Infrared radiation and surfaces

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 Mei and Oliver's investigation.

a. Name the independent variable.

b. Name the dependent variable.

c. Give one control variable.

(3 marks)

a. The type of surface.
b. The infrared detector reading (amount of infrared emitted).
c. The distance between the detector and the face.

Marking points

- Independent: type of surface (colour or texture)
- Dependent: amount of infrared emitted, or the detector reading
- Control: distance from detector, water temperature, same detector

2 Explain why the detector must be the same distance from each face. (2 marks)

The amount of infrared reaching the detector gets smaller the further away it is. If the distances were different, the readings would change because of the distance and not just the surface, so it would not be a fair test.

Marking points

- The reading depends on distance (falls as distance increases)
- So keeping it the same means only the surface affects the reading (fair test)

3 Give one hazard in this investigation and say how to reduce the risk. (2 marks)

The hot water could scald someone if the cube is knocked over. Put the cube on a heat-resistant mat in the middle of the bench and stand up while pouring the water.

Marking points

- Hazard: hot water or hot cube (scalds or burns)
- Matching control: mat, stable position away from the edge, stand while pouring, gloves

4 Which surface is the best emitter of infrared radiation and which is the worst? Use the table to explain your answer. (2 marks)

Matt black is the best emitter because it gave the highest readings, about 125 W/m^2. Shiny silver is the worst because it gave the lowest readings, only about 21 W/m^2.

Marking points

- Best: matt black, with the highest readings
- Worst: shiny silver, with the lowest readings

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5 Identify the anomalous result and say what Mei and Oliver should do with it. (2 marks)

Reading 2 for shiny black, 93 W/m^2, is anomalous because the other two readings were 108 and 110 W/m^2. They should leave it out when working out the mean and take that reading again if they can.

Marking points

- Shiny black reading 2 (93 W/m^2)
- Leave it out of the mean (and repeat the reading)

6 Calculate the mean reading for the matt black face. Give your answer to 1 decimal place. (2 marks)

Mean = (126 + 123 + 125) ÷ 3 = 374 ÷ 3 = 124.7 W/m^2

total = 126 + 123 + 125 = 374

mean = 374 ÷ 3

mean = 124.66...

mean = 124.7 W/m^2 (1 d.p.)

Marking points

- (126 + 123 + 125) ÷ 3
- 124.7 W/m^2

7 Calculate the mean reading for the shiny black face, leaving out the anomalous result. (2 marks)

Mean = (108 + 110) ÷ 2 = 109 W/m^2

leave out the anomaly of 93

total = 108 + 110 = 218

mean = 218 ÷ 2

mean = 109 W/m^2

Marking points

- Leaves out 93 and uses (108 + 110) ÷ 2
- 109 W/m^2

8 The mean reading for shiny silver was 21.0 W/m^2 and for matt black was 124.7 W/m^2. Calculate the shiny silver reading as a percentage of the matt black reading. Give your answer to 2 significant figures. Show your working. (3 marks)

Percentage = 21.0 ÷ 124.7 × 100 = 16.8%, so about 17%.

fraction = 21.0 ÷ 124.7 = 0.1684...

percentage = 0.1684 × 100

percentage = 16.84...%

percentage = 17% (2 s.f.)

Marking points

- 21.0 ÷ 124.7
- × 100 = 16.8...
- 17%

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9 Sofia did the version with painted cans. The water in her matt black can cooled from 80 °C to 62 °C in 10 minutes. Calculate the mean rate of cooling in °C per minute. (2 marks)

Temperature drop = 80 - 62 = 18 °C. Rate = 18 ÷ 10 = 1.8 °C per minute.

temperature drop = 80 - 62 = 18 °C

rate of cooling = temperature drop ÷ time

rate of cooling = 18 ÷ 10

rate of cooling = 1.8 °C per minute

Marking points

- Temperature drop = 18 °C
- 1.8 °C per minute

10 **Higher tier**

Sofia's matt black can held 0.25 kg of water, which cooled by 18 °C in 10 minutes. The specific heat capacity of water is 4200 J/kg °C.

change in thermal energy = mass × specific heat capacity × temperature change

Calculate the mean rate at which the water lost energy, in watts. Show your working. (4 marks)

Energy lost = 0.25 × 4200 × 18 = 18 900 J. Time = 10 × 60 = 600 s. Power = 18 900 ÷ 600 = 31.5 W.

change in thermal energy = 0.25 × 4200 × 18

change in thermal energy = 18 900 J

time = 10 × 60 = 600 s

power = energy transferred ÷ time

power = 18 900 ÷ 600

power = 31.5 W

Marking points

- 0.25 × 4200 × 18
- 18 900 J
- Time converted to 600 s and power = energy ÷ time
- 31.5 W

11 Sofia used thermometers with a resolution of 1 °C. Suggest a better piece of equipment and explain why it would improve her results. (2 marks)

Use digital thermometers (temperature probes) with a resolution of 0.1 °C. They can show smaller changes in temperature, so small differences between the tubes would be easier to see.

Marking points

- Digital thermometer or temperature probe with a resolution of 0.1 °C (or a data logger)
- Higher resolution, so smaller temperature differences can be detected

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12 **Higher tier**

Mei and Oliver always measured the faces in the same order: matt black first and shiny silver last. Explain why this could make the comparison unfair and suggest how to avoid it. (2 marks)

The water cools while they take readings, so the faces measured later are at a slightly lower temperature and give lower readings than they should. They could change the order for each repeat, or top up with fresh hot water and check the temperature is the same before each reading.

Marking points

- The water cools over time, so later faces are cooler and give readings that are too low
- Change the order each repeat, or refill so the water is at the same temperature for each reading

13 Oliver suggests holding his hand near each face instead of using the detector. Give two reasons why the detector is better. (2 marks)

The detector gives a number, so the faces can be compared accurately, while a hand can only give an opinion. A hand also cannot detect small differences, and holding it close to a hot surface risks a burn.

Marking points

- The detector gives a measured value, which is not a matter of opinion
- It can detect small differences that a hand cannot (or a hand risks a burn)

14 Plan an investigation to find out which surface is the best absorber of infrared radiation. You can use two identical metal plates, one painted matt black and one shiny silver, and an electric heater. (6 marks)

Stand the two metal plates upright on heat-resistant mats, facing each other, with the heater exactly halfway between them. Measure the distances with a ruler so each plate is the same distance from the heater. Tape a thermometer, or a temperature probe, to the back of each plate, in the same position on each. Make sure both plates start at room temperature and record the starting temperatures. Switch on the heater and start a stopwatch. Record the temperature of each plate every minute for 10 minutes. Switch off the heater and let everything cool, then repeat twice more and work out mean temperature rises. Swap the plates' sides for one of the repeats in case the heater heats one side more. Compare the temperature rise of the two plates over the same time. The plate whose temperature goes up faster is the better absorber, which should be the matt black plate. Do not touch the heater or the plates while they are hot, and keep the heater away from paper.

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

- Heater placed halfway between the plates, distances measured and equal
- Plates identical in size, material and thickness, only the surface differs
- Thermometer or probe attached to the back of each plate in the same position
- Record starting temperatures and let plates start at the same temperature
- Measure the temperature at regular intervals or after the same time
- Compare temperature rise in the same time (the faster rise means the better absorber)
- Repeat, swapping the plates' positions, and find means
- Safety: do not touch the heater or hot plates, heat-resistant mats

How it is marked

- 5-6 marks: a clear, logical plan that would work, with equal distances from the heater, identical plates, temperature measured over the same time and a clear comparison of the rises, including repeats
- 3-4 marks: a workable plan that heats both plates and measures temperature, but misses key control steps or does not say how the results are compared
- 1-2 marks: a few relevant ideas, such as heating the plates and feeling or measuring them, without a clear method

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Revision notes: the method

Aim: To find out how the colour and texture of a surface affect how much infrared radiation it emits.

Equipment

- Leslie cube (a hollow metal cube with matt black, shiny black, matt white and shiny silver faces)
- Kettle
- Heat-resistant mat
- Infrared detector
- Metre ruler
- Heat-resistant gloves
- Thermometer
- For the tube version: four identical boiling tubes or cans painted with different surfaces, four thermometers and a stopwatch

Method

1. Stand the Leslie cube on a heat-resistant mat.
2. Fill the cube carefully with very hot water from a kettle and put the lid on.
3. Wait about a minute for the faces to heat up evenly.
4. Place the infrared detector 10 cm from the centre of the matt black face, measured with a ruler, and record the reading.
5. Turn the cube to put each of the other faces in front of the detector at the same 10 cm distance, recording the reading each time. Work quickly so the water does not cool much.
6. Repeat the set of readings twice more and work out a mean for each surface.
7. Without a detector: pour the same volume of hot water at the same starting temperature into four identical tubes with different outer surfaces.
8. Put a thermometer in each tube, record the temperature every minute for 10 minutes and compare how quickly each one cools.

Variables

- **Independent:** The type of surface (colour and shininess)
- **Dependent:** The amount of infrared radiation emitted, measured as the reading on an infrared detector (or the temperature drop of the water in a tube)
- **Control:** The distance from the detector to the face, because the reading gets smaller further away; The temperature of the water, which is the same for all four faces of one Leslie cube; In the tube version, the same volume and starting temperature of water and identical tubes

Hazards

Hazard	What could happen	How to reduce the risk
Very hot water	Scalds if it is spilled or the cube is knocked over	Stand while pouring, use a heat-resistant mat on a stable bench and keep the cube away from the bench edge
The hot metal faces of the cube	Burns to the skin	Turn the cube using heat-resistant gloves or by its handle, and do not touch the faces

Key points

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- Matt black surfaces are the best emitters (and absorbers) of infrared; shiny silver surfaces are the worst
- Keep the detector the same distance from every face, because the reading falls with distance
- A Leslie cube is a fair test because all four faces are at the same temperature
- Work quickly, because the water cools and the readings drop over time
- In the tube version, use the same volume and starting temperature of water, and compare temperature drops over the same time

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