

Heating, melting and boiling: energy calculations

Physics grades 9-10 (GCSE · IGCSE · O Level · Class 9-10) · Worksheet answers

Every answer shows the formula, the substitution and the result with its unit. Compare your method as well as your final number, because marks in examinations are awarded for each step. Small rounding differences in the last digit are acceptable.

Level: Physics grades 9-10 (GCSE · IGCSE · O Level · Class 9-10) · **Curriculum:** GCSE P3, IGCSE 2.2

Problem 1 Meaning of c

1. It is the energy needed to raise the temperature of 1 kg of a material by 1 °C.
2. The unit is **J/(kg °C)**. $\Delta\theta$ is the temperature change, final temperature minus initial temperature.

Problem 2 Warming a pan of water

1. 250 g = 0.25 kg
2. $\Delta E = m c \Delta\theta = 0.25 \times 4200 \times 12 = 12\,600 \text{ J} = \mathbf{12.6 \text{ kJ}}$

Problem 3 An aluminium pan

$$\Delta E = 2.0 \times 900 \times 30 = 54\,000 \text{ J} = \mathbf{5.4 \times 10^4 \text{ J}}$$

Problem 4 Melting ice

$$E = m L = 0.60 \times 334\,000 = 200\,400 \text{ J} = \mathbf{2.0 \times 10^5 \text{ J}} \text{ (2 s.f.)}$$

Problem 5 Reading a heating curve

1. B: ice melts at 0 °C. D: water boils at 100 °C. The temperature stays constant in both.
2. Boiling needs $2.26 \times 10^6 \text{ J/kg}$, about seven times the $3.34 \times 10^5 \text{ J/kg}$ for melting, and the energy arrives at the same rate, so it takes about seven times as long.
3. Only section **C** (0 °C to 100 °C).

Problem 6 A cooling copper block

$$\Delta\theta = 95 - 25 = 70 \text{ °C}$$

$$E = 0.80 \times 390 \times 70 = 21\,840 \text{ J} = \mathbf{2.2 \times 10^4 \text{ J}}$$

Problem 7 Finding the rise

$$\Delta\theta = E / (m c) = 63\,000 / (3.0 \times 4200) = 63\,000 / 12\,600 = \mathbf{5.0\,^{\circ}\text{C}}$$

Problem 8 Finding the mass

$$m = E / (c \Delta\theta) = 8400 / (4200 \times 4.0) = 8400 / 16\,800 = \mathbf{0.50\,kg}$$

Problem 9 Boiling dry

$$E = 0.25 \times 2\,260\,000 = 565\,000\,\text{J} = \mathbf{5.65 \times 10^5\,J}$$

Problem 10 Heater and time

- $\Delta E = 0.40 \times 4200 \times 30 = 50\,400\,\text{J}$
- $t = E / P = 50\,400 / 500 = 100.8\,\text{s} = \mathbf{101\,s}$ (3 s.f.)

Problem 11 Unknown metal

$$\Delta\theta = 50 - 18 = 32\,^{\circ}\text{C}$$

$$c = E / (m \Delta\theta) = 14\,400 / (0.50 \times 32) = 14\,400 / 16 = \mathbf{900\,J/(kg\,^{\circ}\text{C})}$$
, so the metal is aluminium.

Problem 12 Why the sand is hotter

Sea water has a high specific heat capacity, so the same solar energy raises its temperature only a little (and the water also mixes and spreads the energy downward). Sand has a much lower c , so its temperature rises quickly. The hot land warms the air above it, which rises, and cooler air flows in from the sea: a **sea breeze**.

Problem 13 Iron or copper?

- Iron: $9000 / (1.0 \times 450) = 20\,^{\circ}\text{C}$. Copper: $9000 / (1.0 \times 390) = 23.1\,^{\circ}\text{C}$.
- Copper**, because its specific heat capacity is smaller.

Problem 14 Kettle efficiency

- $E = P t = 2400 \times 170 = 408\,000\,\text{J}$
- $\Delta E = 1.0 \times 4200 \times 85 = 357\,000\,\text{J}$
- Efficiency = $357\,000 / 408\,000 = 0.875 = \mathbf{87.5\,\%}$

Problem 15 Spot the error

The student used the final temperature ($40\,^{\circ}\text{C}$) instead of the temperature change. $\Delta\theta = 40 - 15 = 25\,^{\circ}\text{C}$, so $Q = 0.4 \times 4200 \times 25 = \mathbf{42\,000\,J}$.

Problem 16 Ice to steam

Warm ice: $0.20 \times 2100 \times 10 = 4200 \text{ J}$

Melt: $0.20 \times 334\,000 = 66\,800 \text{ J}$

Warm water: $0.20 \times 4200 \times 100 = 84\,000 \text{ J}$

Boil: $0.20 \times 2\,260\,000 = 452\,000 \text{ J}$

Total = $4200 + 66\,800 + 84\,000 + 452\,000 = 607\,000 \text{ J} = \mathbf{6.07 \times 10^5 \text{ J}}$

Problem 17 Mixing hot and cool water

Energy lost by hot water = energy gained by cool water.

$$0.30 \times 4200 \times (80 - T) = 0.50 \times 4200 \times (T - 20)$$

$$0.30 (80 - T) = 0.50 (T - 20)$$

$$24 - 0.30 T = 0.50 T - 10$$

$$34 = 0.80 T, \text{ so } T = \mathbf{42.5 \text{ }^\circ\text{C}}$$

Problem 18 Ice in a drink

Ice melts: $0.030 \times 334\,000 = 10\,020 \text{ J}$. (Cooling the juice to $0 \text{ }^\circ\text{C}$ would release $25\,200 \text{ J}$, so all the ice melts.)

Juice loses: $0.25 \times 4200 \times (24 - T) = 1050 (24 - T)$

Melted ice then warms: $0.030 \times 4200 \times T = 126 T$

$$1050 (24 - T) = 10\,020 + 126 T \rightarrow 25\,200 - 1050 T = 10\,020 + 126 T$$

$$15\,180 = 1176 T, \text{ so } T = \mathbf{12.9 \text{ }^\circ\text{C}}$$

Problem 19 Wax from a heater trace

1. P lasts $10.2 - 3.0 = 7.2 \text{ min} = 432 \text{ s}$. $E = 250 \times 432 = 108\,000 \text{ J}$. $L = E / m = 108\,000 / 0.60 = \mathbf{1.8 \times 10^5 \text{ J/kg}}$.

2. Q: rise of $40 \text{ }^\circ\text{C}$ in $3.0 \text{ min} = 180 \text{ s}$, so $E = 250 \times 180 = 45\,000 \text{ J}$. $c = 45\,000 / (0.60 \times 40) = \mathbf{1875 \text{ J/(kg }^\circ\text{C)}}$ (about 1900).

Problem 20 A steam burn

1. Steam: condensing $0.010 \times 2\,260\,000 = 22\,600 \text{ J}$, then cooling $0.010 \times 4200 \times 60 = 2520 \text{ J}$, total $25\,120 \text{ J}$ ($\mathbf{2.5 \times 10^4 \text{ J}}$). Water: only 2520 J .

2. $25\,120 / 2520 \approx \mathbf{10 \text{ times}}$. Condensation releases a large amount of latent heat on top of the energy released by cooling.