CBSE 12 - Physics
Module 4
Ch 3 Current Electricity - Part I

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Learning Objectives & Outcomes

Learning Objective: Objective is to familiarise the learner with the concept of **Electric Current**

Learning Outcome: Upon successful completion of this module, the learner should be able to :

- Describe the motion of electric charges and define **Electric Current**.
- Define the terms **electric current** and **electric potential**
- State the **Ohm's Law** on electric current and electric potential,
- Distinguish between **Ohmic resistors** and **Non-Ohmic resistors**
- Draw the **V-I graph** for Ohmic and Non-Ohmic resistors.
- List the factors that determine the resistance of a resistor.

Presentation Outline

Electric Charges - Electric Current

Electric Current: When an external electric field is applied, positive charges drift along the direction of electric field and negative charges drift against the direction of electric field. The charges in motion constitute electric current.

Electric Current

Electric Current is defined as the rate of flow of charge.

$$I = Q/t \quad : \quad \text{for steady flow;}$$

$$I(t) = \lim_{\Delta t \to 0} \frac{\Delta q}{\Delta t} = \frac{dq}{dt} \quad : \quad \text{for non-steady flow}$$

The **SI** unit of electric current is **ampere (A)**.

$$1A \equiv \frac{1C}{1s} = 1C.s^{-1}$$

$$1mA = 10^{-3}A; \qquad 1\mu A = 10^{-6}A$$

Charge Carriers - Conventional Current

Charge Carriers:

- Electric current is the flow of electric charges. But these electric charges are carried by particles like **electrons** and **ionised atoms**.
- In metals, the charge carriers are negatively charged free electrons; In electrolytes and plasma the charge carriers are positively charged **cations** and negatively charged **anions**,
- If $'n'$ electrons pass through a cross-section in time $'t'$, then total charge passed through the conductor and the electric current are given as:

$$Q = n \times e; \qquad I = \frac{Q}{t} = \frac{ne}{t}$$

- In an electrolyte if $'n_1'$ **cations**, each carrying a charge of $'+q_1'$ move in one direction and $'n_2'$ **anions**, each carrying a charge of $'-q_2'$ move in opposite direction in time $'t'$, the total electric current is:

$$I = \frac{n_1 q_1 + n_2 q_2}{t}$$

Exercise

1. In a conductor 6.25×10^{16} electrons flow from one end to another in $2s$. The fundamental unit of charge is given as $e = 1.6 \times 10^{-19}C$. What is the electric current?

$$\begin{aligned} I &= \frac{Q}{t} = \frac{ne}{t} = \frac{(6.25 \times 10^{16})(1.6 \times 10^{-19}C)}{2s} \\ &= 5.0 \times 10^{-3}A = 5.0\,mA \end{aligned}$$

2. A current of $1.6\,mA$ flows through a conductor. Find the number of electrons passing through the cross-section each second.

$$\begin{aligned} I &= \frac{Q}{t} = \frac{ne}{t} \\ n &= \frac{I.t}{e} = \frac{(1.6 \times 10^{-3}A)(1s)}{1.6 \times 10^{-19}C} = 10^{16}\text{electrons} \end{aligned}$$

Charge Carriers - Conventional Current

Conventional Current:

- Though there is a direction for the flow of charge, this direction information is not usually useful. Often, what is of interest is the rate of flow. Therefore current is considered as a **scalar** quantity.
- Moreover, negative charges moving in a certain direction have the same effect as positive charges of same magnitude moving in opposite direction.
- Even if the electric current is due to the motion of electrons, the **electronic current** can be represented as a flow of positive charges in the opposite direction. This abstract representation of electric current by apparent positive charges is called as **conventional current**.

Presentation Outline

Electric Potential

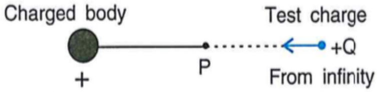
Electric Potential:

- Because charges interact, some work has to be done in moving a charge in the vicinity of other charges,
- Electric potential at a given point in space is a measure of the capacity of a charge placed at that point to do work.

Electric Potential - Definition

The electric potential at a point in space is defined as the amount of work done per unit charge in bringing a positive "test charge" from infinity (far away) to that point.

$$V = \frac{W}{Q}$$



Electric Potential

Unit of Electric Potential:

- If $'W'$ is the work done in bringing a **"test charge"** from infinity to to the point **P**, then the electric potential $'V'$ at that point is given as :

$$V = \frac{W}{Q}$$

- The **SI** unit of electric potential is volt (V) :

$$1V \equiv \frac{1J}{1C} = V.C^{-1}$$

Definition of Volt

The electric potential at a point is defined as 1 V when 1 J of work is done to bring a charge of 1 C from infinity (far away) to that point.

Electric Potential

Electric Potential Difference:

- In practice, we consider the flow of current between two points separated by a finite distance. Therefore, it is sufficient to know the potential difference between those two points,
- If $'W_{AB}'$ is the work done in moving a **"test charge"** between the points **A** and **B**, then the electric potential difference between the points is given as :

$$\Delta V_{AB} = V_A - V_B = \frac{W_{AB}}{Q}$$

Definition of Potential Difference

The electric potential difference between two points in space is equal to the work done per unit charge in moving a "test charge" between the points.

Presentation Outline

Ohm's Law

- Imagine a conductor through which a current I flows when a potential difference (voltage) V is maintained across it.
- In 1828 **Georg Simon Ohm** discovered an empirical relation relating I and V

Ohm's Law

The current through a conductor is directly proportional to the potential difference (voltage) across it.

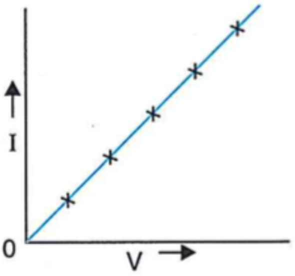
$$V \propto I; \qquad \Longrightarrow \qquad V = RI$$

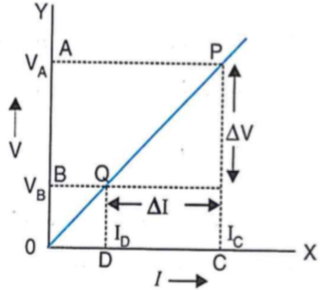
The constant of proportionality R is called the **Resistance** of the conductor.

- **Ohm's Law** is not applicable for all materials. It is applicable only for conductors when the current through them is small.

Ohmic Resistors (V-I graph)

- When Ohm's Law is applicable (R is a constant), the graph of Voltage (V) Vs Current (I) will be a straight line.
- The slope of the $V - I$ **graph** is the **resistance** of the conductor.





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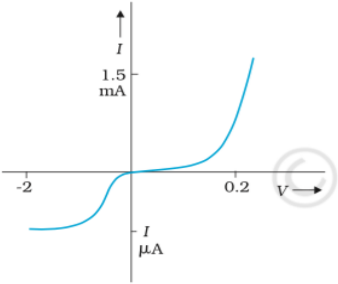
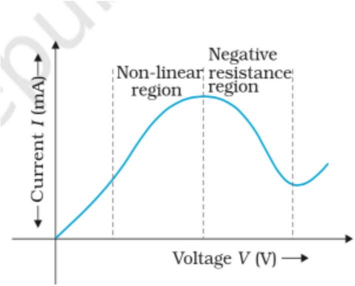
Electric Charges - Electric Current
Electric Potential
Ohm's Law
Electrical Resistance
Solved Examples & Homework
EMF and Terminal PD
Solved Examples &

Ohmic Resistors (V-I graph)

- When Ohm's Law is not applicable (non-ohmic resistors), the $V - I$ **graph** is not a straight line.





Presentation Outline

Factors affecting the resistance

Factors affecting the resistance (R):

1. **Length (l)**: Resistance is directly proportional to the length of the conductor,
2. **Cross Sectional Area (A)** : Resistance is inversely proportional to the cross-sectional area of the conductor,
3. **Resistivity (ρ)**: Resistivity is a material property.

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

SI units of **resistance (R)** is Ω (pronounced **Ohm**)
SI unit of **resistivity (ρ)** is $\Omega - m$

Combination of Resistors

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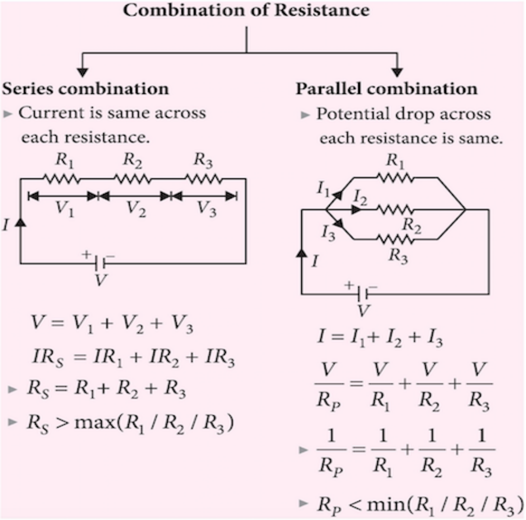
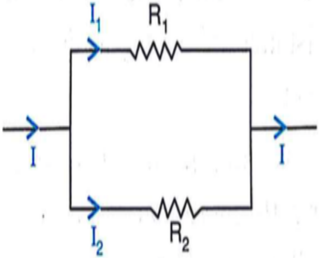


Current Branching Rule

- A current I branches into I_1 through R_1 and I_2 through R_2;
- The **current branching rule** is as follows:

$$I_1 = \left(\frac{R_2}{R_1 + R_2}\right) I$$

$$I_2 = \left(\frac{R_1}{R_1 + R_2}\right) I$$

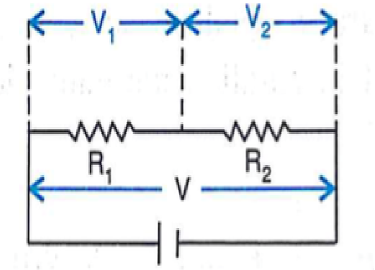


Voltage Division Rule

- A volatge V is divided into V_1 across R_1 and V_2 across R_2, connected in series;
- The **voltage division rule** is as follows:

$$V_1 = \left(\frac{R_1}{R_1 + R_2}\right) V$$

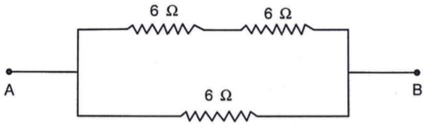
$$V_2 = \left(\frac{R_2}{R_1 + R_2}\right) V$$



Presentation Outline

Solved Examples

1. Find the equivalent resistances between points **A** and **B**.



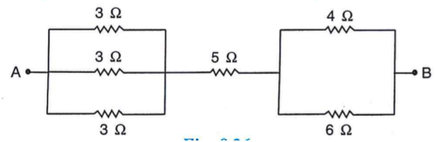
Solution

$$R_{tot} = \left(\frac{1}{6\,\Omega + 6\,\Omega} + \frac{1}{6\,\Omega}\right)^{-1}$$

$$= \left(\frac{1}{12\,\Omega} + \frac{1}{6\,\Omega}\right)^{-1} = 4\,\Omega$$

Solved Examples

2. Find the equivalent resistances between points **A** and **B**.



Solution

$$
\begin{aligned}
R_{tot} &= \left(\frac{1}{3\,\Omega}+\frac{1}{3\,\Omega}+\frac{1}{3\,\Omega}\right)^{-1} + 5\,\Omega + \left(\frac{1}{4\,\Omega}+\frac{1}{6\,\Omega}\right)^{-1} \\
&= 1\,\Omega + 5\,\Omega + 2.4\,\Omega = 8.4\,\Omega
\end{aligned}
$$

Homework

1. Answer the following DC circuit related questions :
   - (a) Find the equivalent resistance between points **a** and **b** in Figure 1a
   - (b) In Figure 1b, if the current through the $20\,\Omega$ resistor is $2.0\,\mathrm{A}$, what is the current I through the $5\,\Omega$ resistor?

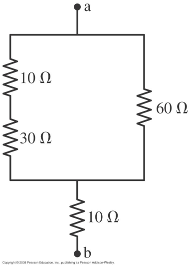


Figure: 1a.

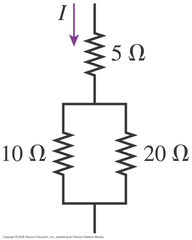


Figure: 1b.

Homework

2. In the circuit shown in Figure 2, the voltage across the $2.0\,\Omega$ resistor is $12\,\mathrm{V}$.
   - (a) What is the voltage across the $1.0\,\Omega$ resistor?
   - (b) What is the **emf** of the battery
   - (c) What is the total current through the circuit?
   - (d) What is the current through the $6.0\,\Omega$ resistor?

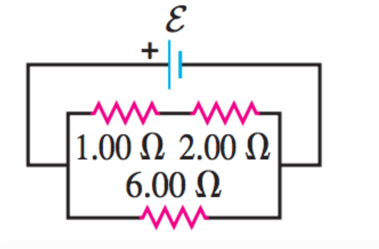


Figure: 2

Thank You!

Thank You!