

Black body radiation and Earth temperature

AQA GCSE Separate Physics 8463 only | Paper 2 | Foundation and Higher routes

Each tier: 23 parts / 44 marks | Alternative routes | Timing estimated/untrialled

Specification points covered

4.6.3.1: infrared emission and absorption; perfect black bodies (both tiers)

4.6.3.2: temperature and emission distributions (both tiers); radiation balance and Earth/atmosphere temperature (Higher only)

An Earth-observation team checks its radiation detector using reference surfaces, then interprets model evidence. Use measurements and radiation ideas to challenge claims in the team's report.

Original PhysicsUK practice, not official AQA. Common sections 1–3: 16 parts/26 marks. Each alternative adds 7 parts/18 marks: chosen route 23 parts/44 marks. Sections 6–7 are Higher-only replacements, not extra work. Printed total across alternatives: 30 parts/62 marks. No required-practical completion claim.

1 Checking reference surfaces

The team uses a coated metal reference plate. A perfect black body is an ideal model; an ordinary black-looking finish need not behave perfectly.

1(a) Coating P reflects some of the radiation incident on it. Explain why P cannot be a perfect black body. **[1 mark]**

Answer / mark points: A perfect black body absorbs all incident radiation, so none can be reflected. [1] A dark appearance does not override this evidence.

1(b) A trainee writes: "A perfect black body is a poor absorber and cannot emit radiation." Correct the two errors. **[2 marks]**

Answer / mark points: It absorbs all incident radiation. [1] It is the best possible emitter (at a given temperature), not a non-emitter. [1] Do not give two marks for rephrasing absorption alone.

1(c) The reference plate is at 20°C and does not visibly glow. Explain why that does not mean it emits no radiation. **[2 marks]**

Answer / mark points: The plate still emits infrared radiation: all objects emit radiation. [1] Infrared is outside the visible range, so lack of visible glow is not evidence of zero infrared emission. [1] Do not say only hot/glowing objects emit.

1(d) The same plate is tested at 20°C, 50°C and 80°C. At which temperature does it emit infrared at the greatest rate? Give a reason. **[1 mark]**

Answer / mark points: 80°C, because the hotter the same object is, the more infrared it emits in a given time. [1 for selection with reason]



1 Checking reference surfaces continued

1(e) A hot small sample gives a different signal from a cooler large sample. Before attributing the difference to their surface finishes, state two conditions the team must make equal. **[2 marks]**

Answer / mark points: Compare at the same actual temperature. [1] Compare the same emitting area viewed by the detector. [1] Also keep distance/orientation unchanged; these do not replace the two stated confounders.

2 Interpreting emission curves

Figure 1 compares equal emitting areas of two ideal black bodies. A is solid and B is dashed. The same axes are used for both; there are no numerical scales.

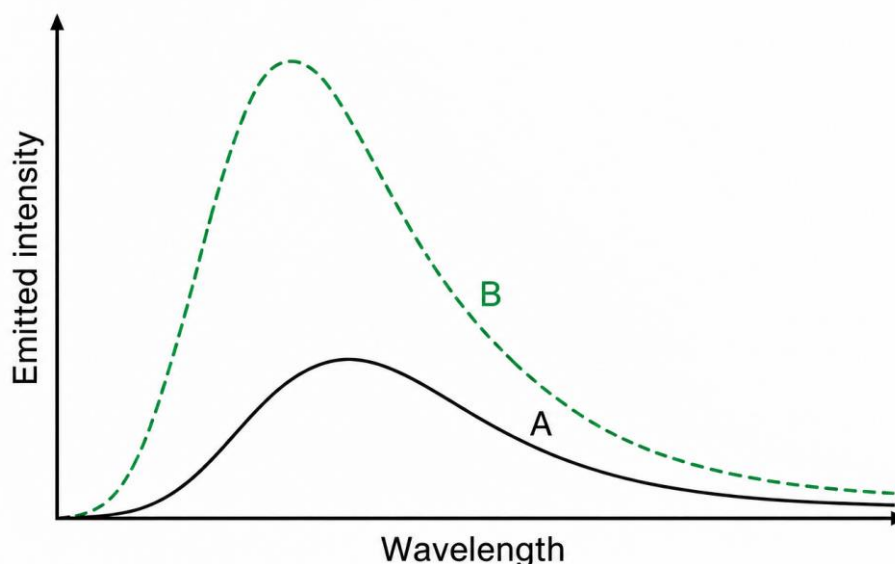


Figure 1

2(a) Which body is hotter, A or B? Give two features of its curve that support your choice. **[2 marks]**

Answer / mark points: B: its peak is at a shorter wavelength. [1] Its peak emitted intensity is greater. [1] No separate mark for B alone; identify both features, not simply “the line is higher”.

2(b) A colleague says B emits only the wavelength at its peak. Use the shape of the curve to correct this claim. **[2 marks]**

Answer / mark points: B emits over a range of wavelengths, with non-zero intensity away from the peak. [1] The peak identifies the wavelength of maximum intensity, not its only emitted wavelength. [1]



2 Interpreting emission curves continued

2(c) B is cooled until its curve becomes A. State the changes in peak wavelength and peak intensity. [2 marks]

Answer / mark points: Peak wavelength increases. [1] Peak emitted intensity decreases. [1] Name the quantities: "the radiation gets lower" is ambiguous.

2(d) Can the team calculate a numerical temperature in °C from Figure 1 alone? Explain your answer. [1 mark]

Answer / mark points: No: there is no numerical wavelength/temperature calibration or supplied numerical relationship. [1] Relative ordering is possible; an exact temperature is not.

2(e) At the same chosen wavelength where both curves are visible, which equal-area body emits more intensely? Refer to the graph. [1 mark]

Answer / mark points: B, because its curve is above A at that same wavelength. [1] Compare at the same horizontal coordinate, not at two unrelated peaks.

3 Checking the detector evidence

Table 1 gives background-corrected detector signals. M and S have different finishes but the same 60°C temperature, emitting area, distance and orientation. Readings are in arbitrary units.

Table 1

Finish	Reading 1 / units	Reading 2 / units	Reading 3 / units
M	44	46	45
S	14	16	15

3(a) Calculate the mean signal for M. [1 mark]

Answer / mark points: Mean = $(44 + 46 + 45)/3 = 45$ units. [1]

3(b) Calculate the mean signal for S. [1 mark]

Answer / mark points: Mean = $(14 + 16 + 15)/3 = 15$ units. [1]

3(c) Calculate the ratio of M's mean signal to S's. Explain why it is not the ratio of their temperatures. [2 marks]

Answer / mark points: Signal ratio = $45/15 = 3$ (3:1). [1] Both surfaces are actually at 60°C; their different finishes change the measured emission, not their stated temperatures. [1]



3 Checking the detector evidence continued

3(d) Which finish gives the stronger reference signal under these conditions? Does that prove it is a perfect black body? Explain both answers. **[2 marks]**

Answer / mark points: M gives the stronger signal at the same temperature/area/geometry. [1] No: these emission measurements do not show absorption of all incident radiation, so they do not establish perfection. [1]

3(e) An unknown sample with a different finish gives the same signal as M. A technician assigns it 60°C without further tests. Explain why the assignment is not justified. **[2 marks]**

Answer / mark points: Emission depends on surface properties as well as temperature. [1] A different finish can give the same measured signal at a different temperature, so the M calibration cannot be assumed valid for it. [1]

3(f) A shield is placed between M and the detector. The corrected signal falls to zero. Explain why that does not prove M has stopped emitting. **[2 marks]**

Answer / mark points: The shield can block/absorb M's infrared before it reaches the detector. [1] A zero background-corrected detector signal is not a measurement of zero emission at M; M still emits at its non-zero temperature. [1]

4 Foundation route comparing model surfaces

FOUNDATION REPLACEMENT: complete sections 4–5 only after sections 1–3. Skip Higher sections 6–7. Two model-surface samples P and Q have identical finishes, areas and viewing geometry. Their corrected signals are 12 and 24 units respectively.

4(a) Which model sample, P or Q, is hotter? Predict how its peak wavelength compares with the other sample. **[2 marks]**

Answer / mark points: Q is hotter because the same-finish/area/geometry sample gives the stronger signal. [1] Its emission peak is at a shorter wavelength. [1] These are matched samples, not unknown different finishes.

4(b) Q gives twice P's signal. Evaluate the claim that Q's temperature in °C must therefore be twice P's temperature. **[2 marks]**

Answer / mark points: Twice the signal does not establish twice the Celsius temperature; no direct proportionality has been supplied. [1] Numerical temperatures require a suitable temperature calibration/independent measurement. [1] Do not apply a temperature-ratio rule to arbitrary detector units.

4(c) A third sample R has an unknown finish and gives 30 units. Can the team safely conclude that R is hotter than Q? Explain. **[2 marks]**

Answer / mark points: No: R's different/unknown emitting properties may cause its larger signal. [1] Compare like finishes or independently measure/calibrate temperature before using the signal to rank them. [1]

4(d) The team only has a visible-light photograph of a candidate reference surface. State what measurement would give useful evidence about its infrared emission, and one comparison condition that must be controlled. **[2 marks]**

Answer / mark points: Measure its emitted infrared signal with a suitable detector. [1] Compare it with the reference at the same measured temperature (accept matched emitting area/detector geometry as a controlled condition). [1] Visible colour alone does not measure infrared output.

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5 Foundation route planning a temperature test

The team will investigate how the temperature of ONE reference plate affects its emitted infrared signal. A contact temperature probe and an infrared detector that reports raw signal are available. A teacher controls the low-power heater; do not touch a hot plate.

5(a) Pilot tests give signals 40, 42, 41 units at one temperature and 49, 51, 50 at a higher temperature. State the evidence that the difference is larger than the spread of these repeats, and one limit of this evidence. **[2 marks]**

Answer / mark points: The repeat ranges, 40–42 and 49–51, do not overlap. [1] This supports a difference in these tests but does not establish the whole temperature relationship or remove systematic detector bias. [1] Do not claim repeats prove perfect accuracy.

5(b) Identify the independent variable and the dependent variable in the proposed temperature test. **[2 marks]**

Answer / mark points: Independent: actual temperature of the same reference plate. [1]
Dependent: measured infrared detector signal. [1] Surface finish is controlled, not changed in this investigation.

5(c) Describe a method to investigate how the plate's temperature affects its emitted infrared signal. Include measurements at several temperatures, controls, repeats, analysis and a safety precaution. You do not need to investigate radiation balance. **[6 marks]**

Answer / mark points: Original best-fit rubric, not an official AQA mark scheme. Level 3 (5–6): a logical, workable method links independently measured plate temperatures to infrared signals, controls important surface/geometry effects, uses repeat measurements/analysis and manages hot-apparatus risk. Level 2 (3–4): most measurements are useful but an important control, temperature measurement or analysis link is unclear. Level 1 (1–2): isolated relevant actions without a workable comparison. 0: no relevant content. Use best fit, not six keyword ticks.

Example: Ask the teacher to set the same coated plate to several safe temperatures. Measure the plate temperature with the contact probe; do not use the uncalibrated infrared signal as its temperature. Fix the detector distance and angle so it views the same plate area. Keep finish, surrounding radiation and detector settings unchanged. At each stable measured temperature record the background-corrected infrared signal. Repeat readings, check unusual values and calculate means. Tabulate actual temperatures and mean signals, then plot signal vertically against temperature horizontally to describe the trend. Use a stand or guard, avoid touching the hot plate and let the teacher switch off and cool the equipment. No radiative-equilibrium explanation is required.

Foundation route complete. Stop here; sections 6–7 replace this route for Higher pupils.

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6 Higher only radiation balance

HIGHER REPLACEMENT: complete sections 6–7 instead of Foundation sections 4–5. Table 2 gives simplified model-planet rates at the same initial temperature, per square metre of the same reference area. Use the whole planet plus atmosphere as the system. No other energy transfers are included.

Table 2

Model	Incoming sunlight / W/m^2	Reflected sunlight / W/m^2	Outgoing thermal / W/m^2
P	320	80	240
Q	320	100	240
R	320	60	240

6(a) Calculate the rate of sunlight absorption for P. Use the emitted rate to explain its initial temperature behaviour. **[2 marks]**

Answer / mark points: Absorbed sunlight = $320 - 80 = 240 \text{ W/m}^2$. [1] Outgoing thermal emission is also 240 W/m^2 , so its model temperature stays constant. [1] Reflected radiation was not absorbed.

6(b) Predict whether Q and R initially warm or cool. Support each prediction with the absorbed and emitted rates. **[2 marks]**

Answer / mark points: Q: absorption $320 - 100 = 220 \text{ W/m}^2$ is below emission 240, so it cools. [1]
R: absorption $320 - 60 = 260 \text{ W/m}^2$ exceeds emission 240, so it warms. [1] Each direction needs its own valid comparison.

6(c) R eventually reaches a new constant temperature with incoming and reflected sunlight unchanged. State its outgoing thermal rate and explain why constant temperature does not mean radiation transfers stop. **[2 marks]**

Answer / mark points: Outgoing thermal emission must be 260 W/m^2 , equal to absorbed sunlight. [1] Absorption and emission continue at equal rates; only the net transfer is zero. [1] Including reflection gives total outgoing $260 + 60 = 320 \text{ W/m}^2$.

6(d) A reference plate in shade absorbs 30 W/m^2 and initially emits 50 W/m^2 . Explain its initial temperature change and how its emission changes as it approaches a steady temperature. Assume absorption stays at 30 W/m^2 . **[2 marks]**

Answer / mark points: It initially cools because emission exceeds absorption by 20 W/m^2 . [1] As temperature decreases it emits less, approaching 30 W/m^2 when absorption and emission balance. [1] It does not stop emitting.



7 Higher only surface and atmosphere

Figure 2 shows selected radiation paths, not a complete energy budget. Some sunlight reaches the surface. The atmosphere absorbs some surface infrared and emits infrared towards space and towards the surface. Other paths, including reflection and direct escape, are omitted. Arrow widths are not proportional to rates.

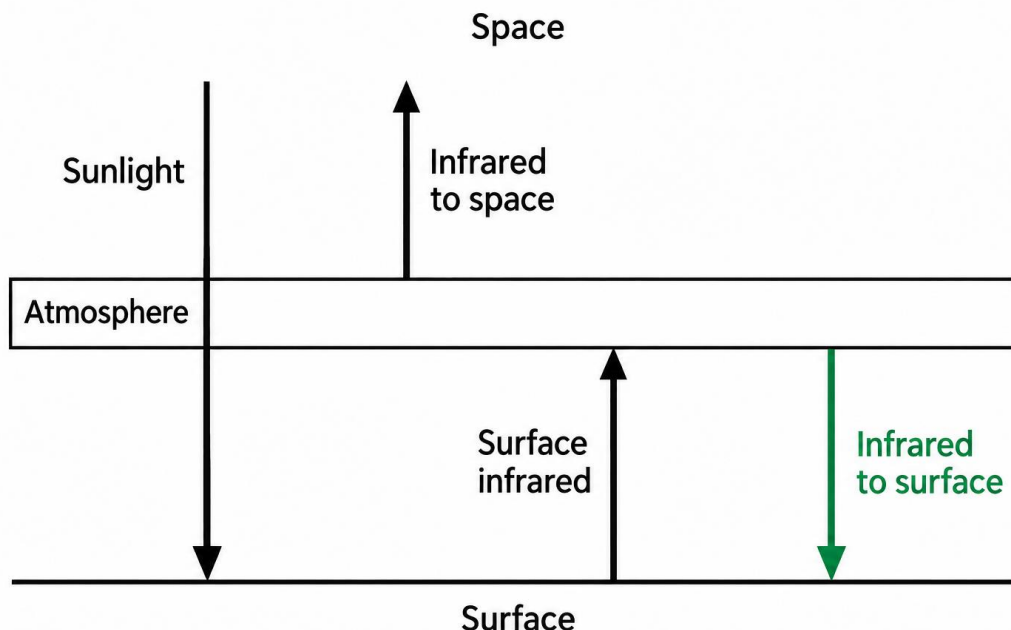


Figure 2

7(a) Does the downward “Infrared to surface” arrow show the atmosphere acting as a mirror? Explain the process represented. **[2 marks]**

Answer / mark points: No: the atmosphere absorbs some surface infrared. [1] It emits infrared of its own towards the surface as well as towards space; the selected downward path is emission, not simple reflection. [1]

7(b) For a 1 m^2 surface patch, absorbed sunlight is 200 W and absorbed atmospheric infrared is 100 W ; the patch emits 300 W . Atmospheric input then rises to 125 W before the surface temperature changes. Calculate the initial net energy gain per second and predict the temperature change. **[2 marks]**

Answer / mark points: Initial new net gain = $200 + 125 - 300 = 25 \text{ W} = 25 \text{ J}$ each second for the 1 m^2 patch. [1] The surface initially warms because total absorption exceeds emission. [1] The 125 W is an internal atmosphere-to-surface transfer, not extra sunlight.



7 Higher only surface and atmosphere continued

7(c) The team increases infrared absorption by a model atmosphere. Absorbed sunlight for the whole planet stays fixed. Explain why the surface can reach a higher steady temperature without any increase in sunlight, and why warming need not continue forever. Refer to absorption, atmospheric emission, the initial imbalance and the new balance. Figure 2 shows selected paths only. **[6 marks]**

Answer / mark points: Original best-fit rubric, not an official AQA mark scheme. Level 3 (5–6): a linked explanation uses atmospheric absorption/emission to explain increased radiation absorbed at the surface, initial warming and greater surface emission at a higher temperature, ending with a correct continuing rate balance and no extra energy source. Level 2 (3–4): some causal links and balance are correct but the transition or surface/whole-planet distinction is incomplete. Level 1 (1–2): isolated relevant facts with weak or incorrect links. 0: no relevant content. Use best fit, not six independent keywords.

Example: The surface emits infrared. The atmosphere absorbs some of it and emits infrared towards both space and the surface. In the changed model more atmospheric infrared is absorbed by the surface. Initially the surface is still at its old temperature and emits at its old rate, so it absorbs energy faster than it emits and warms. A hotter surface emits more radiation. It can reach a new, higher steady temperature at which its total absorption, including atmospheric infrared, equals its emission. Transfers continue; they do not stop. For the whole planet and atmosphere together, outgoing radiation to space again balances the unchanged absorbed sunlight. Atmospheric transfers redistribute energy within that system; they are not an additional source of sunlight. This simplified model does not mean all infrared is trapped or that the real atmosphere has no other effects.

Review and improve

Mark only the chosen route. No temperature ratio or exact temperature follows from an arbitrary signal or unscaled spectrum. Foundation excludes radiative-balance reasoning. Higher: distinguish absorbed sunlight from incident sunlight, and the surface boundary from the whole planet. Continuing emission/absorption is compatible with constant temperature.

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