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

1 Too much steam

ANSWER A · 4

The most the water can take is by warming all the way to 100 °C: 0.2 × 4,200 × 80 = 67,200 J.
All the steam condensing would give 0.05 × 2,260,000 = 113,000 J, more than that. So not all of it condenses, and the mixture ends at **100 °C**.
Steam condensed: m = Q/L = 67,200 ÷ 2,260,000 = 0.0297 kg = 29.7 g. Left as steam: 50 − 29.7 = **about 20 g**.

MARKING SCHEME

- ✓ The water can take at most 67,200 J.
- ✓ All the steam would give 113,000 J, so not all condenses and the final temperature is 100 °C.
- ✓ 67,200 ÷ 2,260,000 = 29.7 g condenses.
- ✓ About 20 g stays as steam.

2 Spot the error

ANSWER U · 4

His equation assumes that all the ice melts, and an answer outside the range of the starting temperatures shows that it doesn't. The water can give at most 0.2 × 4,200 × 10 = 8,400 J by cooling to 0 °C, and melting all the ice needs 33,600 J.
So the mixture ends at **0 °C**. Ice melted: 8,400 ÷ 336,000 = 0.025 kg = 25 g. **75 g of ice is left**, with 225 g of water.

MARKING SCHEME

- ✓ The equation assumes all the ice melts; a final temperature must lie between the starting temperatures.
- ✓ The water can give only 8,400 J, less than the 33,600 J needed.
- ✓ The final temperature is 0 °C.
- ✓ 25 g melts, leaving 75 g of ice.

3 Read the curve

ANSWER HA · 5

(The readings are made up, to fit lead's latent heat of fusion in the unit's table.)

i. The temperature stays at **327 °C** from 7 s to 53 s.
ii. Melting takes 53 − 7 = 46 s, so Q = Pt = 500 × 46 = 23,000 J, and L = Q/m = **23,000 J/kg**: lead.
iii. In the first 7 s: 500 × 7 = 3,500 J raises it by 27 °C, so s = 3,500 ÷ (1 × 27) ≈ **130 J/(kg °C)**.
iv. The solid rises 27 °C in 7 s (3.9 °C/s); the liquid 18 °C in 5 s (3.6 °C/s). The solid warms faster, so its specific heat capacity is smaller than the liquid's (the same power warms the one with the smaller s faster).

MARKING SCHEME

- ✓ Melting point 327 °C.
- ✓ Q = 500 × 46 = 23,000 J in the flat part.
- ✓ L = 23,000 J/kg, so lead.
- ✓ s = 3,500 ÷ 27 ≈ 130 J/(kg °C).
- ✓ The solid warms faster, so it has the smaller specific heat capacity.

4 Snow for tea

ANSWER

i. Warm the snow: 2 × 2,100 × 10 = 42,000 J. Melt it: 2 × 336,000 = 672,000 J. Warm the water: 2 × 4,200 × 85 = 714,000 J. Total 1,428,000 J, and t = Q/P = 1,428,000 ÷ 1,200 = 1,190 s, about **20 minutes**.

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ii. Warming the water takes the longest (595 s), but melting (560 s) is close behind, though the temperature doesn't change at all during it. Warming the snow takes only 35 s. **A · 4**

MARKING SCHEME

- ✓ 42,000 J to warm the snow, and 672,000 J to melt it.
- ✓ 714,000 J to warm the water; total 1,428,000 J.
- ✓ t = 1,190 s, about 20 minutes.
- ✓ Warming the water takes longest, 595 s, with melting close behind at 560 s.

5 Two days, two readings

MARKING SCHEME **U · 3**

- ✓ Day B: the small difference between the readings means little evaporation, so humid air.
- ✓ On Day A evaporation is fast, keeping the wet bulb 8 °C cooler.
- ✓ Clothes and the *matka* both do better on Day A.

6 Fair test

ANSWER **A · 4**

i. She changes the vessel; she measures the temperature of the water in each, every hour for some hours.

ii. Any three: the same amount of water; the same starting temperature; the same place, in shade, side by side (same air and breeze); the same thermometer; the same size of vessel.

iii. Repeat on several days, and take the average; swap the places of the two vessels.

iv. The water in the *matka* is cooler. Water seeps through the clay and evaporates from the outside, and evaporation takes heat from what is left. The steel vessel has no seeping water.

MARKING SCHEME

- ✓ Changes the vessel; measures the water's temperature over time.
- ✓ Any three things kept the same.
- ✓ Repeats and averages.
- ✓ The *matka*'s water cooler, because water seeping through evaporates from the outside.

7 Plan for it

ANSWER **A · 4**

i. 12 mm per km per °C × 0.25 km × 40 °C = **120 mm**.

ii. **Nearly closed.** The gaps of an expansion joint close in summer and open in winter. On the hottest day the bridge is at its longest, so it won't grow more; as it cools it shrinks by up to 120 mm, opening the gap.

iii. About **0.2%**: a plate that grows by 1% each way grows by about 2% in area, so 0.1% each way gives about 0.2%.

MARKING SCHEME

- ✓ 0.25 km and a 40 °C change used.
- ✓ 120 mm.
- ✓ Nearly closed at the hottest, longest moment, opening as it cools.
- ✓ About 0.2%.

8 Find the unknown

ANSWER **A · 3**

Heat gained by the water and the calorimeter: $(0.3 \times 4{,}200 + 0.1 \times 385) \times 5 = 1{,}298.5 \times 5 = 6{,}492.5$ J.
Heat lost by the metal: $0.2 \times s \times (100 - 25) = 15s$.
So $s = 6{,}492.5 \div 15 \approx$ **433 J/(kg °C)**.

MARKING SCHEME

- ✓ Heat gained, including the calorimeter: 6,492.5 J.
- ✓ Heat lost = $0.2 \times s \times 75 = 15s$.
- ✓ $s \approx 433$ J/(kg °C).

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9 Predict, then explain

MARKING SCHEME U · 3

- ✓ Heated: down, with the brass (which grows more) on the outside.
- ✓ Cooled: up, with the iron on the outside.
- ✓ Same metals: it stays straight, since the bending needs a difference in expansion.

10 How much sweat?

ANSWER A · 3

i. $Q = 400 \times 3{,}600 = 1{,}440{,}000$ J, and $m = Q/L = 1{,}440{,}000 \div 2{,}400{,}000 =$ **0.6 kg**.

ii. Only the evaporated half cools him, so he must sweat twice as much: **1.2 kg**, which he must drink back. (Sweat that drips off cools him hardly at all.)

MARKING SCHEME

- ✓ $Q = 1{,}440{,}000$ J in an hour.
- ✓ $m = 0.6$ kg.
- ✓ 1.2 kg, since only the sweat that evaporates cools him.

11 Correct the misconceptions

ANSWER U · 3

1. While water boils, its temperature stays at the boiling point: the extra heat only makes it boil away faster.
2. Blowing doesn't produce cold: it carries the vapor away, more water evaporates, and evaporation takes heat from the tea.
3. Evaporation happens only at the surface, so the wide dish evaporates faster.

MARKING SCHEME

- ✓ The temperature stays at the boiling point during boiling.
- ✓ Evaporation takes heat away; blowing speeds it up by carrying vapor away.
- ✓ A wider surface evaporates faster.

12 Think

ANSWER HA · 3

a. The snow would melt far faster on the first warm days, since each kilogram would need only 33,600 J; rivers would rise in sudden floods, not steadily through spring and summer.

b. The ice would cool the juice much less, and melt quickly: nearly all of its cooling would come from warming up, like cold water (in the unit's Example 5, about 16,800 J of cooling would fall to 1,680 J).

c. It would freeze faster: each kilogram of water would give out far less heat as it froze, so less heat would slow the cooling.

MARKING SCHEME

- ✓ Snow melts faster, with sudden floods.
- ✓ Ice cools a drink much less.
- ✓ Lakes freeze faster, as less heat is given out in freezing.

13 Make your own

ANSWER HA · 2

The water's heat must equal the ice's latent heat: $m(\text{water}) \times 4{,}200 \times T = m(\text{ice}) \times 336{,}000$, so $m(\text{water}) \times T = 80 \times m(\text{ice})$. For example, 100 g of ice and 400 g of water at 20 °C: $0.4 \times 4{,}200 \times 20 = 33{,}600$ J and $0.1 \times 336{,}000 = 33{,}600$ J.

MARKING SCHEME

- ✓ $m(\text{water}) \times 4{,}200 \times T = m(\text{ice}) \times 336{,}000$ written.
- ✓ Numbers that fit, shown by working out both sides.

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See it at Science Playground

Exhibits and plants at the center, Bhaktapur, that go with this unit. Book a class visit at science-playground.com/booking.

- **Galileo Thermometer** (exhibit): As the liquid warms it expands and becomes less dense, so the bulbs sink one by one: thermal expansion read as a temperature.
- **Lava Lamp — Convection in Motion** (exhibit): Heated at the bottom, the wax expands and its density falls, so it rises; cooled at the top, it contracts and sinks again.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	0	13	22	10	**45**