BioMedical Admissions Test (BMAT)

Section 2: Physics

Topic P4 - Thermal Physics

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Conduction

All **matter** consists of microscopic **particles** such as atoms, molecules or ions. These particles are constantly **vibrating** within solids or moving in fluids.

The **temperature** and state of matter determines the **kinetic energy** of the particles comprising the matter.

- ➔ The higher the temperature of the matter, the higher the average kinetic energy of the particles.

Heat or **thermal energy** transfers from regions of **high** to **low temperature**.

Conduction is the transfer of heat energy through the transfer of kinetic energy **between particles**.

- ➔ Particles being heated vibrate with greater **amplitude** causing increased kinetic energy transfer to surrounding particles, causing energy transfer throughout the matter.
- ➔ This process mainly happens in solids and liquids where particles are **closely bound** together.
- ➔ **Solids** are better conductors than liquids or gases as the particles are bound more closely together.
- ➔ **Liquids** are poorer conductors than solids as the particles are further apart and therefore it takes longer for the kinetic energy to be transferred.
- ➔ **Gases** are poorer conductors than liquids and solids as the particles are more diffuse and kinetic energy transfer between particles is less efficient.

Metals are particularly good conductors as they contain **free electrons** which can move throughout the lattice transferring kinetic energy faster than just lattice ions alone.

Good conductors such as metals are used for applications that require **heat transfer** e.g. saucepans.

Objects where heat is not wanting to be transferred such as insulated clothing, introduce air pockets which are poor conductors to reduce heat loss from the body.

Rate of conduction is increased by :

- **Increasing** the temperature **gradient**
- **Decreasing** the **distance** between particles
- **Increasing** the **surface area** of the particles in contact with surrounding matter.

Convection

- When a fluid is heated, the average **speed** of its particles increases.
- The **separation** between the particles increases and the fluid expands.
- As the fluid expands, its **density** decreases.
- Therefore hotter, less dense fluids will **rise** and be replaced by less dense, colder fluid.

This creates what is known as a **convection current** which causes thermal energy to be transferred from one part of the fluid to another.

- ➔ Convection is a much more **rapid** method of heat conduction in fluids than conduction.
- ➔ Convection **cannot** occur in **solids** due to the fixed nature of particles in relation to neighbouring particles.

The principle of convection is used in **room heaters** which heat the air surrounding it, causing it to rise and circulate around the room.

Cavity wall insulation is inserted between the two brick layers of buildings to prevent convection currents establishing which in turn reduces heat loss from buildings by convection.

Radiation

Thermal or **infra-red** radiation is part of the electromagnetic spectrum. Like all **EM waves**, it travels at the speed of light and **does not** require particles for energy transfer like conduction and convection.

- ➔ Thermal radiation can transfer energy through a **vacuum** e.g. the Sun transferring heat to the Earth.
- ➔ Radiation can be used to transfer energy to a far away object **without** heating the space in between e.g. radiant heaters.

Thermal radiation is emitted by **any** object that is above the temperature of absolute zero.

- ➔ The **higher** the temperature of the object, the **greater** the rate of thermal radiation emission.
- ➔ As an object emits radiation, the thermal energy of the object **decreases**.

When thermal radiation hits an object, it is either **absorbed**, **transmitted** or **reflected**.

- ➔ **Absorption** of radiation causes the temperature of the object to **increase**.
- ➔ If absorption of radiation is greater than emission, the object's temperature increases and vice versa.

Air is a **poor** absorber of thermal radiation and therefore thermal radiation from the sun is able to pass through the atmosphere to the Earth's surface.

Shiny objects are **poor** absorbers and emitters of thermal radiation.
Matt objects are **good** absorbers and emitters of thermal radiation

Exam Tip: Pay close attention to what the question is asking as poor absorbers of thermal radiation (shiny objects) are good reflectors of thermal radiation and vice versa. It is therefore important to ascertain what thermal characteristics you want from the object

Thermal Physics

Net transfer of thermal energy to an object causes an increase in an object's temperature.

The temperature increase of the object is dependent on the energy transferred, the mass of the object and an innate quality of the object known as the **specific heat capacity:**

$$Specific\ Heat\ capacity = \frac{Thermal\ Energy}{Mass \times Temperature\ Change}$$

In the above equation, energy is measured in **joules**, temperature change is measured in **°C** and specific heat capacity is measured in **J/Kg/°C.**

Specific heat capacity can therefore be defined as the energy transfer per unit mass per unit temperature change.

- ➔ Different materials have different specific heat capacities which reflect how easily their temperatures change when absorbing thermal radiation.