Specific heat capacity

Answers, marking points and revision notes | AQA Combined Science 8464 and AQA GCSE Physics 8463

GCSE science required practicals

This practical online

Answers

1 Look at Rohan's experiment.

a. Name the dependent variable.

b. Give one control variable.

(2 marks)

a) The temperature of the block.

b) The mass of the block (or the potential difference across the heater, or the amount of insulation).

Marking points

- Temperature of the block
- Any one sensible control: mass of block, material, p.d. or current (power) of heater, insulation

2 Rohan wrapped a thick foam jacket around the block before he switched the heater on. Explain why. (2 marks)

The foam is a thermal insulator, so it reduces the energy transferred from the block to the surroundings. This means more of the energy from the heater goes into raising the temperature of the block, so the value for the specific heat capacity is more accurate.

Marking points

- Reduces energy transfer (heat loss) from the block to the surroundings
- So the temperature rise is due to (nearly) all of the energy supplied, giving a more accurate value

3 Before reading the thermometer, Rohan put a few drops of water into the hole the thermometer sits in. Give the reason for this. (1 mark)

The water fills the air gap, so the thermometer is in good thermal contact with the block and reads the block's real temperature.

Marking points

- Improves thermal contact between the thermometer and the block (air is a poor conductor)

4 Give one hazard in this experiment and say how Rohan can reduce the risk of harm from it. (2 marks)

The heater and the block get hot enough to burn skin. Rohan should not touch them while they are hot and should leave them to cool on a heatproof mat before moving them.

Marking points

- A hazard: hot heater or block (burns), or heater overheating out of the block
- A matching way to reduce the risk, e.g. do not touch until cool, use a heatproof mat, only switch on when heater is in the block

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5 Describe how the temperature of the block changes with time in Rohan's results. (2 marks)

As time goes on the temperature goes up. It rises by about the same amount, between 5.4 °C and 5.8 °C, every 120 s (apart from the odd reading at 480 s), so the temperature increases at a steady rate.

Marking points

- Temperature increases as time increases
- Rises at a roughly constant rate (about the same rise each 120 s, linear)

6 One of Rohan's temperature readings is anomalous.

a. Which reading is it?

b. What should Rohan do with it? (2 marks)

a) The reading at 480 s (40.1 °C). It should be about 43 °C, halfway between 37.2 °C and 48.6 °C.

b) He should leave it out when he draws his line of best fit or works out his answer (or repeat that reading).

Marking points

- 480 s / 40.1 °C
- Ignore it when drawing the line of best fit or calculating (or repeat the reading)

7 Calculate the energy transferred by the heater in 600 s. Use the voltmeter and ammeter readings in the box above the table.

Give your answer to 3 significant figures. Show your working. (3 marks)

Power = 11.8 × 4.20 = 49.56 W

Energy = 49.56 × 600 = 29 736 J, which is 29 700 J to 3 significant figures.

$P = V \times I$

$P = 11.8 \times 4.20$

$P = 49.56\ W$

$E = P \times t$

$E = 49.56 \times 600$

$E = 29\,736\ J$

$E = 29\,700\ J$ (3 s.f.)

Marking points

- Power = potential difference × current = 49.56 W
- Energy = power × time with t = 600 s
- 29 700 J (29 736 J)

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8 Use your answer to the previous question and Rohan's readings at 0 s and 600 s to calculate the specific heat capacity of aluminium.

The change in thermal energy of the block is given by $\Delta E = mc\Delta\theta$, where m is the mass in kg, c is the specific heat capacity in J/kg °C and $\Delta\theta$ is the temperature change in °C.

Give your answer to 3 significant figures. Show your working. (3 marks)

Temperature change = 48.6 - 20.5 = 28.1 °C

c = 29 736 ÷ (1.00 × 28.1) = 1058 J/kg °C, so 1060 J/kg °C to 3 significant figures.

$\Delta\theta = 48.6 - 20.5$

$\Delta\theta = 28.1$ °C

$c = \Delta E \div (m \times \Delta\theta)$

$c = 29\,736 \div (1.00 \times 28.1)$

$c = 1058.2$ J/kg °C

$c = 1060$ J/kg °C (3 s.f.)

Marking points

- Temperature change = 28.1 °C
- Rearranges: $c = \Delta E \div (m \times \Delta\theta)$
- 1060 J/kg °C (allow 1057 to 1059 before rounding, using 29 700 J or 29 736 J)

9 **Higher tier**

A better method uses the steady part of the results. Between 120 s and 360 s the power of the heater was 49.56 W.

a. Calculate the mean rate of temperature rise of the block between 120 s and 360 s, in °C/s.

b. Use your answer to part a) to calculate the specific heat capacity of aluminium.

The change in thermal energy of the block is given by $\Delta E = mc\Delta\theta$.

Give your final answer to 3 significant figures. Show your working. (4 marks)

a) Rise = 37.2 - 25.9 = 11.3 °C in 240 s, so the rate = 11.3 ÷ 240 = 0.04708 °C/s.

b) Every second the heater supplies 49.56 J and the temperature rises by 0.04708 °C, so c = 49.56 ÷ (1.00 × 0.04708) = 1053 J/kg °C, which is 1050 J/kg °C to 3 significant figures.

$\Delta\theta = 37.2 - 25.9$

$\Delta\theta = 11.3$ °C

$\Delta t = 360 - 120$

$\Delta t = 240$ s

rate = $11.3 \div 240$

rate = 0.047083 °C/s

In 1 s: $\Delta E = 49.56$ J and $\Delta\theta = 0.047083$ °C

$c = \Delta E \div (m \times \Delta\theta)$

$c = 49.56 \div (1.00 \times 0.047083)$

$c = 1052.6$ J/kg °C

$c = 1050$ J/kg °C (3 s.f.)

Marking points

- Temperature rise 11.3 °C over 240 s
- Rate = 0.0471 °C/s
- Uses energy per second (power) with $c = P \div (m \times \text{rate})$
- 1050 J/kg °C

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10 Amara did the same experiment with a steel block of mass 800 g. She used a joulemeter instead of a voltmeter and ammeter.

The joulemeter read 0 J at the start and 15 100 J at the end. The temperature of the block went from 19.0 °C to 58.5 °C.

Calculate the specific heat capacity of steel from Amara's results. The change in thermal energy is given by $\Delta E = mc\Delta\theta$.

Give your answer to 2 significant figures. Show your working. (3 marks)

Mass = 800 ÷ 1000 = 0.800 kg. Temperature change = 58.5 - 19.0 = 39.5 °C.

c = 15 100 ÷ (0.800 × 39.5) = 478 J/kg °C, which is 480 J/kg °C to 2 significant figures.

$m = 800 \div 1000$

$m = 0.800\ kg$

$\Delta\theta = 58.5 - 19.0$

$\Delta\theta = 39.5\ °C$

$c = \Delta E \div (m \times \Delta\theta)$

$c = 15\ 100 \div (0.800 \times 39.5)$

$c = 15\ 100 \div 31.6$

$c = 477.8\ J/kg\ °C$

$c = 480\ J/kg\ °C$ (2 s.f.)

Marking points

- Mass converted to 0.800 kg
- Temperature change 39.5 °C
- 480 J/kg °C

11 A data book gives the specific heat capacity of aluminium as 900 J/kg °C. Rohan's value is bigger than this. Explain why. (2 marks)

Some of the energy from the heater was transferred to the surroundings (the air, the bench and the heater itself) instead of to the block. So the temperature rise was smaller than it would be if all the energy went into the block, and dividing by a smaller temperature rise gives a bigger value of c.

Marking points

- Energy is lost (transferred) to the surroundings, not all heats the block
- So the temperature rise is smaller than expected, making the calculated c too large

12 Suggest one change to Rohan's method that would give a value closer to 900 J/kg °C. Explain how it helps. (2 marks)

Stand the block on a thick insulating mat as well as wrapping it, so the base is insulated too. Less energy is then conducted into the bench, so more of the energy supplied heats the block and the temperature rise is closer to the ideal value.

Marking points

- A specific change, e.g. insulate the base as well, use thicker insulation, or put a layer of insulation over the top of the block and the holes
- Linked reason: less energy transferred to the surroundings so measured temperature rise is more accurate

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13 **Higher tier**

Rohan says that if he repeats the experiment three times and takes a mean, his value will get much closer to 900 J/kg °C. Explain why he is wrong. (2 marks)

The energy lost to the surroundings is a systematic error: it makes every result too high by about the same amount. Repeating and taking a mean only reduces the effect of random errors, so the mean would still be too high.

Marking points

- Energy loss causes a systematic error (every result shifted the same way)
- Repeats and means reduce random error only, so accuracy does not improve

14 Plan an investigation to find the specific heat capacity of water, using an electric heater.

Include how you would use your measurements to work out the answer. (6 marks)

Put an empty beaker on a balance, zero it, and pour in about 0.50 kg of water, then write down the mass in kg. Wrap the beaker in an insulating jacket and stand it on an insulating mat, with a lid that has holes for the heater and the thermometer. Put the immersion heater fully into the water. Connect it to a low voltage supply through a joulemeter and reset the joulemeter to zero. Read the starting temperature with a thermometer. Switch on the heater and stir the water gently so the temperature is the same all through it. After about 10 minutes switch off, keep stirring and record the highest temperature reached, and read the energy on the joulemeter. Work out the temperature rise by subtracting the start temperature from the highest temperature. Then calculate the specific heat capacity using $\Delta E = mc\Delta\theta$ rearranged to $c = \Delta E \div (m \times \Delta\theta)$. Repeat the experiment and find a mean. To stay safe, keep water away from the power supply and do not touch the heater until it has cooled.

Marking points (any 6, with the method in a logical order)

- Measure the mass of water on a balance (in kg)
- Insulate the beaker (jacket, lid, mat) to reduce energy loss
- Heater fully under the water before switching on
- Measure energy supplied with a joulemeter, or V, I and time with $E = VIt$
- Measure start temperature and highest temperature with a thermometer
- Stir the water so its temperature is even
- Temperature rise = final - start
- Calculate $c = \Delta E \div (m \times \Delta\theta)$
- Repeat and take a mean, or a sensible safety point

How it is marked

- 5-6 marks: a clear, logical plan someone else could follow, covering the mass of water, the energy supplied, the temperature rise and how c is calculated, with insulation or stirring to improve the result.
- 3-4 marks: most of the measurements are there and in a sensible order, but one important part (how energy is found, or how c is calculated) is missing or unclear.
- 1-2 marks: a few relevant steps or pieces of equipment are mentioned but there is no clear sequence and it would not give a value of c.

Revision notes: the method

Aim: To find the specific heat capacity of a metal block by heating it with an electric heater and measuring the energy supplied and the rise in temperature.

Equipment

- 1 kg metal block (for example aluminium) with two holes drilled in it

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- 12 V immersion heater that fits one hole
- Low voltage power supply
- Joulemeter, or an ammeter and a voltmeter
- Connecting leads
- Thermometer (a digital one reading to 0.1 °C is best)
- Stopwatch
- Insulating jacket or thick layer of foam to wrap the block
- Heatproof mat
- Pipette with a little water or oil
- Top-pan balance

Method

1. Measure the mass of the metal block on the balance and write it down in kg.
2. Stand the block on a heatproof mat and wrap the insulating jacket around its sides and top.
3. Put the heater in the larger hole and the thermometer in the smaller hole.
4. Add a few drops of water or oil to the thermometer hole so the thermometer makes good thermal contact with the metal.
5. Connect the heater to the power supply with the ammeter in series and the voltmeter in parallel across the heater (or connect it through the joulemeter and reset the joulemeter to zero).
6. Read the starting temperature of the block.
7. Switch on the heater and start the stopwatch at the same moment.
8. Write down the ammeter and voltmeter readings, which should stay about the same.
9. Read the temperature every 60 s (or every 120 s) for about 10 minutes.
10. Switch off the heater, then keep watching the thermometer and record the highest temperature it reaches.
11. Work out the energy supplied, $E = VIt$ (or read it from the joulemeter), and the temperature rise.
12. Plot temperature against time, or energy against temperature rise, and use the results to calculate the specific heat capacity.

Variables

- **Independent:** The time the heater is switched on for, which sets the energy supplied to the block.
- **Dependent:** The temperature of the block, read from a thermometer in the block.
- **Control:** Mass of the block (the same block is used throughout); Material of the block; Potential difference across the heater and current through it, so the power stays the same; Amount of insulation around the block

Hazards

Hazard	What could happen	How to reduce the risk
Hot heater and hot metal block	Burns to the skin	Do not touch the heater or block while switched on or for several minutes after; let them cool on the heatproof mat before handling.
Heater left on with nothing to heat, or out of the block	Heater overheats and could start a fire or burn the bench	Only switch the heater on when it is fully inside the block and switch it off as soon as the readings are finished.

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Hazard	What could happen	How to reduce the risk
Water near the electrical supply	Electric shock or short circuit	Use only a few drops in the thermometer hole and keep the power supply and leads dry.

Key points

- Use the temperature rise, not the final temperature, in $\Delta E = mc\Delta\theta$.
- Mass must be in kg: divide grams by 1000.
- Energy supplied is $E = Pt$ with $P = VI$, so $E = VIt$ (time in seconds, not minutes).
- The value you get is usually too big, because some of the energy heats the surroundings instead of the block.
- Insulation and a drop of water or oil in the thermometer hole make the result closer to the true value.
- Keep reading the thermometer after switching off: the block keeps getting warmer for a short time.

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