particle increases; increases when the magnetic field increases; is in the opposite direction if the particle is oppositely charged; and is in the opposite direction if the direction of magnetic field or velocity of charged particle is reversed."*

Partly in the textbook

Gap: The book gives 'more turns per unit length', 'more current' and 'soft iron core' for strengthening an electromagnet (p. 365) and says the force on a charged particle increases when the field increases (p. 371), but nothing about the effect of the particle's speed on the deflection or of the screen distance (geometry of the straight-line path after the field).

LO: 18(c), 18(a)

7(b) **[3]**

State and explain the direction in which the spot moves on the screen.

- the spot moves downwards, towards edge DC [1]
- the field between the poles runs from the N pole X to the S pole Y, i.e. towards the front of the diagram (towards the viewer) [1]
- the protons move to the right, so the conventional current is to the right; by Fleming's left-hand rule (first finger field towards the viewer, second finger current to the right) the force (thumb) is downwards, at right angles to both [1]

```
Axes: beam = right (+x), field X to Y = towards the viewer (+z); force on a positive charge = qv × B = x × z = −y, i.e. down. The figure is an oblique drawing: Y (the large near face) is the nearer pole, the same sense as edges AB to DC of the screen, with B and C nearer the viewer.
```

Accept 'down the page / towards DC'. Reject 'upwards / towards AB' (that is the direction for electrons, part (c)) and 'into or out of the page'. Both the direction of B (N to S, towards the viewer) and the use of the left-hand rule with CONVENTIONAL current should be seen for 2 and 3 marks.

> **Ch 20 Electromagnetism › 20.1 What Are the Magnetic Effects of a Current? (Force on a Current-carrying Conductor) › p. 370 (PDF p. 10)**
>
> *"The direction of the force can be determined using Fleming's left-hand rule. First, the left hand is held out with the forefinger, second finger and thumb perpendicular to each other (Figure 20.18). Next, the first finger is oriented in the direction of the magnetic field from north to south, and the second finger in the direction of conventional current. The resultant force that is induced by the current-carrying conductor will be given by the direction the thumb is pointing to."*

Ch 20 Electromagnetism › 20.1 What Are the Magnetic Effects of a Current? (Force on a Beam of Charged Particles) › p. 371 (PDF p. 11)

"A current-carrying wire experiences a force when its current is flowing perpendicularly to the direction of a magnetic field. Similarly, a beam of moving charged particles would also experience a force when a magnetic field is applied perpendicularly to the beam of particles."

Ch 20 Electromagnetism › 20.1 What Are the Magnetic Effects of a Current? (Figure 20.19) › p. 371 (PDF p. 11)

"Oppositely charged particles move in opposite directions in the same magnetic field. Similar to the current-carrying conductor, the force acting on a charged particle: increases when the charge on the particle increases; increases when the magnetic field increases; is in the opposite direction if the particle is oppositely charged; and is in the opposite direction if the direction of magnetic field or velocity of charged particle is reversed."

In the textbook

LO: 18(d), 18(c)

7(c) **[2]**

Protons are replaced by electrons of the same speed. State and explain two changes in the position of the spot.

- the spot moves in the opposite direction (upwards, towards AB), because the electrons are negatively charged so the force on them is in the opposite direction to that on protons [1]
- the spot moves further (a larger deflection), because the magnetic force is the same size (same speed and same size of charge) but the electron's mass is much smaller, so its acceleration (deflection) is much greater [1]

```
F = qvB is the same for e and p (same |q| and v). a = F/m: m(electron) is about 1/1840 of m(proton), so a is about 1840 times larger.
```

Accept 'opposite direction' with a reason about charge/force reversal, and 'greater deflection' with a reason about smaller mass / larger acceleration. Reject 'electrons are faster' (the question says the same speed) and reasons that quote the same force for both marks.

Ch 20 Electromagnetism › 20.1 What Are the Magnetic Effects of a Current? (Figure 20.19) › p. 371 (PDF p. 11)

"Oppositely charged particles move in opposite directions in the same magnetic field. Similar to the current-carrying conductor, the force acting on a charged particle: increases when the charge on the particle increases; increases when the magnetic field increases; is in the opposite direction if the particle is oppositely charged; and is in the opposite direction if the direction of magnetic field or velocity of charged particle is reversed."

Ch 20 Electromagnetism › 20.1 What Are the Magnetic Effects of a Current? (Force on a Beam of Charged Particles) › p. 371 (PDF p. 11)

"A current-carrying wire experiences a force when its current is flowing perpendicularly to the direction of a magnetic field. Similarly, a beam of moving charged particles would also experience a force when a magnetic field is applied perpendicularly to the beam of particles."

Ch 4 Dynamics II: Forces › 4.1 What Are Newton's Laws of Motion? (Unbalanced Forces and Newton's Second Law) › p. 57 (PDF p. 5)

"Newton's Second Law of Motion states that when a resultant force acts on an object of a constant mass, the object will accelerate in the direction of the resultant force."

Partly in the textbook

Gap: The reversal for an oppositely charged particle is stated in the book (Figure 20.19, p. 371), but the book never discusses the effect of the particle's mass on the size of the deflection (it only gives F = ma for ordinary objects, p. 57).

LO: 18(c)

Question 8 — Mains safety: hair dryer [6]

8(a) **[2]**

The damage to the insulation causes the fuse in the mains plug to melt. Suggest and explain why.

- the damaged insulation allows the live and neutral wires to touch (a short circuit) [1]
- a very large current flows, which heats the fuse wire so that it melts [1]

Accept 'bare wires touch' for the first mark. Reject 'the wire gets wet', and an earth-wire or metal-casing explanation (the cable has no earth wire).

> **Ch 18 Practical Electricity › 18.2 How Do We Use Electrical Components Safely? (Damaged Insulation) › p. 333 (PDF p. 9)**
> *"When insulators age, they become brittle and break apart, exposing the live conducting wires underneath. In some buildings, insulation may become damaged as a result of being gnawed by rats. Regardless of the cause, exposed live wires can cause electric shocks when touched."*

> **Ch 18 Practical Electricity › 18.2 How Do We Use Electrical Components Safely? (Safety Features to Ensure Safe Use of Electricity) › p. 335 (PDF p. 11)**
> *"A fuse is a safety device added to an electric circuit to prevent excessive current flow. It consists of a strip of fusible wire that will melt when the current flowing through it exceeds a certain value"*

Partly in the textbook

Gap: The book says a fuse melts when the current exceeds its rating (p. 335) and that exposed live wires cause shocks (p. 333); it never uses the term 'short circuit' (searched all chapters) or describes live and neutral touching.
LO: 16(e), 16(d)

8(b) **[1]**

State why the hair dryer does not need an earth wire.

- it is double insulated (plastic, non-conducting casing) so the user cannot touch a live part, even if a fault occurs [1]

Accept 'it has a plastic casing / it is double insulated / it has no exposed metal'. Reject 'it has a fuse'.

> **Ch 18 Practical Electricity › 18.2 How Do We Use Electrical Components Safely? (Safety Features to Ensure Safe Use of Electricity) › p. 337 (PDF p. 13)**
> *"Some appliances use double insulation as a safety feature to keep users safe in the event of a fault. These appliances are enclosed in a plastic casing which is not earthed. Double insulation, as the name suggests, has two layers of insulation to enclose all exposed metalwork and "live" parts."*

In the textbook
LO: 16(f)

8(c) **[1]**

State one other situation in the home that causes an electrical hazard.

- any one: damp conditions (e.g. using an appliance with wet hands or in a wet bathroom) / overheating of cables (e.g. overloading a socket with too many plugs) [1]

Reject damaged insulation (the given example) and vague answers such as 'touching electricity'.

> **Ch 18 Practical Electricity › 18.2 How Do We Use Electrical Components Safely? (Electrical Hazards) › p. 332 (PDF p. 8)**
> *"The three most common situations are damaged insulation, overheating of cables and damp conditions."*

> **Ch 18 Practical Electricity › 18.2 How Do We Use Electrical Components Safely? (Overheating of Cables) › p. 333 (PDF p. 9)**
> *"Overheating occurs when: 1 the electrical cable passes current that exceeds its limits; 2 a large current flows through the wires due to too many plugs being connected to a socket (overloading); and 3 the contact between a plug and a socket is poor."*

> **Ch 18 Practical Electricity › 18.2 How Do We Use Electrical Components Safely? (Damp Environment) › p. 334 (PDF p. 10)**
> *"A hair dryer can cause electric shocks if water gets into the hair dryer or if there is damaged insulation. Therefore, do not leave a hair dryer on a wet sink or use one with wet hands."*

In the textbook
LO: 16(d)

8(d) **[2]**

State two advantages of using a circuit breaker instead of a fuse.

- a circuit breaker can be reset (switched on again) after it trips, whereas a blown fuse must be replaced [1]
- a circuit breaker acts (trips) faster / is more sensitive, so the current is cut off sooner [1]

Accept any two of: can be reset / reusable / no need to buy replacements; quicker response; more sensitive; can also be used as an on-off switch; more accurate rating. Reject 'cheaper', 'it never fails'.

> **Ch 18 Practical Electricity › 18.2 How Do We Use Electrical Components Safely? (Safety Features to Ensure Safe Use of Electricity) › p. 335 (PDF p. 11)**
> *"When a fuse limit is reached, the electric circuit is broken until the fuse is replaced with a new one."*

> **Ch 18 Practical Electricity › 18.2 How Do We Use Electrical Components Safely? (Safety Features to Ensure Safe Use of Electricity) › p. 336 (PDF p. 12)**
> *"Circuit breakers also have current ratings. If the current exceeds its rating, then the circuit breaker will trip, causing an open circuit. Circuit breakers are like on-off switches. When a circuit breaker trips, the faulty appliance causing the trip has to be identified and removed from the circuit. Then, the circuit breaker may be turned on again."*

Partly in the textbook

Gap: The book gives the 'turned on again' point for circuit breakers and 'replaced with a new one' for fuses (pp. 335-336) but never says a circuit breaker operates faster or is more sensitive.
LO: 16(e)

Question 9 — Transformers and transmission of electricity [10]

9(a)(i) **[1]**

Lamp 1 is bright. Explain why lamp 2 is dim (long thin transmission wires).

- the transmission wires have resistance, so there is a p.d. across them and energy is transferred as heat in the wires (I^2R); the p.d. across lamp 2 is less than 12 V, so it gets less power [1]

Accept 'voltage drop / power loss in the long thin wires due to their resistance'. Reject 'the current is shared with lamp 1' and 'lamp 2 is far away from the supply'.

> **Ch 21 Electromagnetic Induction › 21.3 Why Is Current Always Generated in Alternating Form? (Transmission of electricity) › p. 391 (PDF p. 13)**
> *"One of the main challenges in the transmission and distribution of electricity from power stations to households is the loss of power due to ohmic heating (P = I2R) in the cables. If very large currents are transmitted, then losses can be very high due to the squaring effect of current in the power loss equation."*

> **Ch 21 Electromagnetic Induction › 21.3 Why Is Current Always Generated in Alternating Form? (Transmission of electricity) › p. 391 (PDF p. 13)**
> *"Energy "losses" during the long-distance transmission of electricity are energy transfers to the internal (thermal) store of the transmission cables."*

In the textbook
LO: 19(f)

9(a)(ii) **[2]**

Transformers (50:600 and 600:50 turns) are added. Explain why lamp 2 is now bright.

- transformer 1 steps the voltage up (12 V × 600/50 = 144 V), so the current in the transmission line is much smaller (P = VI), so much less energy is lost as heat in the wires (smaller p.d. drop along the line) [1]

- transformer 2 steps the voltage back down (144 V × 50/600 = 12 V), so the p.d. across lamp 2 is about 12 V, the same as lamp 1, and it is bright [1]

```
Vs/Vp = Ns/Np: 12 × 600/50 = 144 V; then 144 × 50/600 = 12 V.
```

Both the idea 'high voltage, low current, less energy wasted (I^2R)' and 'stepped back down to the lamp's voltage' are needed. Reject 'the transformers increase the power' (power cannot be increased).

> **Ch 21 Electromagnetic Induction › 21.3 Why Is Current Always Generated in Alternating Form? (Transformers) › p. 389 (PDF p. 11)**
> *"A transformer can change a high alternating voltage (at low current) to a low alternating voltage (at high current) or vice versa."*

> **Ch 21 Electromagnetic Induction › 21.3 Why Is Current Always Generated in Alternating Form? (Transformers) › p. 390 (PDF p. 12)**
> *"This is a step-up transformer. Conversely, if Np > Ns, the secondary (output) voltage will be smaller than the primary (input) voltage. This is a step-down transformer."*

> **Ch 21 Electromagnetic Induction › 21.3 Why Is Current Always Generated in Alternating Form? (Transmission of electricity) › p. 391 (PDF p. 13)**
> *"The second solution is to reduce the current transmitted. This will reduce ohmic heating of transmission cables. However, to maintain the power that is transmitted, the voltage needs to be increased substantially"*

> **Ch 21 Electromagnetic Induction › 21.3 Why Is Current Always Generated in Alternating Form? (Transmission of electricity) › p. 392 (PDF p. 14)**
> *"The second solution is more viable. This is why transmission lines have voltages as high as 400 kV a.c.. This very high voltage is then stepped down with transformers."*

In the textbook
LO: 19(d), 19(f)

9(b)(i) **[1]**

Using Table 9.1, show that the input current is not inversely proportional to R.

- R × Iin is not constant: 2.0 × 3.4 = 6.8 but 100 × 0.43 = 43 (so Iin is not inversely proportional to R) [1]

```
Other rows: 5.0 × 2.8 = 14; 20 × 1.5 = 30. Alternatively R rises 50 times (2.0 to 100 Ω) but
Iin falls only about 7.9 times (3.4 to 0.43 A).
```

Any two rows of the table with the products (or ratios) calculated and a conclusion.

Data skill (answered from the question)
LO: 19(e)

9(b)(ii) **[2]**

Calculate the missing output current when the efficiency is 81%.

- efficiency = (Vout × Iout) ÷ (Vin × Iin): 0.81 = 19 × Iout ÷ (12 × 0.78) [1]
- Iout = 0.81 × 12 × 0.78 ÷ 19 = 0.40 A (0.399 A) [1]

```
Iout = (0.81 × 12 V × 0.78 A) ÷ 19 V = 7.5816 ÷ 19 = 0.3990 A = 0.40 A (2 s.f.). Check: 19 ×
0.399 ÷ (12 × 0.78) = 0.81.
```

Accept 0.40 A or 0.399 A. Unit A required. Reject using 81 (not 0.81) or Iout = Iin × 0.81.

> **Ch 21 Electromagnetic Induction › 21.3 Why Is Current Always Generated in Alternating Form? (Transformers) › p. 390 (PDF p. 12)**
> *"In reality, transformers are not ideal. As a result, the useful output power will be less than the input power. We define the term efficiency η as a ratio of the output power over the input power."*

Ch 21 Electromagnetic Induction › 21.3 Why Is Current Always Generated in Alternating Form? (Transformers) › p. 390 (PDF p. 12)

"In a transformer, the laws of conservation of energy always applies. A higher output voltage does not mean that energy is created."

In the textbook

LO: 19(e), 6(f)

9(b)(iii) **[2]**

Calculate the missing value of R when the efficiency is 81%.

- R = Vout ÷ Iout = 19 ÷ 0.399 [1]
- = 48 Ω (47.6 Ω) [1]

```
R = 19 V ÷ 0.39899 A = 47.6 Ω = 48 Ω (2 s.f.); with the rounded 0.40 A, 47.5 Ω, also 48 Ω to 2 s.f. (fits between 20 Ω and 100 Ω in the table).
```

Accept 47.5 to 48 Ω; ecf from 9(b)(ii). Unit Ω required.

Ch 16 Current of Electricity › 16.2 Why Does the Electrical Resistance of Metals Increase with Temperature? (Resistance) › p. 293 (PDF p. 9)

"The resistance R of a component is the ratio of the potential difference V across it to the current I flowing through it."

In the textbook

LO: 14(h)

9(b)(iv) **[2]**

Suggest and explain one reason why the primary coil is made of thicker copper wire than the secondary coil.

- the primary coil carries the larger current (the secondary has twice the voltage, so for an ideal transformer VpIp = VsIs gives Ip = 2 Is) [1]
- a thicker wire (larger cross-sectional area) has a smaller resistance, so less energy is transferred as heat in the coil (I^2R) / the coil does not overheat [1]

```
Vs/Vp = Ns/Np = 400/200 = 2, so Vp = 12 V, Vs = 24 V (ideal) and Ip/Is = 2.
```

The suggestion (larger current) and the explanation (lower resistance, less heating) are one mark each. Accept 'so that the wire can carry the larger current without overheating'. Reject 'because it has fewer turns' on its own.

Ch 21 Electromagnetic Induction › 21.3 Why Is Current Always Generated in Alternating Form? (Transformers) › p. 389 (PDF p. 11)

"A transformer can change a high alternating voltage (at low current) to a low alternating voltage (at high current) or vice versa."

Ch 21 Electromagnetic Induction › 21.3 Why Is Current Always Generated in Alternating Form? (Transformers) › p. 390 (PDF p. 12)

"In a transformer, the laws of conservation of energy always applies. A higher output voltage does not mean that energy is created."

Ch 21 Electromagnetic Induction › 21.3 Why Is Current Always Generated in Alternating Form? (Transmission of electricity) › p. 391 (PDF p. 13)

"One solution is to make use of very thick cables. The resistivity of copper is a material property and the length of the cables is fixed by the distance between the power station and the cities. Thus, increasing the cross-sectional area is the only option to reduce the resistance."

Ch 21 Electromagnetic Induction › 21.3 Why Is Current Always Generated in Alternating Form? (Transmission of electricity) › p. 391 (PDF p. 13)

"One of the main challenges in the transmission and distribution of electricity from power stations to households is the loss of power due to ohmic heating (P = I2R) in the cables. If very large currents are transmitted, then losses can be very high due to the squaring effect of current in the power loss equation."

Partly in the textbook

Gap: The book says a transformer converts high voltage (low current) to low voltage (high current) (p. 389), that VpIp = VsIs for an ideal transformer (p. 390), and that a thicker cable has a lower resistance and so less heating (p. 391, for transmission cables), but it never states that the primary or secondary coil is wound with thicker wire; the candidate must combine the three ideas.

LO: 14(i), 19(d)

Question 10 — Section B, Option 1 (Question 10): liquids, gases and pressure[10]

10(a)(i) **[1]**

A heavy object is placed on top of each piston (liquid and gas). Compare what happens to the two pistons.

- the piston above the gas moves down (the gas is compressed); the piston above the liquid hardly moves/does not move (the liquid is not compressed) [1]

Both pistons must be compared. Reject 'the liquid piston moves down less' with no idea that it hardly moves.

> **Ch 8 Kinetic Particle Model of Matter › 8.1 How Does the Kinetic Particle Model Relate to the States of Matter? (Observable Properties) › p. 140 (PDF p. 4)**
>
> *"Gases have the lowest densities. Gases have no fixed volume (compressible) and no fixed shape. A gas takes up the volume and shape of its container."*

> **Ch 8 Kinetic Particle Model of Matter › 8.1 How Does the Kinetic Particle Model Relate to the States of Matter? (Observable Properties) › p. 140 (PDF p. 4)**
>
> *"Liquids have a slightly lower density than solids. Liquids have a fixed volume and no fixed shape."*

In the textbook

LO: 7(a)

10(a)(ii) **[2]**

Explain, in terms of particles, why the gas behaves differently from the liquid.

- in a gas the particles are very far apart (much empty space between them), so they can be pushed closer together [1]
- in a liquid the particles are already close together (almost no space between them), so the liquid cannot be compressed [1]

Reject 'gas particles are lighter', 'gas particles move faster' as the only reason, and 'liquid particles are touching so cannot move'.

> **Ch 8 Kinetic Particle Model of Matter › 8.1 How Does the Kinetic Particle Model Relate to the States of Matter? › p. 140 (PDF p. 4)**
>
> *"Arrangement Particles are very far apart from one another in an irregular pattern. The particles in gases have the most energy among the three states of matter. Motion The particles can move freely in any direction. The attractive forces between the particles are weak."*

> **Ch 8 Kinetic Particle Model of Matter › 8.1 How Does the Kinetic Particle Model Relate to the States of Matter? › p. 140 (PDF p. 4)**
>
> *"Arrangement Particles are slightly less closely packed than in solids and arranged in an irregular pattern. Motion The particles slide over each other throughout the liquid without fixed positions. The forces holding the particles together are weaker than in a solid."*

> **Ch 8 Kinetic Particle Model of Matter › 8.1 How Does the Kinetic Particle Model Relate to the States of Matter? (Observable Properties) › p. 140 (PDF p. 4)**
>
> *"Gases have the lowest densities. Gases have no fixed volume (compressible) and no fixed shape. A gas takes up the volume and shape of its container."*

Partly in the textbook

Gap: The book gives the particle arrangements (far apart / slightly less closely packed than in solids) and says gases are compressible and liquids have a fixed volume, but never explains compressibility itself in terms of space between particles (it appears only as an end-of-section practice question, p. 146).
LO: 7(b)

10(a)(iii) **[2]**

State one other physical property that is different for a liquid and a gas of the same substance, and explain the difference in terms of the particles.

- density: the liquid has the higher density [1]
- the liquid particles are much closer together, so there are more particles (more mass) in each unit of volume [1]

Other acceptable properties with matching explanation: volume (a liquid has a fixed volume, a gas fills its container, because the forces between liquid particles hold them together while gas particles are far apart and move freely); the shape differs in the same way (liquid takes the shape of the container's lower part). Reject compressibility (already used in (i) and (ii)) and 'state of matter'.

> **Ch 8 Kinetic Particle Model of Matter › 8.1 How Does the Kinetic Particle Model Relate to the States of Matter? (Observable Properties) › p. 140 (PDF p. 4)**
> *"Gases have the lowest densities. Gases have no fixed volume (compressible) and no fixed shape. A gas takes up the volume and shape of its container."*

> **Ch 8 Kinetic Particle Model of Matter › 8.1 How Does the Kinetic Particle Model Relate to the States of Matter? (Observable Properties) › p. 140 (PDF p. 4)**
> *"Liquids have a slightly lower density than solids. Liquids have a fixed volume and no fixed shape."*

> **Ch 8 Kinetic Particle Model of Matter › 8.1 How Does the Kinetic Particle Model Relate to the States of Matter? › p. 140 (PDF p. 4)**
> *"Arrangement Particles are slightly less closely packed than in solids and arranged in an irregular pattern. Motion The particles slide over each other throughout the liquid without fixed positions. The forces holding the particles together are weaker than in a solid."*

> **Ch 8 Kinetic Particle Model of Matter › 8.1 How Does the Kinetic Particle Model Relate to the States of Matter? › p. 140 (PDF p. 4)**
> *"Arrangement Particles are very far apart from one another in an irregular pattern. The particles in gases have the most energy among the three states of matter. Motion The particles can move freely in any direction. The attractive forces between the particles are weak."*

In the textbook
LO: 7(a), 7(b)

10(b)(i) **[2]**

Using Figure 10.2 (pressure against depth), determine the density of the liquid (g = 10 N/kg).

- read a point on the line, e.g. p = 4000 Pa at depth 0.50 m (or p = 1600 Pa at 0.20 m), i.e. gradient = 4000/0.50 = 8000 Pa/m [1]
- $\rho = p \div (gh) = 4000 \div (10 \times 0.50) = 800$ kg/m³ [1]

```
p = hρg ⇒ ρ = p/(hg) = 4000 Pa ÷ (0.50 m × 10 N/kg) = 800 kg/m³.  Gradient of the line = ρg = 8000 N/m³ ⇒ ρ = 800 kg/m³.
```

Accept any point on the straight line (the line passes through (0.20 m, 1600 Pa) and (0.40 m, 3200 Pa)). Unit kg/m³ required. Reject using the density of water.

> **Ch 6 Pressure › 6.3 How Is a Liquid Used to Measure Pressure? (Measuring Pressure) › p. 103 (PDF p. 12)**
> *"Therefore, the pressure between two levels in a liquid is given by h ρ g. When the top level is the air–liquid interface, the pressure of liquid at the surface is taken as zero. Hence, the pressure P in a liquid at any point h below the air–liquid surface is: P = h ρ g"*

Ch 6 Pressure › 6.3 How Is a Liquid Used to Measure Pressure? (Measuring Pressure) › p. 103 (PDF p. 12)

"The pressure at a given depth beneath a liquid surface depends only on the depth, since its density and the gravitational field strength do not change."

Ch 6 Pressure › 6.3 How Is a Liquid Used to Measure Pressure? (Density) › p. 100 (PDF p. 9)

"Density is defined as mass per unit volume."

In the textbook

LO: 5(e)

10(b)(ii)(A) **[2]**

Using the pressure at 0.20 m from Figure 10.2, determine the upward force on the base of the cylinder (cross-sectional area 1.5×10^{-3} m²).

- from the graph, p = 1600 Pa at a depth of 0.20 m [1]
- F = pA = $1600 \times 1.5 \times 10^{-3} = 2.4$ N [1]

$F = pA = 1600\ N/m^2 \times 1.5 \times 10^{-3}\ m^2 = 2.4\ N$ (upwards).

Accept 2.4 N. Unit N required. Reject 1600 × 0.20 (depth used as the area).

Ch 6 Pressure › 6.1 What Is Pressure? › p. 93 (PDF p. 2)

"Note that pressure is not a force, but a force exerted over the contact area."

Ch 6 Pressure › 6.3 How Is a Liquid Used to Measure Pressure? (Measuring Pressure) › p. 103 (PDF p. 12)

"Therefore, the pressure between two levels in a liquid is given by h ρ g. When the top level is the air–liquid interface, the pressure of liquid at the surface is taken as zero. Hence, the pressure P in a liquid at any point h below the air–liquid surface is: P = h ρ g"

In the textbook

LO: 5(b), 5(e)

10(b)(ii)(B) **[1]**

Calculate the tension in the string (weight of the cylinder 3.0 N).

- the cylinder is in equilibrium: upward forces = downward forces, T + 2.4 = 3.0 so T = 0.60 N [1]

$T = W - F = 3.0\ N - 2.4\ N = 0.60\ N.$ (The atmosphere acts equally on the top face and, through the liquid, on the base, so it cancels.)

Accept 0.6 N; ecf from (A). Unit N required. Reject 3.0 + 2.4 = 5.4 N.

Ch 4 Dynamics II: Forces › 4.1 What Are Newton's Laws of Motion? (Balanced Forces and Newton's First Law) › p. 55 (PDF p. 3)

"Newton's First Law of Motion states that every object will continue in its state of rest or uniform motion in a straight line unless a resultant force acts on it."

Ch 4 Dynamics II: Forces › 4.1 What Are Newton's Laws of Motion? › p. 55 (PDF p. 3)

"Based on Newton's First Law of Motion, when the resultant force acting on a body is zero, the body is at rest or is moving at a constant velocity."

Partly in the textbook

Gap: The book teaches that the resultant force on a body at rest is zero (p. 55) and works a similar force balance on a small volume of liquid (p. 102), but it has no example of a solid object held in a liquid by a string; the candidate must identify all the forces (tension, weight, upward force on the base).

LO: 3(g), 3(h)

Question 11 — Section B, Option 2 (Question 11): radioactivity, fission and fusion [10]

11(a) **[3]**

Complete Table 11.1: nature of alpha, beta and gamma radiation and a material that just stops alpha.

- alpha: 2 protons and 2 neutrons [1]
- beta: fast-moving electrons; gamma: high-frequency electromagnetic radiation (waves) [1]
- alpha is just stopped by a (thin) sheet of paper [1]

```
Mark allocation across the five blanks is assumed (no scheme): alpha composition / beta and gamma nature / alpha stopping material, one mark each.
```

Accept for alpha: a few centimetres of air, thin card, human skin, a thin aluminium foil (the book's list). Accept 'electromagnetic wave(s)' for gamma. Reject 'neutrons' for beta, and 'thick lead' (that is for gamma).

> **Ch 22 Radioactivity › 22.2 What Is Radioactivity? (Table 22.2 The three types of nuclear emissions) › p. 402 (PDF p. 6)**
> *"An α-particle consists of two protons and two neutrons tightly bound together. It is identical to a helium nucleus. An β-particle is a fast-moving electron ejected from a radioactive nucleus. A γ-ray is electromagnetic radiation emitted by a radioactive nucleus with excess energy."*

> **Ch 22 Radioactivity › 22.2 What Is Radioactivity? (Table 22.2, relative penetrating ability) › p. 402 (PDF p. 6)**
> *"α-particles: Least. They are easily absorbed by a piece of paper, a thin aluminium foil or human skin. β-particles: Medium. They are absorbed by a piece of aluminium that is a few millimetres thick. γ-rays: Highest. They pass through most materials easily. They are absorbed by lead that is a few centimetres thick or very thick concrete."*

> **Ch 22 Radioactivity › 22.2 What Is Radioactivity? (Disciplinary Idea) › p. 402 (PDF p. 6)**
> *"Gamma radiation is a form of electromagnetic radiation. Gamma rays have the shortest wavelength and the highest frequency among the waves in the EM spectrum. It has high energy."*

In the textbook

LO: 20(e)

11(b)(i) **[3]**

Describe the nuclear fission process.

- a (slow-moving) neutron hits / is absorbed by a large unstable nucleus (e.g. uranium-235) [1]
- the nucleus splits into two smaller (daughter) nuclei, releasing a large amount of energy [1]
- two or more neutrons are released, which go on to split more nuclei, giving a (self-sustaining) chain reaction [1]

Accept 'energy released as kinetic energy of the fragments / as heat'. Reject 'atom splits into protons and neutrons', and fusion language.

> **Ch 22 Radioactivity › 22.3 What Are Nuclear Fission and Nuclear Fusion? (Nuclear Fission) › p. 410 (PDF p. 14)**
> *"Nuclear fission is a process in which the nucleus of an atom splits (usually into two parts) and releases a huge amount of energy."*

> **Ch 22 Radioactivity › 22.3 What Are Nuclear Fission and Nuclear Fusion? (Energy Changes During Nuclear Processes) › p. 412 (PDF p. 16)**
> *"When the unstable nuclei of these atoms are hit by a slow-moving neutron, they split. Thus, two daughter nuclei and two or more neutrons are created."*

> **Ch 22 Radioactivity › 22.3 What Are Nuclear Fission and Nuclear Fusion? (Energy Changes During Nuclear Processes) › p. 412 (PDF p. 16)**
> *"The neutrons produced in the nuclear fission will go on to split more nuclei. This creates a self-sustaining chain reaction that is controlled in a nuclear reactor (Figure 22.17)."*

In the textbook

LO: 20(j)

11(b)(ii) **[1]**

Describe how nuclear fusion differs from nuclear fission.

- in fusion two light nuclei combine (join) to form one heavier nucleus, whereas in fission one heavy nucleus splits into smaller nuclei [1]

Accept an extra comment that fusion needs very high temperature and pressure. Reject a statement that describes only one of the two processes.

> **Ch 22 Radioactivity › 22.3 What Are Nuclear Fission and Nuclear Fusion? (Nuclear Fusion) › p. 411 (PDF p. 15)**
> *"Nuclear fusion is a process in which two light atomic nuclei combine to form one heavier atomic nucleus and releases a huge amount of energy."*

> **Ch 22 Radioactivity › 22.3 What Are Nuclear Fission and Nuclear Fusion? (Energy Changes During Nuclear Processes) › p. 413 (PDF p. 17)**
> *"Nuclear fusion cannot happen at low temperature and pressure as the two nuclei cannot come into close range of each other due to the repulsive forces. Hence, nuclear fusion requires very high temperatures and pressures"*

> **Ch 22 Radioactivity › 22.3 What Are Nuclear Fission and Nuclear Fusion? (Nuclear Fission) › p. 410 (PDF p. 14)**
> *"Nuclear fission is a process in which the nucleus of an atom splits (usually into two parts) and releases a huge amount of energy."*

In the textbook

LO: 20(j)

11(c)(i) **[1]**

State and explain which points in Figure 11.1 represent isotopes of the same element.

- P and S (both 92 protons, nucleon numbers 238 and 234) and Q and T (both 90 protons, nucleon numbers 234 and 230): the same proton number but different nucleon numbers [1]

```
Reading Figure 11.1 (proton number, nucleon number): P (92, 238), Q (90, 234), R (91, 234), S (92, 234), T (90, 230).
```

Give both pairs; one correct pair with the explanation will probably be credited, but the paper says 'which points' (plural). Reject P and Q (different proton numbers), and Q and R/R and S (same nucleon number).

> **Ch 22 Radioactivity › 22.1 What Is the Composition of an Atom? (Isotopes) › p. 400 (PDF p. 4)**
> *"Isotopes are atoms of the same element that have the same number of protons but different numbers of neutrons. Isotopes have the same proton number but different nucleon numbers."*

In the textbook

LO: 20(b), 20(c)

11(c)(ii) **[1]**

Underline all the decays in which beta particles are emitted: P to Q, Q to R, R to S, S to T.

- Q to R and R to S (the proton number rises by 1 with the nucleon number unchanged) [1]

```
P to Q: (92, 238) to (90, 234): alpha.  Q to R: (90, 234) to (91, 234): beta.  R to S: (91, 234) to (92, 234): beta.  S to T: (92, 234) to (90, 230): alpha.
```

Both decays and no others. An extra underlined decay loses the mark.

> **Ch 22 Radioactivity › 22.2 What Is Radioactivity? (Beta Decay) › p. 404 (PDF p. 8)**
> *"When a nucleus undergoes β-decay: it emits a β-particle (an electron); and the nucleon number remains the same and the proton number increases by one."*

> **Ch 22 Radioactivity › 22.2 What Is Radioactivity? (Alpha Decay) › p. 403 (PDF p. 7)**
> *"When a nucleus undergoes α-decay: it emits an α-particle (identical to helium nucleus 4He); and the nucleon number decreases by four and the proton number decreases by two."*

In the textbook
LO: 20(e), 20(f)

11(c)(iii) **[1]**

Explain what is meant by 'spontaneous' nuclear decay.

- the decay happens on its own, it cannot be started, stopped or changed by external factors such as heating, cooling, pressure or chemical reactions [1]

Accept 'not caused by any outside influence'. Reject 'random' alone (a different idea: the timing cannot be predicted) and 'it happens quickly'.

> **Ch 22 Radioactivity › 22.2 What Is Radioactivity? (Nuclear Decay, Figure 22.5) › p. 401 (PDF p. 5)**
> *"In other words, it is not possible: to make the radioactive nucleus emit radiation by heating, cooling, chemical means or any other method; to predict when a radioactive nucleus will emit radiation; and to know the direction in which the emitted radiation will leave a nucleus."*

> **Ch 22 Radioactivity › 22.2 What Is Radioactivity? (Nuclear Decay) › p. 401 (PDF p. 5)**
> *"The radiation emitted by a radioactive nucleus is spontaneous and random in direction (Figure 22.5). The direction of the emissions and the time between emissions cannot be predicted."*

In the textbook
LO: 20(d)

Section B choice

Option 2 (Question 11, radioactivity) is the kinder choice: all 10 marks are straight recall that the book teaches in so many words (Table 22.2, the fission and fusion definitions, isotopes, alpha and beta decay, 'spontaneous'), and the only reasoning is reading a proton/nucleon-number diagram. Option 1 (Question 10) mixes particle-model explanations (10(a)(ii) is only partly taught), a graph-based density, and a force-balance on a cylinder in a liquid (10(b)(ii)(B) is only partly taught), so a student who knows Chapter 22 well can score 10/10 on Option 2 with less risk than on Option 1. Both options are worth 10 marks, so the paper total is 70 + 10 = 80 either way.

Notes

- NO TRANSCRIPTION: ROOT\Phy\Pure Papers\2026 P2 (transcription).md did not exist when this sheet was written; every question, figure and table was read from the scan itself (20 pages rendered with pypdfium2 at scale 2). Figure 11.1 and Table 9.1 values were read directly from the scan and the table was checked for internal consistency (efficiency = Vout Iout / Vin Iin; R = Vout / Iout in the rows where both are given).
- SOURCE OF THE KEY: the 'ChatGPT answers only' PDF is unofficial. Every part was first solved independently from the scan and only then compared with it. The key agrees with the independent solution on every numerical answer and every final result; the disagreements below are of completeness, wording and presentation, not of physics, except 1(b) where the key gives no usable construction.
- DISAGREEMENT 1(b): ChatGPT's entry is the fragment 'P / P+Q Q' (no construction). The scan shows P and Q drawn pointing to the right with a COMMON HEAD, so neither the head-to-tail nor the parallelogram method can be used as drawn: one vector must be translated. My answer gives the construction (Q redrawn from the head of P, resultant from the tail of P, measured about 2.06 times the length of P and about 14 degrees above P's direction) with two mark points.
- CHECKED, AGREE, 2(d)(ii): ChatGPT 'Less ice is required: each kilogram also absorbs energy while warming to 0 °C before melting.' Verified by m [c_ice Δθ + l_f] = 16 800 J, so m < 16 800/330 000 = 0.051

kg (e.g. 0.048 kg for ice at −10 °C with c_ice about 2100). The key is right but does not say 'smaller than 0.051 kg' or that the same 16 800 J is absorbed; I added both, and made the mark conditional on the reason as well as the direction.

- CHECKED, AGREE, 4(b)(ii): ChatGPT x = 2(1.6 tan 35°) = 2.24 cm. Counting reflections: P 10%, bottom surface 1%, top surface 0.10%: the third reflection, after TWO crossings of the rod (each 1.6 tan 35° = 1.12 cm). The key shows the sequence but not the counting rule; I also give the value to 2 s.f. (2.2 cm) because the data are 2 s.f. (the key's 2.24 cm is within tolerance). A reader who forgets that P itself is the first reflection would get three crossings (3.4 cm); that is the trap.
- CHECKED, AGREE, 4(c): ChatGPT theta_c = $\sin^{-1}(1/1.5)$ = 41.8° and 45° exceeds it, so TIR 'at every encounter'. Correct. Incomplete: it does not state the two conditions for TIR (denser to less dense; i > critical angle) as the book (p. 250) does, and does not say why later reflections also have i = 45° (parallel sides). I added these to the two mark points (c = 41.8° is 3 s.f., acceptable as the key's intermediate value).
- AGREE BUT INCOMPLETE, 2(b): the key's wording ('the change of its internal energy per unit mass for each unit change in its temperature') is the textbook's own definition (Ch 10, p. 169, verbatim), so it is right for this school; I added the equivalent Cambridge-style form ('energy required to raise 1 kg by 1 K') as an accept. Same for 2(c) (the book's sentence) and 6(a) (the book's e.m.f. definition, p. 289).
- AGREE BUT INCOMPLETE, 3(a): the key gives only 'the velocity changes by the same amount in each unit of time'. The question is worth 2 marks, so I give two mark points (constant rate of change of velocity; equal changes in equal time intervals), both from the book (pp. 22-23). Marks within every multi-mark part (3(a), 1(a)(ii), 5(b), 11(a)) are my allocation; no official scheme exists.
- AGREE BUT INCOMPLETE, 3(c): the key uses only Newton's first law. The question says 'Newton's laws'; I accept the first law or the second (a = F/m = 0) provided 'no resultant force because the string is slack' and 'constant velocity' are both shown.
- SIG FIGS (key correct, presentation differs): 4(b)(i) 59.4° given to 3 s.f. from 2 s.f. data (I give 59°, accept 59.4°); 4(b)(ii) 2.24 cm (I give 2.2 cm); 6(c)(iii) 137.5 h shown to 4 s.f. (I give 4.95×10^5 s, about 5.0×10^5 s, 1.4×10^2 h); 3(b)(i) 0.2025 shown then 0.20 J, correct. 9(b)(ii), 9(b)(iii): key's 0.40 A and 48 Ω agree; I accept 0.399 A and 47.5-47.6 Ω.
- AGREE BUT INCOMPLETE, 5(c): the key's 3.0 m / 20 m/s is right; the mark points now show the three steps (20 ns, c Δt / 2, distance / 0.15 s) and the ecf for forgetting ÷ 2 (40 m/s).
- AGREE, 7(b): ChatGPT 'downwards towards DC', field 'from X (N) to Y (S), towards the front'. I derived this independently from the figure geometry. X is the rear arm and Y the front arm of the U-shaped core in an oblique drawing (the same convention as the screen, where AB runs from far to near); beam right, field toward the viewer, conventional current right, Fleming's left-hand rule gives force down (qv × B = −y). This is the one answer that depends on reading a 3-D drawing; if the official scheme says 'upwards' the figure was read the other way round. The key gives only a conclusion; I give the three mark points (direction; field direction; left-hand rule).
- AGREE, 7(a): the key's 'increase turns per unit length' and 'move the screen further away' are both valid; I also accept 'decrease the speed of the protons' and a stronger field by closer poles. 'Increase the current' is excluded because the question already gives it.
- AGREE, 8(a): short circuit between live and neutral then a large current melts the fuse. Neither phrase 'short circuit' nor 'live and neutral touching' appears in the textbook (searched all 22 chapters), hence status 'partly'.
- AGREE, 8(c): ChatGPT's 'hair dryer with wet hands' is taken from the book (p. 334); damp conditions is one of the three hazards in K323 16(d). 8(d): both advantages are right; only 'can be reset' is in the book.
- AGREE, 9(a)(ii): the key gives no numbers; I added the voltages 12 V to 144 V to 12 V. 9(b)(iv): ChatGPT's reason (primary carries the larger current, so a thicker wire with less resistance and less heating) is right; for the ideal case Ip = 2 Is.
- AGREE, 10(a)(iii): ChatGPT chose density; fine. I list other acceptable properties (fixed volume) so a marking decision is easy. 10(b): all four numerical answers agree (800 kg/m³, 1600 Pa, 2.4 N, 0.60 N).
- AGREE, 11: all answers in the key are right (alpha 2p and 2n and paper; beta electrons; gamma EM radiation; fission with a slow neutron and chain reaction; fusion definition; isotope pairs P and S, Q and T; beta decays Q to R and R to S; spontaneous = not triggered by temperature, pressure or chemical conditions). Added: the other acceptable stopping materials for alpha and the fact that 'random' is not the answer to 'spontaneous'.

- ASSUMED PHYSICS: 3(b)(iii): the data are not perfectly consistent (after 3.0 s X has fallen 1.35 m, not 1.4 m), but the intended explanation is the kinetic energy of load X. 6(c)(iii): assumes the battery delivers the same charge (10 800 C) that it took to charge it, i.e. no losses. 2(d)(i): glass and surroundings ignored. 10(b)(ii)(B): atmospheric pressure acts equally on the top face and the base and cancels.
- SYLLABUS (K323) CHECK: 2(b) specific heat capacity is 9(b)/9(c); optical fibres and TIR are 12(f)/12(g); everything on this paper maps to a K323 outcome, but three parts go a little beyond the outcome wording: 4(b)(ii) (energy fractions on reflection), 9(b)(iv) (coil wire thickness) and 7(c) (effect of mass on deflection). Specific heat capacity, total internal reflection and optical fibres ARE covered by Physics Matters (Ch 10 p. 169, Ch 14 pp. 249-252), so they are not gaps.
- PAGE NUMBERS: all printed page numbers were read from the rendered page images (header or footer of each cited page). The Markdown pages use the chapter PDF's page index (pdf_page in each citation), which differs from the printed page. Quotes were matched against the OCR Markdown page and the PDF text layer; table and formula quotes were checked on the page image (Table 1.1, Table 1.5, Table 22.2, Figure 13.1, $E_k = \frac{1}{2}mv^2$, $E_p = mgh$, $a = \Delta v/\Delta t$, $c = Q/(m\Delta\theta)$, $L_f = lf\ m$, $n = 1/\sin\theta c$, $n = \sin x/\sin y$, $I = Q/t$). The book prints the specific latent heat of fusion as lf and the critical angle as θc.
- DATA ON THE SCAN: Figure 10.2 line passes through (0, 0) and (0.50 m, 4000 Pa) (gradient 8000 Pa/m; at 0.20 m, 1600 Pa), confirmed on the grid. Q7 figure: X is a rear arm of the U core, Y the front arm; protons travel left to right.