Current Electricity

1. The rate of flow of charge across any cross-section is called electric current.

$$I = \frac{dq}{dt}.$$

2. Current density is the current flowing per unit area through any cross-section.

$$J = \frac{I}{A} \qquad I = \vec{J} \cdot \vec{A} = JA\cos\theta.$$

(direction of $\vec{J}$ = direction of I).

3. Drift velocity is the avg. velocity with which e^-s get drifted from low potential to high potential of a conductor.
(+ve terminal) (−ve terminal)

- $V_d = a\tau = -\frac{eE}{m}\tau$
- $I = neAV_d$
- $J = neV_d.$
- μ = mobility $= \frac{V_d}{E} = \frac{e\tau}{m}.$

→ When no external electric field is applied ⇒ avg. thermal vel. = 0
avg. thermal speed ≠ 0.

$$\frac{1}{2} m V_{rms}^2 = \frac{3}{2} KT$$

→ λ = mean free path $= \frac{\text{total distance travelled}}{\text{no. of collisions}}$ = distance between 2 successive collisions.

→ τ = relaxation time $= \frac{\text{total time between 2 collisions for all } e^-\text{s}}{\text{no. of } e^-\text{s}}.$

4. $J = neV_d = \sigma E$ ⇒ ohm's law at microscopic level.

- σ = conductivity $= \frac{ne^2\tau}{m}.$ $\quad \underline{V = IR} \quad R = \frac{\rho l}{A}.$
- ρ = resistivity $= \frac{1}{\sigma} = \frac{m}{ne^2\tau}.$

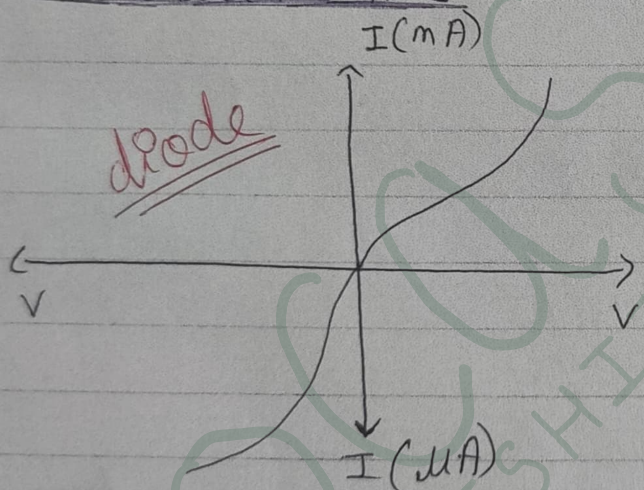
→ Thus, according to Ohm's law, the current flowing thr. a conductor is directly proportional to the potential ↑ difference across the ends of the conductor, provided that the physical state (T, P) of the conductor remains constant.

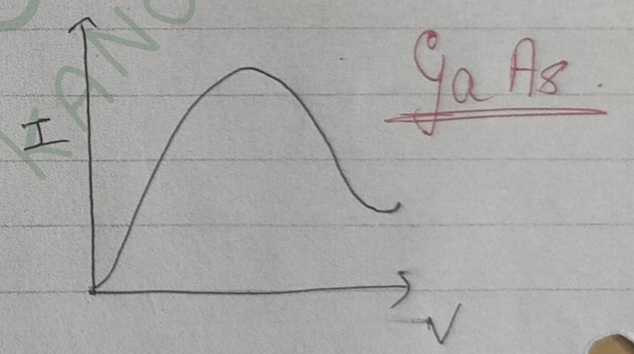
5. α = temp. coefficient of resistance / resistivity.

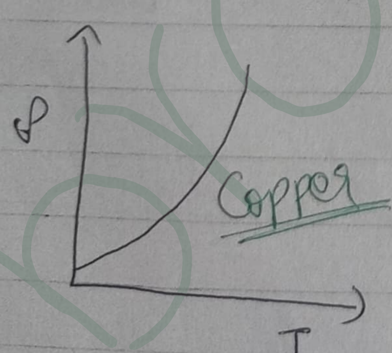
→ For conductors - $\alpha = +ve$ ⇒ Temp. ↑ ⇒ τ ↓ ⇒ ρ ↑ ⇒ R ↑
For semiconductors, insulators - $\alpha = -ve$ ⇒ Temp. ↑ ⇒ bonds break
∴ n ↑ ⇒ ρ ↓ ⇒ R ↓.

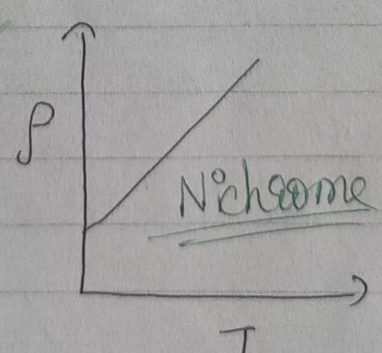
→ $\rho_t = \rho_0 (1 + \alpha T)$
$R_t = \left[R_0 \left(1 + \int_{T_0}^{t} \alpha \, dT \right) \right] = R_0 (1 + \alpha T)$.

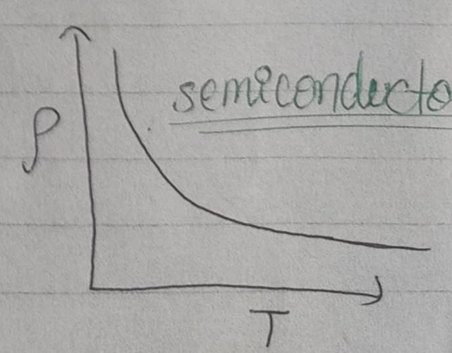
6. I - V characteristics











7. **Combination -**

→ **Series** - $R = R_1 + R_2 + \dots$

$V = V_1 + V_2 + \dots$

$I =$ same

→ **Parallel** - $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots$

$I = I_1 + I_2 + \dots$

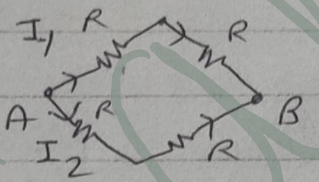
$V =$ same.

8. **Kirchoff's Law** - ① **Junction law** - based on conservation of charge.

② **Loop law** - based on conservation of energy.

→ **Symmetricity** -

ⓐ **Path symmetry** -



$\underline{I_1 = I_2}$

ⓑ **$\perp^r$ axis symmetry** -

- All points lying on the same line of symmetry have same potential. (Line of symmetry = equipotential line).
- All resistances on the line of symmetry can be removed.
- point of symmetry = false junction
  ∴ remove the junction.

ⓒ **Infinite Ladder** - leave one unit ⇒ take rest as x.

$(R_{eq} \approx x.)$

9. **Cell**

ⓐ **EMF** ⇒ The potential difference across the electrodes of the cell when no current is being drawn from the cell.

ⓑ **Internal resistance (r)** ⇒ The opposition to the flow of current inside the cell.

- distance between electrodes ↑ ⇒ r ↑
- area of electrodes ↑ ⇒ r ↓
- conc. of electrolyte ↑ ⇒ r ↑
- temp. ↑ ⇒ r ↓.

→ Series – $E = E_1 + E_2 + E_3 + \cdots$

$r = r_1 + r_2 + \cdots\cdots$

$E_{eq} = nE$

$r_{eq} = nr$. $\qquad i = \dfrac{nE}{nr + R_{eq}}$.

→ Parallel – $E_{eq} = \dfrac{\frac{E_1}{r_1} + \frac{E_2}{r_2} + \cdots}{\frac{1}{r_1} + \frac{1}{r_2} + \cdots\cdots}$

$$r_{eq} = \frac{1}{\frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3} + \cdots\cdots}$$

$E_{eq} = E$

$r_{eq} = \dfrac{r}{m}$.

→ Mixed – n columns (series) (total cells $= m \times n$)

– m rows (parallel).

$E_{eq} = nE$

$r_{eq} = \dfrac{nr}{m}$. $\qquad I = \dfrac{nE}{R_{eq} + \frac{nr}{m}}$

• Current in the circuit is maximum when external resistance (R_{eq}) = total internal resistance.

$$R_{eq} = \frac{nr}{m}.$$

→ Open circuit – $R = \infty$, $I = 0$ $\quad \boxed{V = \varepsilon}$

Short circuit – $R = 0$, $I = \dfrac{\varepsilon}{r + R} = \dfrac{\varepsilon}{r}$ $\quad \boxed{V = 0}$.

10. For balanced Wheatstone – $\dfrac{P}{Q} = \dfrac{R}{S}$ or $\dfrac{R_1}{R_2} = \dfrac{R_3}{R_4}$.

• when $\dfrac{R_1}{R_2} < \dfrac{R_3}{R_4}$ $\Rightarrow$ I from top to bottom

• when $\dfrac{R_1}{R_2} > \dfrac{R_3}{R_4}$ $\Rightarrow$ I from bottom to top.

11. <u>Meter bridge</u>

For zero deflection ($I_g = 0$) / balanced condition

$$\frac{P}{Q} = \frac{R}{S} \Rightarrow \frac{l}{(100-l)} = \frac{R}{S}.$$

12. <u>Potentiometer</u> - It is a linear conductor of uniform cross-section with a steady current set up in it.

- uniform potential gradient $x = \frac{V}{l}$.

(any potential difference which is less than the potential difference across the potentiometer wire can be measured.

- Ideal voltmeter

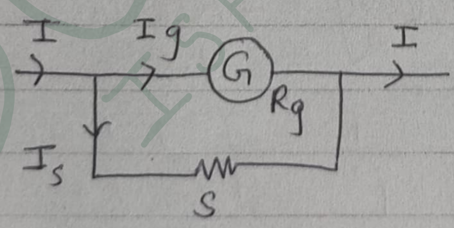
→ <u>Applications</u> - (i) comparison of emf of two cells
(ii) internal resistance of a given primary cell
(iii) comparison of two resistances.

13. <u>Galvanometer</u> - an instrument used to measure the strength of current by measuring the deflection of the coil due to torque acting on it produced by a magnetic field.

$$i \propto \theta$$
$$i = K\theta$$

(K = figure of merit of galvanometer)

14. <u>Ammeter</u>.



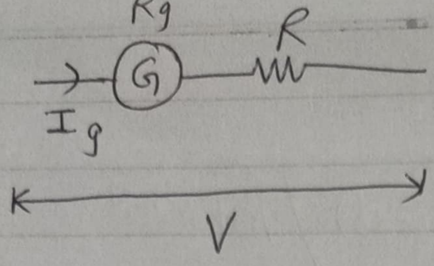
S = shunt resistance (small)
I = max. current that can be measured by the ammeter.
I_g = max. current that can flow through the galvanometer

$$I = I_g + I_S.$$

$$S = \frac{I_g R_g}{I - I_g}.$$

Ideal ammeter has zero resistance.

15. **Voltmeter** -



$$R = \frac{V}{I_g} - R_g.$$

$R \to \infty$
for ideal voltmeter.

16. **Power** - If current enters the high potential point of the device, then power is consumed by it. (load).
- If current enters the low potential point of the device, then power is supplied by it. (source).

$$P = VI = I^2R = \frac{V^2}{R}.$$

17. **Heating effect** - When current passes through a resistor, energy is wasted in overcoming the resistance of the wire. This energy is converted into heat.

$$H = \int P\,dt = I^2Rt = \frac{V^2}{R}t = VIt.$$

(1 cal = 4.2 J
1 J = 10^7 erg).

$$H = \int_0^t I^2R\,dt \Rightarrow \text{for variable } I.$$

→ One unit of electrical energy = 1 kilowatt hour = 1 kWh
= 3.6×10^6 J.

18. **Bulbs** - Series → $\frac{1}{P} = \frac{1}{P_1} + \frac{1}{P_2} + \dots$
parallel → $P = P_1 + P_2 + \dots$

→ $R_{bulb} = \frac{V_{rated}^2}{P_{rated}}$

→ brightness of bulb $\propto$ Power consumed by the bulb.

19. To convert voltmeter of $R_g\,\Omega$ and range V volts into a voltmeter of range nV volts, the value of resistance to be connected in series - $R = (n-1)R_g\ \Omega$

To convert ammeter of $R_g\,\Omega$ and range I A into ammeter of range nI A, value of resistance to be connected in parallel -
$$R = \frac{R_g}{(n-1)}\ \Omega$$

20. For two identical heater coils -
heat generated (H) -
(P = Parallel
S = series)

$$\boxed{\frac{H_P}{H_S} = 4}$$

$$T_S = T_1 + T_2 \qquad T_P = \frac{T_1 T_2}{T_1 + T_2}$$

NCERT Points

1. Commercially produced resistors for domestic use or in laboratories are of two major types: wire bound resistors and carbon resistors.

2. Carbon Coding

Colour	Number	Multiplier	Tolerance (%)
Black	0	10^0	
Brown	1	10^1	
Red	2	10^2	
Orange	3	10^3	
Yellow	4	10^4	
Green	5	10^5	
Blue	6	10^6	
Violet	7	10^7	
Gray	8	10^8	
White	9	10^9	
Gold		10^{-1}	5
Silver		10^{-2}	10
No colour			20

4 bands
$36 \times 10^4\ \Omega$

B
B
Roy
of Great
Britain and
Victor
Gray
Were
Good
Souls.

3. **Junction rule** : At any junction, the sum of the currents entering the junction is equal to the sum of the currents leaving the junction.

Loop rule : The algebraic sum of changes in potential around any closed loop involving resistors and cells in the loop is zero

4. **Jockey** is essentially a metallic rod whose one end has a knife - edge which can slide over the wire to make electrical connection.