Edexcel GCSE Physics

Your notes

Thermal Radiation

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Thermal Radiation

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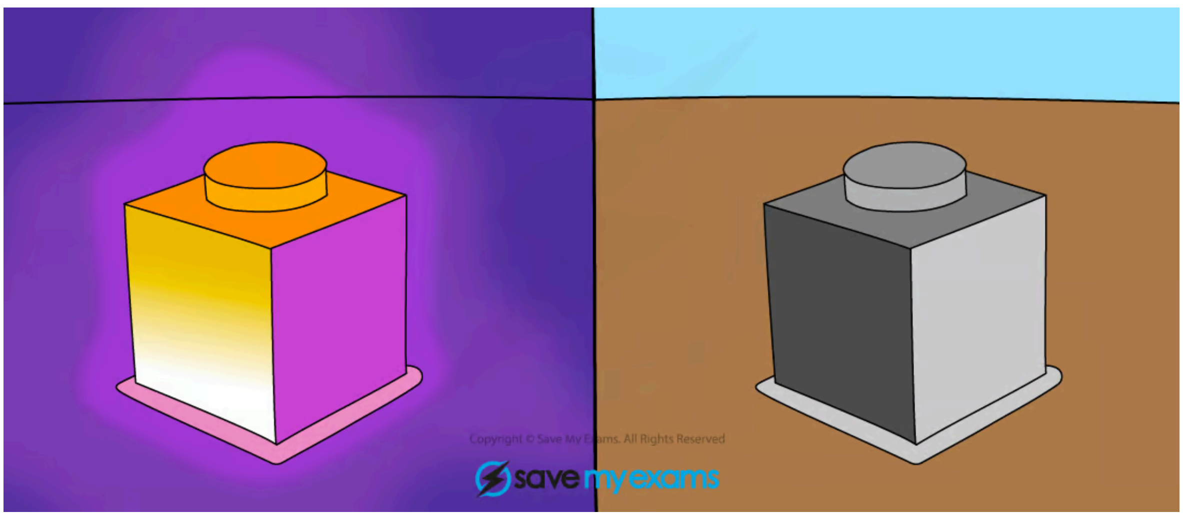
Thermal Radiation

- All bodies (objects), no matter what temperature, emit a spectrum of thermal radiation in the form of electromagnetic waves
    - These electromagnetic waves usually lie in the **infrared** region of the spectrum but could be emitted in the form of visible light or other wavelengths, depending on the temperature
- The **hotter** object, the **more** infrared radiation it radiates in a given time



The infrared radiation emitted from a hot object can be detected using a special camera

- The **intensity** and **wavelength** distribution of any emitted waves depends on the **temperature** of the body
- This can be represented on a thermal radiation curve
    - As the temperature increases, the peak of the curve moves
    - This moves to a **lower** wavelength and a **higher** intensity

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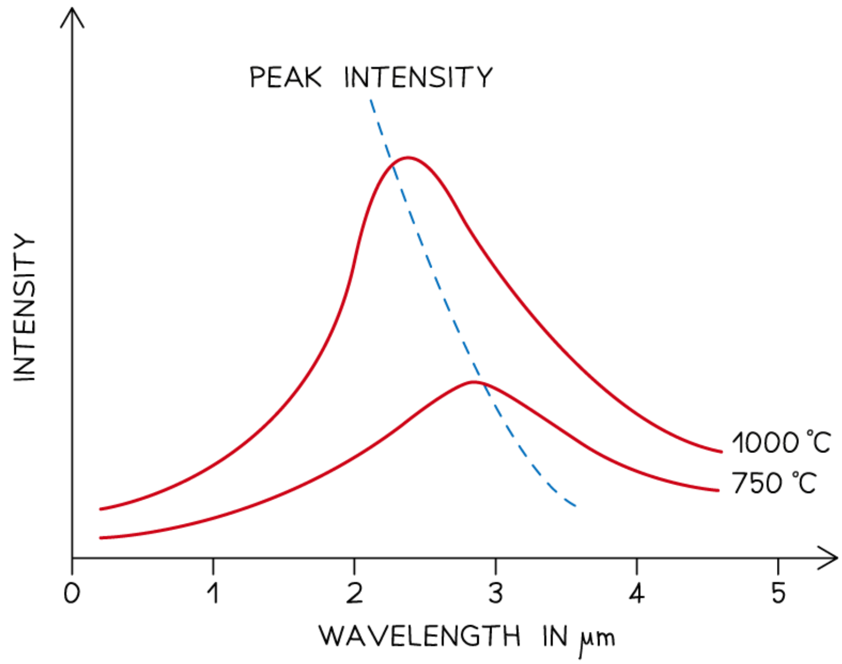


The peak of a thermal radiation curve moves to the left with increasing temperature

- From the electromagnetic spectrum, waves with a **smaller** wavelength have **higher** energy (e.g. UV rays, X-rays)
- When an object gets hotter, the amount of **thermal radiation** it emits increases
- This increases the energy emitted and therefore the **wavelength** of the emitted radiation **decreases**
  - At room temperature objects emit thermal radiation in the infrared region of the spectrum
  - At around 1000 °C an object will emit a significant amount of **red light**
  - At 6000 °C an object will mainly emit **white** or **blue light** (and some ultraviolet)
  - At even higher temperatures objects will emit **ultraviolet** or even **X-rays**

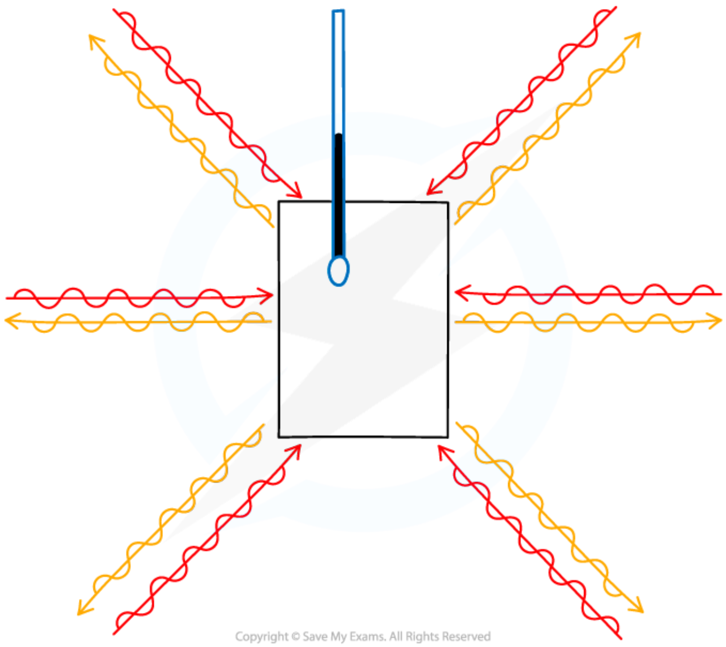
Thermal Equilibrium

Higher Tier Only

- As an object **absorbs** thermal radiation it will become **hotter**
- As it gets hotter it will also **emit** more thermal radiation

- The temperature of a body increases when the body absorbs radiation faster than it emits radiation

- Eventually, an object will reach a point of **constant temperature** where it is **absorbing** radiation at the **same rate** as it is **emitting** radiation
  - At this point, the object will be in **thermal equilibrium**



An object will remain at a constant temperature if it absorbs heat at the same rate as it loses heat

Radiation & Temperature

Higher Tier Only

- The temperature of a body can be regulated by balancing how much incoming radiation is absorbed and emitted (or reflected)
- If an object starts to absorb radiation at a higher rate than it radiates it, then the object will **heat up**
  - Likewise, if it loses radiation at a greater rate than it absorbs it, then the object will **cool down**
- This is how an emergency blanket works, to keep a trauma victim warm:
  - Rescue teams use light-coloured, shiny emergency blankets to keep accident survivors warm
  - A light, shiny outer surface emits a lot less radiation than a dark, matt (non-glossy) surface

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- This keeps the patient warm, as less infrared radiation is emitted than if an ordinary blanket had been used

The reflective nature of a emergency blanket helps to keep a trauma patient warm

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Radiation & Temperature Change

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Temperature of the Earth

Higher Tier Only

- If the Earth had no atmosphere, the temperature on the surface would drop to about –180 °C at night, the same as the Moon's surface at night
  - This would happen because the surface would be emitting **all** the radiation from the Sun into space
- The temperature of the Earth is affected by factors controlling the balance between **incoming** radiation and radiation **emitted**
- The Earth receives the majority of its heat in the form of thermal radiation from the Sun
  - At the same time, the Earth **emits** its own thermal radiation, with a slightly longer wavelength than the thermal radiation it receives (the surface temperature of the Earth is significantly smaller than the surface temperature of the Sun)
- Some gases in the atmosphere, such as water vapour, methane, and carbon dioxide (greenhouse gases) absorb and reflect back longer-wavelength infrared radiation from the Earth and prevent it from escaping into space
  - These gases **absorb** the radiation and then **emit** it back to the **surface**
- This process makes the Earth warmer than it would be if these gases were not in its atmosphere

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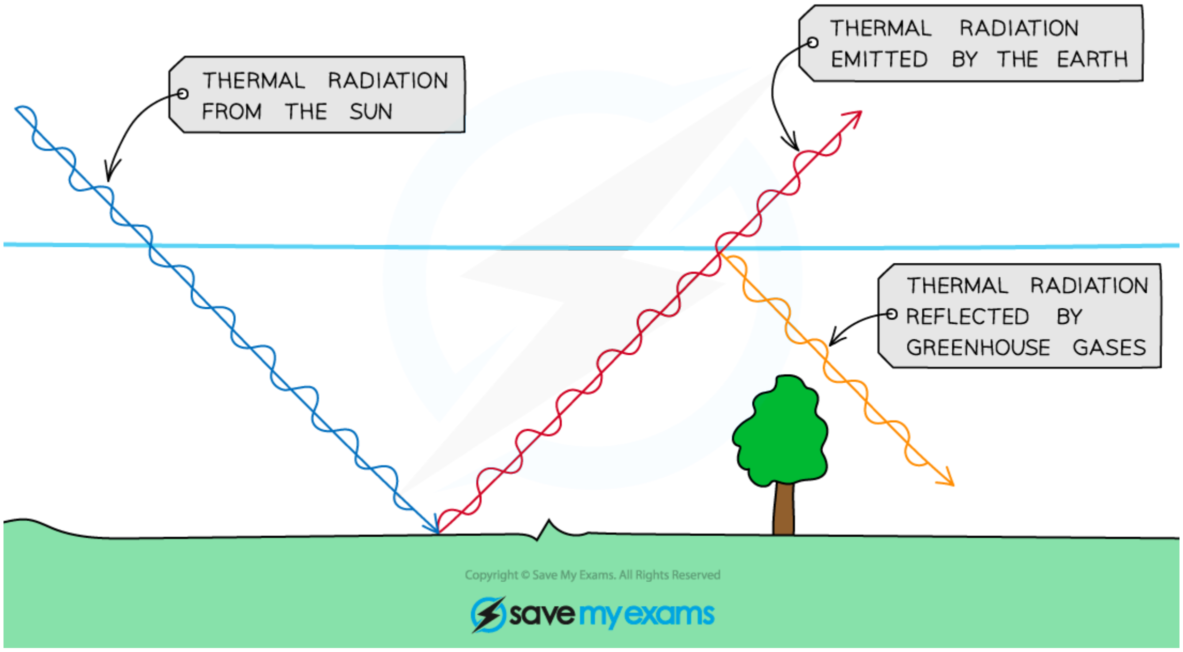
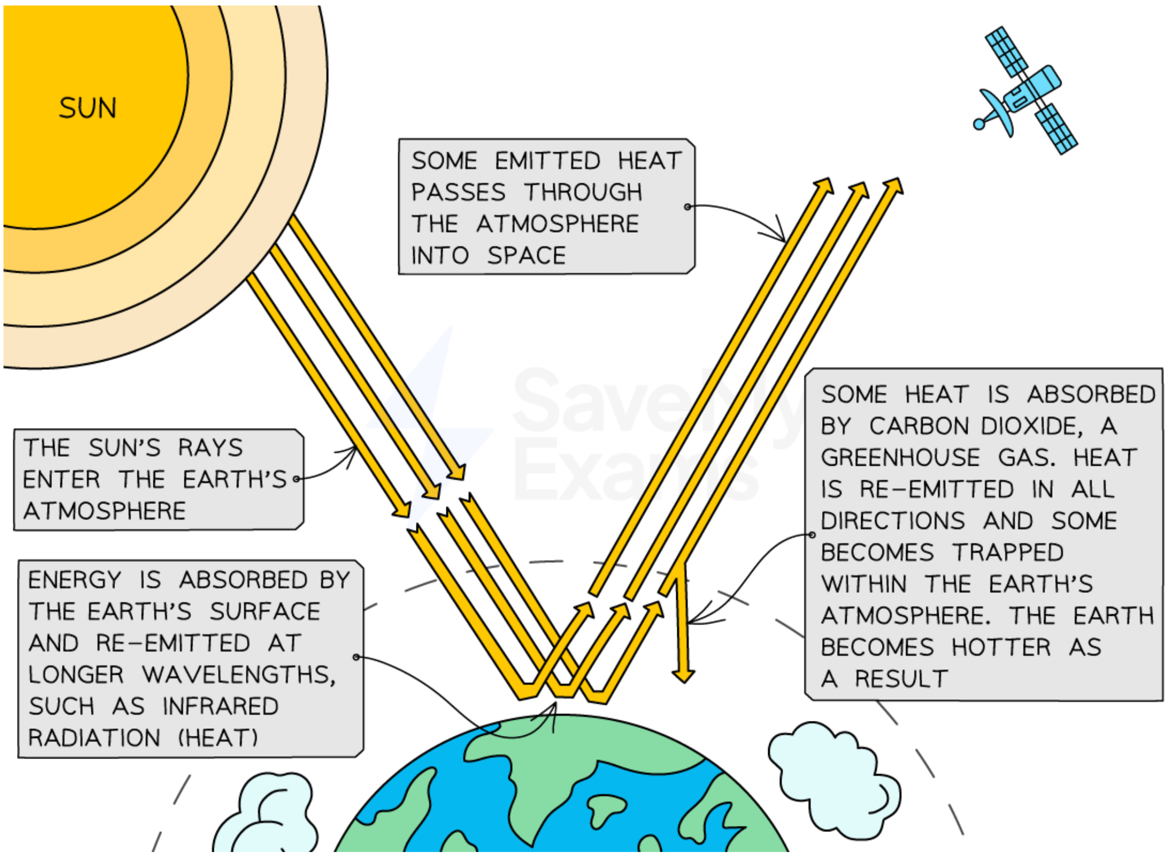


The Earth receives thermal radiation from the Sun but emits its own thermal radiation at the same time

- The temperature of the Earth, therefore, depends on several factors, such as the rate that light and infrared radiation from the Sun are:
  - **Reflected** back into space
  - **Absorbed** by the Earth's atmosphere or by the Earth's surface
  - **Emitted** from the Earth's surface and from the Earth's atmosphere into space

The Greenhouse Effect

- The rate of absorption and emission of radiation on Earth contributes to the **Greenhouse Effect**
  - This is the natural process that warms the Earth's surface from the Sun
- The Sun's thermal radiation reaches the Earth's atmosphere where:
  - Some radiation is **reflected** back to space
  - Any radiation not reflected is **absorbed** and re-radiated by greenhouse gases
- The absorbed radiation then warms the atmosphere and the surface of the Earth
  - This is similar to what happens in a greenhouse to keep a humid, and warm temperature to grow plants


SUN
SOME EMITTED HEAT PASSES THROUGH THE ATMOSPHERE INTO SPACE
THE SUN'S RAYS ENTER THE EARTH'S ATMOSPHERE
SOME HEAT IS ABSORBED BY CARBON DIOXIDE, A GREENHOUSE GAS. HEAT IS RE-EMITTED IN ALL DIRECTIONS AND SOME BECOMES TRAPPED WITHIN THE EARTH'S ATMOSPHERE. THE EARTH BECOMES HOTTER AS A RESULT
ENERGY IS ABSORBED BY THE EARTH'S SURFACE AND RE-EMITTED AT LONGER WAVELENGTHS, SUCH AS INFRARED RADIATION (HEAT)

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Core Practical: Investigating Thermal Radiation

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Core Practical 3: Investigating Thermal Radiation

Aims of the Experiment

The aim of the experiment is to investigate how the amount of infrared radiation absorbed or radiated by a surface depends on the nature of that surface

Variables:

- Independent variable = Colour
- Dependent variable = Temperature
- Control variables:
  - Identical flasks (except for their colour)
  - Same amounts of hot water
  - Same starting temperature of the water
  - Same time interval

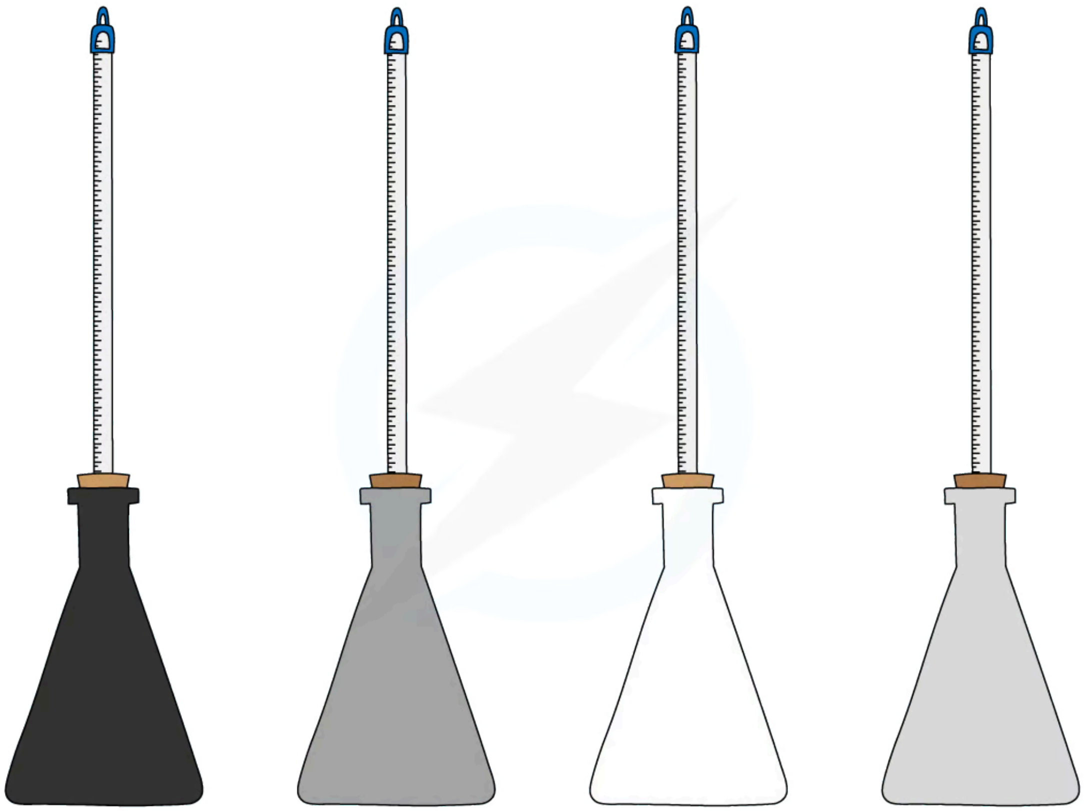
Equipment List

Equipment	Purpose
Kettle	To boil water
4 Thermometers	To measure the temperature of the water
Flasks painted different colours (black, dull grey, white, silver)	To investigate the heat loss of the different colours
Heatproof mat	To protect the surface and to prevent heat loss from the bottom of the flask
Stopwatch	To record the time it takes for water to cool

- Resolution of measuring equipment:

- Thermometer = 1°C
- Stopwatch = 0.01 s

Method



1. Set up the four identical flasks painted black, grey, white and silver
2. Fill the flasks with hot water, ensuring the measurements start from the same initial temperature
3. Note the starting temperature, then measure the temperatures at regular intervals e.g. every 30 seconds for 10 minutes

Analysis of Results

- All warm objects emit thermal radiation in the form of **infrared** waves
- The intensity (and wavelength) of the emitted radiation depends on:
  - The **temperature** of the body (hotter objects emit more thermal radiation)
  - The **surface area** of the body (a larger surface area allows more radiation to be emitted)

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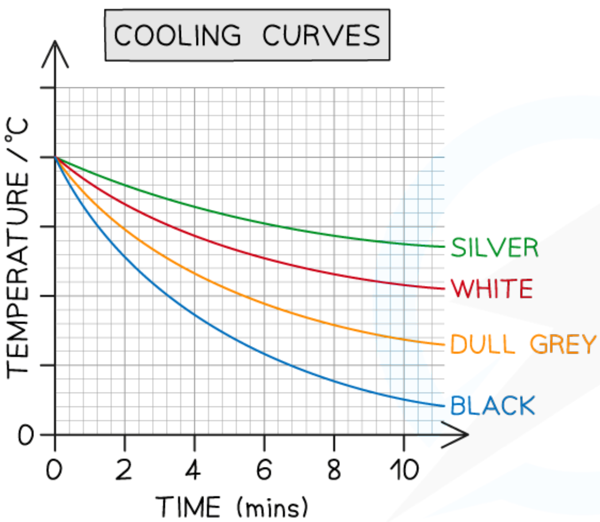
- The **colour** of the surface
- Most of the heat lost from the beakers will be due to conduction and convection
    - This will be the same for each beaker, as colour does not affect heat loss in this way
- Any difference in heat loss between the beakers must, therefore, be due to infrared (thermal) radiation
- To compare the rate of heat loss of each flask, plot a graph of temperature on the y-axis against time on the x-axis and draw curves of best fit
- The expected results are shown on the graph below:



Colour	Good or bad emitter?
Black	Good (cools fastest)
Dull grey	Reasonable (second fastest)
White	Poor (second slowest)
Silver	Very poor (cools slowest)

- An example table of results might look like this:

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TIME / mins	BLACK / °C	WHITE / °C	DULL GREY / °C	SILVER / °C
0.5				
1.0				
1.5				
2.0				
2.5				
3.0				
3.5				
4.0				
4.5				
5.0				
5.5				
6.0				
6.5				
7.0				

Evaluating the Experiment

Systematic Errors:

- Make sure the starting temperature of the water is the same for each material since this will cool very quickly
    - It is best to do this experiment in pairs to coordinate starting the stopwatch and immersing the thermometer
- Use a data logger connected to a digital thermometer to get more accurate readings

Random Errors:

- Make sure the hole for the thermometer isn't too big, otherwise the heat will escape through the hole
- Take repeated readings for each coloured flask
- Read the values on the thermometer at eye level, to avoid parallax error

Safety Considerations

- Keep water away from all electrical equipment
- Make sure not to touch the hot water directly

- Run any burns immediately under cold running water for at least 5 minutes
- Do not overfill the kettle
- Make sure all the equipment is in the middle of the desk, and not at the end to avoid knocking over the beakers
- Carry out the experiment only whilst standing, in order to react quickly to any spills

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