Science Physics 5086/02 2026

Model answers aligned to **Discover Physics 5th ed.** · Discover Physics (G2 Science and G3 Science Textbook, for GCE 'O' Level), 5th edition 2023 (Dr Charles Chew, Dr Ho Boon Tiong, Low Beng Yew, Yeow Kok Han; Marshall Cavendish Education). Printed page numbers, which run continuously through the book (Ch 1 starts p. 1, Ch 9 p. 153, Ch 17 p. 318). The book has 17 chapters, so its chapter numbers differ from the syllabus topic numbers; the 'lo' codes use the SYLLABUS numbering (taxonomy_phy.json, e.g. 12(g) = p.d. definition). The image field names the page image in References\S34 G23 Science Physics\Discover Physics Textbook\images (DP5-C<chapter>-p<printed page>.jpg). Quotes were checked against the page images.

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.

Teacher-grade model answers for the whole of the real Oct/Nov 2026 Science (Physics) 5086/02 Paper 2: Section A (Q1 to Q9, 55 marks) plus BOTH Section B options (Q10 and Q11, 10 marks each; a candidate answers one, so the paper totals 65). Cambridge has not released a mark scheme; every mark point and accept/reject note is the author's own, written in Cambridge style from the scan, solved independently first and then compared part by part with the unofficial ChatGPT answers-only key. Wherever the book teaches the answer, the key sentence is quoted verbatim with its printed page; each part says whether the book teaches the idea (in_textbook), only the ingredients (partly), not at all (not_in_textbook) or whether it is answered from data in the paper (data_skill).

Concepts not (fully) covered by the textbook

Parts by status: In the textbook **39** · Partly in the textbook **4** · NOT in the textbook **1** · Data skill (answered from the question) **5**

Part	Concept	Status	What to do
5(d)(ii)	Pressure applied to an enclosed liquid is transmitted equally, so the oil pressure at the load equals the pressure at the piston (hydraulic principle)	NOT in the textbook	Not in the book or the syllabus (only p = F/A, p. 57). Teach in one line: 'the oil is one connected liquid, so the pressure is the same everywhere in it', then drill p = F/A twice (find p at the small piston, then F = pA at the large piston).
9(b), 9(c)(i), 9(c)(ii)	Thinking distance, braking distance and stopping distance read from a bar chart (and the v^2 growth of braking distance)	NOT in the textbook	The terms never occur in the book (Worked Example 2K, p. 36, has the idea of a driver delay of 0.4 s but not the names). The stem defines them, so teach students to read the stippled and hatched parts of the bars separately, to use d = vt for thinking distance, and to estimate a missing speed by noting that braking distance roughly quadruples when speed doubles.
9(d)(iv)	Effect of extra mass on braking distance and thinking distance	Partly in the textbook	Use p. 67 ('with the same resultant force F, doubling the mass m halves the acceleration a') and extend it: same braking force, larger mass, smaller deceleration, longer braking distance; thinking distance depends on reaction time only.
3(c)	Terminal (constant) velocity and scaled free-body diagrams	Partly in the textbook	The book has balanced forces giving constant velocity (p. 65) but not the word 'terminal velocity'. Tell students: when speed becomes constant, air resistance has grown until it equals the (unchanged) weight, so redraw the upward arrow the same length as the weight arrow.

2(a)	Wavelength from the spacing of ripple-tank wavefronts over a long distance (count gaps, not lines)	Partly in the textbook	Link p. 162 (wavefront = a crest line) to p. 159 (wavelength = distance between successive crests): consecutive wavefronts are one wavelength apart; divide the measured length by the number of gaps.
10(c)	Reasons why a heating experiment transfers less energy to the water than the source releases	Partly in the textbook	Only conservation of energy (p. 108) and heat loss to surroundings (p. 135) are in the book. Give students the stock reasons: energy lost to the air, energy absorbed by beaker / thermometer / stand, evaporation, incomplete combustion.
10(a)(i)	Energy to heat water from the statement '4.2 J for each 1.0 g per 1.0 °C' (specific heat capacity)	NOT in the textbook	Specific heat capacity is neither in the syllabus nor the book (searched); the stem supplies the value, so it is a data skill. Teach the reading: E = mass in g × 4.2 × temperature rise.

Question 1 — Base units and unit-to-quantity matching [4]

1(a) **[2]**

Complete Table 1.1: SI unit and unit symbol for time and for temperature.

- time: second, s [1]
- temperature: kelvin, K [1]

One mark per row, and each row needs BOTH the unit name and its symbol. Reject minute or hour for time. For temperature the symbol must be a capital K (reject 'k', 'degrees Kelvin' and the degree sign), and reject degree Celsius / °C (not the SI base unit).

> **Ch 1 Physical Quantities, Units and Measurements › 1.2 What Are Physical Quantities? › p. 3**
> *"A physical quantity is a quantity that can be measured. It consists of a numerical magnitude and a unit."*

> **Ch 1 Physical Quantities, Units and Measurements › 1.2 What Are Physical Quantities? (Table 1.1 Base quantities and their SI units, rows for time and temperature) › p. 3**
> *"time | second | s; thermodynamic temperature | kelvin | K"*

In the textbook

LO: 1(b)

1(b) **[2]**

Complete Table 1.2: the physical quantity measured by the unit Bq and by the unit kWh.

- Bq: activity (of a radioactive source) / amount of radioactivity / number of nuclear disintegrations (decays) per second [1]
- kWh: energy (electrical energy consumed or transferred) [1]

Bq: accept 'activity', 'radioactivity', 'amount of radioactivity' (the book's own phrase), 'rate of radioactive decay', 'decays per second'. Reject 'radiation', 'intensity', 'half-life'; 'count rate' on its own is not credited (the book treats count rate as a related but separate measurement). kWh: accept 'energy', 'electrical energy', 'energy consumed'. Reject 'power' (the commonest slip: kW is power, kW h is energy).

> **Ch 17 Radioactivity › 17.2 What Is Radioactivity? (Becquerel) › p. 327**
> *"The SI unit of the amount of radioactivity is the Becquerel (Bq). The unit is named in honour of Henri Becquerel, a French physicist who discovered radioactivity in 1896. One becquerel (1 Bq) is equal to 1 disintegration per second."*

> **Ch 15 Practical Electricity › 15.1 What Is Electric Heating and How Is Electricity Consumption Measured? › p. 271**
> *"The amount of electricity consumed is measured in kilowatt-hours. Each kilowatt-hour is equivalent to 3.6 MJ. That is 3 600 000 J of energy."*

> **Ch 15 Practical Electricity › 15.1 (Disciplinary Idea box) › p. 271**
> *"Many appliances are powered electrically. A common practical unit of energy consumption is in kW h."*

In the textbook

Gap: Wording only: the syllabus summary of key quantities (p. 24) names the quantity 'activity of a radioactive source' but the book never uses the word 'activity'; it says 'amount of radioactivity'. Tell students both are accepted.
LO: 1(a); 14(c); 16(g)

Question 2 — Ripple-tank wavefronts: wavelength, period, speed [3]

2(a) [1]

Use Figure 2.1 (P to Q = 57.6 cm) to determine the wavelength.

- P to Q contains 12 wavelengths (12 gaps between wavefronts, 13 wavefronts counted inclusively), so wavelength = 57.6 / 12 = 4.8 cm [1]

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On the scan the wavefronts are equally spaced (about 54 px apart) and P to Q spans 650 px = 12 spaces. wavelength = 57.6 cm ÷ 12 = 4.8 cm.
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Answer 4.8 cm (accept 4.80). Reject 57.6 ÷ 13 = 4.43 cm (counting wavefronts instead of gaps: the standard error) and 57.6 ÷ 11. The unit cm is printed on the answer line.

> **Ch 9 General Wave Properties I: Introduction › 9.2 How Can We Describe the Characteristics of Waves? (Basic Characteristics of Waves) › p. 159**
> *"Wavelength λ is the shortest distance between two successive crests or troughs."*

> **Ch 9 General Wave Properties I: Introduction › 9.2 (Wavefronts) › p. 162**
> *"A wavefront is an imaginary line joining all adjacent points that are in phase."*

> **Ch 9 General Wave Properties I: Introduction › 9.2 (Wavefronts) › p. 162**
> *"Each continuous circle of a crest or trough can be taken as a wavefront. Wavefronts are always perpendicular to the direction of the waves."*

Partly in the textbook

Gap: The book defines wavelength as the distance between two successive crests or troughs and says each crest or trough line is a wavefront, but it never says that the spacing of consecutive wavefronts in a ripple tank is one wavelength, nor how to find it from a long measured distance by dividing by the number of GAPS. Students must count gaps, not lines.
LO: 9(a); 9(c)

2(b) [1]

Calculate the period of the water waves (frequency 4.0 Hz).

- T = 1 / f = 1 / 4.0 = 0.25 s [1]

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T = 1/f = 1 ÷ 4.0 Hz = 0.25 s
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Accept 0.25 s or 0.250 s. Reject 4.0 or a value with the wrong unit.

> **Ch 9 General Wave Properties I: Introduction › 9.2 (Relationship Between Period, Frequency, Wavelength and Wave Speed) › p. 161**
> *"The period T is the time taken by each point on the wave to complete one oscillation."*

> **Ch 9 General Wave Properties I: Introduction › 9.2 (Relationship Between Period, Frequency, Wavelength and Wave Speed) › p. 161**
> *"Frequency and period are related by this equation: f = 1/T"*

In the textbook

LO: 9(c)

2(c) **[1]**

Calculate the speed of the water waves.

- v = f × λ = 4.0 × 4.8 = 19.2 cm/s (19 cm/s) [1]

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v = fλ = 4.0 Hz × 4.8 cm = 19.2 cm/s   (check: v = λ/T = 4.8 ÷ 0.25 = 19.2 cm/s)
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Accept 19 or 19.2 cm/s. Ecf from (a): v = 4.0 × (their wavelength). If the answer is given in m/s it must be 0.192 m/s with the unit written. Reject an answer that has not used f = 4.0 Hz.

> **Ch 9 General Wave Properties I: Introduction › 9.2 (Relationship Between Period, Frequency, Wavelength and Wave Speed) › p. 161**
> *"Wave speed v is the distance travelled by the wave per unit time. Since f = 1/T, v = fλ."*

In the textbook

LO: 9(d)

Question 3 — Parachutist: forces, motion and constant velocity [6]

3(a) **[2]**

Name the two forces F1 (up) and F2 (down) in the free-body diagram.

- F1: air resistance (drag) [1]
- F2: weight / gravitational force (pull of the Earth) [1]

F1: accept 'drag', 'air friction', or 'upward force from the parachute' if it is clearly the resistance of the air. Reject 'upthrust', 'lift', 'normal reaction' and 'tension'; a bare 'friction' is borderline (the book calls air resistance 'a type of friction in air', so accept 'air friction' but not 'friction' alone). F2: accept 'gravity', 'gravitational force', 'weight'. Reject 'mass' and 'gravitational field strength'.

> **Ch 4 Dynamics › 4.3 What Are Some Effects of Resistive Forces on Motion? (skydivers) › p. 77**
> *"The resultant forces acting downwards on the skydivers are their respective weights minus the respective air resistances acting upwards on them."*

> **Ch 4 Dynamics › 4.3 (Figure 4.27 Forces acting on each skydiver) › p. 77**
> *"air resistance (upward force); weight of the skydiver (downward force)"*

> **Ch 3 Force and Pressure › 3.2 Is Mass the Same as Weight? (Weight) › p. 50**
> *"Weight is the gravitational force acting on an object that has mass."*

In the textbook

LO: 3(a); 4(b)

3(b) **[2]**

Describe the motion of the parachutist at t1 and explain in terms of F1 and F2.

- the parachutist is moving downwards but slowing down / decelerating (her speed is decreasing) [1]
- because F1 (air resistance, upward) is greater than F2 (weight, downward): the forces are unbalanced and the resultant force acts upwards, opposite to her motion [1]

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In Figure 3.1 the upward arrow F1 is about 1.5 times as long as the downward arrow F2 (about
245 px against 170 px on the scan), so the resultant F1 - F2 is upward.
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First mark needs 'downwards' (or 'falling', which the stem already gives) together with 'slowing down / decelerating'; 'accelerating' is wrong. Second mark must compare F1 with F2 (F1 > F2) AND state a non-zero upward resultant force (or a deceleration). Reject 'F1 = F2' (that is t2) and 'resultant force is downwards'.

> **Ch 4 Dynamics › 4.1 What Are Newton's Laws of Motion? (Effects of a Force on the Motion of a Body, Figure 4.1) › p. 64**
> *"A descending parachutist slows down due to air resistance. There is a decrease in speed."*

Ch 4 Dynamics › 4.1 (Unbalanced Forces and Newton's Second Law) › p. 66
"If the resultant force acting on an object is not zero, we say the forces acting on the object are unbalanced."

Ch 4 Dynamics › 4.1 (Newton's Second Law) › p. 66
"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."

In the textbook
LO: 4(a)

3(c) **[2]**

On Figure 3.2 draw the two forces at constant velocity (t2) to scale, using the scale of Figure 3.1.

- two arrows from the dot, one vertically up (air resistance) and one vertically down (weight), of EQUAL length [1]
- each arrow the same length as the weight arrow F2 of Figure 3.1 (about two-thirds of the length of F1 in Figure 3.1) [1]

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Constant velocity means resultant force = 0, so air resistance = weight. Her weight has not changed (same person, same parachute), so the downward arrow keeps the F2 length of Figure 3.1; the upward arrow has shrunk from the longer F1 to the same length.
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Both arrows must start at the dot, be vertical, point in opposite directions (arrowheads required) and be equal; the second mark is for the correct common length, equal to F2 of Figure 3.1 (tolerance about one small division). Reject arrows of length F1 (the common error: keeping the upward arrow its original size) and equal arrows that are longer or shorter than F2. Labels are not required.

Ch 4 Dynamics › 4.1 (Balanced Forces and Newton's First Law, Figure 4.4) › p. 65
"Thus, the resultant force is zero and the book continues moving at a constant velocity."

Ch 4 Dynamics › 4.1 (Effects of a Force on the Motion of a Body) › p. 64
"Zero acceleration implies that the object can be stationary or moving with constant velocity (Figure 4.2)."

Ch 4 Dynamics › 4.2 What Are Free-body Diagrams? › p. 71
"In Section 4.1, we have been using arrows to represent forces acting on individual objects. These diagrams are called free-body diagrams."

Partly in the textbook

Gap: The book teaches that balanced forces give constant velocity and how to draw force arrows, but never uses the idea of terminal velocity (the term does not occur) and never asks for arrows drawn to a common scale; students must work out that the weight arrow is unchanged and the air-resistance arrow has grown to match it.
LO: 4(a); 4(b)

Question 4 — Current, potential difference, and a series circuit with a wire [6]

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

State what is meant by current.

- current is the rate of flow of (electric) charge [1]

Accept 'charge passing a point per unit time' or I = Q/t with the symbols defined. Reject 'flow of electrons' alone (no 'rate'), 'amount of charge' (no 'rate') and 'flow of current'.

Ch 13 Electric Charge and Current of Electricity › 13.2 What Is an Electric Current? › p. 228
"Electric current is the rate of flow of electric charge."

In the textbook
LO: 12(c)

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

State what is meant by potential difference.

- the potential difference across a component is the work done (energy transferred) per unit charge in driving charges through the component [1]

Both 'work done / energy transferred' AND 'per unit charge' are needed, tied to the component (accept 'between two points'). Accept V = W/Q with the symbols defined. Reject 'voltage' (the word being defined), 'difference in voltage' and 'the push of the battery'.

> **Ch 13 Electric Charge and Current of Electricity › 13.3 What Are the Differences Between Electromotive Force and Potential Difference? (Potential Difference) › p. 233**
>
> *"The potential difference (p.d.) across a component in a circuit is the work done per unit charge in driving charges through the component."*

In the textbook

LO: 12(g)

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

Ammeter 100 mA, voltmeter (across the 29 Ω resistor) 2.9 V, e.m.f. 4.5 V: calculate the resistance of wire W.

- p.d. across W = 4.5 - 2.9 = 1.6 V (series circuit: the p.d.s add up to the e.m.f.); or total resistance = 4.5 / 0.100 = 45 Ω [1]
- R = V / I = 1.6 / 0.100 = 16 Ω (or 45 - 29 = 16 Ω) [1]

```
I = 100 mA = 0.100 A. Consistency check: voltmeter reading ÷ current = 2.9 V ÷ 0.100 A = 29 Ω, which agrees with the printed 29 Ω. V(W) = 4.5 V - 2.9 V = 1.6 V; R(W) = 1.6 V ÷ 0.100 A = 16 Ω.
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Answer 16 Ω (accept 16.0 Ω). Reject 29 Ω (using the voltmeter reading as the p.d. across W) and 45 Ω (the total). The mA to A conversion must be shown or implied (1.6 ÷ 100 is wrong). Ecf on the second mark if V(W) is wrongly found but R = V ÷ 0.100 is used.

> **Ch 13 Electric Charge and Current of Electricity › 13.4 How Is the Electrical Resistance of Metals Related to Potential Difference and Current? (Resistance) › p. 237**
>
> *"The resistance R of a component is the ratio of the potential difference V across it to the current I flowing through it."*

> **Ch 14 D.C. Circuits › 14.1 How Are Current, Potential Difference and Resistance Related in a Series Circuit? › p. 251**
>
> *"In a series circuit, the total potential difference supplied to the circuit Vε is equal to the sum of the individual potential differences across the resistors."*

> **Ch 14 D.C. Circuits › 14.1 (Worked Example 14C, Thought Process) › p. 253**
>
> *"The current at every point in a series circuit is the same. The sum of the potential differences in a series circuit is equal to the potential difference across the whole circuit."*

In the textbook

LO: 12(h); 12(i); 13(b); 13(c); 13(g)

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

Wire W is shortened to 40.0 cm: determine the new ammeter reading.

- resistance is proportional to length, so the new R(W) = 16 × 40.0 / 80.0 = 8.0 Ω [1]
- I = e.m.f. / total R = 4.5 / (29 + 8.0) = 4.5 / 37 = 0.12 A = 122 mA (120 mA) [1]

```
R ∝ length (same material and cross-section): 80.0 cm to 40.0 cm halves R, so 16 ÷ 2 = 8.0 Ω. Total R = 29 + 8.0 = 37 Ω. I = V/R = 4.5 ÷ 37 = 0.1216 A = 121.6 mA, i.e. 122 mA (3 s.f.) or 0.12 A (2 s.f.).
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Accept 120 mA, 122 mA, 121.6 mA, 0.12 A, 0.122 A (the answer line is in mA, so a bare '0.12' must be read as 0.12 A and converted). Ecf from (i): R(W) = (their R) ÷ 2. Reject 200 mA (current doubled because the length halves: ignores the fixed 29 Ω resistor), the usual error.

Ch 13 Electric Charge and Current of Electricity › 13.4 (Table 13.4 Relationship between resistance and the cross-sectional area and length of a wire) › p. 239

"The longer the cylinder, the more collisions the electrons will make with its atom. Hence, the resistance R of the cylindrical resistor is directly proportional to the length of the cylinder l."

Ch 14 D.C. Circuits › 14.1 (effective resistance in series) › p. 251

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

In the textbook

LO: 12(j); 13(g)

Question 5 — Hydraulic pump: moments, pressure and measuring the load [9]

5(a) **[1]**

Explain why the 25 N is positioned as shown in Figure 5.2.

- the weight of the (uniform) arm acts at its centre of gravity, which is the midpoint of the arm (4.5 + 35.5 = 40.0 cm from the pivot, half of the total length 80.0 cm) [1]

```
Length of arm = 4.5 + 35.5 + 40.0 = 80.0 cm; the 25 N weight is 4.5 + 35.5 = 40.0 cm from the pivot = 80.0 ÷ 2.
```

Need the idea of the weight acting at the centre of gravity / centre / middle of a uniform arm. Reject 'because the pivot is there', 'where the force is applied' and 'the weight is spread out' with no single point.

Ch 5 Turning Effects of Forces › 5.3 What Is the Centre of Gravity? › p. 88

"The centre of gravity of an object is an imaginary point where the entire weight of the object seems to act."

Ch 5 Turning Effects of Forces › 5.3 (Centre of Gravity) › p. 88

"The centre of gravity for an object that has a regular shape and uniform density is at the centroid or centre of the object."

Ch 5 Turning Effects of Forces › 5.3 (Worked Example 5D, Thought Process) › p. 90

"Since the beam is uniform, the weight is evenly distributed and can be represented by a single point acting through the centre of the beam."

In the textbook

LO: 5(e)

5(b) **[3]**

Show that the force exerted at the piston is 2000 N.

- take moments about the pivot; for equilibrium the sum of clockwise moments = the sum of anticlockwise moments [1]
- clockwise moments = 100 × 80.0 + 25 × 40.0 (= 9000 N cm); anticlockwise moment = F × 4.5 [1]
- F × 4.5 = 9000, so F = 9000 / 4.5 = 2000 N [1]

```
Distances from the pivot: piston 4.5 cm; 25 N at 4.5 + 35.5 = 40.0 cm; 100 N at 40.0 + 40.0 = 80.0 cm. Clockwise = 100 N × 0.800 m + 25 N × 0.400 m = 80 + 10 = 90 N m; anticlockwise = F × 0.045 m. F = 90 ÷ 0.045 = 2000 N (equivalently 9000 N cm ÷ 4.5 cm).
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Units must be consistent (all cm or all m). Both terms 100 × 80.0 and 25 × 40.0 must be seen for the second mark; leaving out the 25 N gives 1778 N, and using 40.0 cm for the 100 N is the usual slip. 'Show that' needs the working to end in 2000 N, not a back-substitution that merely verifies it. The pivot force has zero moment about the pivot and need not be mentioned.

> **Ch 5 Turning Effects of Forces › 5.2 What Are the Conditions Required for Objects to Remain Balanced? (Principles of Moment) › p. 85**
> *"The principle of moments states that when a body is in equilibrium, the sum of clockwise moments about a pivot is equal to the sum of anticlockwise moments about the same pivot."*

> **Ch 5 Turning Effects of Forces › 5.3 (Worked Example 5D, Answer) › p. 90**
> *"By the principle of moments, taking moments about the pivot: Sum of clockwise moments = Sum of anticlockwise moments"*

In the textbook

LO: 5(d)

5(c) **[2]**

Piston cross-sectional area 180 mm²: calculate the pressure in the oil, including a unit.

- p = F / A with the area converted correctly: 180 mm² = 180 × 10^{-6} m² = 1.8 × 10^{-4} m² [1]
- p = 2000 / (1.8 × 10^{-4}) = 1.1 × 10^{7} Pa (1.11 × 10^{7} N/m²) [1]

```
1 mm = 10⁻³ m so 1 mm² = 10⁻⁶ m²; A = 180 × 10⁻⁶ = 1.80 × 10⁻⁴ m². p = 2000 N ÷ 1.80 × 10⁻⁴ m²
= 1.11 × 10⁷ Pa.
```

Accept 1.1 × 10^{7} or 1.11 × 10^{7} Pa or N/m², 11 MPa, or 11 N/mm² (2000 ÷ 180 = 11.1 N/mm² is a valid unit-consistent answer). The unit is part of the answer mark: a bare number scores the method mark only. Reject 1.1 × 10^{4} (mm² to m² converted by 10^{-3} instead of 10^{-6}) and an answer in N with no area unit.

> **Ch 3 Force and Pressure › 3.4 How Is Pressure Related to Force? › p. 57**
> *"Pressure is the force acting per unit area."*

> **Ch 3 Force and Pressure › 3.4 (Pressure) › p. 57**
> *"P = F/A where P = pressure (Pa), F = force (N), A = contact area (m²)"*

> **Ch 3 Force and Pressure › 3.4 (Pressure) › p. 57**
> *"The SI unit of pressure is newton per square metre (N/m²). It is also known as pascal (Pa), named after the French mathematician and physicist Blaise Pascal (1623–1662)."*

In the textbook

LO: 3(h); 3(i)

5(d)(i) **[1]**

State the measuring instrument used to measure the diameter of the cylindrical load (recorded as 48.0 mm).

- (digital / vernier) calipers [1]

Accept 'digital calipers' (the book's term), 'vernier calipers', 'callipers'. Reject micrometer screw gauge (the book gives its range as zero to 2.5 cm, too small for 48 mm), metre rule / ruler / tape (smallest division 1 mm, cannot give 48.0 mm to 0.1 mm) and 'measuring cylinder'.

> **Ch 1 Physical Quantities, Units and Measurements › 1.3 How Do We Measure Physical Quantities? (Digital Calipers) › p. 7**
> *"The digital calipers are used to measure the internal and external diameters of an object accurately (Figure 1.7)."*

> **Ch 1 Physical Quantities, Units and Measurements › 1.3 (Helpful Note beside Digital Calipers) › p. 7**
> *"Take note not to refer the digital calipers as digital vernier calipers."*

> **Ch 1 Physical Quantities, Units and Measurements › 1.3 (Table 1.3 Common measuring instruments with their range, smallest division and usage) › p. 8**
> *"digital calipers | zero to 15 centimetres | 0.001 cm or 0.01 mm | diameter of a test tube; digital micrometer screw gauge | zero to 2.5 centimetres | 0.0001 cm or 0.001 mm | diameter of a wire"*

> **Ch 1 Physical Quantities, Units and Measurements › 1.3 (Precision of an Instrument) › p. 8**
> *"When recording the measurements, we can record the measurements shown on the digital display of: the digital calipers to 0.1 mm; and the digital micrometer screw gauge to 0.01 mm."*

In the textbook

Gap: Wording only: the book insists on 'digital calipers' and warns against 'digital vernier calipers'; the examiners will almost certainly accept 'vernier calipers' too, which is what most schools call the instrument. A recorded value of 48.0 mm (0.1 mm) matches the book's rule for the digital calipers.
LO: 1(e)

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

Calculate the weight of the load.

- the pressure in the oil is the same at the load as at the piston (pressure is transmitted through the liquid); area of the load = π r² = π × (0.0240)² = 1.81 × 10^{-3} m² (r = 48.0 / 2 = 24.0 mm) [1]
- weight of load = force = p × A = 1.11 × 10^{7} × 1.81 × 10^{-3} = 2.0 × 10^{4} N (2.01 × 10^{4} N) [1]

```
r = 48.0 mm ÷ 2 = 24.0 mm = 0.0240 m; A = π × 0.0240² = 1.810 × 10⁻³ m². W = pA = 1.111 × 10⁷
Pa × 1.810 × 10⁻³ m² = 2.01 × 10⁴ N. Check by area ratio: 2000 N × (1810 mm² ÷ 180 mm²) = 2000
× 10.05 = 2.01 × 10⁴ N.
```

Accept 2.0 × 10^{4}, 2.01 × 10^{4}, 20 000 N, 20 100 N. Ecf from (c): W = (their p) × 1.81 × 10^{-3}. Reject using the diameter as the radius (A = π × 0.048² gives about 80 000 N) and 2000 N (forgetting that the load is wider than the piston). Do not use W = mg: no mass is given.

> **Ch 3 Force and Pressure › 3.4 (the only pressure relationship taught, used here twice) › p. 57**
> *"Pressure is the force acting per unit area."*

NOT in the textbook

Gap: The central idea that pressure applied to an enclosed liquid is transmitted to every part of it, so the pressure in the oil at the load equals the pressure at the piston (the hydraulic principle), is not in the book (searched 'hydraulic', 'transmitted', 'pascal' and Ch 3) and not in the syllabus (LO 3(h) and 3(i) give only p = F/A). Students can only get it by reasoning that the oil has one pressure. The area of a circle from its diameter is maths, not physics.
LO: 3(i)

Question 6 — Hair dryer: fuse, power, energy, double insulation [7]

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

State the name of component X (in the live wire, Figure 6.2).

- fuse [1]

Accept 'cartridge fuse'. Reject 'circuit breaker', 'resistor' (X is the rectangle with a line through it, the fuse symbol, placed in the live wire as a safety device) and 'switch'.

> **Ch 15 Practical Electricity › 15.2 How Do We Use Electrical Components Safely? (Fuse) › p. 276**
> *"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 (Figure 15.12(a))."*

> **Ch 15 Practical Electricity › 15.2 (Switches and fuses on the live wire) › p. 281**
> *"Switches and safety features such as fuses and circuit breakers have to be connected to the live wire in order to break or complete a circuit."*

In the textbook

LO: 14(e); 14(i); 13(a)

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

Explain the function of component X in the circuit.

- it melts (breaks the circuit) if the current becomes too large / exceeds its rating, protecting the hair dryer and wiring from overheating or fire [1]

The idea needed is: breaks / melts when the current is too large (exceeds a safe value or its rating). Add 'protects the appliance / wires / user, prevents fire or overheating' for safety. Reject 'to control the current', 'to reduce the current' (a fuse does not reduce current) and 'to switch off the dryer'. 'Protects against a short circuit' is credited only if it is linked to too large a current.

> **Ch 15 Practical Electricity › 15.2 (Fuse) › p. 276**
> *"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 (Figure 15.12(a))."*

> **Ch 15 Practical Electricity › 15.2 (Figure 15.12 caption) › p. 276**
> *"(a) A fuse consists of a strip of wire which melts, or fuses, and breaks an electric circuit if the current exceeds a safe level."*

In the textbook

LO: 14(e)

6(b) **[2]**

Switch P closed, switch Q open: calculate the total current in component X.

- only the motor and ONE heating element are on: total power = 46 + 920 = 966 W [1]
- I = P / V = 966 / 230 = 4.2 A [1]

```
Parallel branches: the current in X is the sum of the branch currents. Motor: 46 ÷ 230 = 0.20 A; heating element: 920 ÷ 230 = 4.0 A; total = 4.2 A. Or P total = 966 W, I = 966 ÷ 230 = 4.2 A.
```

Accept 4.2 A or 4.20 A. Reject 8.2 A (using both heating elements: ignores that Q is open) and 4.0 A (forgetting the motor). Accept the branch-by-branch method (0.20 + 4.0). Unit A is printed on the answer line.

> **Ch 15 Practical Electricity › 15.1 What Is Electric Heating and How Is Electricity Consumption Measured? (Power rating) › p. 269**
> *"P = VI"*

> **Ch 14 D.C. Circuits › 14.2 How Are Current, Potential Difference and Resistance Related in a Parallel Circuit? › p. 255**
> *"In a parallel circuit, the total current flowing into or out of the parallel branches is equal to the sum of the individual currents in each parallel branch."*

In the textbook

LO: 14(b); 13(d)

6(c) **[2]**

Switches P and Q both closed: calculate the energy transferred electrically in joules in 11 minutes.

- total power = 46 + 920 + 920 = 1886 W; time = 11 × 60 = 660 s [1]
- E = P t = 1886 × 660 = 1 244 760 J ≈ 1.2 × 10^6 J (1.24 × 10^6 J) [1]

```
P = 46 W + 920 W + 920 W = 1886 W; t = 11 min × 60 = 660 s; E = Pt = 1886 × 660 = 1 244 760 J. (Alternative: I = 1886 ÷ 230 = 8.2 A; E = VIt = 230 × 8.2 × 660 = 1.24 × 10⁶ J.)
```

Accept 1.2 × 10^6, 1.24 × 10^6, 1 244 760 or 1 240 000 J. The minutes must be converted to seconds: 1886 × 11 = 20 746 is wrong (that is in W min). Ecf from a wrong total power. Reject 1886 × 660 written without a unit or in kJ without conversion.

> **Ch 15 Practical Electricity › 15.1 (Worked Example 15A, Answer (c)) › p. 269**
> *"The energy transferred to the LED bulb is: W = Pt W = 10 × (30 × 60) = 18 kJ"*

> **Ch 15 Practical Electricity › 15.1 (Link box: Recall from Chapter 6) › p. 269**
> *"Recall from Chapter 6, we learnt that power is the rate of change of work done. It is given by: P = W/t"*

In the textbook
LO: 14(b); 13(d)

6(d) **[1]**

The cable has no earth wire since the hair dryer is double insulated. Suggest why double insulation is needed.

- so that the user cannot get an electric shock: the casing is made of plastic (an insulator) with two layers of insulation round the live parts, so if the live wire came loose and touched the casing it could not make the casing live, and no earth wire is needed [1]

The idea needed is: prevents the user receiving an electric shock if the live wire touches / becomes loose inside the casing (accept 'no metal parts are exposed', 'the casing cannot become live'). Accept the extra link to 'no earth wire needed because there is no metal casing to earth'. Reject 'to stop the dryer overheating', 'to prevent short circuit', 'to protect the hair' and a bare 'for safety' (the stem already says 'safety').

> **Ch 15 Practical Electricity › 15.2 (Double Insulation) › p. 280**
> *"Not all appliances use earthed metal casing. Metal casing can increase the cost of the appliances. Some appliances use double insulation as a safety feature to shield users from electric shocks. 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."*

> **Ch 15 Practical Electricity › 15.2 (Figure 15.19 annotation, live wire loose) › p. 281**
> *"Live wire may become loose and come into contact with the casing."*

In the textbook
LO: 14(f)

Question 7 — Electromagnet and plotting compasses [5]

7(a) **[1]**

On Figure 7.2 draw the direction of the conventional current at point X.

- an arrow drawn on the wire at X pointing UP (towards the coil) [1]

```
In the cell symbol the longer plate is positive. Reading the scan, the left-hand plate of the battery is the tall one (positive) and the right-hand plate is the short one (negative). Conventional current leaves the positive terminal, so it passes up the left-hand wire through X, round the coil, down the right-hand wire and through the switch back to the negative terminal.
```

Arrow must be on or beside the wire at X and point upwards. Reject a downward arrow (that is electron flow) and an arrow on any other part of the wire.

> **Ch 13 Electric Charge and Current of Electricity › 13.2 What Is an Electric Current? (Conventional Current and Electron Flow) › p. 228**
> *"The direction of flow of positive charges is described as the conventional current, which assumes that positive charges flow out of the positive terminal of a battery to the negative terminal (Figure 13.6)."*

In the textbook
LO: 12(d)

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

On Figure 7.2 draw the position of the compass needle for each of the four compasses (switch closed).

- left-hand and right-hand compasses: needle (north-seeking end) pointing to the left (←) [1]
- top and bottom compasses: needle (north-seeking end) pointing to the right (→) [1]

Current is up at the left, so on the front of the coil the current runs upwards: right-hand grip rule (fingers curl along the current, thumb gives the north pole) gives the NORTH pole at the LEFT end of the iron bar and the south pole at the right end. The field outside the bar runs from N to S, so beside the middle of the bar (above and below) it points left to right, at the left-hand compass it points away from N (left), and at the right-hand compass it points towards S (left again). The electromagnet's field is much stronger than the Earth's, so the needles line up with it.

Mark an arrowhead or shading on the needle to show which end is north; if no end is marked, award nothing for that compass. Mark each pair as one mark. A reversed answer (all four needles reversed) scores 0 for the drawing but may still earn the explanation marks. This answer depends on reading the winding of the coil on the scan (front turns slant upward) and on the polarity of the cell; both were checked: it is the same geometry as the book's Worked Example 16H, where current going up on the left gives a north pole at the left.

Ch 16 Magnetism and Electromagnetism › 16.2 How Do We Show the Magnetic Field Around a Magnet? (Worked Example 16E, Thought Process) › p. 299

"The needles of the plotting compasses will point in the direction tangential to the magnetic field line."

Ch 16 Magnetism and Electromagnetism › 16.1 (solenoid and right-hand grip rule) › p. 292

"A current-carrying solenoid produces a magnetic field similar to that of a bar magnet (Figure 16.13)."

Ch 16 Magnetism and Electromagnetism › 16.1 (Figure 16.14, labels) › p. 292

"The thumb points in the same direction as the north pole. The fingers curl in the same direction as the current flowing through the solenoid."

Ch 16 Magnetism and Electromagnetism › 16.3 What Are the Magnetic Effects of a Current? (Worked Example 16H, Answer) › p. 307

"When a current flows into the solenoid, the solenoid is magnetised with the north pole on the left, facing the bar magnet."

In the textbook

LO: 15(d); 15(f)

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

Explain why the compass needles change direction when the switch is closed.

- the current in the coil produces a magnetic field and magnetises the iron bar (the coil and bar form an electromagnet) [1]
- the compass needles line up with (point along) the field of the electromagnet, which is stronger than the Earth's field, so they turn away from north [1]

First mark: current gives magnetic field / iron becomes an electromagnet (accept 'solenoid magnetised the iron'). Second mark: needles align with the new field (accept 'the field of the electromagnet is stronger than the Earth's field' or 'the needles now point along the field lines of the electromagnet'). Reject 'the iron attracts the needles' (needles are magnets, they turn, they are not attracted as a whole), 'the battery pushes the needles' and 'electricity makes them move'.

Ch 16 Magnetism and Electromagnetism › 16.1 What Are the Interactions Between Magnets and Between Magnets and Magnetic Materials? (Induced magnetism) › p. 292

"By placing a magnetic material, such as an iron rod, inside the current-carrying solenoid, the magnetic material becomes a magnet."

Ch 16 Magnetism and Electromagnetism › 16.3 (Magnetic Field due to Current in Solenoid) › p. 306

"A current-carrying solenoid is an electromagnet. When a current is passed through a solenoid, a resultant magnetic field similar to a bar magnet is generated."

Ch 16 Magnetism and Electromagnetism › 16.3 (Worked Example 16G, Thought Process) › p. 307

"When no current flowing, the needle of the compass comes to rest in the north-south direction. When a current flows from A to B, the needle will deflect."

In the textbook

LO: 15(b); 15(f)

Question 8 — Carbon-12 and carbon-14: isotopes, beta decay, half-life [5]

8(a) **[1]**

Describe one similarity and one difference between the particles in a nuclide of carbon-12 and a nuclide of carbon-14.

- similarity: both contain 6 protons (same number of protons) AND difference: carbon-14 has 8 neutrons whereas carbon-12 has 6 neutrons (carbon-14 has two more neutrons) [1]

ONE mark for giving both, each correct. Similarity: same number of protons (6) (accept 'same proton number' and, since the book also says so, 'six electrons' in the neutral atom, though a nuclide is the nucleus, so protons is the safer answer). Difference: different number of neutrons (6 against 8). Reject 'different number of protons', 'carbon-14 has more protons / electrons', 'different nucleon number' without the neutron statement and a similarity/difference pair that is the same fact said twice.

> **Ch 17 Radioactivity › 17.1 What Is the Composition of an Atom? (Isotopes, Figure 17.4) › p. 322**
> *"Each atom has six protons and six electrons. They are carbon atoms. They have different numbers of neutrons."*

> **Ch 17 Radioactivity › 17.1 (Isotopes) › p. 322**
> *"Isotopes are atoms of the same element that have the same numbers of protons but different numbers of neutrons."*

In the textbook

LO: 16(a); 16(b); 16(c)

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

Explain what is meant by the term nuclear decay.

- a random and spontaneous process in which an unstable nucleus loses energy by emitting radiation (alpha, beta, gamma radiation / particles) [1]

Need an unstable nucleus emitting radiation (or particles) AND random / spontaneous (accept 'cannot be predicted'). Accept 'radioactive decay'. Reject 'nucleus splits into two' (fission), 'electrons leave the atom', 'atoms break down' and a definition of half-life.

> **Ch 17 Radioactivity › 17.2 What Is Radioactivity? (Nuclear Decay) › p. 323**
> *"Nuclear decay is a random process by which an unstable atomic nucleus loses its energy by emission of electromagnetic radiation or particle(s)."*

> **Ch 17 Radioactivity › 17.2 (Nuclear Decay) › p. 323**
> *"The radiation emitted by a radioactive nucleus is spontaneous and random in direction (Figure 17.5)."*

In the textbook

LO: 16(d)

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

State the nature of beta (β) radiation.

- fast-moving electrons (β-particles) ejected from (the nucleus of) a radioactive nucleus [1]

Accept 'high-speed electrons', 'electron from the nucleus', 'β particle = electron'. Reject 'electromagnetic radiation' (that is gamma), 'helium nucleus' (alpha), 'positron' (the syllabus says only β^- is assumed) and a bare 'negative charge'.

> **Ch 17 Radioactivity › 17.2 (Table 17.2 The three types of nuclear emissions, β-particles, Nature) › p. 324**
> *"An β-particle is a fast-moving electron ejected from a radioactive nucleus."*

In the textbook

LO: 16(e)

8(c) **[2]**

Half-life of carbon-14 is 5700 years; original 3.2×10^{11} and present 4.0×10^{10} nuclides: calculate the age of the wood.

- $3.2 \times 10^{11} / 4.0 \times 10^{10} = 8 = 2^3$, so 3 half-lives have passed ($3.2 \times 10^{11} \rightarrow 1.6 \times 10^{11} \rightarrow 8.0 \times 10^{10} \rightarrow 4.0 \times 10^{10}$) [1]
- age = 3 × 5700 = 17 100 years (1.7×10^4 years) [1]

```
Number of half-lives n: (½)ⁿ = 4.0 × 10¹⁰ ÷ 3.2 × 10¹¹ = 1/8, so n = 3. Age = 3 × 5700 years = 17 100 years.
```

Accept 17 100, 17 000, 1.7×10^4 or 1.71×10^4 years. The halving table ($3.2 \rightarrow 1.6 \rightarrow 0.8 \rightarrow 0.4 \times 10^{11}$) earns both marks if the final age is stated. Reject 5700 × 8 = 45 600 years (multiplying by the ratio) and 2 half-lives or 4 half-lives.

> **Ch 17 Radioactivity › 17.2 (Half-life) › p. 328**
> *"The half-life of a radioactive nuclide is the time taken for half the nuclei of that nuclide in any sample to decay."*

> **Ch 17 Radioactivity › 17.2 (Figure 17.10) › p. 329**
> *"Based on Figure 17.10, we can see that the number of iodine-131 atoms decreases by half every eight days."*

> **Ch 17 Radioactivity › 17.2 (Worked Example 17C, Answer) › p. 329**
> *"Number of half-lives = 18 ÷ 6 = 3 600 Bq → 300 Bq → 150 Bq → 75 Bq"*

In the textbook

LO: 16(g)

Question 9 — Stopping distance of an electric car [10]

9(a) **[1]**

State the type of potential energy store of the car battery.

- chemical (potential energy store / chemical potential store) [1]

Accept 'chemical', 'chemical potential', 'chemical energy store'. Reject 'electrical', 'elastic', 'gravitational', 'nuclear', 'kinetic'.

> **Ch 6 Energy › 6.1 What Are Energy Stores and Transfers? (Figure 6.2 Types of energy stores) › p. 99**
> *"Chemical potential store: The food that we eat, fossil fuels and batteries have energy in the chemical potential store (chemical potential energy)."*

In the textbook

LO: 6(a)

9(b) **[1]**

Use Figure 9.1 to calculate the thinking time when the car travels at 10 m/s.

- thinking distance at 10 m/s read from the chart = 8 m; thinking time = distance / speed = 8 / 10 = 0.80 s [1]

```
Reading the stippled (lower) part of the 10 m/s bar: top at 7.8 m, i.e. about 8 m (one small square = 1 m). t = d ÷ v = 8 ÷ 10 = 0.80 s. Cross-check: the same bars give 4 m at 5 m/s, 12 m at 15 m/s, 20 m at 25 m/s and 24 m at 30 m/s, all 0.80 s × speed.
```

Accept 0.75 to 0.80 s (reading of 7.5 to 8.0 m). Reject the total height of the bar (18 m ÷ 10 = 1.8 s) and the braking part only (10 m ÷ 10 = 1.0 s), the two commonest misreads. Unit s is printed.

> **Ch 2 Kinematics › 2.1 What Are Speed, Velocity and Acceleration? (Speed) › p. 18**
> *"Speed is the distance travelled per unit time. Its SI unit is metre per second (m/s)."*

Data skill (answered from the question)

Gap: The stem defines thinking distance and thinking time and the answer is read from the chart; the only taught fact is speed = distance ÷ time. The book never uses the terms thinking time or thinking distance (searched every chapter file

and the index).
LO: 2(b)

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

Thinking time is constant: determine the thinking distance at 20 m/s.

- distance = speed × thinking time = 20 × 0.80 = 16 m [1]

```
d = v t = 20 m/s × 0.80 s = 16 m (the 10 m/s bar's 8 m doubled)
```

Accept 16 m, or 15.5 to 16 m; ecf from (b): 20 × (their thinking time). Reject 8 m (no scaling) and 32 m.

> **Ch 2 Kinematics › 2.1 (Speed) › p. 18**
> *"Speed is the distance travelled per unit time. Its SI unit is metre per second (m/s)."*

Data skill (answered from the question)

Gap: Pure use of distance = speed × time on the quantity found in (b).
LO: 2(b)

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

Use Figure 9.1 to estimate the stopping distance at 20 m/s.

- stopping distance = thinking distance + braking distance ≈ 16 + 40 = 56 m (estimate; accept 54 to 60 m) [1]

```
The chart has no 20 m/s bar, so estimate. Braking parts read from the chart: 2.5 m (5 m/s), 10 m (10 m/s), 22.5 m (15 m/s), 62.5 m (25 m/s), 90 m (30 m/s): they grow with speed², i.e. braking distance = v² ÷ (2 × 5.0): at 20 m/s this is 400 ÷ 10 = 40 m. So stopping distance = 16 + 40 = 56 m. (A straight-line midpoint between the totals at 15 m/s (34 m) and 25 m/s (82 m) gives 58 m, so any value from about 54 to 60 m is a fair estimate.)
```

Accept 54 to 60 m; the value must come from adding a thinking distance (16 m) to a braking distance read or interpolated from the chart. Reject 16 m (thinking only), 40 m (braking only) and 96 m or any value above the 25 m/s total (82 m) or below the 15 m/s total (34 m).

Data skill (answered from the question)

Gap: Answered from the chart. The pattern that braking distance grows with the square of the speed is not taught anywhere in the book (the book treats braking only through uniform deceleration and the area under a speed-time graph, Worked Example 2K, p. 36), so students who do not see the pattern can only interpolate between the neighbouring bars.
LO: 2(b); 2(h)

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

Car and driver 1600 kg, travelling at 30 m/s: calculate the energy in the kinetic store.

- $E_k = \frac{1}{2} m v^2 = \frac{1}{2} \times 1600 \times 30^2 = 7.2 \times 10^5$ J (720 000 J) [1]

```
Ek = ½ × 1600 kg × (30 m/s)² = ½ × 1600 × 900 = 720 000 J = 7.2 × 10⁵ J
```

Accept 720 000, 7.2×10^5 or 7.20×10^5 J. Reject mv^2 without the ½ (1 440 000 J) and ½ m v written with v not squared (24 000 J).

> **Ch 6 Energy › 6.1 (Calculating the Size of an Energy Store) › p. 107**
> *"To calculate the amount of energy in the kinetic store of a body moving at speed v, we use the following equation: $E_k = \frac{1}{2} mv^2$ where Ek = energy in the kinetic store (J), m = mass of the body (kg), v = speed of the body (m/s)"*

In the textbook
LO: 6(b)

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

The car decelerates at 5.0 m/s²: calculate the average braking force.

- F = m a = 1600 × 5.0 = 8000 N (8.0×10^3 N) [1]

`F = ma = 1600 kg × 5.0 m/s² = 8000 N.  Check with work done: braking distance = 30² ÷ (2 × 5.0) = 90 m and 720 000 J ÷ 90 m = 8000 N (the chart's 90 m braking distance at 30 m/s agrees).`

Accept 8000 N, 8.0 × 10³ N, 8 kN. Reject 1600 ÷ 5.0 = 320 N and answers with unit J or N/kg.

> **Ch 4 Dynamics › 4.1 What Are Newton's Laws of Motion? (Newton's Second Law in symbols) › p. 67**
> *"F = ma where F = resultant force (N), m = mass of object (kg), a = acceleration of object (in m/s²)"*

In the textbook

LO: 4(c)

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

Calculate the time from when the driver first sees a hazard to when the car is stationary (30 m/s).

- braking time = change in speed / deceleration = 30 / 5.0 = 6.0 s [1]
- total time = thinking time + braking time = 0.80 + 6.0 = 6.8 s [1]

`a = Δv ÷ t so t = 30 m/s ÷ 5.0 m/s² = 6.0 s. The car also travels during the thinking time of 0.80 s (from (b)): 0.80 + 6.0 = 6.8 s.`

Accept 6.8 s (6.75 to 6.80). Ecf from (b): 6.0 + (their thinking time). Reject 6.0 s (forgetting the thinking time) and answers that use the distance 90 m ÷ 30 m/s = 3 s (braking at constant speed).

> **Ch 2 Kinematics › 2.1 (Acceleration) › p. 23**
> *"Acceleration is the rate of change of velocity. Acceleration = change of velocity ÷ time taken"*

> **Ch 2 Kinematics › 2.2 How Do We Analyse Motion Graphically? (Worked Example 2K) › p. 36**
> *"If he takes 0.4 s before applying the brakes, and his car slows down at a rate of 3.75 m/s², determine whether the motorist can stop his car in time."*

In the textbook

LO: 2(c)

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

The car is now driven with four passengers: suggest the change, if any, to the thinking distance and the braking distance.

- thinking distance: no change (thinking time depends on the driver's reaction, not on the mass of the car; the speed is the same) [1]
- braking distance: increases (a larger mass needs a larger force for the same deceleration; for the same braking force the deceleration is smaller / more kinetic energy has to be removed, so the car travels further) [1]

`For the same braking force F, a = F ÷ m falls when m increases, and braking distance = v² ÷ 2a rises. (Equivalently the work done by the brakes F × d must equal ½ m v², so d increases with m.)`

Thinking distance: 'no change / same / unchanged'. Braking distance: 'increases / longer'. Accept 'increases slightly'. Reject 'braking distance decreases' and 'thinking distance increases' (the driver's reaction does not depend on the load).

> **Ch 4 Dynamics › 4.1 (Newton's Second Law) › p. 67**
> *"with the same resultant force F, doubling the mass m halves the acceleration a."*

Partly in the textbook

Gap: The book gives F = ma and the statement that doubling the mass halves the acceleration for the same force, but never applies this to vehicles, braking distance or the extra load; the link to longer braking distance, and the independence of thinking distance from mass, has to be reasoned out.

LO: 4(c)

Question 10 — Section B option 1: candle heating water (energy transfer, particle model) [10]

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

Calculate the energy transferred to the water in 18.0 minutes (220 g, 23.5 °C to 64.5 °C; 4.2 J for each 1.0 g per 1.0 °C).

- rise in temperature = 64.5 - 23.5 = 41.0 °C; energy = 220 × 4.2 × 41.0 = 37 884 J ≈ 3.8 × 10⁴ J [1]

```
Δθ = 64.5 °C - 23.5 °C = 41.0 °C. Energy = mass (g) × 4.2 J/(g °C) × Δθ = 220 × 4.2 × 41.0 = 37 884 J.
```

Accept 37 884, 37 900, 3.8 × 10⁴ or 3.79 × 10⁴ J. Reject an answer using 18.0 minutes or 69.0 g in the calculation (irrelevant data) and 220 × 4.2 × 64.5 (not using the rise in temperature).

Data skill (answered from the question)

Gap: Energy = mass × 4.2 × temperature rise is supplied in the stem as 'for each 1.0 g of water … 4.2 J … to raise the temperature by 1.0 °C'. Specific heat capacity is not in the syllabus or the textbook (searched), so the paper rightly gives the value; students must turn the sentence into E = m × 4.2 × Δθ.

LO: 6(a)

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

Calculate the energy per unit mass of wax that is transferred to the water.

- mass of wax burned = 69.0 - 67.2 = 1.8 g [1]
- energy per unit mass = 37 884 / 1.8 = 2.1 × 10⁴ J/g (2.1 × 10⁷ J/kg) [1]

```
Loss of mass = 69.0 g - 67.2 g = 1.8 g. Energy per unit mass = 37 884 J ÷ 1.8 g = 21 047 J/g ≈ 2.1 × 10⁴ J/g = 2.1 × 10⁷ J/kg.
```

Accept 21 000, 2.1 × 10⁴, 2.10 × 10⁴ J/g; also 2.1 × 10⁷ J/kg. The unit (J/g or J/kg) must be given for the second mark: the answer line is blank, so a bare number scores 1 mark. Ecf from (a)(i): (their energy) ÷ 1.8. Reject 37 884 ÷ 69.0 or ÷ 67.2 (using the total mass instead of the mass burned).

Data skill (answered from the question)

Gap: All data are in the stem. The only idea needed is 'energy per unit mass = energy ÷ mass'; the book has the pattern of a quantity 'per unit' (speed, pressure, p.d.) but not this quantity.

LO: 6(a)

10(b) **[2]**

Describe how thermal energy is transferred from the candle to the water.

- energy is transferred from the flame to the beaker by convection (hot gases / hot air rise from the flame) and radiation (infrared) [1]
- energy is then conducted through the glass of the beaker to the water (and convection currents / stirring spread it through the water) [1]

Credit the chain in two marks: (1) flame to beaker by convection of the hot gases and / or infrared radiation; (2) through the glass by conduction (accept 'conduction through the glass base' and 'convection in the water'). Any two correctly described processes in the right place earn the two marks; a bare list of 'conduction, convection and radiation' with no link to the apparatus scores 1 at most. Reject 'heat rises' with no mention of hot gases or air, and 'the flame touches the water'.

> **Ch 8 Thermal Processes › 8.2 How Is Energy Transferred by Heating? (Thermal Conduction) › p. 136**
>
> *"Conduction is a process of energy transfer where energy is transferred through the passing on of vibrational motion from one particle to another."*

> **Ch 8 Thermal Processes › 8.2 (Convection) › p. 139**
>
> *"Convection is a process of energy transfer by means of convection currents of a fluid (liquid or gas), due to a difference in density."*

Ch 8 Thermal Processes › 8.2 (Radiation) › p. 140

"Radiation is the process of energy transfer by electromagnetic waves. It does not require a medium."

In the textbook

LO: 8(b); 8(c); 8(d); 8(e)

10(c) **[2]**

Suggest two reasons why the energy transferred to the water is less than the energy released by the candle wax.

- some of the energy is transferred to the surroundings (the air) instead of the water, e.g. the hot gases and radiation miss the beaker, or the beaker and water lose energy to the air [1]
- some of the energy is used to heat the beaker, the thermometer and the stand (they take energy from the flame / the water) instead of the water [1]

Any two different reasons: energy lost to the surrounding air (convection / radiation / conduction); energy absorbed by the beaker, thermometer or stand; energy lost from the water's surface by evaporation or by the water losing energy to the cooler air; incomplete combustion of the wax. Reject vague 'heat is lost' with no destination, 'human error', 'the thermometer is inaccurate', 'energy is destroyed / used up' and two versions of the same reason.

Ch 8 Thermal Processes › 8.1 What Is Thermal Equilibrium? (Figure 8.2) › p. 135

"The energy transfer by heating occurs only when there is a difference in temperature (Figure 8.2)."

Ch 6 Energy › 6.1 What Are Energy Stores and Transfers? (Principle of Conservation of Energy) › p. 108

"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."

Partly in the textbook

Gap: The book gives conservation of energy and shows energy passing from a hot object to the cooler surrounding air, but it never discusses why a heating experiment transfers less energy than the source releases (losses to the surroundings, apparatus taking energy, evaporation); students must apply it to this set-up.

LO: 6(c); 8(e)

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

Describe the change, if any, in the kinetic energy of the particles of wax as it melts.

- no change: the average kinetic energy of the particles stays constant (the temperature stays constant while the wax melts; the energy goes into the potential energy between particles) [1]

Accept 'stays the same', 'constant', 'does not change'. Reject 'increases' (the commonest wrong answer: confusing melting with heating) and 'decreases'. Reject an answer that says 'no change' but then says the particles move faster.

Ch 7 Kinetic Particle Model of Matter › 7.2 How Does the Kinetic Particle Model Relate to Temperature and Changes of State? (Changes of States) › p. 129

"However, during these processes of changing states, the average kinetic energy of the particles remains constant. Hence, the temperature stays constant."

In the textbook

LO: 7(c); 7(e)

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

Use the kinetic model to describe how the arrangement and motion of particles in liquid wax differ from those in solid wax.

- arrangement: in the solid the particles are closely packed in a regular pattern; in the liquid they are slightly less closely packed and in an irregular pattern [1]
- motion: in the solid the particles vibrate about fixed positions; in the liquid the particles slide over each other without fixed positions (move around) [1]

Each mark needs a comparison of solid with liquid (or the state of each). Arrangement: regular / ordered / fixed pattern → irregular, slightly further apart. Motion: vibrate about fixed positions → move / slide past one another. Reject 'particles in

the liquid move freely in any direction' (the book says that of gases), 'particles in the liquid are far apart' and 'the liquid particles do not vibrate'.

> **Ch 7 Kinetic Particle Model of Matter › 7.1 How Does the Kinetic Particle Model Relate to the States of Matter? (Table 7.1, solid) › p. 125**
>
> *"Arrangement: Particles are closely packed and arranged in a regular pattern. The particles in solids have the least energy among the three states of matter. Motion: Particles vibrate about fixed positions. They are held in position by strong attractive forces between the particles."*

> **Ch 7 Kinetic Particle Model of Matter › 7.1 (Table 7.1, liquid) › p. 125**
>
> *"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."*

In the textbook

LO: 7(b)

Question 11 — Section B option 2: light in glass, the EM spectrum, sound v. EM waves [10]

11(a)(i) [1]

Speed of visible light in vacuum is 3.0 × 10⁸ m/s; refractive index of the glass is 1.5: calculate the speed of light in the glass block.

- v = c / n = 3.0 × 10⁸ / 1.5 = 2.0 × 10⁸ m/s [1]

```
refractive index n = c ÷ v, so v = c ÷ n = 3.0 × 10⁸ ÷ 1.5 = 2.0 × 10⁸ m/s
```

Accept 2 × 10⁸ or 2.0 × 10⁸ m/s. Reject 4.5 × 10⁸ (multiplying by n).

> **Ch 12 Light › 12.2 How Is Light Refracted? (Refractive Index) › p. 210**
>
> *"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 the medium. n = c/v where c = speed of light in a vacuum, v = speed of light in the medium"*

In the textbook

LO: 11(e)

11(a)(ii) [3]

The ray makes 51° with the surface of the glass block: calculate the angle of refraction.

- angle of incidence i = 90° - 51° = 39° (angles are measured from the normal) [1]
- sin r = sin i / 1.5 = sin 39° / 1.5 = 0.4195 [1]
- r = 25° (24.8°) [1]

```
The 51° is the angle between the ray and the SURFACE, so i = 90° - 51° = 39°. sin i ÷ sin r =
1.5, so sin r = sin 39° ÷ 1.5 = 0.6293 ÷ 1.5 = 0.4195; r = sin⁻¹(0.4195) = 24.8°.
```

Accept 24.8° to 25°. The most common error is to use i = 51°, which gives sin r = 0.518 and r = 31° (award method mark 2 only if sin i ÷ sin r = 1.5 is used with that i, and no other marks). Calculator in radian mode gives nonsense (r about 0.4): reject. Ecf: if i is wrong but the sin-law and the inverse sine are used correctly, award the last two marks.

> **Ch 12 Light › 12.2 (Refraction) › p. 209**
>
> *"The refracted ray is the light ray that enters a medium and undergoes a change of direction. The angle of refraction is the angle between the refracted ray and the normal at the point of incidence."*

> **Ch 12 Light › 12.2 (Second law of refraction) › p. 210**
>
> *"The second law of refraction states that for two given media, the ratio of the sine of the angle of incidence to the sine of the angle of refraction is a constant, that is, sin i / sin r = constant."*

Ch 12 Light › 12.2 (Refractive Index) › p. 210

"n = sin i / sin r where i = angle of incidence in a vacuum, r = angle of refraction in the medium"

In the textbook

LO: 11(c); 11(d)

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

Draw on Figure 11.1 the ray that emerges from the lower surface of the glass block.

- a ray drawn from the point where the ray in the glass meets the lower surface, going away from the block and parallel to the incident ray (bending away from the normal, with an arrow) [1]

```
The block has parallel sides, so the angle inside the glass at the lower surface is again r =
24.8° (alternate angles) and the ray leaves at i = 39° to the normal: the emergent ray is
parallel to the incident ray (51° to the lower surface) and slightly shifted sideways.
```

The emergent ray must start at the lower surface where the refracted ray ends, be parallel to the incident ray (tolerance about 3°), point down and to the right and carry an arrow. Reject a ray that continues straight on in the same direction as the ray inside the glass (no bending) and a ray drawn along the surface.

Ch 12 Light › 12.2 (Let's Investigate 12A, Helpful Note) › p. 212

"It is useful to remember that when a ray enters and exits via two parallel sides of a uniform glass block, the incident and emergent rays are parallel."

Ch 12 Light › 12.2 (Effect of Refraction) › p. 213

"The emergent ray is parallel to the incident ray and the ray through the air."

In the textbook

LO: 11(c); 11(d)

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

State the letter of the region used for mobile (cell) phone communication (Table 11.1: A B C visible D E F in order of increasing wavelength).

- E (microwaves) [1]

```
Order of increasing wavelength: gamma rays (A), X-rays (B), ultraviolet (C), visible light,
infrared (D), microwaves (E), radio waves (F). Mobile phones use microwaves, so E.
```

Answer E only. Reject F (radio waves: mobile phones are often confused with radio, but the book names microwaves for mobile phones) and D.

Ch 11 Electromagnetic Waves › 11.1 What Are Electromagnetic Waves? (Figure 11.1 The electromagnetic spectrum and its components) › p. 184

"radio waves | microwaves | infrared | visible light | ultraviolet | X-rays | gamma rays (the Type of wave row, in order from longest to shortest wavelength)"

Ch 11 Electromagnetic Waves › 11.2 What Are the Uses and Dangers of Electromagnetic Waves? (Microwaves) › p. 189

"Communication: Besides radio waves, microwaves can also be used for satellite communication and mobile phones. A mobile phone converts sound waves to microwave signals. The microwaves are sent from the mobile phone to the cell tower."

In the textbook

LO: 10(b); 10(c)

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

Describe the effect of over-exposure to ultraviolet electromagnetic waves.

- skin damage: sunburn / premature skin ageing / increased risk of skin cancer [1]

Accept 'sunburn', 'skin cancer', 'skin damage / burns', 'premature skin ageing'. The book does not mention eye damage but accept 'damage to the eyes / cataracts' as correct physics. Reject 'ozone depletion', 'global warming', 'heating of the body' with no skin / cell damage, and 'radiation poisoning'.

> **Ch 11 Electromagnetic Waves › 11.2 (Harmful Effects of Over-exposure to Electromagnetic Radiation) › p. 195**
>
> *"Sun burn is the most common effect of over-exposure to electromagnetic radiation, specifically caused by too much ultraviolet radiation. Frequent sunburns can cause premature skin aging and higher risk of skin cancer."*

In the textbook

LO: 10(d)

11(c) **[3]**

Describe any three ways in which sound waves differ from electromagnetic waves.

- sound waves are longitudinal (vibrations parallel to the direction of travel) but electromagnetic waves are transverse [1]
- sound needs a material medium (cannot travel in a vacuum) but electromagnetic waves can travel through a vacuum [1]
- sound travels much more slowly (about 340 m/s in air) than electromagnetic waves (3.0×10^8 m/s in a vacuum); or sound is a vibration of particles (compressions and rarefactions) but an electromagnetic wave is oscillating electric and magnetic fields [1]

Any three different differences, one mark each: longitudinal v. transverse; needs a medium v. travels in a vacuum; much slower v. 3.0×10^8 m/s (accept 'speed of sound depends on the medium (solid > liquid > gas) while all EM waves travel at the same speed in a vacuum'); vibrating particles v. oscillating electric and magnetic fields. Each statement must compare sound with EM waves; a statement about only one of them earns nothing unless the comparison is clear. Reject differences in frequency or wavelength ranges without data, 'sound waves are audible' and 'sound cannot be reflected'.

> **Ch 9 General Wave Properties I: Introduction › 9.2 How Can We Describe the Characteristics of Waves? (Types of Wave Motion) › p. 158**
>
> *"A transverse wave has a direction of vibration that is perpendicular to the direction of wave travel (Figure 9.9). A longitudinal wave has a direction of vibration that is parallel to the direction of wave travel (Figure 9.10). Some examples of longitudinal waves are sound waves and certain waves of an earthquake."*

> **Ch 11 Electromagnetic Waves › 11.1 (Nature of Electromagnetic Waves) › p. 185**
>
> *"All electromagnetic waves are transverse waves. Electromagnetic waves are made up of oscillating electric and magnetic fields (Figure 11.2). All electromagnetic waves can travel without a medium and they all travel at the same speed of 3×10^8 m/s in a vacuum."*

> **Ch 10 General Wave Properties II: Sound › 10.1 What Is Sound? (Transmission of Sound) › p. 173**
>
> *"Astronauts are not able to hear each other in space unless they use radio equipment for communication. This is because there is no medium to transmit sound waves. Sound travels when the vibrations of atoms are passed on to neighbouring atoms."*

> **Ch 10 General Wave Properties II: Sound › 10.1 (Transmission of Sound) › p. 173**
>
> *"speed of sound in solid > speed of sound in liquid > speed of sound in gas"*

> **Ch 10 General Wave Properties II: Sound › 10.3 How Is Sound Useful? (Let's Investigate 10A, Questions) › p. 177**
>
> *"The human reaction time is about 0.2 s and the speed of sound in air is around 340 m/s."*

In the textbook

Gap: Every point is in the book but spread over three chapters; the book never sets sound and EM waves side by side, so students must assemble the comparison (a revision table is worth making).

LO: 10(a); 9(e); 9(f); 9(g)

Section B choice

Option 1 (Q10, candle heating water) is the slightly kinder choice. Its two calculations (3 marks) need only the stem's own conversion of the sentence about 4.2 J and a subtraction of the wax masses, and three of the four descriptive parts are verbatim book material (conduction, convection and radiation definitions on pp. 136 to 140; Table 7.1 on p. 125 for the solid and liquid; the constant average kinetic energy during melting on p. 129). Its only soft spots are 10(c) (open 'suggest') and 10(d)(i), where students who confuse melting with heating say 'increases'. Option 2 (Q11) is also fully taught (refractive index p. 210, EM spectrum p. 184, sound v. EM scattered over pp. 158, 173, 177 and 185) but it carries a three-mark trap in 11(a)(ii) (the 51° is to the surface, so i = 39°), a drawing mark that needs a parallel emergent ray, the order of the spectrum for 11(b)(i), and a three-mark comparison that students must assemble themselves because the book never sets sound and EM waves side by side. A student comfortable with ratio and sine work and a good memory for the spectrum will do equally well on Option 2; the average student is safer on Option 1.

Notes

- Marks verified against the scan: Q1 = 2+2 = 4; Q2 = 1+1+1 = 3; Q3 = 2+2+2 = 6; Q4 = 1+1+2+2 = 6; Q5 = 1+3+2+1+2 = 9; Q6 = 1+1+2+2+1 = 7; Q7 = 1+2+2 = 5; Q8 = 1+1+1+2 = 5; Q9 = 1+1+1+1+1+1+2+2 = 10. Section A = 55. Section B: Q10 = 1+2+2+2+1+2 = 10; Q11 = 1+3+1+1+1+3 = 10. Candidate answers one Section B question: 55 + 10 = 65, which is what the cover page and the paper's [Total] boxes print.
- Transcription: ROOT\Phy\Papers\2026 P2 (transcription).md did not exist when this sheet was written, so everything was read directly from the 20-page scan rendered at 2x (4x and 7x for the circuit and coil in Fig 7.2, the bar chart in Fig 9.1 and the free-body arrows in Fig 3.1). Pages 1 and 20 are the cover and a blank page; page 15 is a 'Turn over' filler between Section A and Section B.
- Method: every part was solved from the scan BEFORE the ChatGPT key was opened (g = 10 N/kg was not needed anywhere; mains as the paper states, 230 V in Q6). The key was then compared part by part. Outcome: the key and the independent solution agree on every final answer (all numbers, units, letters, drawings and ticks). There is NO numerical or factual disagreement. The differences are all in completeness, listed below.
- Key v. this sheet, completeness: (1) 6(d): the key's sentence 'Some appliances use double insulation as a safety feature to shield users from electric shocks' is the book's generic sentence (p. 280) and does not say WHY it is needed; the mark needs 'a plastic casing / two layers of insulation so that a loose live wire cannot make the casing live, so the user cannot be shocked (no earth wire needed)'. (2) 5(d)(i): key says 'Vernier calipers (digital calipers are also suitable)'; the book teaches 'digital calipers' and warns against calling them 'digital vernier calipers' (p. 7); both are accepted, and the 48.0 mm (0.1 mm) value matches the book's recording rule (p. 8). (3) 11(c): the key's third point (sound = vibrations of particles; EM = oscillating fields) restates the mechanism; the speed difference (340 m/s v. 3.0×10^8 m/s) is the point examiners most often credit, so both are given. (4) 9(c)(ii): the key says 'smooth interpolation gives about 40 m braking' without a method; the v^2 pattern (braking distance = $v^2/2a$ = 40 m with a = 5.0 m/s²) is shown here and the accepted range is 54 to 60 m. (5) 5(d)(ii): the key does not say why the oil pressure is the same at the load; the mark scheme should carry that step. (6) Significant figures: the key gives 4(b)(ii) as 122 mA (fine), 6(c) as 1.24×10^6 J (fine; the data justify 1.2×10^6) and 10(a)(i) as 3.79×10^4 J (the data justify 3.8×10^4); this sheet accepts all of them. (7) 10(a)(ii): the key gives J g^{-1} only; J/kg (2.1×10^7) is also valid. (8) 4(a)(i), 8(b)(i), 6(a)(ii): the key's wording matches the syllabus and book; mark points here add the accept/reject notes the key lacks.
- Fig 7.2 (Q7): the answer rests on two readings of the scan, both checked at high magnification and by pixel measurement. (a) Cell polarity: the plate heights are tall, short, tall, short from left to right, so the left terminal is positive and conventional current rises at X. (b) Coil winding: the wire leaves X, rises across the FRONT of the bar and spirals to the right, so the front turns carry current upwards; by the right-hand grip rule (book Fig 16.14: fingers along the current, thumb to the north pole) the north pole is at the LEFT end. This is the same geometry as the book's Worked Example 16H (p. 307: current going up on the left, north pole on the left). Both readings agree with the ChatGPT key. If an examiner took the opposite winding, all four needles would reverse; the explanation marks would be unaffected.

- Fig 9.1 (Q9): bar heights were read against the 1 m small squares: thinking distance 4.1, 7.8, 11.7, 19.5, 23.4 m at 5, 10, 15, 25, 30 m/s, i.e. a constant thinking time of about 0.78 to 0.80 s; braking distance 2.5, 10, 22.5, 62.5, 90 m, which equals $v^2/(2 \times 5.0)$ at every speed, confirming the stem's deceleration of 5.0 m/s² and the braking force 8000 N in (d)(ii). The tolerance for 9(b) is therefore 0.75 to 0.80 s; 0.80 s is used in (c) and (d)(iii).
- Fig 3.1 (Q3): measured on the scan, the up arrow F1 is about 245 px and the down arrow F2 about 170 px (ratio about 1.45, roughly 3 : 2). In Fig 3.2 both arrows must equal F2 (about 170 px on the 4x render, 85 px on the 2x render).
- Textbook note: the book uses 240 V for mains in its examples (e.g. p. 276, p. 281) while the paper says 230 V; use the paper's value. The book's term for the unit of radioactive activity is 'amount of radioactivity' (p. 327); the syllabus summary says 'activity of a radioactive source'. The book never uses specific heat capacity, terminal velocity, thinking distance or the hydraulic principle (all searched in every chapter file and the index).
- Status counts (parts): data_skill 5, in_textbook 39, not_in_textbook 1, partly 4. The part list in Section B counts BOTH options, so a candidate attempts 65 marks but the sheet shows 75 marks of model answers (55 + 10 + 10).