Temperature changes in a system and specific heat capacity

6.3.2.2 · Physics · revision notes

Specific heat capacity tells you how much energy is needed to raise the temperature of 1 kg of a material by 1 °C. You need to define it and use $\Delta E = m\,c\,\Delta\theta$, which is on the Physics equation sheet. Expect 2 to 4 mark calculations, often with a rearrangement, unit conversions or a link to power, plus explanations of why one material heats up faster than another.

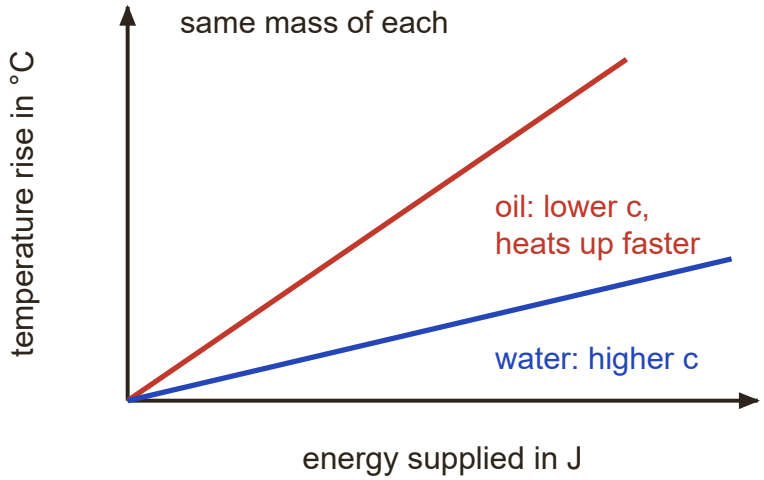
Key facts

- $\Delta E = m\,c\,\Delta\theta$ (on the equation sheet)
- Specific heat capacity: energy to raise the temperature of 1 kg by 1 °C
- $c = \Delta E \div (m \times \Delta\theta)$
- High c: more energy needed per °C, so it heats up and cools down more slowly
- ΔE in J, m in kg, c in J/kg °C, $\Delta\theta$ in °C
- $\Delta\theta$ = final temperature − starting temperature
- Energy from a heater: $E = P\,t$ (P in W, t in s)
- Grade 7+ only A measured c is usually too high: energy is transferred to the surroundings

Notes

What specific heat capacity means

- When you heat a substance without changing its state, its temperature rise depends on the **mass** heated, the **type of material** and the **energy** supplied.
- The **specific heat capacity** (c) of a substance is the amount of energy needed to raise the temperature of **1 kg** of the substance by **1 °C**.
- Its unit is J/kg °C. Water has a high specific heat capacity (about 4200 J/kg °C); metals such as copper and aluminium have much lower values.
- A material with a high specific heat capacity needs more energy for each °C rise, so with the same heating it warms up more slowly. It also transfers more energy to the surroundings for each °C that it cools.



Same mass, same energy: the lower the specific heat capacity, the bigger the temperature rise.

The equation

- change in thermal energy = mass × specific heat capacity × temperature change: **ΔE = m c Δθ** (on the equation sheet).
- ΔE in joules (J), m in kilograms (kg), c in J/kg °C, Δθ in degrees Celsius (°C).
- Δθ is a **change**: a rise from 15 °C to 40 °C is Δθ = 25 °C.
- Rearranged: c = ΔE ÷ (m Δθ); m = ΔE ÷ (c Δθ); Δθ = ΔE ÷ (m c).
- Convert first: grams to kg (÷ 1000) and kJ to J (× 1000).
- The same equation gives the energy transferred away when an object cools down.

Finding c by experiment

- The required practical to measure specific heat capacity is in the Energy topic: you heat a block of known mass with an electric heater and record its temperature rise.
- Energy supplied: read it from a joulemeter, or use E = P t (P = power in W, t = time in s).
- Then calculate c = E ÷ (m Δθ).
- Your value is usually **higher** than the true value. Some energy is transferred to the surroundings instead of the block, so the temperature rise is smaller than it should be. Insulating the block reduces this.

Grade 7+ only

How to answer each type of question

Calculate the energy needed to heat something

2 to 3 marks | Grade 5

1. Choose ΔE = m c Δθ from the equation sheet.
2. Work out Δθ = final − starting temperature, and make sure the mass is in kg.
3. Substitute, calculate and give the unit (J).

Example. An electric kettle heats 0.80 kg of water from 20 °C to 100 °C.
specific heat capacity of water = 4200 J/kg °C
Calculate the energy transferred to the water.

Model answer.

Δθ = 100 − 20 = 80 °C (1)
ΔE = 0.80 × 4200 × 80 (1)
ΔE = 268 800 J (1)

Rearrange to find a temperature change or a mass

3 marks | Grade 5

1. Convert the mass to kg.
2. Substitute into ΔE = m c Δθ, then rearrange for the unknown.
3. Calculate and round as the question asks.

Example. A 450 g copper block is heated. 6000 J of energy is transferred to the block.
specific heat capacity of copper = 385 J/kg °C
Calculate the temperature rise of the block. Give your answer to 2 significant figures.

Model answer.

6000 = 0.450 × 385 × Δθ (1)
Δθ = 6000 ÷ (0.450 × 385) (1)
Δθ = 35 °C (1)

Calculate c from experimental data

4 to 6 marks | Grade 7

1. Find the energy supplied: E = P t, with the time in seconds.
2. Find Δθ from the starting and final temperatures.
3. Calculate c = E ÷ (m Δθ) and give the unit J/kg °C.
4. If asked about accuracy, explain the effect of energy transferred to the surroundings.

Example. A student heats a 1.0 kg aluminium block with a 50 W heater for 10 minutes. The temperature of the block rises from 20.0 °C to 52.0 °C.
(a) Calculate the specific heat capacity of aluminium given by these results. Give your answer to 2 significant figures. (4 marks)
(b) The accepted value is 900 J/kg °C. Explain why the student's value is higher than this. (2 marks)

Model answer.

(a) E = 50 × 600 = 30 000 J (1)
Δθ = 52.0 − 20.0 = 32.0 °C (1)
c = 30 000 ÷ (1.0 × 32.0) (1)
c = 937.5 = 940 J/kg °C (to 2 s.f.) (1)
(b) Some of the energy from the heater is transferred to the surroundings, not to the block (1).
So the temperature rise is smaller than it would otherwise be, which makes the calculated value of c too large (1).

Explain why one material heats up more than another

2 marks | Grade 6

1. Say what is the same (the energy supplied and the mass).
2. Compare the specific heat capacities: the lower one needs less energy for each kg to rise by 1 °C.

Example. Equal masses of water and cooking oil are heated by identical heaters for the same time. The temperature of the oil rises more than the temperature of the water.
Explain why.

Model answer. Both liquids have the same mass and receive the same amount of energy (1). The oil has a lower specific heat capacity, so less energy is needed to raise the temperature of each kilogram by 1 °C (1).

Don’t lose marks

- Using the final temperature instead of the temperature change for Δθ.
- Leaving the mass in grams, which makes the answer 1000 times out.
- Leaving the time in minutes when using E = P t.
- Using ΔE = m c Δθ during a change of state. The temperature does not change then: use E = m L instead.
- Rearranging wrongly, e.g. c = ΔE × m ÷ Δθ. You must divide by both m and Δθ.

More tips

Memory tricks

- Both Δs in ΔE = m c Δθ stand for 'change': a change in energy and a change in temperature.
- Sense check with water: about 4200 J warms 1 kg by 1 °C, so heating 1 kg of water by 80 °C needs roughly 340 000 J.
- Double the mass or double the temperature rise and you double the energy needed.
- The unit J/kg °C reminds you of the rearrangement: c = joules ÷ (kg × °C).
- Calculator tip: for c = ΔE ÷ (m Δθ), put brackets round m × Δθ, or divide twice: ΔE ÷ m ÷ Δθ.

Exam technique

- The equation is on the equation sheet, but you must choose it and know what each symbol means.
- Always write the substitution line with numbers: it usually earns a mark even if the final answer goes wrong.
- Give J/kg °C as the unit of specific heat capacity, and round to the significant figures asked for.
- In practical questions, describe the error precisely: energy is transferred to the surroundings (so the measured temperature rise is too small).

What each grade needs

What you need to be able to do, from the first marks up to the top grade.

Grade 4 — **Define specific heat capacity**
The amount of energy needed to raise the temperature of 1 kg of a substance by 1 °C.

Grade 4 — **Substitute into ΔE = m c Δθ**
Calculate the change in thermal energy with m in kg, c in J/kg °C and Δθ in °C.

Grade 5 — **Work out the temperature change Δθ**
Δθ is the difference between the final and starting temperatures, not the final temperature.

Grade 5 — **Rearrange to find c, m or Δθ**
Use c = ΔE ÷ (m Δθ), m = ΔE ÷ (c Δθ) or Δθ = ΔE ÷ (m c).

Grade 6 — **Explain what affects a temperature rise**
The rise depends on the mass heated, the material (its specific heat capacity) and the energy supplied.

Grade 7 — **Use heater power and time in calculations**
Find the energy supplied with E = P t, then use it in ΔE = m c Δθ.

Grade 7 — **Explain why a measured c is too high**
Energy is transferred to the surroundings, so the temperature rise is smaller and c = ΔE ÷ (m Δθ) comes out larger.

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