

Electromagnetic spectrum and infrared

AQA GCSE Physics 8463 and Combined Science Trilogy 8464 | Paper 2

Worked solutions and teaching prompts | Foundation core and Higher-only section

Specification points covered

Spectrum and wave calculations: 8463 4.6.2.1, 4.6.1.2 / 8464 6.6.2.1, 6.6.1.2 (selected content)

Infrared surfaces practical: 8463 4.6.2.2, RP10 / 8464 6.6.2.2, RP21

Radiation hazards and supplied dose data: 8463 4.6.2.3 / 8464 6.6.2.3 (selected content)

Applications: 8463 4.6.2.4 / 8464 6.6.2.4 (selected content; explanations Higher only)

Higher only: wavelength-dependent transmission and radio circuits, 4.6.2.2–3 / 6.6.2.2–3

A food-drying and packaging line uses infrared heaters, inspection cameras and a shielded X-ray unit. You will check the engineers' calculations, compare surfaces and plan an infrared investigation. Inspection and dose data are supplied case studies, not instructions to operate radiation equipment.

Q1–5 are shared Foundation/Higher content. Q6 is Higher only on both routes. Accept equivalent precise wording and consistent follow-through. The six-mark method is judged for coherence and a valid comparison, not six automatic ticks. Timing is suggested, not classroom-tested. Original PhysicsUK questions, not an official AQA paper.

1 Comparing the waves

The line uses several parts of the electromagnetic spectrum. Work with wavelength and frequency, not vague descriptions such as stronger waves.

1(a) Write the seven groups of electromagnetic waves in order from longest to shortest wavelength, starting with radio waves. **[2 marks]**

Answer / mark points: Radio, microwave, infrared, visible, ultraviolet, X-ray, gamma. [2]

Award 1 mark for an otherwise correct order with one group misplaced or omitted; 2 for the complete correct order.

1(b) Compare visible light from the inspection lamp with infrared from the heater. State how their speeds in a vacuum compare and which has the higher frequency. **[2 marks]**

Answer / mark points: Their speeds in a vacuum are the same. [1] Visible light has the higher frequency. [1]

Teacher prompt: Do not say the higher-frequency wave travels faster in a vacuum.

1(c) One infrared heater emits at a wavelength of 1.2×10^{-5} m. Calculate the frequency of this radiation. **[2 marks]**

Answer / mark points: $f = v / \lambda = (3.0 \times 10^8) / (1.2 \times 10^{-5})$. [1]
 $f = 2.5 \times 10^{13}$ Hz. [1]

Teacher prompt: Divide by the entire wavelength. The answer is a frequency, not a wave speed.



1 Comparing the waves continued

1(d) A radio link operates at 100 MHz. Calculate its wavelength in a vacuum. Use $1 \text{ MHz} = 10^6 \text{ Hz}$. [2 marks]

Answer / mark points: $f = 100 \times 10^6 = 1.0 \times 10^8 \text{ Hz}$. [1]
 $\lambda = v / f = (3.0 \times 10^8) / (1.0 \times 10^8) = 3.0 \text{ m}$. [1]

1(e) An engineer doubles the frequency of a beam in a vacuum and claims its speed must double. State what actually happens to its speed and its wavelength. [2 marks]

Answer / mark points: Its speed stays the same. [1] Its wavelength halves, because $v = f\lambda$ and v is unchanged. [1]

2 Following energy and inspection signals

The visible camera records light reflected from packets. A separate thermal camera detects infrared emitted by warm surfaces. The shielded X-ray unit has a detector behind each packet: metal absorbs more of its X-rays than the food does.

2(a) For the infrared drying stage, identify the source and an absorber, and state what the radiation transfers between them. [2 marks]

Answer / mark points: Source: the infrared heater; absorber: the food. [1 for both]
 The radiation transfers energy from the heater to the food. [1]

2(b) A warm tray emits infrared when the visible inspection lamps are switched off. Can a person see that infrared directly with their eyes? Give the relevant detection limit of the eye. [1 mark]

Answer / mark points: No: the human eye detects visible light, not infrared. [1]

2(c) The factory sends data through a visible-light fibre link and a microwave satellite link. Which has the longer wavelength? Name one spectrum group with still longer wavelengths than microwaves. [2 marks]

Answer / mark points: The microwave satellite signal has the longer wavelength. [1] Radio waves have still longer wavelengths. [1]

2(d) With the same X-ray input, packet region P gives a detector signal of 85 units and region Q gives 22 units. Which region should be checked for a metal fragment? Use the supplied absorption information to justify your answer. [2 marks]

Answer / mark points: Check Q. [1] Its lower transmitted signal is consistent with more X-rays being absorbed, as a metal fragment would do. [1]

Teacher prompt: The low detector signal means greater absorption along that path, not less radiation emitted by the X-ray source.



3 Comparing absorption by surfaces

The engineers test equal-area aluminium plates of the same mass and thickness. They start each trial at 21.0 °C, use the same heater setting, distance, angle and 90 s heating time, and measure temperature with contact probes. All conditions except surface finish are kept the same. Table 1 gives temperature rises, not final temperatures.

Table 1

Surface	Trial 1 rise / °C	Trial 2 rise / °C	Trial 3 rise / °C
Matt black	9.2	8.8	9.0
Polished aluminium	3.1	2.9	3.0

3(a) In a preliminary plate test, a contact probe reads 21.5 °C initially and 28.7 °C afterwards. Calculate the temperature rise. **[1 mark]**

Answer / mark points: Temperature rise = $28.7 - 21.5 = 7.2$ °C. [1]

3(b) Calculate the mean temperature rise for the matt black plate in Table 1. **[1 mark]**

Answer / mark points: Mean = $(9.2 + 8.8 + 9.0) / 3 = 9.0$ °C. [1]

3(c) Calculate the mean temperature rise for the polished plate in Table 1. **[1 mark]**

Answer / mark points: Mean = $(3.1 + 2.9 + 3.0) / 3 = 3.0$ °C. [1]

3(d) The team needs a plate that absorbs radiation strongly from this heater. Choose a surface and support the choice using the mean results and the physics being tested. **[2 marks]**

Answer / mark points: Choose matt black: its mean rise is 9.0 °C, compared with 3.0 °C for polished aluminium. [1]
With equal plates and controlled exposure, the larger temperature rise indicates greater absorption from the heater. [1]

3(e) A trainee says Table 1 directly measures which plate emits more infrared. Explain why this describes the wrong process and state the kind of measurement needed to compare emission directly. **[2 marks]**

Answer / mark points: The plates are being heated by an external source; the temperature rises are evidence about absorption, not a direct measurement of emitted infrared. [1]
For emission, compare infrared detector readings from surfaces held at the same temperature without the external heater shining on them. [1]

3(f) Calculate the range of the three temperature rises for the matt black plate. **[1 mark]**

Answer / mark points: Range = highest – lowest = $9.2 - 8.8 = 0.4$ °C. [1]

3(g) Explain why repeating trials and calculating means is useful, but would not repair a test in which one plate was always closer to the heater. **[2 marks]**

Answer / mark points: Repeats and means reduce the effect of random variation on the comparison. [1]
They do not remove the systematic unfairness of unequal distances: different incident radiation would still affect the results. [1]



4 Planning a surface emission investigation

The team now compares emission, using a hot-water Leslie cube with differently finished faces (Figure 1). An infrared detector and meter give a relative radiation reading, not the water temperature. The contact thermometer checks water temperature. Plan a teacher-supervised investigation; do not use an external heater during detector readings.

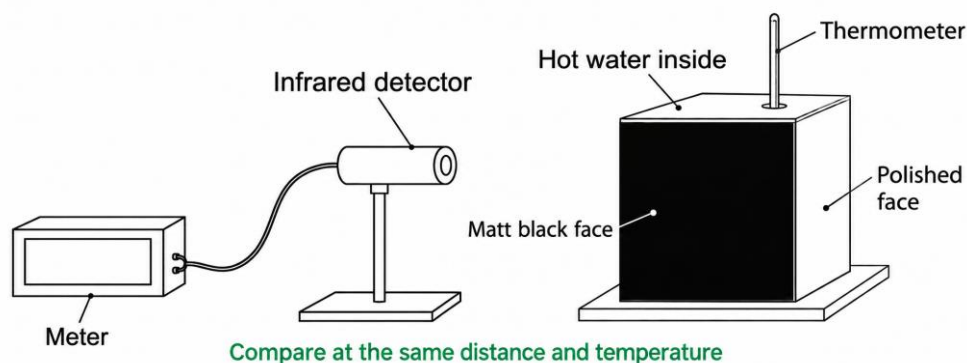


Figure 1

4(a) For the emission investigation in Figure 1, identify the independent variable and the measured dependent variable. **[2 marks]**

Answer / mark points: Independent variable: the nature or finish of the cube face. [1]
Dependent variable: the infrared detector or meter reading. [1]

4(b) State two quantities that must be controlled when comparing the faces, and say how each should be kept the same. **[2 marks]**

Answer / mark points: Any two: keep detector-to-face distance equal, measured with a ruler; keep water or face temperature equal, checked with the contact thermometer; keep the detector facing each face at the same angle and position; keep background radiation and room conditions unchanged. [1 each, maximum 2]

4(c) The detector is 10 cm from the black face but 6 cm from the polished face. A trainee uses the readings to rank the surfaces. Explain why this is not a valid comparison. **[2 marks]**

Answer / mark points: The detector-to-face distance changes as well as the surface finish. [1]
Distance affects the radiation received, so a reading difference cannot be attributed to surface finish alone. [1]



4 Planning a surface emission investigation continued

4(d) Describe a complete method to compare the infrared emitted by the matt black and polished faces. Use Figure 1 and include setup, measurements, controls, repeats, analysis and a safety precaution. **[6 marks]**

Answer / mark points: Example coherent method: place the cube on a heatproof mat and have the teacher fill it with hot water and fit the lid. Allow the faces to warm. Use the contact thermometer to check the water is at the chosen temperature, for example 60 °C.

Use one infrared detector and meter. Measure a fixed distance from its receiving window to the centre of the tested face with a ruler, and aim it normally at that face. Record a stable reading. Keep the same distance, angle, viewed area and meter settings for the other face.

Take the paired readings while the water temperature is unchanged within a stated small tolerance; check it before and after the pair. If it falls appreciably, restore the starting temperature and repeat the pair. Keep nearby heaters off and the room conditions unchanged; check the detector baseline consistently.

Repeat both measurements at least three times at the same starting temperature, reversing the reading order between sets to check cooling effects. Calculate the mean detector reading for each face and compare them: the higher reading indicates greater infrared emission under these conditions.

Avoid hot metal and splashes: use a stable mat and heat-resistant gloves for handling, with teacher control of filling. Do not point the detector at a heater instead of the cube.

Teacher prompt: Use a best-fit six-mark-style judgement: 5–6 for a coherent, workable controlled comparison with measurements and explicit comparison of results; 3–4 for a mainly sensible but incompletely controlled or analysed method; 1–2 for isolated relevant steps; 0 for no relevant method. Repeats and safety strengthen the method but do not substitute for measuring and comparing emission. Do not award six automatic ticks.

5 Interpreting exposure data

Table 2 gives illustrative X-ray dose estimates for two approved servicing plans for trained staff. All listed checks use the same type of radiation. Compare only the exposure in this table; it contains no legal limit or estimate of total lifetime exposure.

Table 2

Plan	Number of checks	Estimated dose per check / mSv
P	20	0.006
Q	60	0.002

5(a) Use Table 2 to calculate the total estimated X-ray dose for plan P and for plan Q. **[2 marks]**

Answer / mark points: P: $20 \times 0.006 = 0.120$ mSv. [1]

Q: $60 \times 0.002 = 0.120$ mSv. [1]

5(b) Express a dose of 0.120 mSv in sieverts. Use $1000 \text{ mSv} = 1 \text{ Sv}$. **[1 mark]**

Answer / mark points: $0.120 / 1000 = 0.000120 \text{ Sv} = 1.20 \times 10^{-4} \text{ Sv}$. [1]

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5 Interpreting exposure data continued

5(c) For the X-ray exposure in Table 2, state one risk comparison the data support and one claim of safety that the data do not establish. **[2 marks]**

Answer / mark points: The plans give the same estimated total dose from this radiation, so there is no dose-based reason here to call Q lower risk. [1]
The table does not establish zero risk, a guaranteed safe exposure or a precise chance of harm; other exposures are not included. [1]

Teacher prompt: A dose estimate measures risk, not certainty that an individual will or will not develop cancer. These numbers are not legal limits.

5(d) Explain why X-rays can damage living tissue, even though they are electromagnetic waves rather than particles of radioactive material. **[2 marks]**

Answer / mark points: X-rays are ionising radiation, so they can ionise atoms or molecules in living cells. [1]
This can damage genes, causing mutations and increasing the risk of cancer. [1]

5(e) An ultraviolet-blocking guard and interlock prevent staff looking into an ultraviolet cleaning unit while it operates. Link one ultraviolet hazard to the purpose of this protection. **[2 marks]**

Answer / mark points: Ultraviolet exposure can damage skin, causing premature ageing or increasing skin-cancer risk; accept a relevant eye-damage hazard. [1]
The guard blocks the radiation and the interlock prevents exposure when the guard is open, reducing the exposure risk. [1]

6 Higher only application explanations

Q6 is Higher-only content for both Separate Physics and Trilogy. Use the relevant interaction of radiation with matter rather than saying that a type is useful because it works.

6(a) Higher only: explain why infrared is suitable for the electrical drying heaters, rather than merely naming its use. **[2 marks]**

Answer / mark points: Infrared from the hot heater is absorbed by the food. [1]
It transfers energy to the food's thermal store, raising its temperature and supporting drying. [1]

6(b) Higher only: a microwave stage warms water-rich food before drying. Explain why microwaves can be used for this stage. **[2 marks]**

Answer / mark points: Microwaves are absorbed by water molecules in the food. [1]
The absorbed energy increases the food's internal energy and temperature. [1]

Teacher prompt: Do not say that all microwave energy is reflected by water, or that it heats food by radioactive contamination.

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6 Higher only application explanations continued

Table 3

Window	Visible transmitted / %	Infrared transmitted / %
F	92	3
G	8	85

6(c) Higher only: the visible camera needs a window that passes visible light but rejects infrared. Choose F or G from Table 3 and justify the choice using both measured percentages. **[2 marks]**

Answer / mark points: Choose F: it transmits 92% of the visible light but only 3% of the infrared. [1]
It therefore passes most of the required visible signal and rejects most infrared; G passes only 8% visible and 85% infrared, the opposite of the requirement. [1]

Teacher prompt: Transparency depends on wavelength. A material that passes visible light need not pass infrared.

6(d) Higher only: oscillations in the 100 MHz transmitter circuit produce radio waves. When they reach the receiving circuit, what can they induce, and what is its frequency? **[2 marks]**

Answer / mark points: They can induce an alternating current or electrical oscillations in the receiving circuit. [1]
Its frequency is the same as the radio wave: 100 MHz (1.0×10^8 Hz). [1]

6(e) Higher only: explain why the supplied difference in X-ray absorption by food and metal makes X-rays suitable for this hidden-fragment inspection. **[2 marks]**

Answer / mark points: Enough X-rays pass through the food to reach the detector, while metal absorbs more. [1]
The resulting difference in transmitted intensity produces contrast that can reveal a metal fragment hidden inside the packet. [1]

Review and improve

Infrared is not a substance called heat, and it is not radioactive decay. Keep wavelength, frequency and speed distinct. A detector reading is not automatically a temperature. Absorption data do not directly measure emission. A method needs a controlled comparison and a stated way to use the results. A lower dose per check need not mean a lower total dose.

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