Transfer of Thermal Energy

Learning Outcomes

Candidates should be able to:

(a) show understanding that thermal energy is transferred from a region of higher temperature to a region of lower temperature

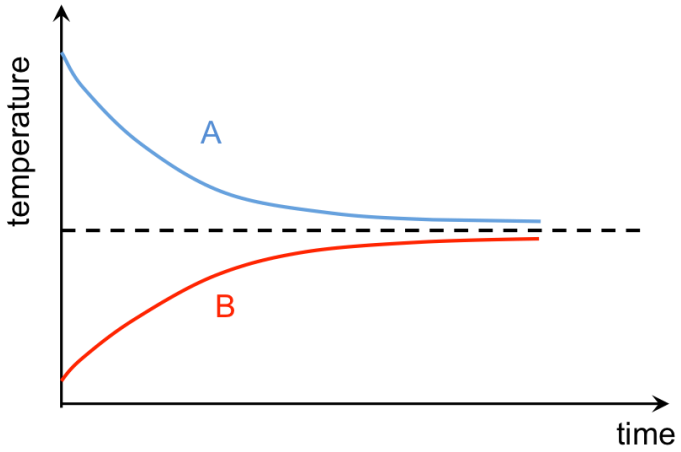
(b) describe, in molecular terms, how energy transfer occurs in solids

(c) describe, in terms of density changes, convection in fluids

(d) explain that energy transfer of a body by radiation does not require a material medium and that the rate of energy transfer is affected by:
  (i) colour and texture of the surface
  (ii) surface temperature
  (iii) surface area

(e) apply the concept of thermal energy transfer to everyday applications

Direction of transfer of thermal energy



- A and B are two objects at different temperatures, insulated from their surroundings but in contact with each other.
- There will be a **net transfer** of thermal energy from the hotter object (A) to the colder object (B).
- As the temperature difference between the two objects get **smaller**, the **rate** of thermal transfer **decreases.**
- This is shown in the graph above where the slopes become gentler as the temperature of A and B become similar.
- When the temperatures of **A** and **B** stop changing, they are at the same temperature, they are said to be in **thermal equilibrium**.
- Thermal energy always flows from a region of **higher temperature** to a region of **lower** temperature. Net flow of thermal energy occurs only when there is a **difference in temperature**.

2 Heat is transferred by conduction, convection and radiation.

(a) **(i)** State which of the three methods is responsible for the transfer of heat from the Sun to the Earth.

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(ii) Explain why the other two methods cannot be involved in this transfer.

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(b) A hand feels hot when placed above a lighted match, as shown in Fig. 2.1.
Explain in detail how convection causes this to happen.

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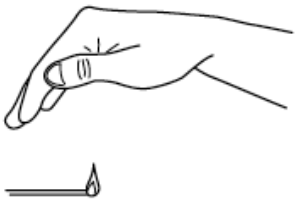

Fig. 2.1 [2]

(c) Fig. 2.2 shows a layer of fibreglass placed between the ceiling of a room and the roof of a house.

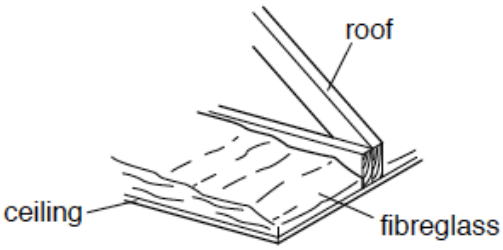

Fig. 2.2

Explain how the layer of fibreglass helps to keep the room warm when it is cold outside.

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	Conduction	Convection	Radiation
Description	Particles in solids **vibrate** about an equilibrium position; as particles at one end get heated up, their temperature rises and the speed of vibration increases. They collide more vigorously with neighbouring particles, passing on their energy from particle to particle, eventually heating up the solid.	When a fluid is heated, it expands, becomes less dense than the surroundings and rises. Cooler, denser fluid is displaced and sinks where the process is repeated. This sets up a convection current, which heats up all the fluid eventually. (vice versa for cooling)	Transfer of thermal energy in the form of electromagnetic radiation like infrared radiation. (all objects radiate energy continuously in the form of electromagnetic waves due to thermal vibrations of their molecules.)
Need medium	Yes	Yes	No. Can occur in vacuum
	Metals have many **free electrons**, which speed up on gaining thermal energy. They move rapidly and collide with particles in the cooler parts of the solid, passing on their energy through electron diffusion.		
Characteristics	**Good conductors/poor insulators** – metals (due to electron diffusion) Speed up **rate** of thermal conduction **Poor conductors/Good insulators** – air and water. **Air**: Particles are far apart so collisions	• Heating element must be placed at the bottom in a water heater tank • Cooling element must be placed at the top in a refrigerator • Involves bulk movement of the medium due to density differences • Works in fluids (liquids and gases)	• Black and rough surfaces are good emitters and absorbers of heat • White and shiny/silvered surfaces are poor absorbers and emitters of heat/good reflectors of heat.

	do not take place regularly and frequently therefore thermal conduction does not occur efficiently **Water:** Particles do not stay in fixed positions long enough for collisions to occur regularly and frequently. The intermolecular forces are also slightly weaker than in solids hence the amount of energy transferred through collisions is reduced. Insulators reduce the **rate** of thermal conduction		• The larger the temperature difference, the higher the rate of radiation • The larger the surface area, the higher the rate of radiation *Rate of thermal radiation $P = e\sigma A(T^4 - T_C^4)$ • e = emissivity of surface • σ = constant (5.67×10^{-8} W/m^{2}K^4) • A = surface area • T = temperature of radiator • T_C = surrounding temperature

Fig. 4.1 shows a computer chip fitted with a heat sink with black metal fins.

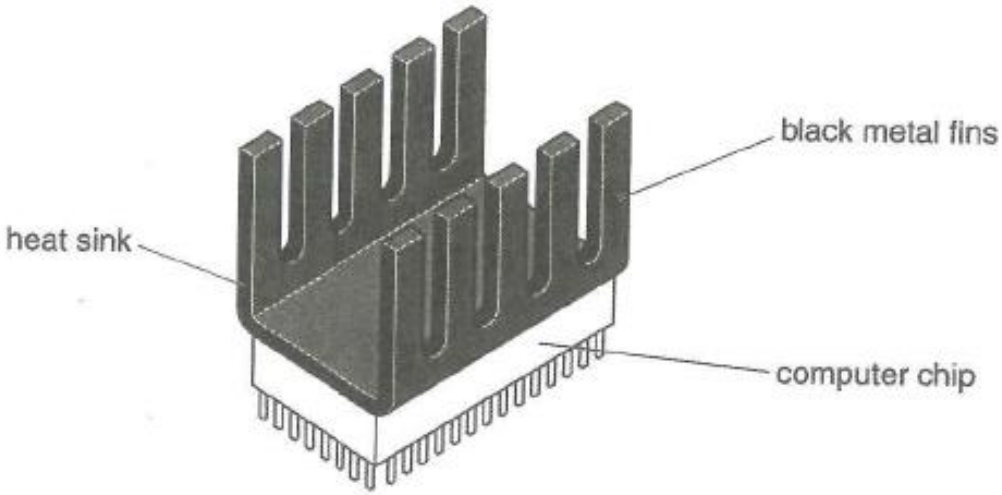

Fig. 4.1

The heat sink keeps the computer chip cool. Thermal energy (heat) is transferred away from the chip by conduction, convection and radiation.

(a) Explain the difference between conduction and convection.

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(b) Explain the features of the heat sink that allow thermal energy to be transferred easily away from the chip.

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4 Fig. 4.1 shows food being cooked in an electric grill.

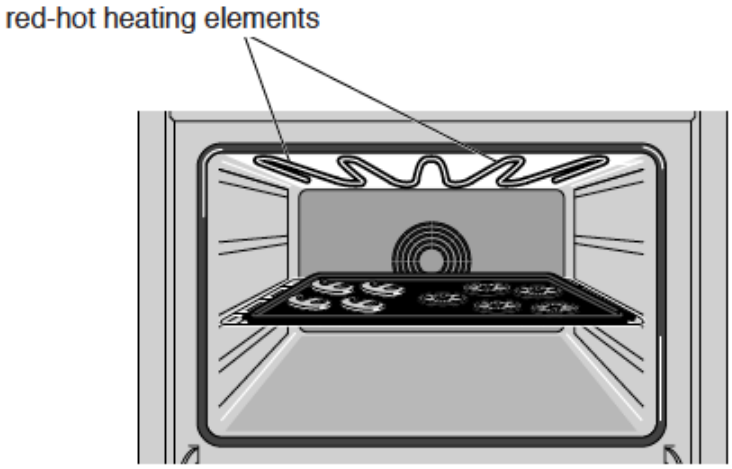

Fig. 4.1

There are red-hot heating elements above the food and thermal energy (heat) is transmitted to the food by radiation.

(a) Explain what is meant, in this case, by *radiation*.

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(b) Explain why very little thermal energy is transmitted to the food by

(i) conduction,

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(ii) convection.

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