

## Infrared absorption required practical

AQA GCSE Combined Trilogy 8464 and Separate Physics 8463 | Foundation and Higher | Paper 2

Worked answers | Foundation and Higher | 28 parts | 52 marks

### Specification points covered

8463 4.6.2.2 / 8464 6.6.2.2: investigating infrared absorption by different surfaces  
Selected absorption strand of Separate Physics RP10 / Combined Trilogy RP21

A solar water-warmer manufacturer tests two otherwise identical water-filled metal absorber cells: M has a matt black test face and S a polished silver test face. You will plan fair trials, analyse the heating evidence and recommend a finish for a prototype.

Original PhysicsUK practice, not an official AQA resource. Shared Foundation/Higher content, absorption strand of RP10/RP21 only. The three method parts in Section 5 total six marks using separate point marking, not an AQA levels-of-response rubric. Temperature rise measures a net heating effect under comparable conditions, not an absorbed fraction by itself. Timing is estimated and untrials.

### 1 Defining the investigation

The manufacturer changes only the test-face finish. Water temperature is recorded during equal heating periods; the first reading is taken before heating starts.

**1(a)** Identify the independent variable in this surface-comparison investigation. **[1 mark]**

**Answer / mark points:** The test-face surface finish: matt black or polished silver. [1] It is not lamp distance.

**1(b)** Identify the dependent measurement used to compare the two finishes after a fixed heating time. **[1 mark]**

**Answer / mark points:** The increase in water temperature / temperature rise over that fixed time.  
[1] Allow final water temperature only if the same initial temperature is made explicit.

**1(c)** In one trial the water warms from 20.0 °C to 29.0 °C in 2.0 minutes. Calculate the temperature rise and the mean rate of temperature rise in °C per minute. **[2 marks]**

**Answer / mark points:** Temperature rise =  $29.0 - 20.0 = 9.0$  °C. [1]  
Mean rate =  $9.0 / 2.0 = 4.5$  °C min<sup>-1</sup>. [1] Do not divide the final temperature by the time.



## 2 Making the comparison fair

Figure 1 is a cutaway schematic of one trial, not transparent metal. Replace M with S in the same marked position. The cells have equal exposed face areas and face the lamp at the same angle.

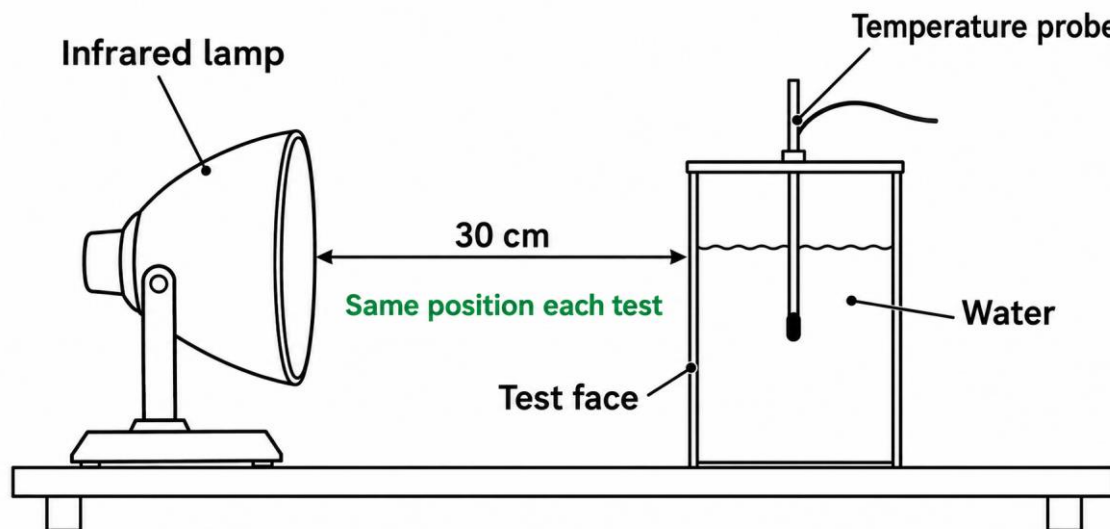


Figure 1

**2(a)** Explain why each test face must be placed the same 30 cm from the lamp opening. [2 marks]

**Answer / mark points:** Changing the distance changes the radiation intensity incident on the face. [1]

This could change the temperature rise independently of finish, preventing a fair comparison of the finishes. [1] Do not award a mark just for repeating "same distance". Measure to the test face, not to the probe.

**2(b)** Explain why the same mass of water is needed in each cell. [2 marks]

**Answer / mark points:** Different water masses have different temperature rises for the same net energy transfer. [1]

An unequal mass could therefore cause a temperature-rise difference that was wrongly attributed to finish. [1] Do not award a mark just for repeating "same mass". A numerical heat-capacity calculation is not required.

**2(c)** Explain why the probe tip should be immersed in the water but not touch the metal cell. [2 marks]

**Answer / mark points:** Immersion lets it measure the water temperature. [1]

Avoiding contact with metal prevents a local metal temperature from being mistaken for the water temperature. [1] Use the same immersion depth for each cell.

**2(d)** Explain why equal exposed areas and the same face angle to the lamp are important. [2 marks]

**Answer / mark points:** Changing the exposed area or face angle changes the amount of radiation incident on the cell. [1]

This could change the heating independently of finish, so the comparison would not isolate the finish effect. [1] Repeating "same area and angle" alone earns no mark.

**2(e)** State one further control for these sequential trials, other than those in (a)–(d), and explain its purpose. [2 marks]

**Answer / mark points:** Any one linked pair: same starting water/cell temperature, to make rises and heat-loss conditions comparable; same lamp output and warm-up state, to keep the source comparable; same heating duration, to compare equal exposure times; same surrounding conditions/other-face insulation, to reduce changes in heat loss. [1 control +1 linked reason]



### 3 Interpreting the heating curves

Figure 2 shows mean water temperatures from controlled trials. M is solid and S dashed. Both start at 20 °C; lamp output is kept constant. Compare measured points, not the truncated vertical axis with zero temperature.

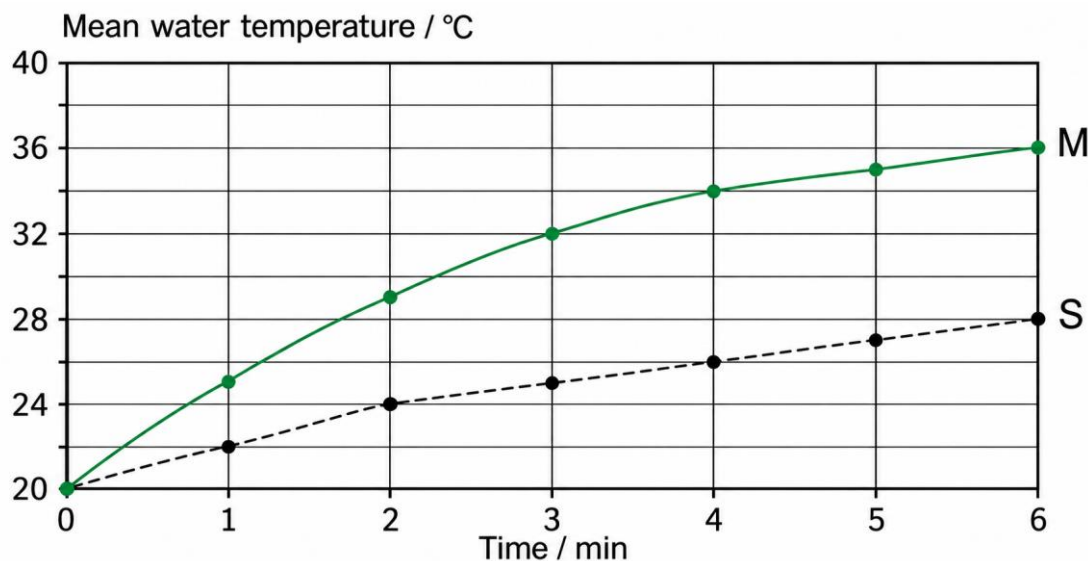


Figure 2

**3(a)** Read M's and S's mean water temperatures after 2.0 minutes. **[2 marks]**

**Answer / mark points:** M  $\approx 29$  °C. [1] S  $\approx 24$  °C. [1] Allow  $\pm 0.3$  °C for each. The time axis is in minutes.

**3(b)** Calculate the temperature rise of each cell after 6.0 minutes. **[2 marks]**

**Answer / mark points:** M:  $36 - 20 = 16$  °C. [1]  
S:  $28 - 20 = 8$  °C. [1] Allow correct follow-through from reasonable graph readings.

**3(c)** Use M's readings at 0 and 2.0 minutes to calculate its mean rate of temperature rise in °C per second. **[2 marks]**

**Answer / mark points:** 2.0 min = 120 s. [1]  
Mean rate =  $(29 - 20) / 120 = 0.075$  °C s<sup>-1</sup>. [1] Allow consistent follow-through from their rise; do not use 29 / 120.

**3(d)** Calculate M's mean rate of temperature rise from 4.0 to 6.0 minutes, in °C per minute. Compare it with the initial 4.5 °C per minute. **[2 marks]**

**Answer / mark points:** Rate =  $(36 - 34) / (6 - 4) = 1.0$  °C min<sup>-1</sup>. [1]  
It is lower than the initial 4.5 °C min<sup>-1</sup>: the rate is not constant. [1]

**3(e)** A trainee says that M's less steep curve later in the trial shows that it has stopped absorbing radiation. Explain why that is not justified. **[2 marks]**

**Answer / mark points:** M continues to absorb radiation from the unchanged lamp. [1]  
As it becomes warmer, energy transfer to the surroundings increases, reducing the net rate of heating. [1] A smaller temperature-rise rate is not evidence of zero absorption.



## 4 Repeats and measurement quality

Table 1 gives three independent temperature rises after 6.0 minutes. Each trial was reset to the same starting conditions. These are temperature changes, not final temperatures.

Table 1

| Finish | Trial 1 rise / °C | Trial 2 rise / °C | Trial 3 rise / °C |
|--------|-------------------|-------------------|-------------------|
| M      | 15.5              | 16.0              | 16.5              |
| S      | 7.5               | 8.0               | 8.5               |

4(a) Calculate the mean 6.0-minute temperature rise for M. [1 mark]

**Answer / mark points:** Mean =  $(15.5 + 16.0 + 16.5) / 3 = 16.0$  °C. [1]

4(b) Calculate S's mean temperature rise and the range of its three rises. [2 marks]

**Answer / mark points:** Mean =  $(7.5 + 8.0 + 8.5) / 3 = 8.0$  °C. [1]  
Range =  $8.5 - 7.5 = 1.0$  °C. [1] The range is not the maximum value alone.

4(c) A fourth trial for M gives a rise of 26.0 °C. Describe how the team should investigate and handle this unusual result before reporting a mean. [2 marks]

**Answer / mark points:** Check records/apparatus/controls and repeat the trial under the intended conditions. [1]  
Keep a record; exclude a result only with a justified reason, for example an identified measurement/setup error, and explain the decision. [1] Do not delete a result merely because it is inconvenient.

4(d) An operator rounds two readings, 31.0 °C and 31.4 °C, to the nearest 1 °C. State the two displayed values and explain why they do not prove that the surfaces behave identically. [2 marks]

**Answer / mark points:** Both round to 31 °C. [1]  
Rounding hides the 0.4 °C difference; the display resolution cannot establish identical underlying temperatures or absorption. [1]

4(e) Explain what close repeat results can show and why repeats do not automatically remove a biased thermometer reading. [2 marks]

**Answer / mark points:** Close repeats show small spread / good repeatability under those conditions. [1]  
A systematic thermometer offset can affect every repeat, so averaging does not remove that bias. [1] Avoid claiming that repeats alone prove accuracy.



## 5 Building a six mark style method

Use the Figure 1 apparatus with otherwise identical cells, equal exposed face areas and the same orientation. Parts (a)–(c) build one six-mark-style investigation in three separately marked steps.

**5(a)** Describe how you would make the lamp distance and the amount of water comparable between the two finishes. **[2 marks]**

**Answer / mark points:** Use the same ruler-measured lamp-opening-to-face distance of 30 cm and the same alignment for each cell. [1]  
Measure equal water masses with a balance, or equal volumes using a measuring cylinder, for the otherwise identical cells. [1]

**5(b)** Describe the starting-temperature and timed-measurement steps for one heating trial. **[2 marks]**

**Answer / mark points:** Bring the cell and water to the same specified starting temperature, check/read the immersed probe and record the initial temperature. [1]  
Expose the face to the stabilised lamp and start timing together; record temperature at regular intervals, for example each minute for 6 minutes. [1] Keep lamp output unchanged.

**5(c)** Describe the repeats and analysis that would let you decide which finish gives greater heating under the controlled conditions. **[2 marks]**

**Answer / mark points:** Reset each cell and water to the same starting conditions; repeat each finish several times and calculate mean rises for equal times. [1]  
Compare the mean temperature increases / initial mean rise rates: the larger value supports the better-absorbing finish when mass, geometry and other conditions are comparable. [1]

**5(d)** A new test places M 20 cm from the lamp and S 30 cm away. M heats faster. Explain why this cannot isolate the effect of finish and state the correction. **[2 marks]**

**Answer / mark points:** Distance changes the radiation intensity incident on the face, so finish is not the only changed variable. [1]  
Repeat with both faces in the same 30 cm position and orientation. [1] Comparing rises does not repair an uncontrolled distance.

**5(e)** State one hazard from the infrared lamp and a suitable precaution linked to it. **[2 marks]**

**Answer / mark points:** Hot lamp housing / bulb can cause burns. [1]  
Switch off and let it cool before handling or moving it; keep hands away during use. [1] Allow another realistic hazard and an explicitly linked control, such as keeping water away from electrical parts.



## 6 Recommending a solar absorber

The manufacturer needs a finish that heats the water effectively under irradiation. It also wants to know which conclusions require a different test. Use the stated trial evidence rather than claims about every black or shiny object.

**6(a)** A colleague turns the lamp off and uses an infrared detector to compare radiation leaving hot surfaces at the same temperature. Which process is now being tested, and how does it differ from the heating trial? **[2 marks]**

**Answer / mark points:** Emission / radiation from the hot surfaces is being compared. [1]  
The main trial compares heating caused by radiation absorbed from an external lamp, rather than a detector signal leaving the surfaces. [1] Do not confuse the water probe with an infrared detector.

**6(b)** Recommend M or S as the absorber finish for the prototype under the stated lamp-test conditions. Support the recommendation with the 6.0-minute mean temperature rises. **[2 marks]**

**Answer / mark points:** M: it gives a 16 °C mean rise compared with 8 °C for S. [1]  
With the other conditions controlled, the greater heating supports M as the better absorber for this prototype test. [1] This is not a claim that the lamp trial proves every outdoor performance condition.

**6(c)** M's mean temperature rise is twice S's. Explain why this alone does not prove that M absorbs exactly twice the fraction of the incident radiation. **[2 marks]**

**Answer / mark points:** Temperature rise reflects the net energy retained, not just the energy absorbed. [1]  
The cells can lose different amounts of energy while heating, and the trial does not separately measure incident and absorbed energy fractions. [1] No black-body equation is required.

**6(d)** The manufacturer also wants to retain hot water after sunset. Describe a different controlled test needed to compare that performance. **[2 marks]**

**Answer / mark points:** Start the two otherwise comparable cells with the same water mass and the same hot temperature, with no lamp and the same surroundings/insulation. [1]  
Record cooling over equal times, repeat and compare temperature falls; the smaller fall indicates better heat retention for that setup. [1] Heating data alone do not establish the cooling winner.

**6(e)** Why should the manufacturer also test the complete prototype outdoors before claiming the same performance in everyday use? **[1 mark]**

**Answer / mark points:** Real sunlight, weather, orientation and the complete system differ from the lamp bench; performance must be checked under relevant outdoor conditions. [1] Allow one relevant limitation tied to the proposed claim.

## Review and improve

Require linked control-and-reason statements. Keep absorption and emission distinct. Repeats show spread and reduce random influence on a mean, not automatically remove bias. A warmer cell is not proof of an exact absorption fraction.

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