12 Electric Current

12.1 Current and Charge

To make an electric current pass round a circuit.

- The circuit must be **complete**.
- There must be a **source of potential difference**.

The electric current is the **rate of flow of charge**.

Electric current is due to the passage of **charged particles**, they are referred to as **charge carriers**.

- In **metals**, the charge carriers are **conduction electrons**.
  - They move about inside the metal.
  - Repeatedly colliding with each other and the fixed positive ions in the metal.
- In a **salt solution**, the charge is carried by **ions**, which are charged atoms or molecules.

Test for Conduction

The meter shows a non-zero reading whenever any conducting material is connected into the circuit.

1. The battery forces the charge carrier **through the conducting material**.
2. Causes them to **pass through the battery** and the meter.
3. Electrons enter the battery at its positive terminal and leave at the negative terminal.

Conventional current flows from positive to negative.

- The unit of current is the **ampere** - defined in terms of the magnetic force between two parallel wires when they carry the same current.
- The unit of charge is the **coulomb** - equal to the **charge flow** in one second when the current is one ampere.

For current I, charge flow ΔQ in time Δt is given by

$$\Delta Q = I\Delta t$$

Charge Carriers

- In an **insulator**, each electrons is attached to an atom and cannot move away from the atom.

  When a voltage is applied across an insulator, no current passes through the insulator, because no electrons can move through the insulator.

- In a **metallic conductor**, some electrons are **delocalised** - they are the **charge carriers in the metal**.

  When a voltage is applied across the metal, these conduction electrons are attracted towards the positive terminal of the metal.

- In a **semiconductor**, the number of charge carriers increases with an increase in temperature.

  The resistance of a semiconductor therefore decreases as its temperature is raised.

  – Conduction is due to electrons that **break free from the atoms** of the semiconductor.

A pure semiconducting material is referred to as an **intrinsic semiconductor**.

12.2 Potential Difference and Power

1. Each electron moves around the circuit and **takes a fixed amount of energy from the battery** as it passes through it.
2. Each electron passing through a circuit component **does work** to pass through the component and therefore transfers some of its energy.

Potential difference is defined as the energy transfer per unit charge.

The unit of potential difference is the **volt**, equal to one joule per coulomb.

$$V = \frac{\Delta E}{\Delta Q}$$

The **emf of a source** of electricity is defined as the electric energy produced per unit charge passing through the source.

$$\text{Electrical energy produced} = Q\epsilon$$

The unit of emf is also the volt.

Energy Transfer in Devices

- Any device with **resistance**, the work done of the device is transferred as thermal energy.

  Charge carriers repeatedly collide with atoms in the device the transfer energy to them, so atoms vibrate more and the resistor becomes hotter.

- In an **electric motor** turning at a **constant speed**, the work done on the motor is equal to the energy transferred to the load and surroundings by the motor.

  The electrons need to be **forced through the wires** against the opposing force on the electrons due to the motor's magnetic field.

- In a **loudspeaker**, work done on the loudspeaker is transferred as **sound energy**.

  Electrons need to be **forced through the wires** of the coil against the force on them due to the loudspeaker magnet.

Electrical Power

Consider a component with pd V across its terminals and a current I passing through it.

$$\begin{aligned}\Delta Q &= I\Delta t\\ \Delta E &= \Delta Q V\\ &= IV\Delta t\end{aligned}$$

So

$$\text{Electrical power } P = \frac{IV\Delta t}{\Delta t} = IV$$