Energy changes in systems

4.1.1.3 · Energy · revision notes

How much energy it takes to change the temperature of a material. You need to know what specific heat capacity means, use ΔE = m c Δθ, and know the required practical in which you measure the specific heat capacity of a material. Expect 2 to 4 mark calculations and practical questions, including 6-mark method questions.

Key facts

- ΔE = m c Δθ (on the equations sheet)
- Units: ΔE in J, m in kg, c in J/kg °C, Δθ in °C
- Water: c ≈ 4200 J/kg °C (given when you need it)
- Practical: c = energy supplied ÷ (mass × temperature rise)
- Specific heat capacity: the energy needed to raise the temperature of 1 kg of a substance by 1 °C
- Δθ = final temperature − starting temperature
- Energy from a heater: E = P t (t in seconds)
- Grade 7+ only Measured c too high: energy was dissipated to the surroundings

Notes

Specific heat capacity

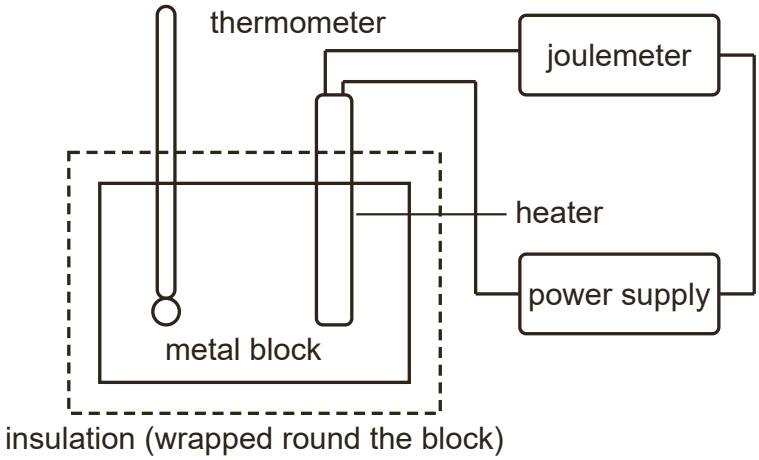
- When you heat a substance, energy goes into its thermal (internal) store and its temperature rises. When it cools, energy is released.
- The **specific heat capacity** (c) of a substance is the amount of energy needed to raise the temperature of 1 kg of the substance by 1 °C.
- Water has a high specific heat capacity (about 4200 J/kg °C), so it takes a lot of energy to heat up and releases a lot as it cools. Most metals have much lower values, so they heat up quickly.

The equation

- ΔE = m c Δθ (on the equations sheet)
- ΔE = change in thermal energy (J), m = mass (kg), c = specific heat capacity (J/kg °C), Δθ = temperature change (°C).
- Δθ = final temperature − starting temperature.
- Rearranged: c = ΔE ÷ (m × Δθ) and Δθ = ΔE ÷ (m × c).
- The energy often comes from an electric heater: E = P t, with P in watts and t in seconds.

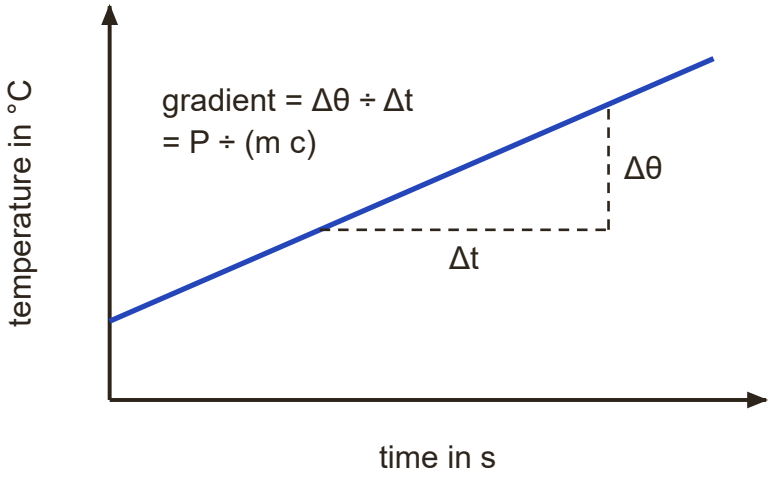
Required practical: measuring specific heat capacity

- Measure the mass of a metal block with a balance.
- Put an electric heater and a thermometer into the holes in the block. Wrap the block in insulation.



Required practical set-up: the joulemeter measures the energy supplied to the block.

- Record the starting temperature, then switch on the heater. Measure the energy supplied with a joulemeter (or record the power and the time and use E = P t).
- After a set time (e.g. 10 minutes), switch off. Record the energy supplied and the highest temperature the block reaches.
- Calculate c = energy supplied ÷ (mass × temperature rise).
- For a liquid (water or oil): mass of liquid = mass of beaker with liquid − mass of empty beaker. Put the heater and thermometer in the liquid and stir before each reading.
- Your value is usually higher than the true value, because some energy is dissipated to the surroundings instead of heating the block. Insulation reduces this. Grade 7+ only
- With a heater of constant power P, a graph of temperature against time is a straight line with gradient P ÷ (m × c), so c = P ÷ (m × gradient). Grade 8+ only



Steady heating gives a straight line; c = P ÷ (m × gradient).

Grade 8+ only

How to answer each type of question

Calculate the energy needed to heat something

2 marks | Grade 5

1. Work out the temperature change first.
2. Substitute into $\Delta E = m\ c\ \Delta\theta$.
3. Give the answer in J (or in kJ if the question asks).

Example. A saucepan contains 1.5 kg of water at 18 °C. The water is heated to 78 °C.
specific heat capacity of water = 4200 J/kg °C
Calculate the energy transferred to the water.

Model answer.

$\Delta\theta = 78 - 18 = 60$ °C

$\Delta E = 1.5 \times 4200 \times 60$ (1)

$\Delta E = 378\,000$ J (1)

Calculate the specific heat capacity from practical results

3 to 4 marks | Grade 7

1. Find the energy supplied: $E = P\ t$ with t in seconds (or read the joulemeter).
2. Find the temperature rise.
3. Rearrange: $c = \Delta E \div (m \times \Delta\theta)$.
4. Give the unit J/kg °C.

Example. A student heats a 1.0 kg aluminium block with a 50 W heater for 6.0 minutes. The temperature of the block rises from 21 °C to 41 °C.
Calculate the specific heat capacity of aluminium given by these results.

Model answer.

$E = 50 \times 360$ (1)

$E = 18\,000$ J (1)

$c = 18\,000 \div (1.0 \times 20)$ (1)

$c = 900$ J/kg °C (1)

6-mark: describe a method to find a specific heat capacity

6 marks | Grade 5

1. Say what you measure and the instrument for each: balance, thermometer, joulemeter.
2. Put the steps in order: mass, set-up, starting temperature, heating, energy supplied, final temperature.
3. Say how you reduce energy dissipated to the surroundings (insulation).
4. Finish with how you calculate c from your measurements.

Example. Describe a method a student could use to determine the specific heat capacity of a metal block.
The student has an electric heater, a joulemeter, a thermometer and any other equipment they need.

Model answer.

Marked by levels. A full answer could include:

measure the mass of the block with a balance

put the heater and the thermometer into the holes in the block

wrap the block in insulation

record the starting temperature

connect the heater through the joulemeter and switch it on

after about 10 minutes switch off, then record the joulemeter reading and the highest temperature reached

work out the temperature rise

c = energy supplied ÷ (mass × temperature rise)

Top level (5 to 6 marks): a logical method that would work, including how c is calculated.

Explain why the result is not accurate

2 to 3 marks | Grade 7

1. Say where the energy goes: it is dissipated to the surroundings.
2. Link this to the result: the block gains less energy than the heater supplies, so c comes out too high.
3. Give an improvement, e.g. more insulation.

Example. A student's value for the specific heat capacity of copper is higher than the accepted value. Explain why, and suggest one improvement to the method.

Model answer. Some energy from the heater is dissipated to the surroundings (1). So the energy supplied is more than the energy gained by the block, and the calculated value of c is too high (1).
Improvement: wrap the block in (more or thicker) insulation (1).

Don't lose marks

- Using the final temperature instead of the temperature change.
- Forgetting to change minutes to seconds in E = P t.
- Using the mass in grams instead of kilograms.

- Confusing specific heat capacity (temperature change) with specific latent heat (change of state, no temperature change).
- Writing that 'heat is lost' without saying it is dissipated to the surroundings or how this affects the value of c.

More tips

Memory tricks

- The definition has three parts: energy needed, 1 kg, 1 °C.
- Sense check: 1 kg of water needs about 4200 J for each 1 °C rise, so heating a kettle of water takes hundreds of thousands of joules.
- Calculator: for c = ΔE ÷ (m × Δθ) use brackets, or divide by m and then by Δθ.
- In this practical, a value that is too high is almost always due to energy dissipated to the surroundings.

Exam technique

- In method questions, name the equipment: balance, thermometer, electric heater, joulemeter (or power supply and stopwatch), insulation.
- Give c the unit J/kg °C.
- If a question gives a power and a time, you almost always need E = P t first.

What each grade needs

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

Grade 3 — **Name what affects the energy needed to heat**
The energy needed depends on the mass, the material and the temperature rise.

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 5 — **Calculate energy using ΔE = m c Δθ**
Find the temperature change first, then multiply mass × specific heat capacity × temperature change.

Grade 5 — **Describe the specific heat capacity practical**
Heat a metal block of known mass with an electric heater, measuring the energy supplied and the temperature rise.

Grade 6 — **Rearrange to find c, m or Δθ**
E.g. c = ΔE ÷ (m × Δθ) or Δθ = ΔE ÷ (m × c).

Grade 7 — **Explain why insulating the block improves the result**
Insulation reduces the energy dissipated to the surroundings, so the energy supplied is closer to the energy the block gains.

Grade 8 — **Find c from a temperature–time graph**
With a heater of constant power P, the gradient is P ÷ (m × c), so c = P ÷ (m × gradient).

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