



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

1 Key words

1. total
2. temperature
3. heat
4. thermal equilibrium
5. specific heat capacity
6. 4 °C
7. anomalous expansion
8. calibration

K • 4

Each carries 0.5 mark.

2 Label the diagram

- | | |
|----------------------|--------------|
| 1. capillary tube | 6. 212 °F |
| 2. thread of mercury | 7. 373 K |
| 3. bulb | 8. 180 parts |
| 4. 100 °C | 9. 32 °F |
| 5. 0 °C | 10. 273 K |

K • 5

Each carries 0.5 mark.

3 Multiple choice

- i. **d. the energy transferred because of a difference in the average kinetic energy of molecules**

K • 1

Heat is energy on the move, flowing because of a temperature difference (a difference in the average kinetic energy of the molecules). The total kinetic energy is thermal energy; the average is what temperature measures.

- ii. **b. the pool, because it has vastly more molecules**

U • 1

The teaspoon has the higher **temperature** (faster molecules on average), but the pool has millions of times as many molecules, so its **total kinetic energy** is much bigger. Temperature and thermal energy are not the same thing.

- iii. **d. the nature of the substance**

U • 1

It is defined for 1 kg and a 1 °C change, so mass and volume don't matter. It is a property of the substance.

- iv. **d. in coastal areas, the land cools faster than the sea at night**

A • 1

Water needs a lot of heat to change its temperature, so the sea heats and cools more slowly than the land. The first three say the opposite.

- v. **d. cool the wider pipe and heat the narrower one**

A • 1

The pipe that goes **inside** must shrink, so cool it; the pipe that goes **outside** must open up, so heat it. Here the wide pipe goes inside the narrow one, so cool the wide pipe and heat the narrow one. When both return to the same temperature, they grip each other very tightly. (This is called a shrink fit.)

4 Very short answers

- a. **MARKING SCHEME**

K • 1

✓ J/kg °C (or J/kg K) written.



- b. MARKING SCHEME A · 1
✓ 300 K worked out.
- c. MARKING SCHEME U · 1
✓ To bring the mercury held above the kink back into the bulb.

5 Short answers

- a. MARKING SCHEME U · 2
✓ Water expands when cooled below 4 °C, and expands about 9% more when it freezes into ice (anomalous expansion).
✓ The full pipe has no room, so the water and ice push on its walls with a large pressure and crack it.
- b. MARKING SCHEME A · 2
✓ Water has a high specific heat capacity (4,200 J/kg °C).
✓ So it takes in a lot of heat from the engine with only a small rise in its own temperature, and gives it off to the air in the radiator.
- c. MARKING SCHEME U · 2
✓ Any one difference, e.g. heat is energy transferred because of a temperature difference; temperature measures the average kinetic energy of the molecules.
✓ Any second difference, e.g. heat is measured in joules (J) with a calorimeter; temperature in kelvin or °C with a thermometer.

6 Long answer

ANSWER

A · 4

- The anomalous expansion of water.
- From 0 °C to 4 °C the volume decreases; from 4 °C to 10 °C it increases. It is smallest at 4 °C.
- At 4 °C, because density = mass ÷ volume and the volume is smallest there.
- Water at 4 °C, the densest, stays at the bottom; colder water stays on top and freezes into ice, which floats and keeps the cold out, so the water below stays liquid at about 4 °C.

MARKING SCHEME

- ✓ i. Anomalous expansion of water.
- ✓ ii. Volume decreases from 0 °C to 4 °C and increases from 4 °C to 10 °C.
- ✓ iii. At 4 °C, where the volume is smallest (density = mass ÷ volume).
- ✓ iv. The lake freezes from the top: ice floats and insulates, and the densest water, at 4 °C, stays liquid at the bottom.

7 Numerical problems

- a. ANSWER A · 2

$$m = 500 \text{ g} = 0.5 \text{ kg}, s = 4,200 \text{ J/kg } ^\circ\text{C}, T_1 = 15 ^\circ\text{C}, T_2 = 85 ^\circ\text{C}$$

$$Q = ms(T_2 - T_1) = 0.5 \times 4200 \times (85 - 15) = 0.5 \times 4200 \times 70 = 147,000 \text{ J}$$

$$Q = 147,000 \text{ J} = 147 \text{ kJ.}$$

MARKING SCHEME

- ✓ $Q = ms(T_2 - T_1)$ with $m = 0.5 \text{ kg}$ and the rise $70 ^\circ\text{C}$ put in.
- ✓ $Q = 147,000 \text{ J}$ (147 kJ).



b. ANSWER

A · 4

Let the final temperature be T . Both are water, so s cancels.

Heat lost by the hot water = heat gained by the cold water:

$$4 \times s \times (80 - T) = 16 \times s \times (T - 25)$$

$$320 - 4T = 16T - 400$$

$$720 = 20T, \text{ so } T = 36^\circ\text{C}$$

The mixture is at 36°C . Check: it lies between 25°C and 80°C , closer to 25°C because there is more cold water.

MARKING SCHEME

- ✓ Heat lost by hot water = heat gained by cold water (principle of calorimetry) written.
- ✓ $4 \times s \times (80 - T) = 16 \times s \times (T - 25)$, with s the same for both.
- ✓ $320 - 4T = 16T - 400$, so $20T = 720$.
- ✓ $T = 36^\circ\text{C}$.

8 Think**ANSWER**

HA · 2

The coldest water would always sink, so the lake would cool right down to 0°C everywhere, and ice would form at the **bottom**, where the sun's warmth can't reach it in summer. Year after year more ice would pile up, until whole lakes and seas froze solid. Life in water as we know it might never have survived the Ice Ages. A small oddity of water makes a very big difference.

MARKING SCHEME

- ✓ The coldest water would sink, so the whole lake would cool to 0°C and ice would form at the bottom, out of the sun's reach.
- ✓ Ice would build up year after year until lakes froze solid, and the fish and plants in them would die.

9 Activity: Which heats faster in the sun?

(not marked)

WHAT STUDENTS SHOULD FIND

The steel plate, the plastic chair (to the touch), the dry sand and the steel vessel get hotter. A substance with a small specific heat capacity needs little heat to warm up, and a good conductor such as steel passes its heat quickly to the hand. Wet soil stays cool because water needs a lot of heat to warm up.

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.

- **Which Feels Cooler?** (exhibit): Two materials at one temperature feel different: skin senses heat flow, not temperature.
- **Galileo Thermometer** (exhibit): As the liquid warms it expands and thins, and the bulbs sink one by one: read the lowest.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	11	7	15	2	35

