

3.3 Specific heat capacity and temperature changes

Name: _____ Class: _____ Date: _____

Total: 24 marks**KEY WORDS** specific heat capacity

Objective

Consolidate $\Delta E = mc\Delta\theta$ from the particle view and read temperature data from graphs and tables. Original questions consolidating spec statement 4.3.2.2 (the RP1 practical itself is on sheet 1.3).

1 Key knowledge and worked examples

$$\Delta E = m c \Delta\theta$$

Symbol	Meaning	Unit
ΔE	energy transferred to the thermal store	J
m	mass	kg
c	specific heat capacity	J/kg °C
$\Delta\theta$	temperature change	°C

From the particle view: c measures how much energy the particles store per kilogram for each degree of temperature rise. Water's large c (4200 J/kg °C) means its particles take a lot of energy to speed up – hence kettles are the most powerful appliance in a home.

Facts that earn quick marks:

- $\Delta\theta$ is a **difference** – subtract the two readings, never insert an absolute temperature.
- The temperature rise depends on the **mass**, the **material** and the **energy input** – the three factors the spec names.
- Equal masses, equal energy: the smaller c , the bigger the temperature rise.

Worked example. A 0.20 kg aluminium heating pad ($c = 900$ J/kg °C) receives 3240 J. Find the temperature rise.

$$\Delta\theta = \frac{\Delta E}{mc} = \frac{3240 \text{ J}}{0.20 \text{ kg} \times 900 \text{ J/kg °C}} = 18 \text{ °C}$$

Worked example (comparison with graph data). A heater supplies 9000 J to 0.50 kg of a liquid; its graph shows a rise from 22 °C to 40 °C.

$$c = \frac{9000}{0.50 \times 18} = 1000 \text{ J/kg } ^\circ\text{C}$$

- If a second liquid, same mass and energy, rose further, its c is smaller – check such comparisons against the numbers, not the picture alone.

2 Practice

2.1 0.030 kg of olive oil ($c = 1800 \text{ J/kg } ^\circ\text{C}$) warms from 21 °C to 96 °C. Calculate the energy transferred. [3]

2.2 6300 J raises 0.25 kg of oil by 15 °C. Calculate c . [2]

2.3 Equal masses of water ($c = 4200$) and copper ($c = 385$) each receive the same energy. State which rises in temperature more, and by roughly what factor. [2]

3 Exam-style questions

3.1 A hand warmer's pad has mass 0.20 kg and $c = 900\text{ J/kg }^{\circ}\text{C}$. When switched on it warms from $22\text{ }^{\circ}\text{C}$ to $46\text{ }^{\circ}\text{C}$.

(a) Calculate the energy transferred to the pad. [3]

(b) The pad is replaced by one with the same mass but a larger specific heat capacity. State and explain the change in temperature rise for the same energy. [2]

3.2 A student plots temperature against energy supplied for 0.50 kg of a liquid. The graph is a straight line rising $9\text{ }^{\circ}\text{C}$ for every 4500 J .

(a) Use the gradient to calculate the liquid's specific heat capacity. [3]

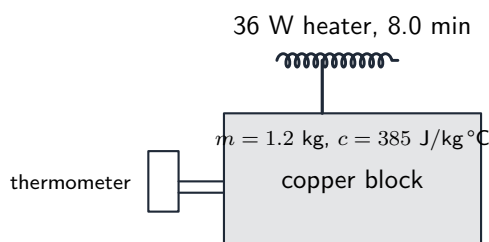
(b) State two factors, other than the material, that the temperature rise depends on. [2]

3.3 A heater of power 36 W runs for 8.0 minutes inside a 1.2 kg copper block ($c = 385\text{ J/kg }^{\circ}\text{C}$). The block warms from $21\text{ }^{\circ}\text{C}$ to $37\text{ }^{\circ}\text{C}$.

(a) Calculate the energy supplied by the heater. [3]

(b) Calculate the energy that raised the block's thermal store. [2]

(c) A reactor has a heat-absorbing pad. Explain how a high specific heat capacity helps limit its temperature rise for a given absorbed energy and pad mass. [2]



Solutions

2.1 Temperature change: $96 - 21 = 75\text{ }^{\circ}\text{C}$ (C1).

$$\Delta E = mc\Delta\theta = 0.030 \times 1800 \times 75 = \mathbf{4050\text{ J}}$$

(substitution C1, answer A1.)

2.2

$$c = \frac{\Delta E}{m\Delta\theta} = \frac{6300}{0.25 \times 15} = \mathbf{1700\text{ J/kg }^{\circ}\text{C}} \text{ (2 s.f.)}$$

(rearrangement 1, answer with unit 1.)

2.3 Copper rises more: for the same energy and mass, $\Delta\theta \propto 1/c$, so water's rise is about $385/4200 \approx 1/11$ of copper's – copper rises about **11 times** more.

3.1 (a) $\Delta\theta = 46 - 22 = 24\text{ }^{\circ}\text{C}$ (C1).

$$\Delta E = 0.20 \times 900 \times 24 = \mathbf{4320\text{ J}}$$

(C1, A1.) (b) The temperature rise is smaller: with a larger c , the same energy spread over more joules per degree gives fewer degrees of rise – $\Delta\theta = \Delta E/(mc)$.

3.2 (a) The gradient gives $\Delta E/\Delta\theta = 4500/9 = 500\text{ J/}^{\circ}\text{C}$ (C1); with $m = 0.50\text{ kg}$:

$$c = \frac{4500}{0.50 \times 9} = \mathbf{1000\text{ J/kg }^{\circ}\text{C}}$$

(C1, A1.) (b) Any two: the mass heated; the energy input (or power and time).

3.3 (a) Convert time: $8.0\text{ min} = 480\text{ s}$ (C1).

$$E = Pt = 36 \times 480 = \mathbf{17\,280\text{ J}}$$

(C1, A1.) (b)

$$\Delta E = mc\Delta\theta = 1.2 \times 385 \times 16 = \mathbf{7392\text{ J}} \approx 7400\text{ J}$$

(temperature change 1, answer 1.) (c) A high c means each kilogram absorbs a lot of energy for each degree of rise, so for the same absorbed energy and mass the pad has a smaller temperature rise. This limits heating but does not guarantee a safe temperature for an unlimited energy input.