Thermal insulation

Answers, marking points and revision notes | AQA GCSE Physics 8463 only (not Combined Science)

GCSE science required practicals

This practical online

Answers

1 In Priya's experiment, what was:

a. the independent variable

b. the dependent variable?

(2 marks)

a) The number of layers of newspaper.

b) The drop in temperature of the water in 10 minutes.

Marking points

- Number of layers of newspaper
- Temperature drop (or final temperature) after 10 minutes

2 Priya used 200 cm^3 of water in every beaker. Explain why it was important to keep the volume of water the same.

(2 marks)

A bigger volume of water has a bigger mass, so it needs more energy to be lost for the same drop in temperature and it would cool more slowly anyway. Keeping the volume the same means the only thing changing the cooling is the number of layers, so the test is fair.

Marking points

- Different volume (mass) would change how quickly the temperature falls
- So any difference is only due to the number of layers (fair test)

3 Every beaker had the same card lid on it. Explain why.

(2 marks)

Hot water loses a lot of energy from its top surface by evaporation and convection. Using the same lid each time cuts this down and keeps it the same, so the difference between the beakers is caused by the layers around the sides.

Marking points

- Reduces energy lost from the top surface (evaporation or convection)
- Keeps this the same for all beakers so only the layers affect the result

4 Give one hazard in Priya's experiment and one way she can reduce the risk.

(2 marks)

The hot water from the kettle can scald her. She should stand the beaker on a heatproof mat and pour slowly so it does not splash, and not carry full beakers around.

Marking points

- Hazard: hot water (scalds) or broken glass (cuts)
- Matching control, e.g. pour slowly on a mat, do not move full beakers, cool a scald under cold water

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5 Describe the pattern in Priya's results. (2 marks)

The more layers of newspaper there are, the smaller the drop in temperature. Each extra layer makes less difference than the one before: going from 0 to 1 layer reduced the drop by 4.4 °C, but going from 4 to 5 layers only reduced it by 0.6 °C.

Marking points

- More layers gives a smaller temperature drop (cools more slowly)
- The effect gets smaller with each extra layer (levels off), with data quoted

6 One result does not fit the pattern.

a. Which result is anomalous?

b. Suggest one thing that could have gone wrong to cause it. (2 marks)

a) The result for 3 layers (a drop of 12.6 °C, which is bigger than the drop for 2 layers).

b) The newspaper may have been wrapped loosely or left a gap, or the lid was not pushed on properly, so more energy escaped.

Marking points

- 3 layers, 12.6 °C
- A sensible cause, e.g. loose or gapped layers, lid not on properly, draught, less water poured in

7 Calculate the mean rate of cooling of the water in the beaker with no layers, in °C per minute. (2 marks)

Rate = 18.4 ÷ 10 = 1.84 °C per minute.

rate = temperature drop ÷ time

rate = 18.4 ÷ 10

rate = 1.84 °C per minute

Marking points

- Uses 18.4 °C ÷ 10 minutes
- 1.84 °C per minute

8 The beaker with no layers held 200 g of water. The specific heat capacity of water is 4200 J/kg °C.

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

Calculate the energy transferred from the water to the surroundings in 10 minutes. Give your answer to 3 significant figures. Show your working. (3 marks)

Mass = 200 ÷ 1000 = 0.200 kg.

ΔE = 0.200 × 4200 × 18.4 = 15 456 J, which is 15 500 J to 3 significant figures.

$m = 200 \div 1000$

$m = 0.200$ kg

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

$\Delta E = 0.200 \times 4200 \times 18.4$

$\Delta E = 15\,456$ J

$\Delta E = 15\,500$ J (3 s.f.)

Marking points

- Mass converted to 0.200 kg
- Substitutes 0.200 × 4200 × 18.4
- 15 500 J

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9 The water in the beaker with no layers lost 15 456 J of energy in 10 minutes.

Calculate the mean rate at which energy was transferred from the water, in watts. Give your answer to 2 significant figures. Show your working. (3 marks)

Time = 10 × 60 = 600 s.

Power = 15 456 ÷ 600 = 25.76 W, which is 26 W to 2 significant figures.

t = 10 × 60

t = 600 s

P = E ÷ t

P = 15 456 ÷ 600

P = 25.76 W

P = 26 W (2 s.f.)

Marking points

- Time converted to 600 s
- Power = energy ÷ time
- 26 W

10 Calculate the percentage decrease in the temperature drop when the number of layers goes from 0 to 5. Give your answer to 2 significant figures. (2 marks)

Decrease = 18.4 - 7.8 = 10.6 °C. Percentage = 10.6 ÷ 18.4 × 100 = 57.6%, which is 58% to 2 significant figures.

decrease = 18.4 - 7.8

decrease = 10.6 °C

percentage = (10.6 ÷ 18.4) × 100

percentage = 57.6%

percentage = 58% (2 s.f.)

Marking points

- Decrease of 10.6 °C divided by 18.4 °C
- 58%

11 **Higher tier**

Explain why wrapping the beaker in newspaper slows down the cooling, and suggest why adding a fifth layer made much less difference than adding the first layer. (3 marks)

The layers of newspaper trap air between them, and air is a very poor conductor, so less energy is conducted out through the sides and convection currents next to the glass are reduced. The first layer stops most of the convection from the hot glass and adds the first trapped air gap, which makes a big change. By the fifth layer most of the energy is escaping another way, such as through the lid, the base and by evaporation, so slowing the loss through the sides a little more hardly changes the total.

Marking points

- Newspaper traps air, which is a poor thermal conductor (reduces conduction)
- Reduces convection (and radiation) from the sides of the beaker
- Later layers help less because energy still escapes through the top and base, which the layers do not cover

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12 Tomasz did the same experiment using a liquid-in-glass thermometer marked every 1 °C. Suggest why Priya's digital thermometer, which reads to 0.1 °C, is a better choice for this investigation. (2 marks)

The digital thermometer has a better resolution, so it can show smaller changes in temperature. The differences between 4 and 5 layers are under 1 °C, so with a 1 °C scale Tomasz could not tell them apart properly.

Marking points

- Higher resolution (reads smaller changes)
- Needed because some differences are less than 1 °C (e.g. 4 and 5 layers differ by 0.6 °C)

13 **Higher tier**

Kwame says Priya did not need to wait for each beaker to cool to exactly 80.0 °C before starting the stopwatch. Explain why he is wrong. (2 marks)

The rate of energy transfer depends on the temperature difference between the water and the room. Water starting hotter would cool faster whatever the insulation, so different starting temperatures would change the temperature drop and the comparison would not be fair.

Marking points

- Hotter water cools faster because the temperature difference with the surroundings is bigger
- So starting temperatures must match or the temperature drops cannot be compared fairly

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14 Plan an investigation to find out which of four materials (bubble wrap, cotton wool, felt and fleece fabric) is the best thermal insulator.

(6 marks)

Take five identical beakers. Wrap four of them in the same thickness of each material, for example a 1 cm layer, held on with elastic bands, and leave one unwrapped to compare. Use a measuring cylinder to put 200 cm^3 of hot water into each beaker and cover each with the same card lid. Put a thermometer through each lid. When each beaker reaches 75 °C, start a stopwatch and read the temperature every 2 minutes for 20 minutes. Keep the beakers away from windows and radiators so the room conditions are the same. Work out the temperature drop for each material. The material with the smallest drop is the best insulator. Repeat the whole test twice more and find the mean drop for each material, so that odd results can be spotted. For safety, pour the hot water slowly on a heatproof mat to avoid scalds. Plot cooling curves of temperature against time for each material on the same axes to compare them.

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

- Identical beakers, one per material, plus a control with no wrapping
- Same thickness (or number of layers) of each material
- Same volume of hot water, measured with a measuring cylinder
- Same lid and same starting temperature for every beaker
- Measure temperature with a thermometer at regular times, or after a fixed time, with a stopwatch
- Calculate the temperature drop; smallest drop is the best insulator
- Repeat and calculate a mean
- Plot cooling curves (temperature against time) to compare
- Safety point about hot water

How it is marked

- 5-6 marks: a clear, ordered plan that keeps thickness, volume, starting temperature and time the same, says what is measured and how, and how the best insulator is decided from the results.
- 3-4 marks: a workable plan with most of the measurements, but some control variables are missing or it is not clear how the results are compared.
- 1-2 marks: some relevant steps or equipment, but the plan is muddled and it would not give a fair comparison of the materials.

Revision notes: the method

Aim: To find out how the thickness of an insulating layer, and the type of material, affects how quickly a beaker of hot water cools.

Equipment

- Several identical 250 cm^3 beakers
- Kettle to supply hot water
- Measuring cylinder (250 cm^3)
- Thermometer (a digital one reading to 0.1 °C is best)
- Stopwatch
- Sheets of newspaper (or other insulating materials such as bubble wrap, cotton wool, felt)
- Elastic bands or tape
- Card lids with a hole for the thermometer
- Heatproof mat

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Method

1. Wrap one layer of newspaper around the sides of a beaker and hold it in place with an elastic band.
2. Use the measuring cylinder to pour 200 cm^3 of hot water from the kettle into the beaker.
3. Put a card lid on the beaker and push the thermometer through the hole into the water.
4. When the water has cooled to 80 °C, start the stopwatch.
5. Read the temperature again after 10 minutes and work out the drop in temperature.
6. Empty the beaker, then repeat with two, three, four and five layers of newspaper, and with a beaker that has no layers.
7. Keep the volume of water, the starting temperature, the time and the lid the same each time.
8. Plot a graph of temperature drop against number of layers.
9. To compare materials, wrap identical beakers in the same thickness of each material and repeat the test.

Variables

- **Independent:** The number of layers of newspaper around the beaker (or the type of insulating material).
- **Dependent:** The drop in temperature of the water in 10 minutes, worked out from thermometer readings at the start and end.
- **Control:** Volume (mass) of water; Starting temperature of the water; Time the water cools for; Size and type of beaker; Same lid on every beaker; Room temperature, and no draughts

Hazards

Hazard	What could happen	How to reduce the risk
Very hot water from the kettle	Scalds if it is spilled on the skin	Stand the beaker on a heatproof mat, pour slowly, do not carry full beakers around the room, and run any scald under cold water straight away.
Glass beaker or thermometer breaking	Cuts from broken glass	Keep the beaker in the middle of the bench, rest the thermometer so it cannot roll, and tell the teacher about any breakage instead of picking it up.

Key points

- A smaller temperature drop in the same time means a better insulator.
- Start every test at the same temperature, because hot water loses energy faster when it is much hotter than the room.
- Use the same volume of water each time, so the same mass of water is cooling.
- Insulators like newspaper and bubble wrap work mainly by trapping air, which is a poor conductor.
- Each extra layer helps less than the one before, so the graph curves and levels off.
- Use the lid on every beaker, otherwise energy lost from the top hides the effect of the layers.

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