12 Electric Current

12.1 Current and Charge

To make an electric current pass round a circuit

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

Electric current is the rate of flow of charge in the wire or component. Current flow due to the passage of **charge carries**.

- **Conduction electrons** for metals.
- **Ions** in a salt solution.

Current flows from positive to negative.

- The unit of current is the **ampere**.
- The unit of charge is the **coulomb**.

For a current I, the **charge flow** ΔQ in time Δt

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

Charge Carriers

- **Insulator** - each electron is attached to an atom and **cannot move away** from the atom. When a voltage is applied across an isolator, no current pass through.
- **Metallic conductor** - some electrons are **delocalised**, they are the charge carriers of the metal. When a voltage is applied across the metal, conduction electrons are attracted towards the positive terminal.
- **Semiconductor** - the number of charge carriers **increases with temperature**. The resistance of a semiconductor decreases as its temperature is raised.

12.2 Potential Difference and Power

- **Potential difference** is defined as the energy transferred per unit charge.

  If work W is done when charge Q flows through the component

  $$\text{Potential difference } V = \frac{W}{Q}$$

- The **emf** of a source of electricity is the electrical energy produced per unit charge passing through the source.

The electrical energy produced when charge Q passes through the source.

$$W = Q\varepsilon$$

The unit for pd and emf is the **volt**, equal to 1 joule per coulomb.

$$\text{Work done } W = IV\Delta t$$
$$\text{Electrical power } P = IV$$

12.3 Resistance

The resistance of a component is a measure of the **difficulty of making current pass through** the component.

The resistance of any component is defined as

$$R = \frac{V}{I}$$

The unit of resistance is the **ohm** (Ω), equal to 1 volt per ampere.

Measuring Resistance

1. An **ammeter** measures the current through the resistor.
2. A **voltmeter** measures the pd across the resistor.
3. A **variable resistor** to adjust the current and pd as necessary.

The graph for a resistor is a straight line through the origin, showing the resistance is the same, regardless of the current.

Ohm's law states that the pd across a metallic conductor is proportional to the current through it, provided its physical conditions do not change.

Resistivity

Since resistance R

$$R \propto L$$
$$R \propto \frac{1}{A}$$

Therefore

$$R = \frac{\rho L}{A}$$

where ρ is a constant for that material, known as its resistivity.

$$\rho = \frac{RA}{L}$$

The unit for resistivity is the **ohm metre** (Ωm).

Measuring Resistivity

1. **Measure the diameter** of the wire.
2. **Calculate its cross-sectional area**.
3. **Measure the resistance** R for different lengths L of wire.
4. **Plot a graph** of R against L.

The resistivity of the wire is given by **graph gradient** $\times A$.

Superconductivity

A **superconductor** is a material that has zero resistivity below a **critical temperature** depending on the material - this property of the material is called **superconductivity**.

- The wire has **zero resistance** below its critical temperature.
- When a current passes through it, there is **no pd** as its resistance is zero, so current has **no heating effect**.

A superconductor loses its superconductivity if its temperature is raised above its critical temperature.

12.4 Components and Their Characteristics

Each type of component has its own symbol used to represent the component in a **circuit diagram**.

- A **cell** is a source of electrical energy.
- A **battery** is combination of cells.
- An **indicator** is a light source.
- A **diode** allows current in one direction only.
- A **light-emitting diode** emits light when it conducts.
- A **resistor** is a component designed to have a certain resistance.
- A **light-depending resistor** has a resistance that decreases with light intensity.

Component Characteristics

To measure the variation of a current with pd for a component

- A **potential divide** varies the pd from zero.
- A **variable resistor** varies the current to a minimum.

Using a potential divider the current and pd across the component can be **reduced to zero**, this is not possible with a variable resistor circuit.

Measurements are plotted as a graph of **current against pd**.

- A **wire** gives a straight line through the origin - its resistance does not change when the current changes.
- A **filament bulb** gives a curve with **descending gradient** - resistance increases as it becomes hotter.
- A **thermistor at constant temperature** gives a straight line, the higher the temperature the greater the gradient.
- A **diode** conducts easily above a pd of 0.6V, but hardly at all below 0.6V or in the **opposite direction**.

The Temperature Coefficient

- A metal has a **positive coefficient** - its resistance increases with increase of temperature.
- An **intrinsic semiconductor** has a **negative temperature coefficient**.