Perfect black bodies and radiation

4.6.3.2 · Waves · revision notes

How the intensity and wavelength distribution of the radiation a body emits depend on its temperature, and (Higher tier) how the balance between the radiation a body absorbs and emits decides whether it warms up, cools down or stays at a constant temperature, including for the Earth. GCSE Physics only, not in Combined Science.

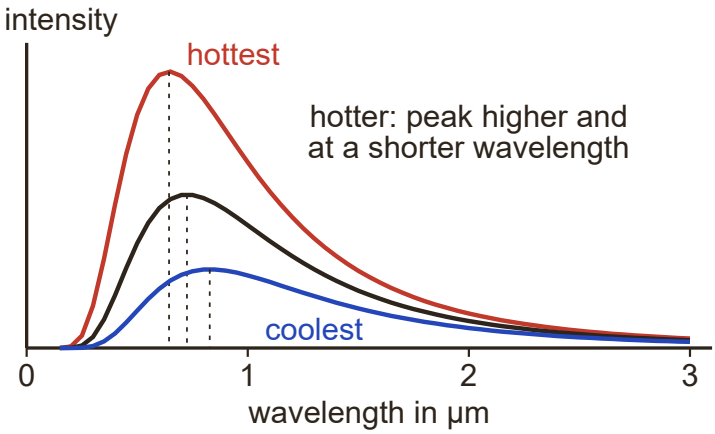
Key facts

- All bodies emit radiation
- Hotter → more radiation at every wavelength; the peak moves to a shorter wavelength
- Grade 7+ only Constant temperature: rate of absorption = rate of emission
- Grade 8+ only Earth's temperature depends on absorption, emission and reflection of radiation into space
- Intensity and wavelength distribution depend on temperature
- Sun (very hot): lots of visible light. Earth (cooler): mainly infrared
- Grade 7+ only Absorbs faster than it emits → temperature rises; emits faster → temperature falls

Notes

Emission depends on temperature

- All bodies emit radiation. The **intensity** (how much is emitted) and the **wavelength distribution** (how it is spread across the wavelengths) depend on the temperature of the body.
- As a body gets hotter it emits more radiation at every wavelength, and the intensity at shorter wavelengths increases the most.
- So the peak of an intensity–wavelength graph is higher, and at a **shorter wavelength**, for a hotter body.



As the temperature rises, the peak gets higher and moves to shorter wavelengths.

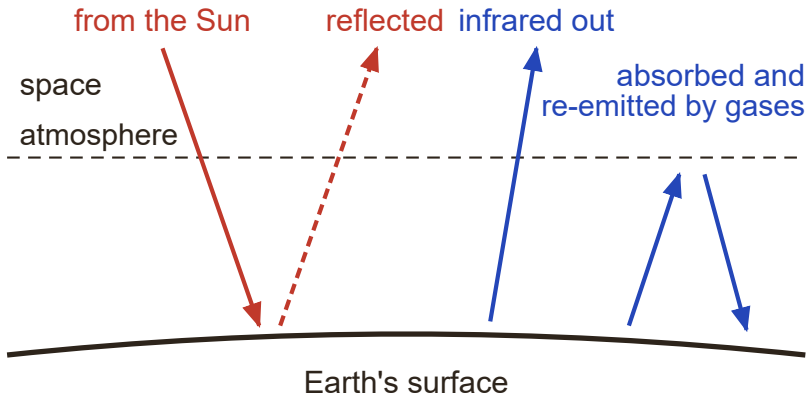
- Example: a metal rod being heated at first emits infrared that you can feel but not see; as it gets hotter it glows dull red, then orange-yellow and finally white.
- The Sun is very hot, so it emits a lot of visible light. The Earth is much cooler, so it emits mainly longer-wavelength infrared.

Balancing absorption and emission Grade 7+ only

- A body at **constant temperature** is absorbing radiation at the **same rate** as it is emitting radiation.
- Its temperature **increases** when it absorbs radiation faster than it emits it, and **decreases** when it emits radiation faster than it absorbs it.
- Everyday example: a car parked in sunshine absorbs radiation faster than it emits it, so it warms up. As it gets hotter it emits radiation faster, until the two rates are equal and its temperature stays constant.

The temperature of the Earth Grade 8+ only

- The Earth absorbs radiation from the Sun and emits infrared radiation into space.
- Some of the Sun's radiation is **reflected** back into space, for example by clouds, ice and snow, without being absorbed.
- The Earth's temperature depends on the rates of **absorption** and **emission** of radiation and on how much radiation is **reflected** into space.
- During the day a place absorbs radiation faster than it emits it, so it warms up. At night it absorbs no radiation from the Sun but keeps emitting, so it emits faster than it absorbs and cools down.
- Clouds absorb some of the infrared emitted by the ground and emit some of it back down, so a cloudy night cools more slowly than a clear one.
- Gases in the atmosphere, such as carbon dioxide and water vapour, absorb some of the infrared emitted by the Earth's surface and emit some of it back towards the surface. More of these gases slows the rate at which radiation escapes to space, so the temperature rises until a new balance is reached.



The temperature depends on absorption, emission and reflection of radiation.

How to answer each type of question

Describe how the radiation emitted changes with temperature 2 marks **Grade 5**

1. Say the total radiation (intensity) increases at all wavelengths.
2. Say the peak moves to shorter wavelengths (a greater proportion at short wavelengths).

Example. A metal rod is heated in a flame. It starts to glow red and later glows yellow-white. Describe how the radiation emitted by the rod changes as its temperature increases.

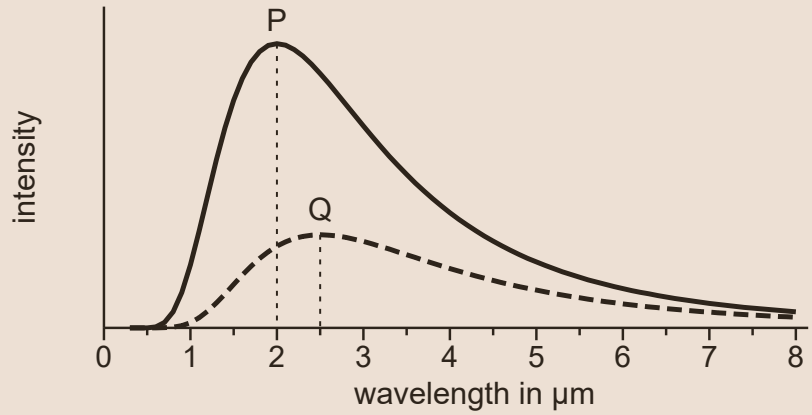
Model answer. The rod emits more radiation (a greater intensity) at all wavelengths (1). A greater proportion is emitted at shorter wavelengths, so the peak wavelength decreases and its colour changes from red towards white (1).

Interpret an intensity–wavelength graph

2 to 3 marks | **Grade 6**

1. Check the axes: which is intensity and which is wavelength.
2. The hotter body has the higher curve.
3. The hotter body's peak is at the shorter wavelength. Quote values from the graph.

Example. The graph shows how the intensity of the radiation emitted by two hot objects, P and Q, varies with wavelength.



Which object is hotter? Give **two** reasons for your answer.

Model answer. Object P (1). Its peak intensity is at a shorter wavelength, 2.0 μm compared with 2.5 μm (1). It emits more radiation (a higher intensity) at every wavelength (1).

Explain temperature changes using absorption and emission

3 marks | **Grade 7**

1. Compare the rates: absorbing faster than emitting means warming up.
2. Say that a hotter body emits radiation faster.
3. Say the temperature becomes constant when the two rates are equal.

Example. A dark-coloured car is parked in the sun. Its temperature rises for a while and then stays constant.
Explain why, in terms of radiation.

Model answer. At first the car absorbs radiation faster than it emits it, so its temperature rises (1). As it gets hotter, it emits radiation at a greater rate (1). When the rate of emission equals the rate of absorption, its temperature stays constant (1).

Explain a change in the Earth's temperature

4 marks | Grade 8

1. Say what the change does to reflection, absorption or emission.
2. Compare the new rates of absorption and emission.
3. State the effect on temperature, and that a new balance is reached.

Example. Large areas of ice near the poles are melting, exposing darker ground and sea underneath. Explain how this could affect the temperature of the Earth.

Model answer. Ice reflects much of the Sun's radiation back into space (1). The darker ground and sea reflect less and absorb more of the radiation (1). So the Earth absorbs radiation faster than it emits it (1). So the Earth's temperature rises, until the rate of emission increases enough to balance absorption again (1).

Don't lose marks

- Saying a body at constant temperature is not emitting or absorbing radiation. It is doing both at the same rate.
- Saying a hotter body emits 'only shorter wavelengths'. It emits more at all wavelengths; the peak moves to shorter wavelengths.
- Reading the graph the wrong way round: check which axis is wavelength and which is intensity.
- In Earth questions, forgetting reflection: some radiation is reflected into space without being absorbed.

More tips

Memory tricks

- Hotter = higher and further left: on an intensity–wavelength graph (wavelength increasing to the right) the hotter curve is higher and peaks at a shorter wavelength.
- Bank account picture: absorption is money in, emission is money out. In = out, the temperature stays constant; in > out, it rises; in < out, it falls.
- Red hot to white hot: as an object heats up, more of the shorter wavelengths are added, so the peak wavelength gets shorter.

Exam technique

- Use the word 'rate' in Higher tier answers: 'absorbs radiation at a greater rate than it emits radiation'.
- In Earth questions, give the change, then its effect on reflection, absorption or emission, then the effect on temperature.
- When a graph is given, quote peak wavelengths or intensities from it to support your answer.

What each grade needs

What you need to be able to do, from the first marks up to the top grade.

Grade 3 — **State that all bodies emit radiation**

Every object emits radiation; how much, and at which wavelengths, depends on its temperature.

Grade 5

Describe how emission changes with temperature

A hotter body emits more radiation at every wavelength, and relatively more at shorter wavelengths.

Grade 6

Interpret intensity–wavelength graphs

The hotter body's curve is higher and its peak is at a shorter wavelength.

Grade 7

Explain constant temperature using absorption and emission

A body at constant temperature absorbs radiation at the same rate as it emits radiation.

Grade 7

Explain why a body warms or cools

It warms up if it absorbs radiation faster than it emits it, and cools down if it emits faster than it absorbs.

Grade 8

Explain what controls the Earth's temperature

The rates of absorption and emission of radiation, and how much radiation is reflected into space.

Grade 9

Interpret diagrams of the Earth's radiation balance

Use given data or diagrams to explain changes in the temperature of the Earth's surface and atmosphere.

Free notes, Full packs, practice papers and mock exams at chhetriacademy.com. Written for this site; not taken from past papers. Stuck? 1-to-1 tutoring with a free 30-minute trial lesson.