Unit 11 · Quantity of Heat

HARDER PRACTICE QUESTIONS · ANSWER KEY

Full marks 28

Give the marks for the points in the marking scheme; an answer in other words that says the same is right.

1 Spot the error

ANSWER U · 3

He forgot the ice's **latent heat**: before it can warm up, the ice must take $0.10 \times 3.36 \times 10^5 = 33\,600$ J to melt.

$0.40 \times 4200 \times (50 - \theta) = 33\,600 + 0.10 \times 4200 \times \theta$, so $84\,000 - 1680\theta = 33\,600 + 420\theta$, and $\theta = 50\,400 \div 2100 =$ **24 °C**.

MARKING SCHEME

- ✓ The mistake: the latent heat of fusion is left out.
- ✓ The corrected equation with mL.
- ✓ $\theta = 24$ °C.

2 Predict, then explain

ANSWER A · 3

i. **0 °C**, all of it water.

ii. The warm water gives out $1 \times 4200 \times 80 = 336\,000$ J in cooling to 0 °C. Melting 1 kg of ice takes $1 \times 3.36 \times 10^5 = 336\,000$ J: exactly the same. So all the ice just melts, and everything ends as water at 0 °C.

MARKING SCHEME

- ✓ 0 °C.
- ✓ Heat from the water 336 000 J.
- ✓ Exactly the heat to melt the ice, so all water at 0 °C.

3 Read the data

ANSWER HA · 5

i. 60.0, 40.0, 26.7, 17.8 °C.

ii. $40.0 \div 60.0 = 0.667$; $26.7 \div 40.0 = 0.667$; $17.8 \div 26.7 = 0.667$: the same fraction, ⅔, each time, as Newton's law of cooling predicts.

iii. Excess $17.8 \times ⅔ = 11.9$ °C, so about **31.9 °C**.

iv. The rate of cooling is proportional to the excess temperature, so it slows down as the tea nears the room's temperature: it never cooled by 20 °C again, and in theory never quite reaches 20 °C.

MARKING SCHEME

- ✓ The excesses 60.0, 40.0, 26.7, 17.8 °C.
- ✓ Each ratio ⅔.
- ✓ About 31.9 °C at 20 minutes.
- ✓ He is wrong: the rate falls with the excess.
- ✓ So the tea approaches room temperature more and more slowly.

4 Show that

ANSWER A · 3

With no heat lost, heat lost by the hotter one = heat gained by the colder one, or (taking θ_1 hotter)

$ms_1(\theta_1 - \theta) = ms_2(\theta - \theta_2)$. The m cancels: $s_1\theta_1 + s_2\theta_2 = (s_1 + s_2)\theta$, so $\theta = \dfrac{s_1\theta_1 + s_2\theta_2}{s_1 + s_2}$.

For the same liquid, $s_1 = s_2$, and $\theta = (\theta_1 + \theta_2)/2$, the average.

MARKING SCHEME

- ✓ Heat lost = heat gained, $ms_1(\theta_1 - \theta) = ms_2(\theta - \theta_2)$.
- ✓ $\theta = (s_1\theta_1 + s_2\theta_2)/(s_1 + s_2)$.
- ✓ The average when $s_1 = s_2$.

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5 Read the phase diagram

ANSWER U · 3

0.006 atm is the pressure of water's triple point. Below it, the phase diagram has no liquid region: the only boundary is the sublimation curve between solid and vapour. So, as the frozen food is warmed gently at that low pressure, its ice turns straight into vapour (it sublimes) without becoming water, and the vapour is pumped away, leaving the food dry.

MARKING SCHEME

- ✓ Below the triple point's pressure there is no liquid phase.
- ✓ The ice sublimes straight into vapour.
- ✓ The vapour is removed, so the food dries without melting.

6 Estimate it

ANSWER A · 3

Heat taken: $1 \times 2.26 \times 10^6 = 2.26 \times 10^6$ J in 3600 s.
Rate $= 2.26 \times 10^6 \div 3600 \approx$ **630 W**: why sweating cools so well.

MARKING SCHEME

- ✓ $Q = mL = 2.26 \times 10^6$ J.
- ✓ Divided by 3600 s.
- ✓ About 630 W.

7 Correct the misconceptions

ANSWER U · 3

1. While it boils at a given pressure, the water stays at its boiling point (100 °C at standard pressure); more heat only makes it boil away faster.
2. Water evaporates at any temperature, from its surface (wet clothes dry at room temperature); 100 °C is its boiling point.
3. Specific heat capacity belongs to the substance, so both are the same, 4200 J/(kg K); their heat capacities (ms) differ.

MARKING SCHEME

- ✓ The temperature stays at the boiling point while boiling.
- ✓ Evaporation happens at any temperature.
- ✓ Same specific heat capacity; different heat capacities.

8 Think

ANSWER HA · 3

Pressure lowers the melting point of ice, because ice contracts on melting. Ice near 0 °C, pressed hard where the cubes touch, is then above its new melting point, so a little melts; when the pressure is released, the melting point returns to 0 °C and the film of water freezes again, joining them (regelation).
But pressure lowers the melting point only slightly, about 0.0075 °C per atmosphere: 100 atmospheres lower it by less than 1 °C. To melt ice at −20 °C would need thousands of atmospheres, far more than hands can press, so nothing melts.

MARKING SCHEME

- ✓ Pressure lowers ice's melting point, so ice near 0 °C melts where pressed.
- ✓ The water refreezes when the pressure is released (regelation).
- ✓ The lowering is tiny (about 0.0075 °C per atm), so ice at −20 °C can't be melted by hand pressure.

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9 Make your own

HA · 2

ANSWER

Heat lost by the hot = heat gained by the cold: $m_h \times 30 = m_c \times 25$, with $m_h + m_c = 20$ L. So $m_h = 20 \times 25 \div 55 =$ **9.1 L hot** and **10.9 L cold**. Check: $9.1 \times 30 = 273$ and $10.9 \times 25 = 273$.

MARKING SCHEME

- ✓ $m_h(70 - 40) = m_c(40 - 15)$ with $m_h + m_c = 20$.
- ✓ 9.1 L and 10.9 L, checked.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	0	9	9	10	**28**

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