Current Electricity

Some important Definitions :-

(1) **Mean free Path** :- The fast moving e^- keep striking other atoms/ions in the conductor. They are reflected and move in other direction. They keep moving till they strike another atom/ion. The path b/w two consecutive collisions is called free path. The average length of these free paths is called "Mean free Path"

(2) **Relaxation Time** (τ) :- The time taken to travel mean free path ~~to~~ is called relaxation time, denoted by greek letter Tau 'τ'. If $t_1, t_2, t_3 \ldots t_n$ are the time periods for 'n' collisions then Relaxation time $\tau = \frac{1}{n}(t_1 + t_2 + \cdots t_n)$

(3) **Drift Velocity** (V_d) :- when electric field is applied across a conductor, the free electrons experience a force in the direction opposite to the field. Due to this force they start drifting in the direction of the force. The velocity of this drift is called "Drift Velocity" (V_d)

current and drift velocity are related as

$i = neAV_d$ → where n is no of e^- per unit vol of conductor

V_d → drift velocity → A → area of cross-section

(4) **Mobility** (μ) :- Drift velocity per unit electric field is called mobility of electron i.e. $\boxed{\mu = \frac{V_d}{E}}$

(5) **Resistance** :- The property of substance by virtue of which it opposes the flow of current through it.

Cause of resistance of a conductor → It is due to the collision of free electrons with the ions or atoms of the conductor while drifting towards the +ve end of the conductor

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For a conductor if $l \rightarrow$ length of the conductor
$A \rightarrow$ Area of crossection

then $R \propto l$, $R \propto \frac{1}{A}$

$\Rightarrow R \propto \frac{l}{A} \Rightarrow \boxed{R = \rho \frac{l}{A}}$ where ρ is called resistivity and is constant for a material

Unit & Dimension

→ Its SI unit is volt/Amp or Ohm (Ω)

→ Dim. Formula – $[ML^2T^{-3}A^{-2}]$

Resistivity :– Resistivity of a material of a conductor is given by → ~~$\rho = m/ne^2\tau$~~ $\boxed{\rho = \frac{m}{ne^2\tau}}$ *

from $R = \frac{\rho l}{A}$. If $l = 1m$, $A = 1m^2$ then $R = \rho$ i.e resistivity is numerically equal to the resistance of a substance having unit area of the crossection and unit length

Unit & Dimension :– Its S.I unit is ohm-meter and dimension is $[ML^3T^{-3}A^{-2}]$

Dependence :– Resistivity is the intrinsic property of the substance. It is independent of shape and size of the body. It depends on nature of material and temperature.

Resistivity of metals increases with increase in temperature as → $\rho_t = \rho_0 (1 + \alpha t)$

where ρ_0 & ρ_t are resistivity of metals at $0°C$ & $t°C$ and α is the temperature coefficient of the resistivity of the material.

⇒ For metals α is +ve, for some alloys like nichrome, constantan and manganin, α is +ve but very low

→ For semiconductors & Insulators, α is –ve

→ Resistivity is low for metals, more for semi conductors and very high for alloys like nichrome & constantan.

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..., Potential Difference & emf of a cell

Internal Resistance :- Every source of EMF has a resistance of its own called internal resistance (r). Resistance offered by the electrolyte of the cell when the electric current flows through it is known as internal resistance.

The value of 'r' depends on :-

(a) surface area of electrodes
(b) The separation b/w them
(c) The nature, concentration & temperature of electrolyte.

EMF – Electro Motive Force :-

The Potential difference across the terminals of a cell when it is not giving any current is called emf of the cell. or
The energy given by the cell in the flow of unit charge in the whole circuit (including the cell) is called emf of the cell.

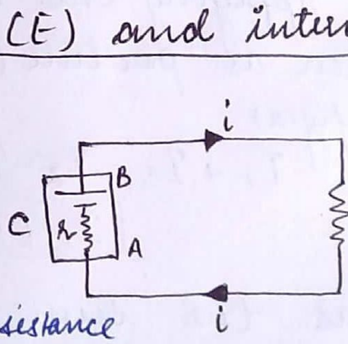
emf depends on :-

(a) nature of electrolyte (b) metal of electrodes

emf doesn't depend on :-

(a) Area of the plates (b) distance b/w the electrodes (c) quantity of electrolyte (d) Size of the cell.

Relation b/w Potential difference (V), emf (E) and internal resistance (r) :-



In this fig. when a current 'i' flows through C, the source C does work to transfer +ve charges from one end A to the other end B. If E is the emf of the cell and 'r' its internal resistance then a part v of E is used up in transferring charge from A to B. From Ohm's law, this part is given by

$$v = ir \quad \text{—— (1)}$$

The remaining part $V = (E - v)$ drives the charge through external resistor 'R' and is given by

$$V = iR \quad \text{—— (2)}$$

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Now $E = V + v$ — (3)

Eq (1) to (3) will give

$$V = \frac{ER}{(R+r)} \Rightarrow \frac{V}{E} = \frac{R}{R+r}$$

Also $i = \frac{E-v}{R}$ and $i = \frac{E-V}{r}$ — (4)

or

$$r = \frac{E-V}{i} = \left(\frac{E-V}{V}\right)R \quad \text{or} \quad \boxed{E-V = ir} \text{ — (5)}$$

From Eq^n (5) if $i = 0$, $E = V$ i.e if no current is drawn from the cell (i.e. in an open circuit) the potential difference V across ~~the~~ its terminals equals its EMF 'E'. If $i \neq 0$, $V < E$

Also from (5) $E = V$ when $r = 0$, $V < E$ if $r \neq 0$.

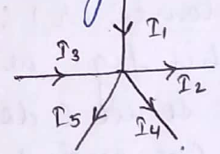
KIRCHHOFF'S LAWS :-

Kirchoff gave two rules for determining the current and resistance in a complicated circuit. These laws are as follows:

First law :- Kirchhoff's current law :

It states that in an electric circuit the algebric sum of the currents meeting at any junction or node in the circuit is zero, that is $\Sigma I = 0$

When applying this law, the current going towards the junction is taken as positive (+ve) while that going away is negative (-ve)



(a)

In fig(a)

$$I_1 + I_3 - I_2 - I_4 - I_5 = 0 \quad \text{or}$$

$$\boxed{I_1 + I_3 = I_2 + I_4 + I_5} *$$

Towards the junction

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Conductance & conductivity

Reciprocal of Resistance is called conductance

$C = \frac{1}{R}$. Its unit is $\frac{1}{\Omega}$ or Ω^{-1} or "Siemen" or "mho"

Reciprocal of Resistivity is called conductivity

$$\text{conductivity } (\sigma) = \frac{1}{\rho} = \frac{ne^2\tau}{m}$$

Its S.I unit is $ohm^{-1} m^{-1}$ or $mho\, m^{-1}$ or $siemen\, m^{-1}$

Relation b/w current density (J) and electrical conductivity (σ) is given by

$\boxed{J = \sigma E}$ where E = electric field intensity

Superconductors :- ~~no~~ A superconductor is a material that can conduct electricity or transport e^- from one atom to another with no resistance. The phenomenon of sudden disappearance of all electrical resistivity at a low temperature, is called super conductivity.

The low temperature at which all electrical resistivity disappears is called critical temperature (T_c). Its value is different for different materials

When few metals are cooled, then below a certain critical temperature their electrical resistance suddenly becomes zero. In this state, these substances are called superconductor.

Mercury behaves as superconductor when cooled below 4.2 K

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