Chapter-3: Current Electricity

1. Relation among charge (q) to flow, current (I) and time t

$$\boxed{I = \frac{q}{t} = \frac{ne}{t}}$$

For positive q, current is in forward direction and for negative q, it is in backward direction.

2. Relation between very small charge dq to flow for small time dt

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

3. Current density (J) is the current (I) distributed uniformly over the cross section area (A)

$$\boxed{J = \frac{I}{A}}$$

Or

$$\boxed{I = \vec{J} \cdot \vec{A}}$$

4. Ohm's law

$$\boxed{I \propto V \; or \; V \propto I \Rightarrow V = RI}$$

$$\boxed{R \propto l, R \propto \frac{1}{A} \; So, R = \rho \frac{l}{A}}$$

5. Effect of temperature on resistance:

If R_1 be the resistance at temperature t_1 and R_2 be the resistance at temperature t_2, then

$$R_2 = R_1(1 + \alpha\Delta t)$$

Where α is the temperature coefficient of resistance and $\Delta t = t_2 - t_1$.
If the temperature is not sufficiently large, as in practical cases, then the equation is

$$\boxed{R_t = R_0(1 + \alpha t) \; or \; \alpha = \frac{R_t - R_0}{R_0 t} = \frac{Change \; in \; resistance}{original \; resistance \; x \; rise \; in \; temperature}}$$

6. Temperature dependence of resistivity

Resistivity of a metal conductor is given by

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

7. Conductance (G) and conductivity (σ):

Conductance (G) is given by reciprocal of resistance and will be written as

$$\boxed{G = \frac{1}{R}}$$

And conductivity (σ) is given by reciprocal of resistivity and will be written as

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

8. Drift velocity and relaxation time

Drift velocity

$$\boxed{\vec{v}_d = \frac{-e\vec{E}\tau}{m}}$$

Drift Speed

$$\boxed{|\vec{v}_d| = v_d = \frac{eE}{m}\tau}$$

9. Relation between average drift velocity, relaxation time and current

$$\boxed{I = neAv_d}$$

$$\boxed{R = \frac{ml}{ne^2A\tau} = constant}$$

10. Relation between resistivity (ρ), number density (n) and relaxation time (τ)

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

11. Mobility is the magnitude of drift velocity per unit electric field applied

$$\boxed{\mu = \frac{q\tau}{m}}$$

a) Mobility due to charge carrier electrons in a conductor is given by

$$\boxed{\mu_e = e\frac{\tau_e}{m_e}}$$

b) Mobility due to charge carrier holes in a conductor is given by

$$\boxed{\mu_h = e\frac{\tau_h}{m_h}}$$

12. Equivalent Resistance in series

$$\boxed{R = R_1 + R_2 + R_3 - - - -}$$

For two resistors R_1 and R_2 connected in series and the combination is connected with a battery of potential difference across it,
Then

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

And,

$$\boxed{V_2 = V - V_1}$$

Or

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

In series, n resistors, each capacity R

$$\boxed{R_{eqvt} = nR}$$

13. Equivalent Resistance in Parallel

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} - - - -$$

For two resistors R_1 and R_2 connected in parallel and the combination is connected with a battery of potential difference V across it,
Then

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

And,

$$I_2 = I - I_1$$

Or

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

In parallel, n resistors each capacity R

$$\frac{1}{R_{eqvt}} = \frac{n}{R} \Rightarrow R_{eqvt} = \frac{R}{n}$$

14. Power Supplied by a Battery

When the current enters the positive plate of a battery, Then

$$P = +EI$$

15. Power Delivered / Consumed by a Battery

When current enters the negative plate of a battery, Then

$$P = -EI$$

16. Electrical Power (P) and Heat generated across a resistor

Electrical power (P) dissipated or generated across a resistor is given by

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

Heat generated across a resistor is given by

$$H = VIt = I^2Rt = \frac{V^2}{R}t$$

17. Power of two bulbs

Series Connection

$$P = \frac{P_1P_2}{P_1 + P_2}$$

Parallel Connection

$$\boxed{P = P_1 + P_2}$$

18. EMF (E) of cell and internal resistance (r)

$$\boxed{E = \frac{W}{q}}$$

Discharging Equation of a cell

- **In Closed Circuit**

When a load resistance R is connected across the cell, Then

$$\boxed{V < E}$$

And,

$$\boxed{V = E - Ir}$$

For V = IR;

$$\boxed{I = \frac{E}{r + R}}$$

For $I = \frac{V}{R}$

$$\boxed{V = \frac{E}{r + R}}$$

- **If a cell is shorted, then**

$$\boxed{V = 0}$$

And,

$$\boxed{I = \frac{E}{r}}$$

- **In Open Circuit**

$$\boxed{I = 0}$$

Then

$$\boxed{V = E}$$

This shows that

$$\boxed{V \leq E}$$

Charging Equation of a cell

In Closed Circuit

When battery is discharged (it draws the current)

$$\boxed{V = E + Ir}$$

If resistance R is connected in series with a battery which supplies the current and charges the cell then

$$\boxed{\boldsymbol{I = \frac{V' - E}{r + R}}}$$

19. Combination of cells

a) **Series Connection**:

Equivalent emf (same polarity)

$$\boxed{E_{eq} = E_1 + E_2 + E_3 + ------}$$

Equivalent Internal Resistance

$$\boxed{r_{eq} = r_1 + r_2 + r_3 + ---}$$

If external resistance R is connected in a closed loop,

$$\boxed{I = \frac{E_1 + E_2 + E_3 + ---}{(r_1 + r_2 + r_3 + ---) + R}}$$

So, it can be said that two cells connected in series,

$$\boxed{Net\ EMF = E_1 + E_2}$$

$$\boxed{I = \frac{Net\ EMF}{Net\ Resistance}}$$

(i). N cells of same emf (E) and same internal resistance (r) are connected in series, then

$$\boxed{I = \frac{nE}{nr + R}}$$

(ii). In series connection, there are n cells of each emf E. If polarity of m cells is reversed, then equivalent emf

$$\boxed{E_{eq} = (n - 2m)E}$$

Whereas, total resistance is

$$\boxed{R_{eq} = R + nr}$$

$$\boxed{I = \frac{(n-2m)E}{nr+R}}$$

b) Parallel Combination

- If n cells of emf E_1, E_2, E_3, ---- (polarity of each same) with internal resistance r_1, r_2, r_3---are connected in parallel (with no external resistance R across the combination), then

$$\boxed{\frac{E_{eq}}{r_{eq}} = \frac{E_1}{r_1} + \frac{E_2}{r_2} + \frac{E_3}{r_3} + ----}$$

- Equivalent internal resistance

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

- If n cells each emf E (polarity of each same), internal resistance r, are connected in parallel, then
  Equivalent emf

$$\boxed{E_{eq} = E}$$

  Equivalent resistance

$$\boxed{E_{eq} = nr}$$

- If an external resistance R is connected across the parallel combination of n cells with each emf E and internal resistance r, then Current

$$\boxed{I = \frac{E}{R + \frac{r}{n}}}$$

- If two cells or three cells with integral multiple of E connected in parallel and no internal resistance given, then take the average of all as,

$$\boxed{E_{eq} = Average\ value\ of\ all\ emfs}$$

20. Maximum Power Transfer Theorem

Current I will be maximum when

$$\boxed{\sqrt{mR} = \sqrt{nr}}$$

Or,

$$\boxed{R = \frac{nr}{m}}$$

Hence, power transferred to the load is maximum when load resistance = total internal resistance

21. Kirchhoff's Law:

Junction Rule:

The algebraic sum of current at any junction is equal to zero.

$$\boxed{\sum_{junction} I = 0}$$

That is, net current entering the junction = net current leaving the junction

So,

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

Kirchhoff's Loop Rule

The net voltage in a closed loop is equal to zero.

$$\boxed{\sum_{closed\ loop} V = 0\ or \sum E_{net} = \sum IR}$$

22. Wheatstone bridge:

Balancing of Wheatstone Bridge.

. That is $I_g = 0$

$$\boxed{\frac{P}{Q} = \frac{R}{S}}$$