13 Direct Current Circuits

13.1 Circuit Rules

Current Rules

- **Kirchoff's first law**: At any junction in a circuit, the total current leaving the junction is equal to the total current entering the junction.
- For **components in series**
  - The current entering a component is the same as the current leaving the component.
  - The current passing through two or more components in series is the **same through each component**.

Potential Difference Rules

- If the charge carriers lose energy, the potential difference is a **potential drop**.
- If the charge carriers gains energy, the potential difference is a **potential rise** equal to the pd across the battery of the cell's terminal.
- For two or more **components in series**, the total pd across all the components is equal to the sum of the potential differences across each component.
- The pd across components in parallel is the same.
- **Kirchoff's second law**: For any complete loop of a circuit, the sum of the emfs around the loop is equal to the sum of the potential drops around the loop.

13.2 More about Resistance

For **resistors in series**, the total resistance is equal to the **sum of the individual resistances**.

$$R = R_1 + R_2 + R_3 + \cdots$$

For **resistors in parallel**, the resistance total resistance is given by

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots$$

Resistance Heating

The heating effect of an electric current in any component is due to the **resistance of the component**.

$$P = IV = I^2R$$

13.3 Electromotive Force and Internal Resistance

The **internal resistance of a source** of electricity is due to opposition to the flow of charge through the source.

- **Electromotive force** ε of the source is the electrical energy per unit charge produced by the source.

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

- The **pd across terminals** of the source is the electrical energy per unit charge delivered by the source when it is in a circuit.

The **internal resistance** of a source is the **loss of potential difference per unit current** in the source when current passes through the source.

$$\varepsilon = IR + Ir$$

The **lost pd** inside the cell is equal to the difference between the cell emf and the terminal pd.

Power Supplied by Cell

$$P = I\varepsilon = I^2R + I^2r$$

Since $I = \dfrac{\varepsilon}{R+r}$, the power delivered to $R = \dfrac{\varepsilon^2}{(R+r)^2}R$

The peak of the **power curve** is at $R = r$ - **maximum power** is delivered to the load when the load resistance is equal to the internal resistance of the source.

Internal Resistance Measurements

- A **voltmeter** connected directly across the cell to measure the **terminal pd**.
- An **ammeter** in series with the cell to measure the **cell current**.
- A **variable resistor** to adjust the current.

The measurements of terminal pd and current can be plotted on a graph.

- Terminal pd is **equal to the emf** at zero current.
- Graph is a **straight line with negative gradient**.

$$V = \varepsilon - Ir$$

The **internal resistance** is given by $r = \dfrac{V_1 - V_2}{I_2 - I_1}$

13.5 The Potential Divider

A **potential divider** consists of

- Two or more **resistors in series** which each other.
- A source of **fixed potential difference**.

Supply a Fixed PD

The **ratio of the pds** across each resistor is equal to the **resistance ratio** of the two resistors.

$$\frac{V_1}{V_2} = \frac{R_1}{R_2}$$

and

$$V_2 = \frac{V_0 R_2}{R_1 + R_2}$$

Supply a Variable PD

The source pd connected to a **fixed length of uniform resistance wire** where a **sliding contact** on the wire can be moved along the wire. Giving a variable pd between the contact and the end of the wire.

Sensor Circuits

A sensor circuit produces an output pd which **changes as a result of a change of a physical variable**.

- A **temperature sensor** consists of a potential divider made using a **thermistor** and a **variable resistor**.
- A **light sensor** uses a **light-dependent resistor** and a **variable resistor**.