

CBSE Class-12 Physics Quick Revision Notes

Chapter-03: Current Electricity

- **Electrical Conductivity:**

It is the inverse of specific resistance for a conductor whereas the specific resistance is the resistance of unit cube of the material of the conductor.

$$\sigma = \frac{1}{\rho} = \frac{ne^2\tau}{m}$$

Where σ is the conductivity and ρ is resistivity.

- **SI Unit of Conductivity:**

The SI unit of conductivity is mhm^{-1} .

- **Current through a given area of a conductor:**

It is the net charge passing per unit time through the area.

- **Current Density Vector:**

The current density vector \vec{J} gives current per unit area flowing through area ΔA when it is held normal to the direction of charge flow. Note that the direction of \vec{J} is in the direction of current flow.

- **Current Density:**

Current density j gives the amount of charge flowing per second per unit area normal to the flow.

$$J = nqV_d$$

where n is the number density (number per unit volume) of charge carriers each of charge q and v_d is the drift velocity of the charge carriers. For electrons $q = -e$. If j is normal to a cross-sectional area A and is constant over the area, the magnitude of the current I through the area is $neV_d A$.

- **Mobility:**

Mobility μ is defined to be the magnitude of drift velocity per unit electric field.

$$\mu = \left(\frac{V_d}{E} \right)$$

$$\text{Now, } V_d = \frac{q\tau E}{m_q}$$

where q is the electric charge of the current carrier and m_q is its mass.

$$\therefore \mu = \left(\frac{q\tau}{m_q} \right)$$

Thus, mobility is a measure of response of a charge carrier to a given external electric field.

- **Resistivity:**

Resistivity ρ is defined to be reciprocal of conductivity.

$$\rho = \frac{1}{\sigma}$$

It is measured in ohm-metre (Ωm).

- **Resistivity as a function of temperature:**

It is given as,

$$\rho_T = \rho_0[1 + \alpha(T - T_0)]$$

Where α is the temperature coefficient of resistivity and ρ_T is the resistivity of the material at temperature T.

- **Ranges of Resistivity:**

- Metals have low resistivity: Range of ρ varies from $10^{-8} \Omega m$ to $10^{-6} \Omega m$.
- Insulators like glass and rubber have high resistivity: Range of ρ varies from 10^{22} to 10^{24} times greater than that of metals.
- Semiconductors like Si and Ge lie roughly in the middle range of resistivity on a logarithmic scale.

- **Total resistance in Series and in Parallel**

(a) Total resistance R of n resistors connected in series is given by $R = R_1 + R_2 + \dots + R_n$

(b) Total resistance R of n resistors connected in parallel is given by

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \dots + \frac{1}{R_n}$$

- If the mass of a charge carrier is large, then for a given field \vec{E} , its acceleration will be small and will contribute very little to the electric current.

- **Electrical Conductivity:**

When a conducting substance is brought under the influence of an electric field \vec{E} , free charges (e.g. free electrons in metals) move under the influence of this field in such a manner, that the current density \vec{J} due to their motion is proportional to the applied electric field.

$$\vec{J} = \sigma \vec{E}$$

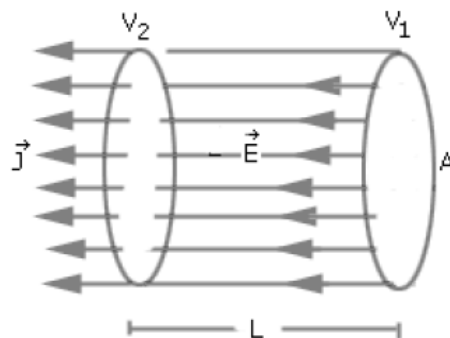
where σ is a constant of proportionality called electrical conductivity. This statement is one possible form of Ohm's law.

- Consider a cylindrical material with cross sectional area A and length L through which a current is passing along the length and normal to the area A, then, since \vec{J} and \vec{E} are in the same direction,

$$J = \sigma E$$

$$JAL = \sigma ELA$$

Where A is cross sectional area and L is length of



the material through which a current is passing along the length, normal to the area A . But, $JA = I$, the current through the area A and $EL = V_1 - V_2$, the potential difference across the ends of the cylinder denoting $V_1 - V_2$ as V ,

$$V = \frac{IL}{\sigma A} = RI$$

Where $R = \frac{L}{\sigma A}$ is called resistance of the material. In this form, Ohm's law can be stated as a linear relationship between the potential drop across a substance and the current passing through it.

- **Measuring resistance:**

R is measured in ohm (Ω), where $1\Omega = \frac{1V}{A}$

- **EMF:**

Emf (Electromotive force) is the name given to a non-electrostatic agency. Typically, it is a battery, in which a chemical process achieves this task of doing work in driving the positive charge from a low potential to a high potential. The effect of such a source is measured in terms of work done per unit charge in moving a charge once around the circuit. This is denoted by ϵ .

- **Significance of Ohm's Law:**

Ohm's law is obeyed by many substances, but it is not a fundamental law of nature. It fails if

- V depends on I non-linearly. Example is when ρ increases with I (even if temperature is kept fixed).
 - The relation between V and I depends on the sign of V for the same absolute value of V .
 - The relation between V and I is non-unique. For e.g., GaAs
- An example of (a) & (b) is of a rectifier

- When a source of emf (ϵ) is connected to an external resistance R , the voltage V_{ext} across R is given by

$$V_{ext} = IR = \frac{\epsilon}{R + r} R$$

Where r is the internal resistance of the source.

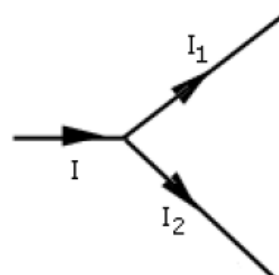
- **Kirchhoff's First Rule:**

At any junction of several circuit elements, the sum of currents entering the junction must equal the sum of currents leaving it.

In the above junction, current I enters it and currents I_1 and I_2 leave it. Then,

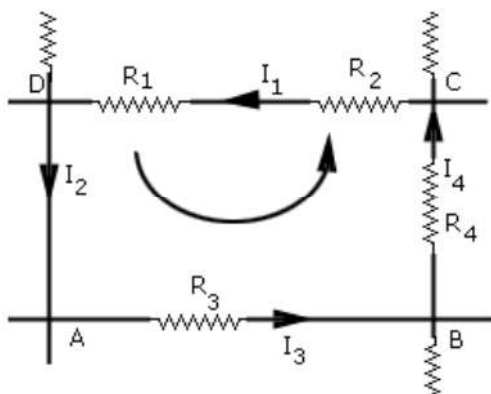
$$I = I_1 + I_2$$

This is a consequence of charge conservation and assumption that currents are steady, that is no charge piles up at the junction.



- **Kirchhoff's Second Rule:**

The algebraic sum of changes in potential around any closed resistor loop must be zero. This is based on the principle that electrostatic forces alone cannot do any work in a closed loop, since this work is equal to potential difference, which is zero, if we start at one point of the loop and come back to it.



This gives: $(R_1 + R_2) I_1 + R_3 I_3 + R_4 I_4 = 0$

- **In case of current loops:**

- Choose any closed loop in the network and designate a direction (in this example counter clockwise) to traverse the loop.
- Go around the loop in the designated direction, adding emf's and potential differences. An emf is counted as positive when it is traversed (-) to (+) and negative in the opposite case i.e., from (+) to (-). An IR term is counted negative if the resistor is traversed in the same direction of the assumed current, and positive if in the opposite direction.
- Equate the total sum to zero.

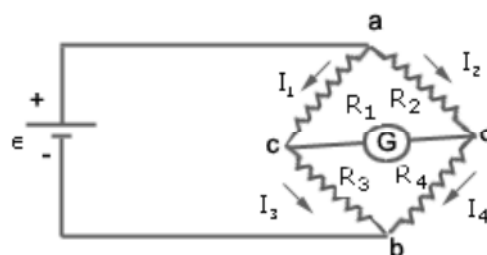
- **Wheatstone Bridge:**

Wheatstone bridge is an arrangement of four resistances R_1, R_2, R_3, R_4 . The null point condition is given by,

$$\therefore \frac{R_1}{R_2} = \frac{R_3}{R_4}$$

This is also known as the balanced condition. If R_1, R_2, R_3 are known, R_4 can be determined.

$$R_4 = \left(\frac{R_2}{R_1} \right) R_3$$



- In a balanced condition of the meter bridge,

$$\frac{R}{S} = \frac{P}{Q} = \frac{\sigma l_1}{100 - l_1}$$

$$\therefore R = \frac{S l_1}{(100 - l_1)}$$

Where σ is the resistance per unit length of wire and l_1 is the length of wire from one end where null point is obtained.

- **Potentiometer:**

The potentiometer is a device to compare potential differences. Since the method involves a condition of no current flow, the device can be used to measure potential differences; internal resistance of a cell and compare emf's of two sources.

- **Potential Gradient:**

The potential gradient of the wire in a potentiometer depends on the current in the wire.

- If an emf ϵ_1 is balanced against length l_1 , then

$$\epsilon_1 = \rho l_1$$

Similarly, if ϵ_2 is balanced against l_2 , then

$$\epsilon_2 = \rho l_2$$

The comparison of emf's of the two cells is given by,

$$\therefore \frac{\epsilon_1}{\epsilon_2} = \frac{l_1}{l_2}$$

