13 Direct Current Circuits

13.1 Circuit Rules

Current Rules

Kirchoff's first rule: At any junction in a circuit, the total current leaving the junction is equal to the total current entering the junction.

For component **in series**:

- The current entering a component is the **same as the current leaving** the component.
  - Components do not use the current.
- The current passing through two or more components in series is the **same through each component**.

Potential Difference Rules

The potential difference between any two points in a circuit is defined as the **energy transfer per coulomb of charge** that flows from one point to the other.

- If the charge carriers lose energy, the potential difference is a **potential drop**.
- Charge carriers gain energy when they **pass through a cell**, the potential difference is a **potential rise** equal to the pd across the cell's terminals.
- For any two 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 each component is the **energy delivered per coulomb charge** to that component.
  - So the sum of pds across the components is the **total energy** delivered to the components per coulomb of charge passing through them.
- 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 round the loop is equal to the sum of potential drops around the loop.

- The statement follows from the **conservation of energy**.
- The total emf in a loop is the **total electrical energy** per coulomb produced in the loop.
- The sum of the potential drops is the **electrical energy per coulomb delivered** around the loop.

13.2 More about Resistance

Resistors in Series

Since resistors in series **pass the same current**. For two resistors R_1 and R_2 in series

- $V_1 = IR_1$
- $V_2 = IR_2$

The total pd is given by

$$V = V_1 + V_2 = IR_1 + IR_2$$

So the total resistance is given by

$$R = \frac{V}{I} = \frac{IR_1 + IR_2}{I} = R_1 + R_2$$

So the **total resistance** is equal to the sum of the individual resistances.

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

Resistors in Parallel

Since resistors in parallel have the **same pd**. For two resistors R_1 and R_2 in parallel.

- $I_1 = \frac{V}{R_1}$
- $I_2 = \frac{V}{R_2}$

The **total current** through the combination is

$$I = I_1 + I_2 = \frac{V}{R_1} + \frac{V}{R_2}$$

Since total current is $I = \frac{V}{R}$

$$\frac{V}{R} = \frac{V}{R_1} + \frac{V}{R_2}$$
$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$$

So the **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 tot he resistance of the component.

- The charge carriers **repeatedly collide** with the positive ions of the conducting material.
- There is a **net transfer of energy** from the charge carriers to the positive ions as a result of these collisions.

- The force due to the pd across the material accelerates the charge carrier until it collides with another positive ions.

Since $V = IR$, $P = IV = I^2R = \dfrac{V^2}{R}$

- So the **energy transferred to the object** by electric current in time Δt

$$\Delta E = I^2 R \Delta t$$

- The energy transfer per second to the component **does not depend on the direction** of the current.