

Solutions: thermal physics, mock test

Self-marking: award the marks part by part, as shown. Total: 60 marks. The lifebuoy parts are worth 36 marks (60 %): with 36 marks or more you have passed. Rounding differences in the last digit are accepted. Write your total and the lifebuoy subtotal here: total _____/60 lifebuoy _____/36.

I Multiple choice

[12]

1. **C.** Temperature is the same; the larger mass holds more thermal energy ($Q \propto m$). [1]
2. **B.** $T = -23 + 273 = 250 \text{ K}$. [1]
3. **D.** A narrower tube makes the liquid column move further for each degree. [1]
4. **D.** $\Delta L \propto L_0 \Delta T$: factor $1.5 \times 2 = 3$, so $3 \times 0.60 = 1.8 \text{ mm}$. [1]
5. **B.** Volume expansion: three times the linear fractional change, $3 \times 0.20 = 0.60 \%$. [1]
6. **C.** Brownian motion: unequal collisions with fast-moving air particles. [1]
7. **A.** Faster particles hit the walls harder and more often. [1]
8. **D.** The most energetic particles escape, so the average kinetic energy of those left falls. [1]
9. **A.** With the same energy, a smaller rise means a larger c : $c = Q/(m \Delta T)$. [1]
10. **B.** $Q = 0.40 \times 4200 \times 5.0 = 8400 \text{ J}$. [1]
11. **C.** $E = Pt = 2000 \times 180 = 360\,000 \text{ J} = 360 \text{ kJ}$. [1]
12. **A.** The vacuum has no particles, so there is no conduction and no convection. [1]

Check and common mistakes. Question 4: using only the factor for the length gives 0.90 mm, only the factor for ΔT gives 1.2 mm; both factors multiply. Question 10: 84 000 J comes from a factor-ten slip ($\Delta T = 50 \text{ K}$). Question 11: 6.0 kJ comes from minutes not converted to seconds (2000×3.0).

II Alternative to practical

[24]

- (a) Independent variable: time t (heating time). Dependent variable: temperature T of the block. [2]
- (b) 300 s (the reading 40.0 °C). [1]
- (c) The reading is much lower than the straight-line trend: the temperature rises by about 8 °C every 100 s, but only 3.5 °C between 200 s and 300 s (then 12.5 °C). [1]
- (d) $E = Pt = 60 \times 500 = 30\,000 \text{ J}$. [1]
- (e) Axes labelled t / s (horizontal) and $T / ^\circ\text{C}$ (vertical); scales using more than half of the grid in both directions (for example 1 cm for 25 s and 1 cm for 2 °C), and a convenient, linear scale. [2]
- (f) Six points plotted correctly, each to within half a small square: 3 marks; 4–5 points correct: 2 marks; 2–3 points: 1 mark. [3]
- (g) One thin ruled straight line through the five consistent points, with points balanced above and below. The anomalous point at 300 s is not used. [2]
- (h) Triangle on the line, as large as possible. For example: $\Delta T = 56.6 - 28.3 = 28.3 ^\circ\text{C}$ and $\Delta t = 450 - 100 = 350 \text{ s}$, so gradient = $0.081 ^\circ\text{C/s}$ (accept 0.078 to 0.084). [2]
- (i) $Q = mc \Delta T$ and $E = Pt$. [1]
- (j) With no loss $Q = E$: $mc \Delta T = Pt$, so $\frac{\Delta T}{t} = \frac{P}{mc}$, and $\Delta T/t$ is the gradient. [1]

(k) $c = \frac{P}{m \times \text{gradient}}.$

⚙️ [1]

(l) $c = \frac{60}{0.80 \times 0.0807} = 930 \text{ J/(kg}^\circ\text{C)}$ (accept 890 to 960).

[2]

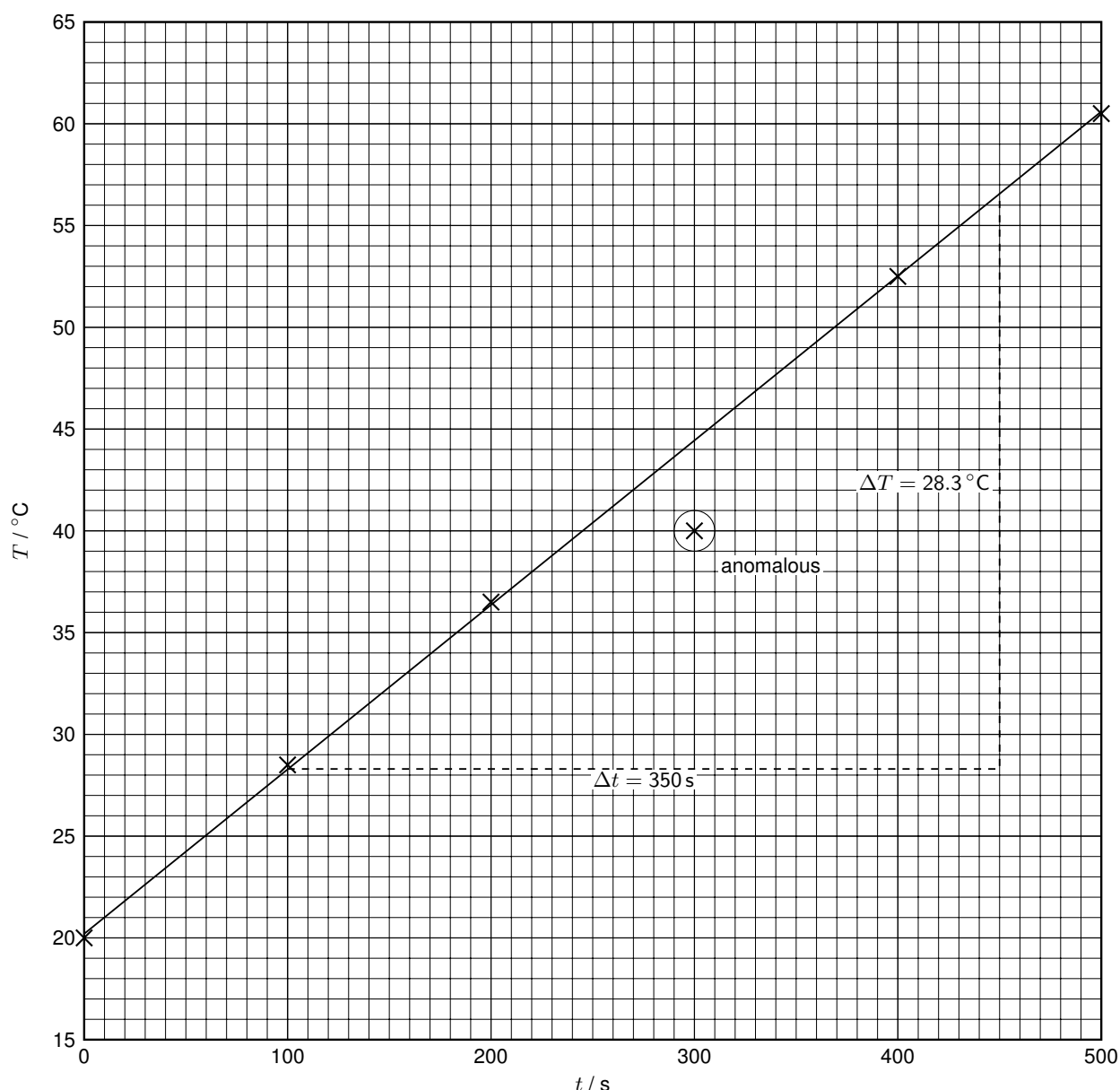
(m) Aluminium (900 J/(kg°C) is the closest value).

⚙️ [1]

(n) Some of the energy supplied is lost to the surroundings (and heats the thermometer and the oil). The temperature rises more slowly, so the gradient is smaller and the calculated c is larger. [1]

(o) Any one of: wrap the block in insulation; repeat the experiment and average; use a digital thermometer; take readings at shorter intervals. [1]

(p) $\Delta T = \frac{E}{mc} = \frac{30\,000}{0.80 \times 900} = 41.7^\circ\text{C} \approx 42^\circ\text{C}$. Measured rise: $60.5 - 20.0 = 40.5^\circ\text{C}$, slightly smaller than expected: some energy is lost. [2]

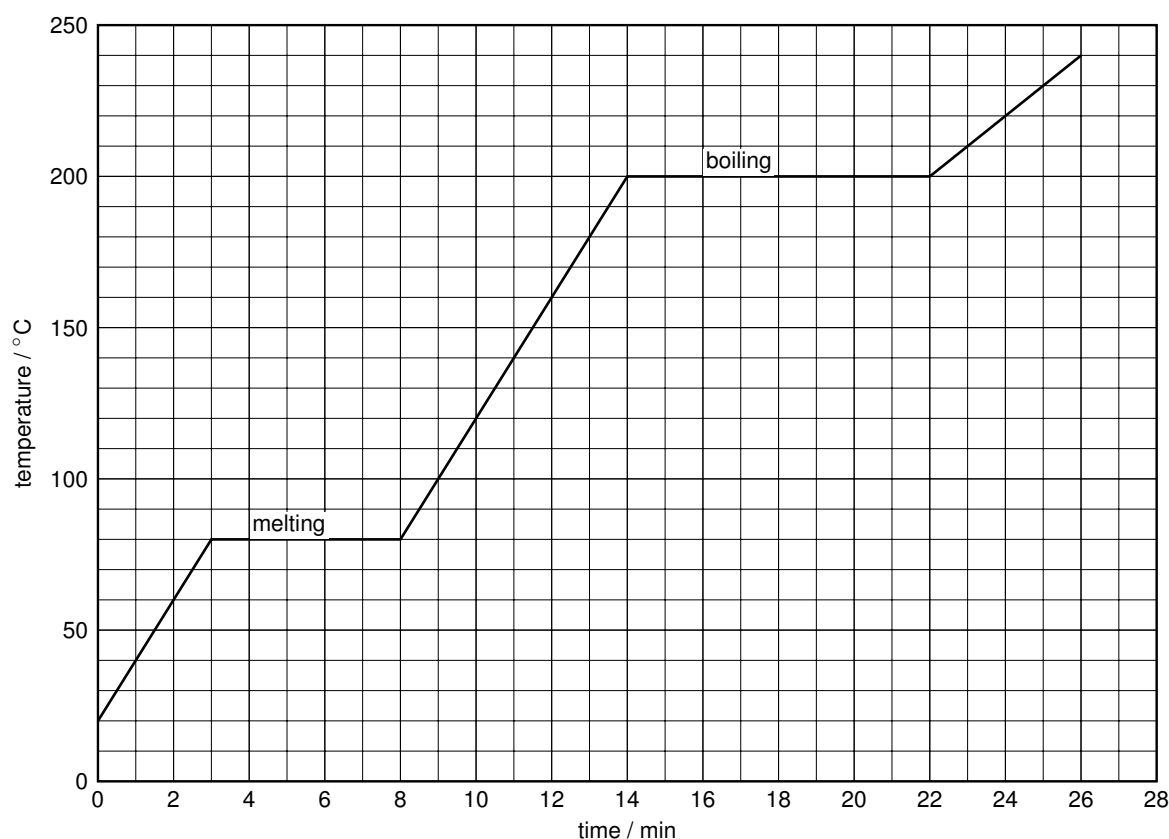


Check and common mistakes. Anomalous point included in the best-fit line (gradient 0.079°C/s , $c = 944 \text{ J/(kg}^\circ\text{C)}$, still aluminium but the line is wrong). Gradient taken from two close points around the anomaly $((40.0 - 36.5)/100 = 0.035^\circ\text{C/s})$: $c = 2140 \text{ J/(kg}^\circ\text{C)}$, which matches no metal in the table. Mass forgotten: $c = 60/0.0807 = 743$, which is the thermal capacity C in $\text{J/}^\circ\text{C}$, not c . Time kept in minutes while P is in watts: $c = 60/(0.80 \times 4.84) = 15.5$. Reasonableness: c must lie between 130 and 900 for the metals listed.

III Structured questions

[12]

1. (a) Solid: particles touching, in a regular pattern, vibrating about fixed positions. Liquid: particles touching but in a disordered arrangement. Gas: particles far apart, in random positions. One mark for each state. [3]
(b) The heated particles gain kinetic energy and move faster. They hit the walls more often and with a greater force. The volume is fixed, so the pressure rises. [2]
2. (a) Temperature rises, then a flat part (melting), rises again, then a second, higher flat part (boiling), and rises again. One mark for the rise before the first flat part; one for two flat parts with the lower one first; one for rises between and after them (graph below). [3]
(b) The energy supplied is used to overcome the forces between the particles, so that they leave their fixed positions. It does not increase their average kinetic energy, so the temperature stays constant. [2]
3. (a) Radiation. [1]
(b) Conduction. [1]



Check and common mistakes. Plateau drawn at the same temperature twice, or the boiling plateau below the melting one. Plateau sketched as a gentle slope. In (b) writing that the particles “stop moving” or that “the energy is lost”: the energy goes into the potential energy between particles. Reasonableness: the boiling point is higher than the melting point.

1. (a) $\Delta L = \alpha L_0 \Delta T$, where ΔL is the increase in length, α the linear expansion coefficient, L_0 the original length and ΔT the change in temperature.  [2]
 (b) $\Delta T = 35 - (-5) = 40^\circ\text{C}$; $\Delta L = 1.2 \times 10^{-5} \times 120 \times 40 = 0.0576 \text{ m} = 5.76 \text{ cm} \approx 5.8 \text{ cm}$. [2]
2. (a) $Q = mc \Delta T$.  [1]
 (b) $E = Pt$.  [1]
 (c) $Q = 2.0 \times 4200 \times 15 = 126\,000 \text{ J}$; $t = \frac{126\,000}{500} = 252 \text{ s} (\approx 4.2 \text{ min})$. [2]
3. (a) $Q = mc \Delta T$ and $E = Pt$; with $E = Q$: $t = \frac{mc \Delta T}{P}$.  [2]
 (b) $t = \frac{0.30 \times 4200 \times 15}{30} = \frac{18\,900}{30} = 630 \text{ s} = 10.5 \text{ min}$. [2]

Check and common mistakes. Problem 1: $\Delta T = 35 - 5 = 30^\circ\text{C}$ (sign of the negative temperature lost) gives 4.3 cm; the answer left in metres (0.058 m) when centimetres were asked. Problem 2: $\Delta T = 35^\circ\text{C}$ instead of 15°C gives 588 s. Problem 3: the time left in seconds (630) when minutes were asked; $\Delta T = 85^\circ\text{C}$ instead of 15°C gives 59.5 min. Reasonableness: a cup of tea cools by 15°C in about ten minutes; a 120 m bridge grows by a few centimetres.