Exam Papers Practice

# 8.2 Thermal Energy Transfer

## Mark Schemes

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| Course | DP IB Physics |
| Section | 8. Energy Production |
| Topic | 8.2 Thermal Energy Transfer |
| Difficulty | Easy |



To be used by all students preparing for DP IB Physics SL
Students of other boards may also find this useful

1

The correct answer is **D** because:

- Conduction is the main method of thermal transfer in **solids**

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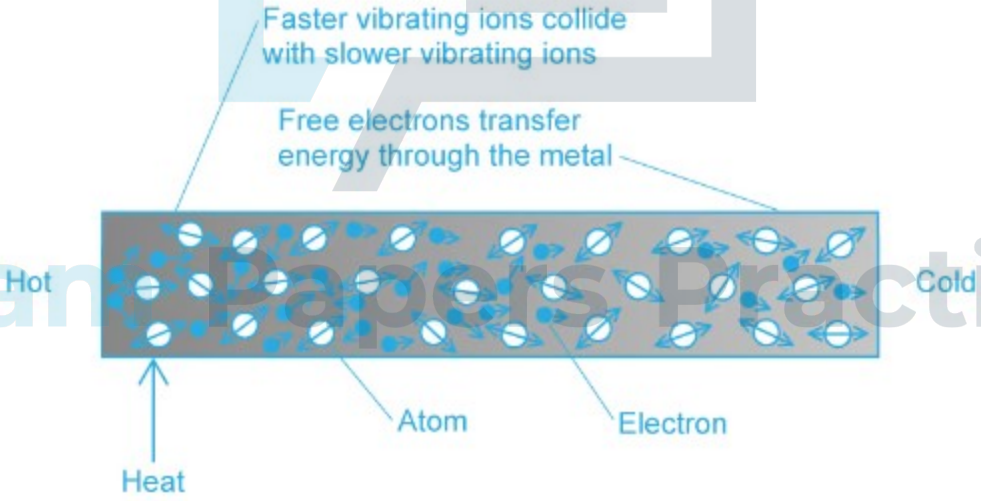
| **A**, **B** and **C** are incorrect as | conduction does not easily take place in a liquid or a gas because it requires particles to vibrate close together to transfer thermal energy. In a fluid (liquid or gas) the particles are far apart. |

Conduction occurs when the atoms in a solid vibrate and bump into each other:

- When two solids of different temperatures come in contact with one another thermal energy is transferred from the hotter object to the cooler object
- Conduction occurs through atomic vibrations and free-electron collisions






2

The correct answer is **A** because:

- Convection is the main way heat travels through liquids and gases

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| **B** is incorrect as | convection occurs only in fluids (liquids and gases) and not in solids because it relies on particles being further apart so they gain kinetic energy more easily |

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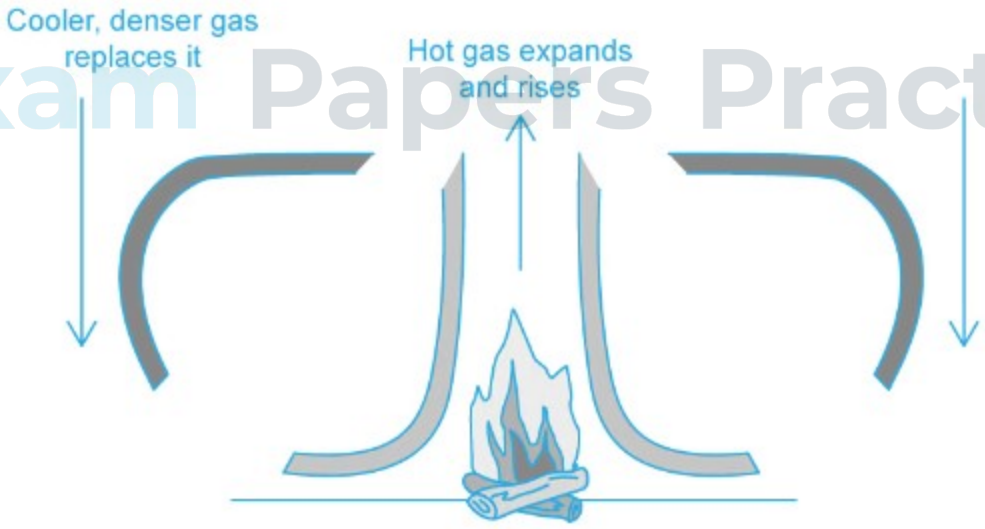
| **C** is incorrect as | in a convection current, warm fluid rises and cool fluid moves in to take its place and not the other way around |
| **D** is incorrect as | in a convection current, heated molecules gain energy and make the fluid expand. The heated molecules do not gain energy and become denser |

Convection occurs as follows:

- When a fluid (a liquid or a gas) is heated from below:
  - The heated molecules gain kinetic energy and push each other apart, making the fluid **expand**
  - This makes the hot part of the fluid **less dense** than the surrounding fluid
  - The **hot fluid rises**, and the cooler (surrounding) fluid moves in to take its place
  - Eventually, the hot fluid cools, contracts and sinks back down again
  - The resulting motion is called a **convection current**



- Convection currents occur in:
  - ocean currents
  - heating a room with a radiator
  - boiling water in a pan
  - a breeze over the ocean
  - fridges
  - hot air balloons

3

The correct answer is **C** because:

- Thermal radiation involves heat transfer by means of electromagnetic radiation in the infrared region

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|---|---|
| **A** is incorrect as | ultraviolet radiation is the radiation from the Sun that causes our skin to darken but is not the heat from the Sun's rays |
| **B** is incorrect as | microwaves are not the radiation emitted from the Sun that provides heat. Microwaves are mainly used for communication |
| **D** is incorrect as | visible light is not the radiation emitted from the Sun that provides heat |



The heat we feel from the Sun's rays comes in the form of infrared radiation. Infrared cameras can be used to search for objects that give off a lot of heat such as animals and humans

The **hotter** the object, the **more** infrared radiation it radiates in a given time

- This is because atoms and molecules above absolute zero are in constant motion
- Electric charges within the atoms in a material vibrate causing **electromagnetic radiation** to be emitted
- Therefore, the higher the **temperature**, the greater the **thermal motion** of the atoms and the greater the **rate** of emission of **radiation**

4

The correct answer is **B** because:

- A black body is: An object that absorbs all of the radiation incident on it and does not reflect or transmit any radiation

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|---|---|
| **A** is incorrect as | a black body is an object that absorbs and does not transmit all of the radiation incident on it |
| **C** is incorrect as | a black body absorbs all of the radiation incident on it |
| **D** is incorrect as | a black body absorbs and does not transmit all of the radiation incident on it |

Black body radiation is the name given to the **thermal radiation** emitted by all bodies (objects) with a temperature above absolute zero. All objects, no matter what temperature (unless they are at 0 K), emit black body radiation in the form of electromagnetic waves. The **hotter** the object, the **more** infrared radiation it radiates in a given time.

Since a good emitter is also a good absorber, a perfect black body would be the best possible absorber too. As a result, an object which perfectly absorbs all radiation will be black. This is because the colour black is what is seen when **all** colours from the visible light spectrum are absorbed.



5

The correct answer is **A** because:

- The shorter the wavelength the higher the peak intensity

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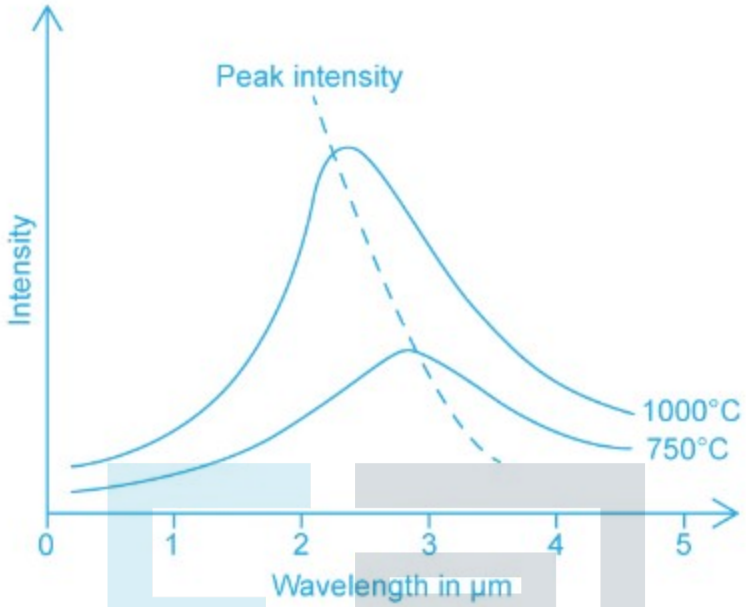
| **B** is incorrect as | it is 'the lower the wavelength the higher the peak intensity', not 'the higher the wavelength' |
| **C** and **D** are incorrect as | the intensity is not affected by the wavelength range |

The dotted line on the diagram shows the peak intensity.

A wavelength of 2 μm has a higher intensity than a wavelength of 3 μm.




6

The correct answer is **D** because:

- Wien's Displacement Law states that: $\lambda_{max} \propto \frac{1}{T}$
- So, $\lambda_{max}$ is proportional to $\frac{1}{T}$

| | |
|---|---|
| **A** is incorrect as | Wien's Displacement Law states that $\lambda_{max} \propto \frac{1}{T}$ so $\lambda_{max}$ is **proportional** and not equal to $\frac{1}{T}$ |
| **B** is incorrect as | Wien's Displacement Law states that $\lambda_{max}$ and not $\lambda_{min}$ is proportional to $\frac{1}{T}$ |
| **C** is incorrect as | Wien's Displacement Law states that $\lambda_{max} \propto \frac{1}{T}$ so $\lambda_{max}$ is **proportional** and not less than or equal to $\frac{1}{T}$ |

This equation for Wien's Displacement Law shows:

- The **higher** the **temperature** of a body, the **shorter** the **wavelength** it emits at the peak intensity
- The **higher** the **temperature** of a body, the **greater** the **intensity** of the radiation at each wavelength

7

The correct answer is **B** because:

- The power output of a black body depends on two factors:
  - Its surface temperature
  - Its radius

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| **A** is incorrect as | the mass and volume of an object are related to its density and not its power output, as $density = \frac{mass}{volume}$ |
| **C** is incorrect as | density and luminosity are not related to an object's power output |
| **D** is incorrect as | the wavelength of the radiation does not help to calculate the power output of an object. Spectral analysis can tell us the elements found within an object but again this does not affect the power output |

The relationship between the surface temperature and radius of an object is known as the Stefan-Boltzmann Law:

**The total energy emitted by a black body per unit area per second is proportional to the fourth power of the absolute temperature of the body**

- It is equal to:

$$P = \sigma A T^4$$

- Where:
  - $P$ = total power emitted by the black body (W)
  - $\sigma$ = the Stefan-Boltzmann constant ($W\,m^{-2}\,K^{-1}$)
  - $A$ = total surface area of the black body ($m^2$)
  - $T$ = absolute temperature of the body (K)

8

The correct answer is **D** because:

- Calculations of the solar constant assume that:
  - Radiation is incident perpendicular to the Earth's surface
  - The Earth is at its mean distance from the Sun

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| **A** is incorrect as | the Earth is in an elliptical orbit around the Sun and the Sun's output varies during its 11-year sunspot cycle are both reasons why the solar constant's value changes throughout the year and not assumptions made when calculating the solar constant |
| **B** is incorrect as | radiation is incident on the Earth in one second and on one square meter of its surface are both statements that form part of the solar constant definition |
| **C** is incorrect as | the assumptions of the solar constant are:<br>• radiation is incident perpendicular and not parallel to the Earth's surface<br>• the Earth is at its mean and not maximum distance from the Sun |

It is really important that you learn the definition, assumptions and the reasons why the solar constant changes to make answering more complex questions easier.

The solar constant is defined as:

**The amount of solar radiation across all wavelengths that is incident in one second on one square metre at the mean distance of the Earth from the Sun**

The value of the solar constant varies year-round because:

- The Earth is in an **elliptical orbit** around the Sun, meaning at certain times of year the Earth is closer to the Sun, and at other times of year it is further away
- The **Sun's output varies** by about 0.1% during its 11-year sunspot cycle

Calculations of the solar constant assume that:

- This radiation is incident on a **plane perpendicular** to the Earth's surface
- The Earth is at its **mean distance** from the Sun

9

The correct answer is **C** because:

- Ozone absorbs nearly 100% of ultraviolet radiation
- It is the ozone that restricts most of the outgoing infrared radiation from leaving the Earth's atmosphere
- The absorption spectrum for ozone looks different to other absorption spectra with dark lines in the ultraviolet wavelengths and in the outgoing infrared radiation

| | |
|---|---|
| **A** is incorrect as | this is the absorption spectra for water vapour and not for ozone |
| **B** is incorrect as | this is the absorption spectra for carbon dioxide and not for ozone |
| **D** is incorrect as | this is the absorption spectra for the whole atmosphere and not just for ozone |

It is important to know the differences between the absorption spectra; specifically the wavelengths of radiation absorbed by each type of greenhouse gas. Whilst you do not need to memorise this diagram you will need to be able to interpret it to answer questions on greenhouse gases in your examination.

10

The correct answer is **A** because:

- The equation for emissivity, $e$ is: $\frac{power\ radiated\ by\ an\ object}{power\ emitted\ by\ a\ black\ body}$

| | |
|---|---|
| **B** is incorrect as | the equation is power **radiated** by an object and not power **emitted** by an object ÷ power emitted by a black body |
| **C** is incorrect as | this is the equation for albedo and not emissivity |
| **D** is incorrect as | the equation is power **radiated** by an object and not power **absorbed** by an object ÷ power **emitted** and not absorbed by a black body |

Emissivity and albedo are new and slightly unusual terms that you are unlikely to have come across before. It is important you are confident with the differences, definitions and equations for both.

Albedo, $a$, is defined as: The proportion of light that is reflected by a given surface



It can be calculated using the equation: $a = \frac{total\ scattered\ power}{total\ incident\ power}$

Emissivity, $e$, is defined as: "The power radiated by a surface divided by the power radiated from a black body of the same surface area and temperature"

It can be calculated using the equation: $e = \frac{power\ radiated\ by\ an\ object}{power\ emitted\ by\ a\ black\ body}$