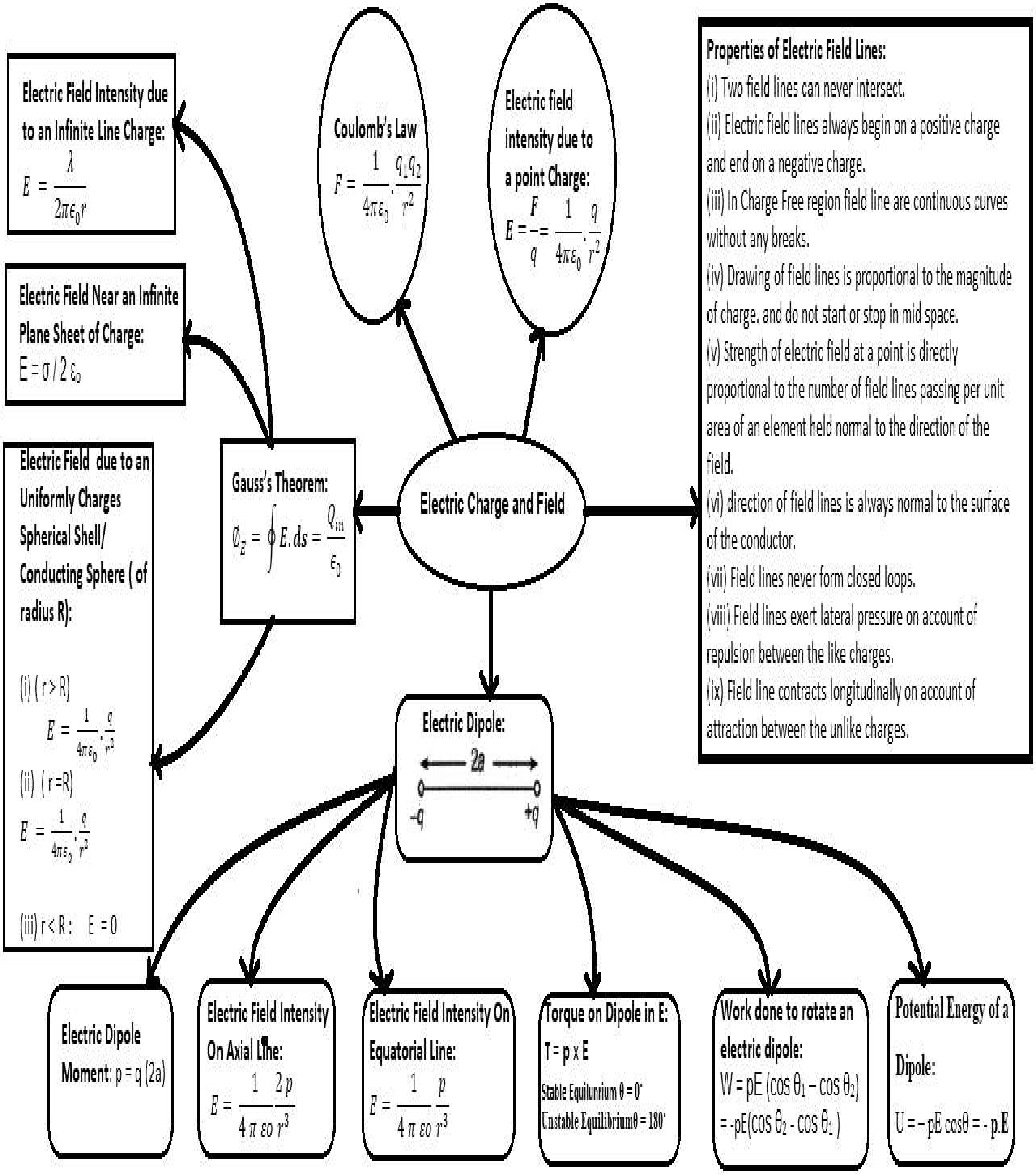
CHAPTER1: ELECTRIC CHARGES & ELECTRIC FIELD

SYLLABUS: - Electric charges, Conservation of charge, Coulomb's law-force between two- point charges, forces between multiple charges; superposition principle and continuous charge distribution. Electric field, electric field due to a point charge, electric field lines, electric dipole, electric field due to a dipole, torque on a dipole in uniform electric field. Electric flux, statement of Gauss's theorem and its applications to find field due to infinitely long straight wire, uniformly charged infinite plane sheet and uniformly charged thin spherical shell (field inside and outside).

MIND/CONCEPT MAP:



GIST OF THE LESSON

Electrostatic force of interaction acting between two stationary point charges is given by

$$F = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1 q_2}{r^2}$$

where q_1, q_2 are magnitude of point charges, r is the distance between them and ε_o is permittivity of free space.

Here, $\frac{1}{4\pi\varepsilon o}$ = 9 x 10^9 N-m^2/C^2

The value of ε_o is 8.85 X 10^{-12} C^2 / N-m^2.

If there is another medium between the point charges except air or vacuum, then ε_o is replaced by $\varepsilon_o K$ or $\varepsilon_o \varepsilon_r$ or ε.

where K or ε_r is called dielectric constant or relative permittivity of the medium.

$K = \varepsilon_r = \varepsilon / \varepsilon_o$ where, ε = permittivity of the medium.

For air or vacuum, K = 1 For water K = 81 For metals, K = ∞

In Medium Culomb's force becomes $F_m = \frac{F_0}{K}$

Coulomb Law implies:

Force on q_1 due to q_2 = – Force on q_2 due to q_1

$\mathbf{F}_{12} = -\mathbf{F}_{21}$

The forces due to two-point charges are parallel to the line joining point charges; such forces are called central forces and electrostatic forces are conservative forces.

Electric Field:

The space in the surrounding of any charge in which its influence can be experienced by other charges is called electric field.

Electric Field Lines:

"An electric field line is an imaginary line or curve drawn through a region of space so that its tangent at any point is in the direction of the electric field vector at that point. The relative closeness of the lines at some place gives an idea about the intensity of electric field at that point."

Properties of Field Lines:

(i) Two field lines can never intersect.
(ii) Electric field lines always begin on a positive charge and end on a negative charge.
(iii) In Charge Free region field line are continuous curves without any breaks.
(iv) Drawing of field lines is proportional to the magnitude of charge. and do not start or stop in mid space.
(v) Strength of electric field at a point is directly proportional to the number of field lines passing per unit area of an element held normal to the direction of the field.
(vi) direction of field lines is always normal to the surface of the conductor.
(vii) Field lines never form closed loops.

Electric Field Intensity (E):

The electrostatic force acting per unit positive charge on a point in electric field is called electric field intensity at that point.

Electric field intensity $\boldsymbol{E} = \frac{\boldsymbol{F}}{q}$

Its SI unit is NC^{-1} or V/m and its dimension is [MLT^{-3} A^{-1}].

It is a vector quantity and its direction is in the direction of electrostatic force acting on positive charge.

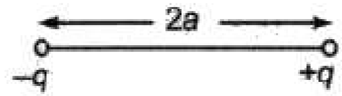
Electric field intensity due to a point Charge:

due to a point charge q at a distance r is given by

Magnitude - $E = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{r^2}$

Electric Dipole:

An electric dipole consists of two-point charges of equal magnitude and opposite sign separated by a very small distance. e.g., a molecule of HCL, a molecule of water etc.



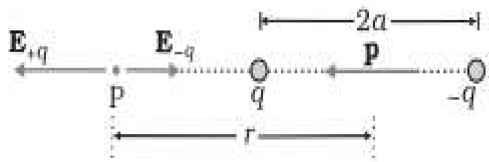
Electric Dipole Moment: Product of magnitude of either charge and distance between them. i.e. $p = q\,(2a)$

Its SI unit is 'coulomb-metre' and its dimension is [LTA].

It is a vector quantity and its direction is from negative charge towards positive charge.

Electric Field Intensity and Potential due to an Electric Dipole:

(i) **On Axial Line:**



Electric field intensity

$$E = \frac{1}{4\pi\varepsilon o}\frac{2pr}{(r^2-a^2)^2}$$

If r > > 2a, then $E = \frac{1}{4\pi\varepsilon o}\frac{2p}{r^3}$ (Short Dipole)

Electric potential $V = \frac{1}{4\pi\varepsilon o}\frac{p}{r^2-a^2}$

If r > > 2a, then $V = \frac{1}{4\pi\varepsilon o}\frac{p}{r^2}$ (Short Dipole)

(ii) **On Equatorial Line:**

Electric field intensity $E = \frac{1}{4\pi\varepsilon o}\frac{p}{(r^2+a^2)^{3/2}}$

If r > > 2a, then $E = \frac{1}{4\pi\varepsilon o}\frac{p}{r^3}$ (Short Dipole)

Electric potential V = 0

(iii) At any Point along a Line Making θ Angle with Axis

Electric field intensity

Magnitude of electric field

$$E = \frac{1}{4\pi\varepsilon o}\frac{p\sqrt{1+3\cos^2\theta}}{r^3}$$

Electric potential $V = \frac{1}{4\pi\varepsilon o}\frac{p\cos\theta}{r^2-a^2\cos^2\theta}$

If r > > 2a, then $V = \frac{1}{4\pi\varepsilon o}\frac{p\cos\cos\theta}{r^2}$ (Short Dipole)

Torque on a Electric Dipole in Uniform Electric Field:

Torque acting on an electric dipole placed in uniform electric field is given by

$\tau = pE\sin\theta$

or $\boldsymbol{\tau} = \mathbf{p} \times \mathbf{E}$

When θ = 90°, then '$\tau_{max} = pE$ (Maximum)

When electric dipole is parallel to electric field, it is in stable equilibrium and when it is anti-parallel to electric field, it is in unstable equilibrium. (In this Case Torque = 0)

Electric Dipole in Non-Uniform Electric Field:

When an electric dipole is placed in a non-uniform electric field, then a resultant force as well as a torque act on it.

Net force on electric dipole = $(qE_1 - qE_2)$, along the direction of greater electric field intensity.

Therefore, electric dipole undergoes rotational as well as linear motion.

Work done to rotate an electric dipole in Uniform electric Field:

Work done is rotating an electric dipole in a uniform electric field from angle θ_1 to θ_2 is given by

$W = pE(\cos\theta_1 - \cos\theta_2) = -pE(\cos\theta_2 - \cos\theta_1)$

If initially it is in the direction of electric field, then work done in rotating through an angle θ,

$W = pE(1 - \cos\theta)$.

Potential Energy of a Dipole:

Potential energy of an electric dipole in a uniform electric field is given by

$U = -pE\cos\theta = -\mathbf{p}.\mathbf{E}$

Stable Equilibrium:

When angle between **p** and **E** is 0 degree.

Unstable Equiibrium:

When angle between p and E is 180^0 .

Electric Flux (φ_E):

Electric flux over an area is equal to the total number of electric field lines crossing this area.

Electric flux through a small area element **dS** is given by

$d\varphi_E = \mathbf{E}.\,\mathbf{dS}$

where E= electric field intensity and dS = area vector.

Its SI unit is Nm^2C^{-1}.

For a curved surface, it is divided into smaller area element and flux through each element is calculated to find total flux i.e.

$$\varphi_E = \sum_{i=1}^{n} E.\Delta s = \oint E.ds$$

Gauss's Theorem:

The electric flux over any closed surface is $1/\varepsilon_o$ times the total charge enclosed by that surface, i.e.,

$$\emptyset_E = \oint \boldsymbol{E}.\boldsymbol{ds} = \frac{Q_{in}}{\epsilon_0}$$ where Q_{in} = Net Charge enclosed in the surface.

Important points regarding Gauss's Law:

(i) The law is valid for a surface of any shape and size.

(ii) Q_{in} includes only those charges which are inside the closed surface (may be located anywhere in the surface)

(iii) E in LHS is due to all the charges located inside or outside the surface.

(iv) Any violation of Gauss law will indicate the departure from inverse square law or Coulomb's law.

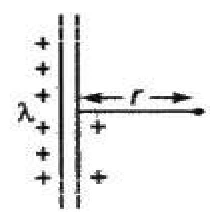
Note: If a charge q is placed at the centre of a cube, then total electric flux linked with the whole cube = q/ε_o, electric flux linked with one face of the cube = $q/6\varepsilon_o$.

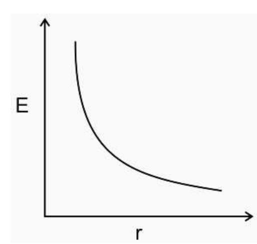
Electric Field Intensity due to an Infinite Line Charge:

$$E = \frac{\lambda}{2\pi\epsilon_0 r}$$

(Direction –Radially outwards for q > 0 and inwards or q<0)

where λ is linear charge density and r is distance from the line charge.





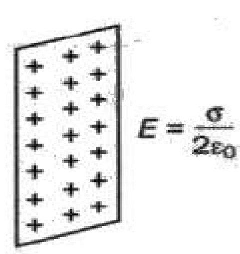
Electric Field Near an Infinite Plane Sheet of Charge:

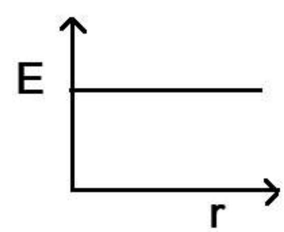
$E = \sigma / 2\varepsilon_o$

where σ = surface charge density.

If infinite plane sheet has uniform thickness, then

$\mathbf{E} = \sigma/\varepsilon_o$



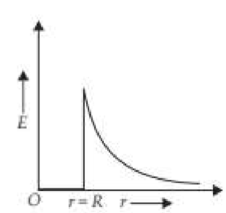


Electric Field Intensity due to an Uniformly Charges Spherical Shell/ Conducting Sphere (of radius R):

(i) At a point lying outside the shell (r > R) $E = \frac{1}{4\pi\varepsilon_0}.\frac{q}{r^2}$

(ii) At a point on the Surface of the shell (r =R) $E = \frac{1}{4\pi\varepsilon_0}.\frac{q}{r^2}$

(iii) At a point inside the shell: E = 0

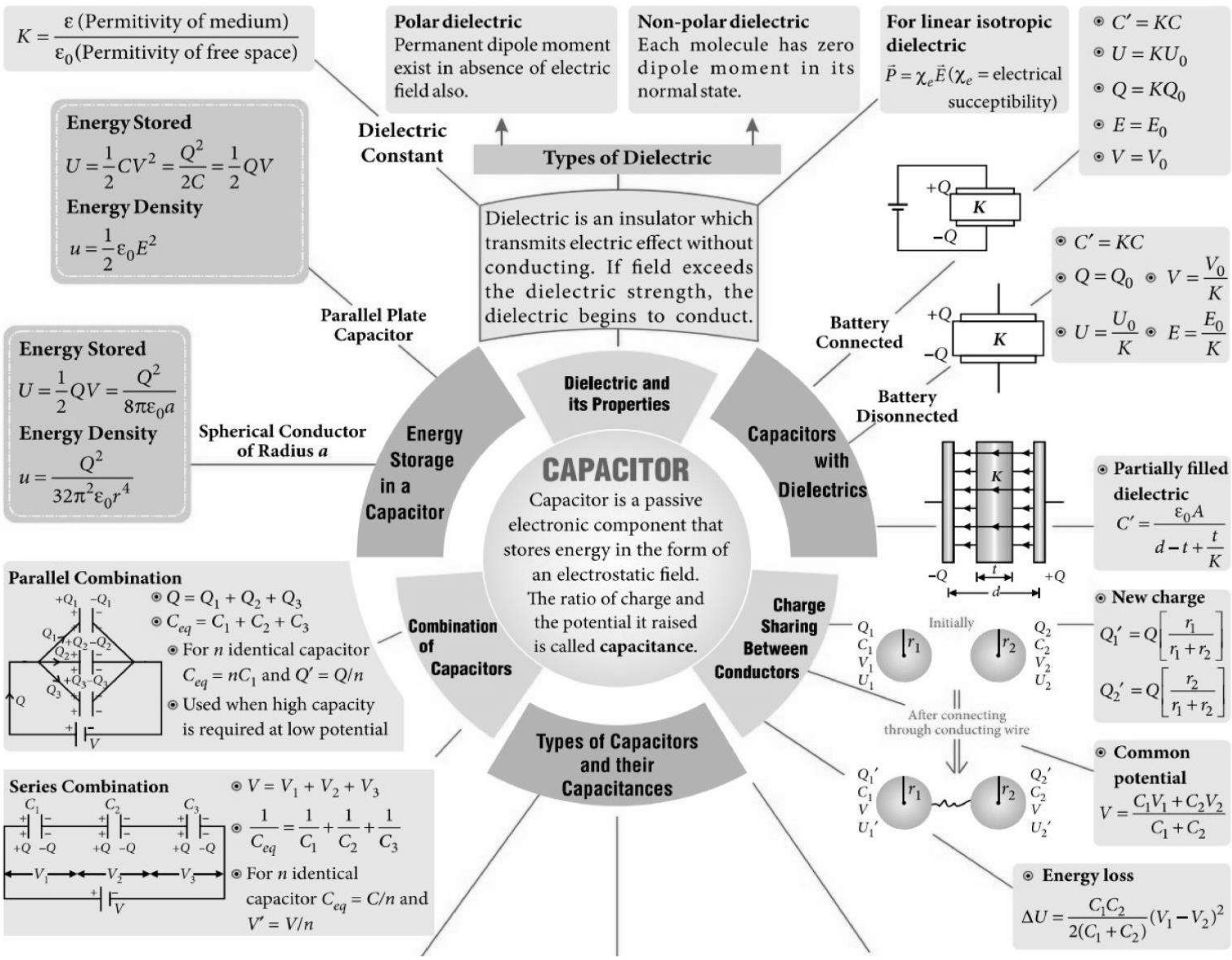


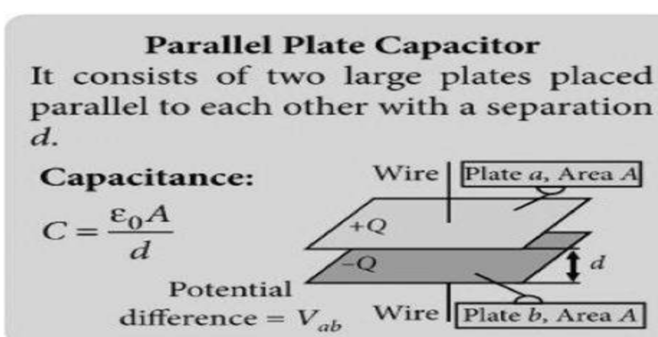
CHAPTER–2: ELECTROSTATIC POTENTIAL AND CAPACITANCE

Syllabus:- Electric potential, potential difference, electric potential due to a point charge, a dipole and system of charges; equipotential surfaces, electrical potential energy of a system of two-point charges and of electric dipole in an electrostatic field.

Conductors and insulators, free charges and bound charges inside a conductor. Dielectrics and electric polarization, capacitors and capacitance, combination of capacitors in series and in parallel, capacitance of a parallel plate capacitor with and without dielectric medium between the plates, energy stored in a capacitor (no derivation, formulae only)

MIND MAP

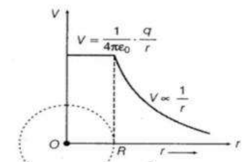




GIST OF THE CHAPTER

The concept of electric potential and capacitor used in daily life as

1. **Power Distribution**: Electric potential, or voltage, is what drives current flow in electrical circuits, ensuring that power is delivered to devices.



Variation of potential due to charged shell with distance r from its centre

2. **Electronic Devices**: Electric potential is used to control the movement of charges, as seen in TV screens, electron microscopes, and other devices.
3. **Lightning Rods**: Lightning rods are designed to facilitate the transfer of charge, preventing damage during lightning strikes
4. **High-Voltage Transmission Lines**: Smooth surfaces are used on high-voltage transmission lines to prevent charge leakage
5. **Household Appliances**: In refrigerators, air conditioners, and other appliances, capacitors help start motors efficiently and reduce power consumption.
6. **Audio Equipment**: Capacitors are crucial in audio equipment for filtering out unwanted noise and stabilizing signals, ensuring clear and reliable sound.
7. **Camera Flashes**: Capacitors store energy to provide a burst of power for camera flashes, allowing them to capture images in low-light conditions.
8. **Automotive Systems**: In hybrid and electric vehicles, capacitors are used for energy recuperation systems.
9. **Medical Devices**: Capacitors are used in medical devices like defibrillators to deliver a burst of energy to restore a normal heartbeat.

Electrostatic potential (V)

Electrostatic potential (V) at any point in a region with electrostatic field is the work done in bringing a unit positive charge (without acceleration) from infinity to that point.

$$V = -\int_{\infty}^{r} \vec{E}\cdot\vec{dr}$$

https://ophysics.com/em4.html

1. Electric potential due to point charge $V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$

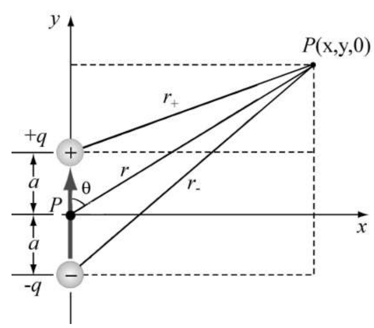
2. A system of charges $q_1, q_2, \ldots, q_n$ with position vectors $r_1, r_2, \ldots, r_n$ relative to some origin

The potential V at any point P due to the total charge configuration is the algebraic sum of the potentials due to the individual charges

$$V = V_1 + V_2 + V_3 + \text{-------------} + V_n$$

$$V = \frac{1}{4\pi\varepsilon_0}\left(\frac{q_1}{r_{1P}} + \frac{q_2}{r_{2P}} + \frac{q_3}{r_{3P}} + \cdots\ldots\ldots + \frac{q_n}{r_{nP}}\right)$$

3. Electric potential due to Electric dipole



(i) At any point

$$V = \frac{1}{4\pi\varepsilon_0}\frac{p\cos\theta}{r^2} \text{ or } V = \frac{1}{4\pi\varepsilon_0}\frac{\vec{p}.\hat{\imath}}{r^2}$$

(ii) At a point on the dipole axis (θ = 0, π)

$$V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r} \text{ or } V = -\frac{1}{4\pi\varepsilon_0}\frac{q}{r}$$

(iii) Potential in the equatorial plane ($\theta = \frac{\pi}{2}$)

$$V = 0$$

4. Electric potential uniformly charged spherical shell

(i) At a point outside the shell (r > R)

$$V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$$

(ii) At a point on the surface of shell (r = R)

$$V = \frac{1}{4\pi\varepsilon_0}\frac{q}{R}$$

(iii) At a point inside the shell (r < R)

$$V = \frac{1}{4\pi\varepsilon_0}\frac{q}{R}$$

Electric Potential Difference (ΔV)

It is the work done against electric field in moving a unit positive charge from one point to other. That is

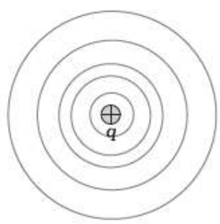
$$V_2 - V_1 = -\int_1^2 \vec{E}.\vec{dr}$$

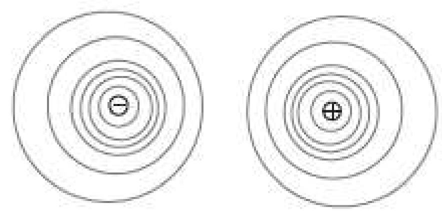
If W_{12} is work done in moving a charge q from one point to another point then

$$V_2 - V_1 = \frac{W_{12}}{q} \Longrightarrow W_{12} = q(V_2 - V_1)$$

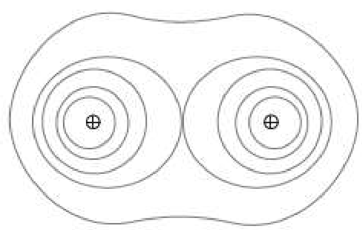
EQUIPOTENTIAL SURFACES

1. The electric potential is the same at all locations on the surface.
2. The electric field lines are always perpendicular to the equipotential surface.
3. Two equipotential surfaces cannot intersect.
4. No work is required to move a charge along an equipotential surface because the potential difference is zero along the surface.
5. No work is required to move a charge along an equipotential surface because the potential difference is zero along the surface.
6. Shape of equipotential surfaces

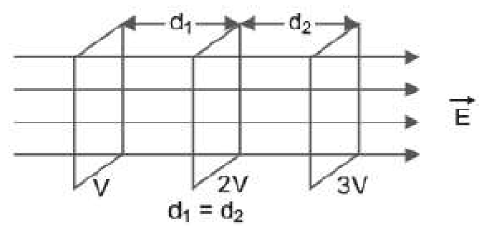




Point charge a dipole



Two identical positive charges



Uniform electric field

Relation between field and potential

$$E = -\frac{dV}{dr}$$

(i) Electric field is in the direction in which the potential decreases steepest.

(ii) Its magnitude is given by the change in the magnitude of potential per unit displacement normal to the equipotential surface at the point.

Electric Potential Energy(U)

Potential energy of charge q at a point (in the presence of field due to any charge configuration) is the work done by the external force (equal and opposite to the electric force) in bringing the charge q from infinity to that point.

(i) Potential energy for a system of two charges q_1 and q_2 is

$$U = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r_{12}}$$

(ii) Potential energy of a system of two charges in an external field

$$U = q_1\, V(r_1) + q_2\, V(r_2) + \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r_{12}}$$

(iii) Potential energy of a dipole in an external field

The amount of work done by the external torque rotating dipole from angle θ_0 to angle θ_1 at an infinitesimal angular speed and without angular acceleration will be given by

$W = pE\ (\cos\theta_0 - \cos\theta_1)$

This work is stored as the potential energy of the system. Take $\theta_0 = \frac{\pi}{2}$ and $\theta_1 = \theta$

$U = -\ pE\cos\theta = -\ \vec{p}.\vec{E}$

Simulation link for topic:- Capacitor

https://phet.colorado.edu/en/simulations/capacitor-lab-basics

MULTIPLE CHOICE QUESTIONS

1. A uniform electric field pointing in positive x-direction exists in a region. Let A be the origin, B be the point on the x-axis at x = + 1 cm and C be the point on the y-axis at y = + 1 cm. Then, the potentials at the points A, B and C satisfy

(a) $V_A < V_B$ (b) $V_A > V_B$ (c) $V_A < V_C$ (d) $V_A > V_C$

2. Which statement is not correct for an equipotential surface?
(a) Electric field intensity is always perpendicular to the equipotential surface.
(b) Potential difference between any two points on it is zero.
(c) Equipotential surfaces are spherical in shape.
(d) No work is required to move a charge on an equipotential surface

3. An electron mass m and charge e travels from rest through a potential difference of V. What will be the final velocity of electron?

(a) eV (b) $\frac{2eV}{m}$ (c) $\sqrt{\frac{2eV}{m}}$ (d) $\sqrt{\frac{2mV}{e}}$

4. Four point charges –Q, -q, 2q and 2Q are placed, one at each corner of the square. The relation between Q and q for which the potential at the centre of the square zero, is

(a) Q = -q (b) $Q = \frac{-1}{q}$ (c) Q = q (d) $Q = \frac{1}{q}$

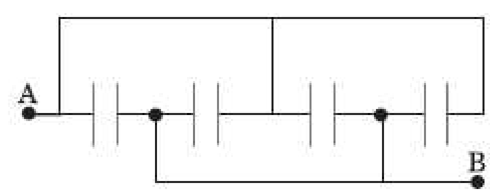
5. A hollow metal sphere of radius 10 cm is charged such that the potential on its surface is 80 V. The ratio of potential at a distance 5cm from the centre of the sphere to the potential at the surface of sphere is

(a) 1:2 (b) 2:1 (c) 1:1 (d) 1:4

6. There is one charged isolated air capacitor and *U* is the energy stored in it. Separation between the plates of the capacitor is increased to double of the initial value. Energy stored becomes

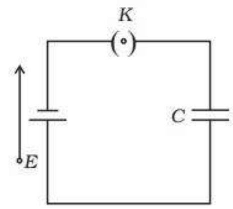
(a) U/2 (b) 2U (c) U/3 (d) 3U

7. Four condensers are joined as shown in the figure and the capacity of each condenser is 8 μF. The equivalent capacity between the points A and B will be:



(*a*) 16 μF (*b*) 8 μF
(*c*) 32 μF (*d*) 2 μF

8. A parallel plate capacitor is connected to a battery as shown in Fig. Consider two situations:
A: Key K is kept closed and plates of capacitors are moved apart using insulating handle.
B: Key K is opened and plates of capacitors are moved apart using insulating handle.
Choose the correct option(s).



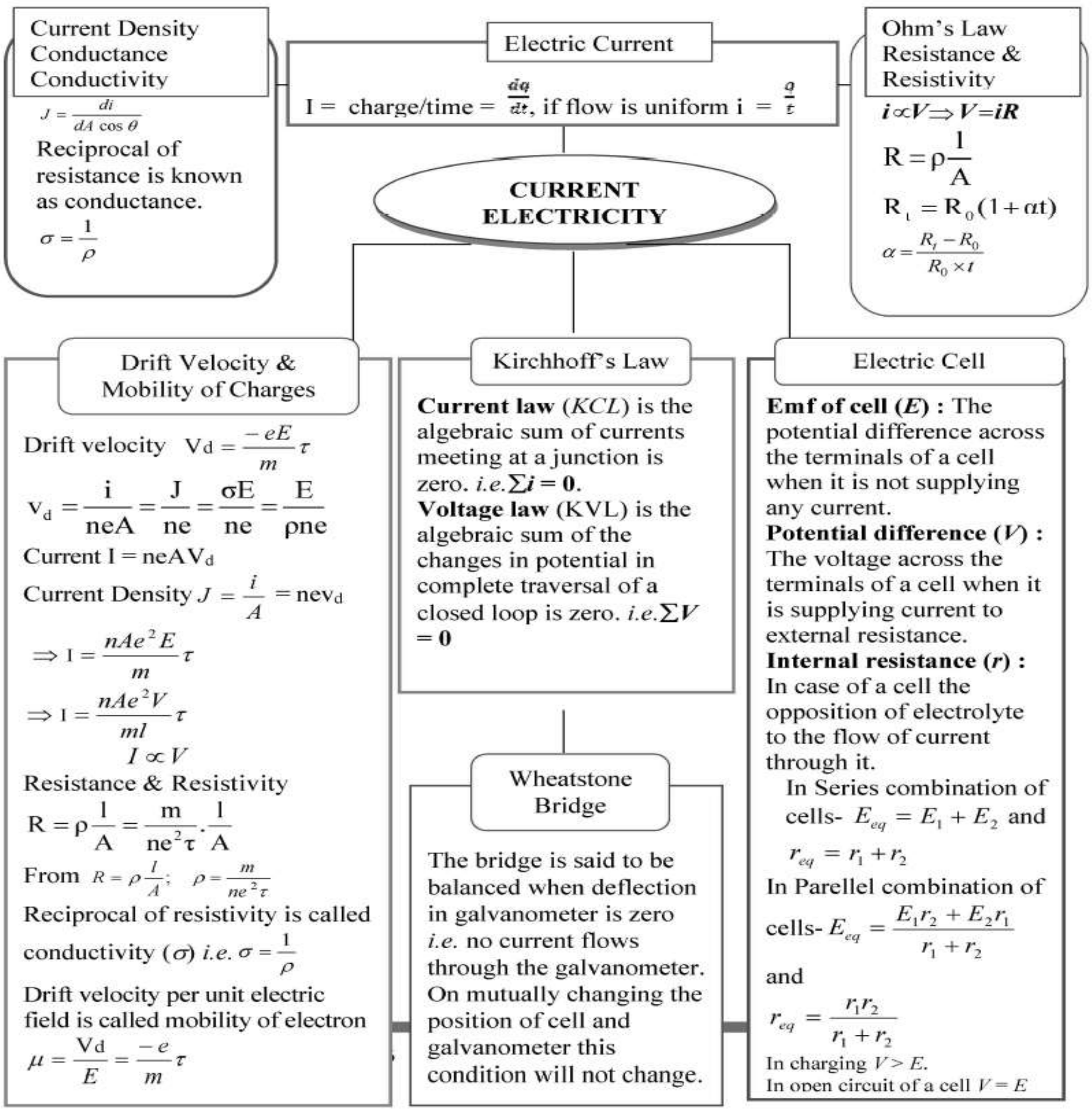
(a) In A : Q remains same but C changes.
(b) In B : V remains same but C changes.
(c) In A : V remains same and hence Q changes.
(d) In B : C remains same and hence V changes.

CHAPTER-03 - CURRENT ELECTRICITY

SYLLABUS

Electric current, flow of electric charges in a metallic conductor, drift velocity, mobility and their relation with electric current; Ohm's law, V-I characteristics (linear and non-linear), electrical energy and power, electrical resistivity and conductivity, temperature dependence of resistance, Internal resistance of a cell, potential difference and emf of a cell, combination of cells in series and in parallel, Kirchhoff's rules, Wheatstone bridge.

CONCEPT MAP

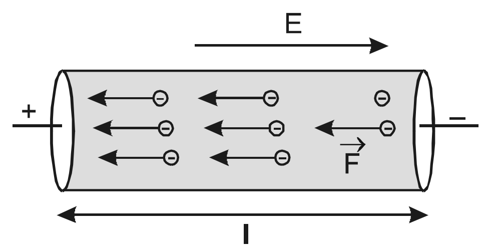


GIST OF THE CHAPTER

ELECTRIC CURRENT

- The electric current in measured by 'rate of flow of charge'.Or Charge flowing per second from any cross section of the conductor is called electric current,
- Current i = charge/time = $\frac{dq}{dt}$, if flow is uniform i = $\frac{Q}{t}$
- **Unit :** Ampere (A), Dimension : ($M^0L^0T^0A^1$)
- 1 ampere = 1 coulomb/second. i.e. if 1 coulomb of charge flows per second then 1 ampere of current is said to be flowing.

- 1 ampere of current means the flow of 6.25×10^{18} electrons per second through any cross section of conductor
- If n electrons pass through any cross section in every t seconds then $i = \frac{ne}{t}$ where e = 1.6×10^{-19} coulomb.
- The conventional direction of current is taken to be the direction of flow of positive charge, *i.e.* field
- Value of the current is same throughout the conductor, irrespective of the cross section of conductor at different points.
- Net charge in a current carrying conductor is zero at any instant of time.



Note : A current carrying conductor cannot said to be charged, because in conductor the current is caused by electron (free electron). The no. of electron (negative charge) and proton (positive charge) in a conductor is same. Hence the net charge in a current carrying conductor is zero.

- Electric field outside a current carrying conductor is zero, but it is non zero inside the conductor and is given by $e = -\frac{v}{l}$

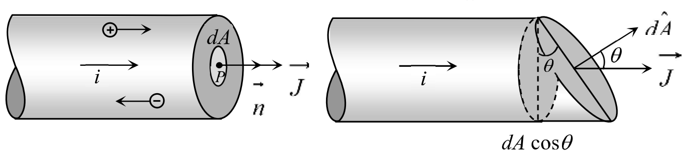
Note : The electric field inside charged conductor is zero, but it is non zero inside a current carrying conductor

Note : Current is a scalar quantity because it does not obey law of vector

CURRENT DENSITY

Current density at any point inside a conductor is defined as a vector having magnitude equal to current per unit area surrounding that point. Remember area is normal to the direction of charge flow (or current passes) through that point.

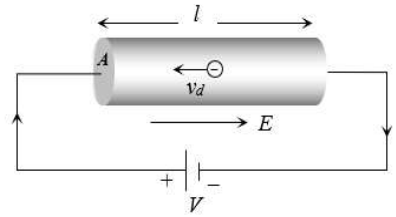
- Current density at point *P* is given by $\vec{J} = \frac{di}{dA}\vec{n}$



- If the cross-sectional area is not normal to the current, but makes an angle θ with the direction of current then $J = \frac{\text{di}}{\text{dAcos}\theta} \Rightarrow di = JdA\cos\theta = \vec{J}\cdot\vec{dA} \Rightarrow i = \int \vec{J}\cdot\vec{dA}$
- If current density $\vec{J}$ is uniform for a normal cross-section **A** then J= i/A
- Current density **J** is a vector quantity. It's direction is same as that of **E**. It's S.I. unit is *amp/m*^{2} and dimension $[L^{-2}A]$.
- In case of uniform flow of charge through a cross-section normal to it as $i = \text{nqvA} \Rightarrow J = \frac{i}{A} = \text{nqv}$
- Current density relates with electric field as $\vec{J} = \sigma\vec{E} = \frac{\vec{E}}{\rho}$; where σ = conductivity and ρ = resistivity or specific resistance of substance.

Drift Velocity

Drift velocity is the average uniform velocity acquired by free electrons inside a metal by the application of an electric field which is responsible for current through it. Drift velocity is very small it is of the order of $10^{-4} m/s$ as compared to thermal speed ($\simeq 10^5 m/s$) of electrons at room temperature.

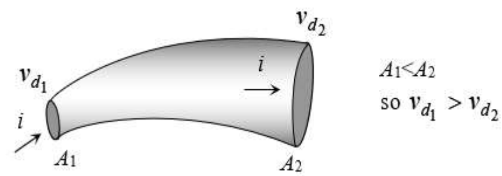


If suppose for a conductor n = Number of electron per unit volume of the conductor,

A = Area of cross-section, V = potential difference across the conductor, **E** = electric

field inside the conductor**,** i = current, J = current density, ρ = specific resistance, σ conductivity $\left(\sigma = \frac{1}{\rho}\right)$ then current relates with drift velocity as $i = \text{neAv}_d$ we can also write $v_d = \frac{i}{\text{neA}} = \frac{J}{\text{ne}} = \frac{\sigma \text{E}}{\text{ne}} = \frac{E}{\rho\text{ne}} = \frac{V}{\rho lne}$.

- The direction of drift velocity for electron in a metal is opposite to that of applied electric field (*i.e.* current density$\vec{J}$).$v_d \propto E$ *i.e.*, greater the elecic field, larger will be the drift velocity.
- When a steady current flows through a conductor of non-uniform cross-section drift velocity varies inversely with area of cross-section $\left(v_d \propto \frac{1}{A}\right)$



- If diameter (d) of a conductor is doubled, then drift velocity of electrons inside it will not change.

Relaxation time (τ) : The time interval between two successive collisions of electrons with the positive ions in the metallic lattice is defined as relaxation time $\tau = \frac{\text{mean free path}}{\text{r.m.s. velocity of electrons}} = \frac{\lambda}{v_{rms}}$. With rise in temperature v_{rms} increases consequently τ decreases.

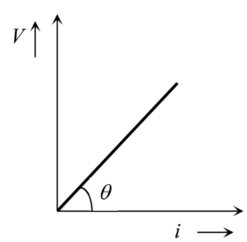
Mobility : Drift velocity per unit electric field is called mobility of electron *i.e.*$\mu = \frac{v_d}{E}$. It's unit is $\frac{m^2}{volt-sec}$.

Ohm's Law

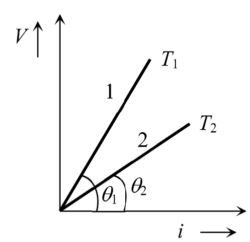
If the physical conditions of the conductor (length, temperature, mechanical strain etc.) remains some, then the current flowing through the conductor is directly proportional to the potential difference across it's two ends *i.e.*$i \propto V \Rightarrow V = iR$ where R is a proportionality constant, known as electric resistance.

(1) Ohm's law is not a universal law, the substances, which obey ohm's law are known as ohmic substance.

(2) Graph between V and i for a metallic conductor is a straight line as shown. At different temperatures V-i curves are different.



(A) Slope of the line = $\tan\theta = R$



(B) Here $\tan\theta_1 > \tan\theta_2$ So $R_1 > R_2$ *i.e.* $T_1 > T_2$

Ohm's law is true For metallic conductors at low temperature Because with rise in temperature resistance of conductor increase, so graph between V and i becomes non linear.

Resistance

- The property of substance by virtue of which it opposes the flow of current through it, is known as the resistance.
- **Formula of resistance :** For a conductor if l = length of a conductor A = Area of cross-section of conductor, n = No. of free electrons per unit volume in conductor, τ = relaxation time then resistance of conductor $R = \rho\frac{l}{A} = \frac{m}{\text{ne}^2\tau}.\frac{l}{A}$; where ρ = resistivity of the material of conductor
- **Unit and dimension :** It's S.I. unit is *Volt/Amp*. or *Ohm* (Ω).It's dimension is $[ML^2T^{-3}A^{-2}]$
- **Dependence of resistance :** Resistance of a conductor depends upon the following factors.

(i) Length of the conductor :Resistance of a conductor is directly proportional to it's

length *i.e.* $\boldsymbol{R \propto l}$ and inversely proportional to it's area of cross-section *i.e.* $R \propto \frac{1}{A}$
(ii) Temperature : For a conductor
If R_0 = resistance of conductor at 0^oC
R_t = resistance of conductor at t^oC
and α, β = temperature co-efficient of resistance
then $R_t = R_0(1 + \alpha t)$ for $t \le 300^oC$ or $\alpha = \frac{R_t - R_0}{R_0 \times t}$
If R_1 and R_2 are the resistances at $t_1{}^oC$ and $t_2{}^oC$ respectively then $\frac{R_1}{R_2} = \frac{1+\alpha t_1}{1+\alpha t_2}$.
The value of α is different at different temperature. Temperature coefficient of resistance averaged over the temperature range $t_1{}^oC$ to $t_2{}^oC$ is given by $\alpha = \frac{R_2 - R_1}{R_1(t_2 - t_1)}$ which gives
$R_2 = R_1\,[1 + \alpha\,(t_2 - t_1)]$.

Resistivity (ρ), Conductivity (σ) and Conductance (C)

Resistivity : From $R = \rho \frac{l}{A}$; If $l = 1m$, $A = 1\ m^2$ then $R = \rho$ *i.e.* resistivity is numerically equal to the resistance of a substance having unit area of cross-section and unit length.

- Unit and dimension : It's S.I. unit is *ohm×m* and dimension is $[ML^3T^{-3}A^{-2}]$
- (ii) It's formula : $\rho = \frac{m}{ne^2\tau}$
- (iii) Resistivity is the intrinsic property of the substance. It is independent of shape and size of the body (*i.e.* l and A).

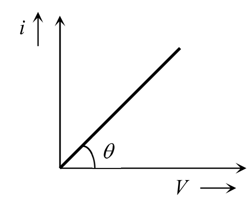
For different substances their resistivity is also different

$$\underset{(\text{Maximum for fused quartz})}{\rho_{insulator}} > \rho_{alloy} > \rho_{semi-conductor} > \underset{(\text{Minimum for silver})}{\rho_{conductor}}$$

- Resistivity depends on the temperature. For metals $\rho_t = \rho_0(1 + \alpha \Delta t)$ *i.e.* resistivity increases with temperature.
- Resistivity increases with impurity and mechanical stress.

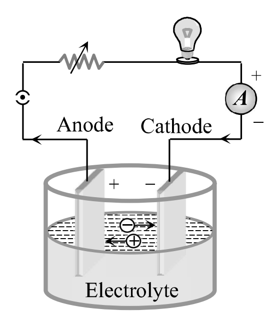
Conductivity : Reciprocal of resistivity is called conductivity (σ) *i.e.* $\sigma = \frac{1}{\rho}$ with unit *mho/m* and dimensions $[M^{-1}L^{-3}T^3A^2]$.

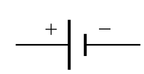
Conductance: Reciprocal of resistance is known as conductance. $C = \frac{1}{R}$ It's unit is $\frac{1}{\Omega}$ or Ω^{-1}.



Cell

The device which converts chemical energy into electrical energy is known as electric cell. Cell is a source of constant emf but not constant current.





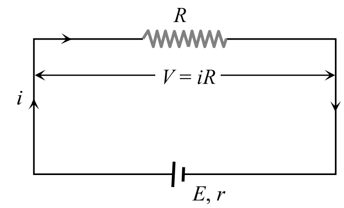
Symbol of cell

(1) **Emf of cell (E) :** The potential difference across the terminals of a cell when it is not supplying any current is called it's emf.
(2) **Potential difference (V) :** The voltage across the terminals of a cell when it is supplying current to external resistance is called potential difference or terminal voltage.
Potential difference is equal to the product of current and resistance of that given part
i.e. $V = iR$.
(3) **Internal resistance (r) :** In case of a cell the opposition of electrolyte to the flow of current through it is called internal resistance of the cell. The internal resistance of a cell

depends on the distance between electrodes ($r \propto d$), area of electrodes [$r \propto (1/A)$] and nature, concentration ($r \propto C$) and temperature of electrolyte [$r \propto$ (1/ temp.)].

A cell is said to be ideal, if it has zero internal resistance.

Cell in Various Positions



(1) **Closed circuit :** Cell supplies a constant current in the circuit.

(i) Current given by the cell $i = \frac{E}{R+r}$

(ii) Potential difference across the resistance $V = iR$

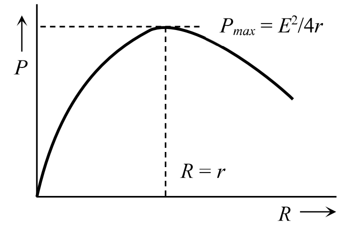
(iii) Potential drop inside the cell = ir

(iv) Equation of cell $E = V + ir$ ($E>V$

(v) Internal resistance of the cell $r = \left(\frac{E}{V} - 1\right) \cdot R$

(vi) Power dissipated in external resistance (load)

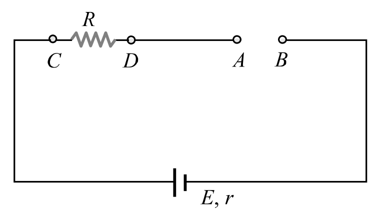
$$P = Vi = i^2 R = \frac{V^2}{R} = \left(\frac{E}{R+r}\right)^2 . R$$



Power delivered will be maximum when$R = r$ so $P\frac{E^2}{4r}_{max}$.

This statement in generalised from is called "*maximum power transfer theorem*".

(vii) When the cell is being charged *i.e.* current is given to the cell then $E = V - ir$ and $E<V$.

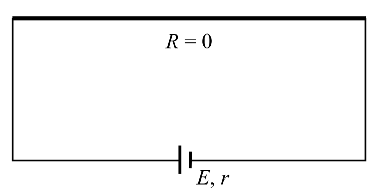


(2) **Open circuit :** When no current is taken from the cell it is said to be in open circuit

(i) Current through the circuit $i = 0$

(ii) Potential difference between A and B, $V_{AB} = E$

(iii) Potential difference between C and D, $V_{CD} = 0$



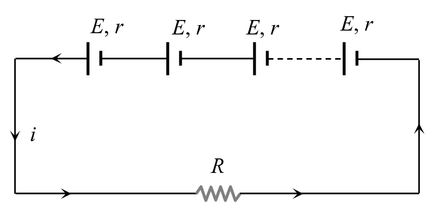
(3) **Short circuit :** If two terminals of cell are join together by a thick conducting wire

(i) Maximum current (called short circuit current) flows momentarily $i_{sc} = \frac{E}{r}$

(ii) Potential difference $V = 0$

Grouping of Cells

(1) **Series grouping :** In series grouping anode of one cell is connected to cathode of other cell and so on. If n identical cells are connected in series



(i) Equivalent emf of the combination $E_{eq} = nE$

(ii) Equivalent internal resistance $r_{eq} = nr$

(iii) Main current = Current from each cell= $i = \frac{nE}{R+nr}$

(iv) Potential difference across external resistance $V = iR$

(v) Potential difference across each cell $V' = \frac{V}{n}$

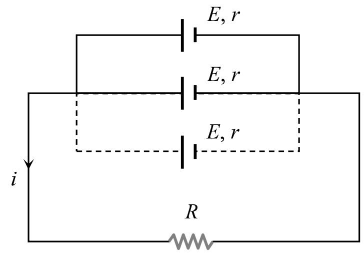
(vi) Power dissipated in the external circuit = $\left(\frac{nE}{R+nr}\right)^2 . R$

(vii) Condition for maximum power $R = nr$ and$P\left(\frac{E^2}{4r}\right)_{max}$

(viii) This type of combination is used when $nr<<R$.

(2) **Parallel grouping :** In parallel grouping all anodes are connected at one point and all cathode are connected together at other point. If n identical cells are connected in

parallel.



(i) Equivalent emf $E_{eq} = E$

(ii) Equivalent internal resistance $R_{eq} = r/n$

(iii) Main current $i = \frac{E}{R+r/n}$

(iv) Potential difference across external resistance = p.d. across each cell = $V = iR$

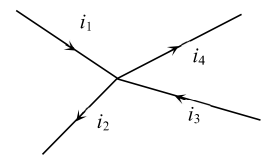
(v) Current from each cell $i' = \frac{i}{n}$

(vi) Power dissipated in the circuit $P = \left(\frac{E}{R+r/n}\right)^2 .R$

(vii) Condition for max. power is $R = r/n$ and$P \left(\frac{E^2}{4r}\right)_{max}$

(viii) This type of combination is used when $nr >> R$

Kirchoff's Laws



(1) **Kirchoff's first law :** This law is also known as junction rule or current law (*KCL*). According to it the algebraic sum of currents meeting at a junction is zero *i.e.* $\sum i = 0$. In a circuit, at any junction the sum of the currents entering the junction must equal the sum of the currents leaving the junction. $i_1 + i_3 = i_2 + i_4$

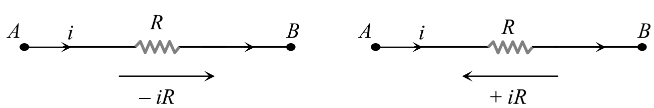
(ii) This law is simply a statement of "*conservation of charge*".

(2) **Kirchoff's second law :** This law is also known as loop rule or voltage law (KVL) and according to it "the algebraic sum of the changes in potential in complete traversal of a mesh (closed loop) is zero", *i.e.* $\sum V = 0$

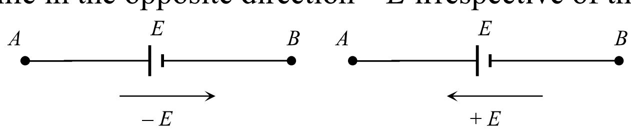
(i) This law represents "*conservation of energy*".

(3) **Sign convention for the application of Kirchoff's law :** For the application of Kirchoff's laws following sign convention are to be considered

(i) The change in potential in traversing a resistance in the direction of current is $-iR$ while in the opposite direction $+iR$



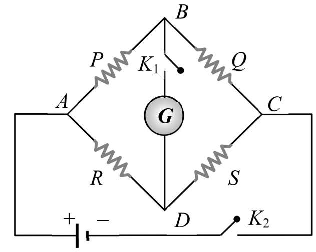
(ii) The change in potential in traversing an emf source from negative to positive terminal is $+E$ while in the opposite direction $-E$ irrespective of the direction of current in the circuit.



Wheatstone bridge : Wheatstone bridge is an arrangement of four resistance which can be used to measure one of them in terms of rest. Here arms *AB* and *BC* are called ratio arm and arms *AC* and *BD* are called conjugate arms

(i) **Balanced bridge :** The bridge is said to be balanced when deflection in galvanometer is zero *i.e.* no current flows through the galvanometer or in other words $V_B = V_D$. In the balanced condition $\frac{P}{Q} = \frac{R}{S}$, on mutually changing the position of cell and galvanometer this condition will not change.

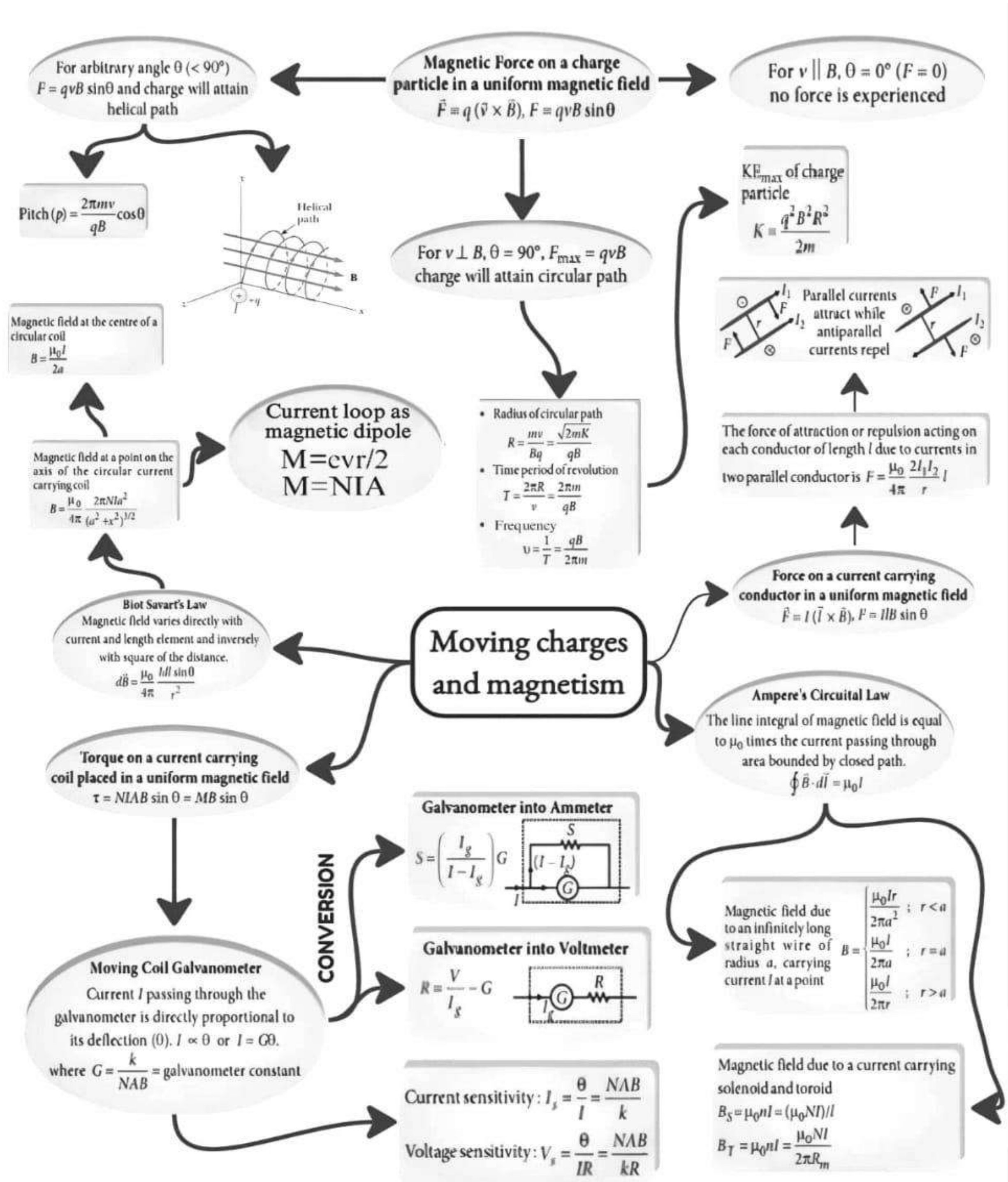
(ii) **Unbalanced bridge :** If the bridge is not balanced current will flow from *D* to *B* if $V_D > V_B$ *i.e.* $(V_A - V_D) < (V_A - V_B)$ which gives $PS > RQ$.



CHAPTER 4: Magnetic Effects of Current and Magnetism

Syllabus- Chapter–4: Moving Charges and Magnetism Concept of magnetic field, Oersted's experiment. Biot - Savart law and its application to current carrying circular loop. Ampere's law and its applications to infinitely long straight wire. Straight solenoid (only qualitative treatment), force on a moving charge in uniform magnetic and electric fields. Force on a current-carrying conductor in a uniform magnetic field, force between two parallel current-carrying conductors-definition of ampere, torque experienced by a current loop in uniform magnetic field; Current loop as a magnetic dipole and its magnetic dipole moment, moving coil galvanometer- its current sensitivity and conversion to ammeter and voltmeter.

MIND MAP



GIST OF THE CHAPTER

Magnetic field- It is a region of space around a magnet or a current carrying conductor in which it can exert force on other magnetic materials, moving charges, magnets and current carrying conductor.
A moving charge produces both electric and magnetic field while a stationary electron produces an electric field only.

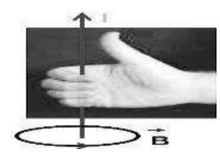
SI Unit of Magnetic field-

The SI unit of magnetic field is Wm^{-2} or T (tesla).
If 1A current is flowing through a straight conductor and it is kept at right angle to a magnetic field such that force per unit length on it is $1Nm^{-1}$ the strength of magnetic field is called one tesla,

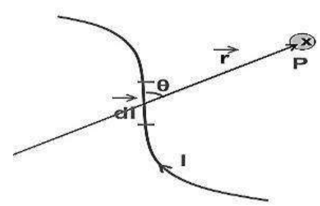
1 tesla (T) = 1 weber meter^{-2} (Wbm^{-2}) = 1 newton ampere^{-1} meter^{-1} (NA^{-1} m^{-1})
CGS units of magnetic field is called gauss or oersted. 1 gauss = 10^{-4} tesla.
Right hand thumb rule- Hold a conductor is Right Hand in such a way that thumb indicates the direction of current then the curled finger encircling the conductor will give the direction of magnetic field lines around it.

Biot- Savart law- It states that the magnetic field strength d**B** produced due to a current element (of current I and length dl) at a point having position vector r relative to current element is-

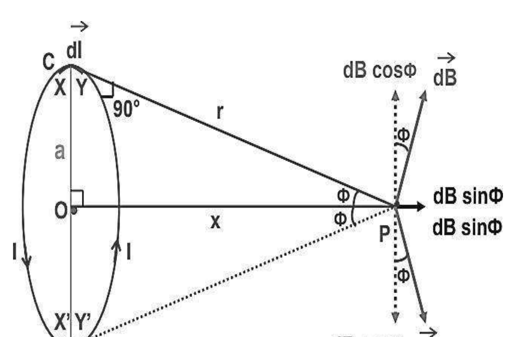
$$d\boldsymbol{B} = \frac{\mu_0}{4\pi}\frac{(i\vec{dl}\times\vec{r})}{r^3} \quad or \quad d\boldsymbol{B} = \frac{\mu_0}{4\pi}\frac{idl\,sin\theta}{r^2}$$



where μ_0 is the permeability of free space,
θ is the angle between current element and position vector **r** as shown in the figure.
The direction of magnetic field **B** is perpendicular To the plane containing I**dl** and **r**
The value of $\mu_0 = 4\pi \times 10^{-7}$ Wb/A-m.



Magnetic field due to a current carrying circular loop –
The magnetic field due to current carrying circular loop having radius 'a',carrying current 'I' at a distance 'x' from the centre of coil is –



$$B = \frac{\mu_0 I a^2}{2(a^2 + x^2)^{3/2}}$$

(μ_0 , I, a, sinΦ are constants, ∫dl = 2πa and r & sinΦ are replaced with measurable and constant values.)

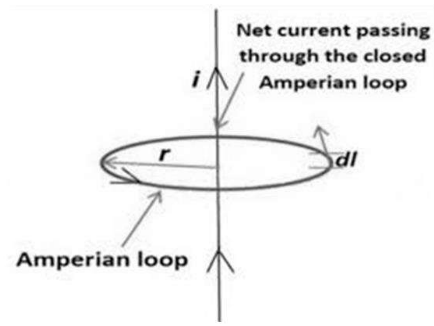
In case of coil having N turn, B(coil) = N x B(loop) $\therefore \boxed{B = \frac{\mu_0 I}{2a}}$

The magnetic field due to current carrying circular coil is along the axis. At the center, x=0

The direction of the magnetic field at the center is perpendicular to the plane of the coil.

Ampere's Circuital law - It states that line integral of magnetic field around any closed loop (called Amperean loop) is equal to μ_0-times the current (I) threading through that loop.

$$\oint \vec{B}.\vec{dl} = \mu_0 I_{enclosed}$$



Magnetic field due to infinitely long straight wire using Ampere's law- Accordingto Ampere's circuital law.

$$\oint \vec{B}.\vec{dl} = \mu_0 I_{enclosed}$$

$$B\,(2\pi r) = \mu_0 I$$

$$\boldsymbol{B = \frac{\mu_0 I}{2\pi r}}$$

Straight solenoid- At the axis of a long solenoid, carrying current I , $B=\mu_0\, nI$, where n = N/L = number of turns per unit length.

Force on a current-carrying conductor in a uniform magnetic field $\vec{B}$

Magnitude of force is F = I L Bsinθ.

Direction of force is normal to and B & I ,given by Fleming's Left Hand Rule. If θ=0 (i.e. I or L is parallel to $\vec{B}$), then the magnetic force is zero.

Force on a moving charge in uniform magnetic field-The force on a charged particle moving with velocity 'v' in a uniform magnetic field is given by $\vec{F} = q(\vec{v} \times \vec{B})$ or F = qvb sinθ

θ is the angle between velocity(**v**) and magnetic field(**B**). Force (**F**) is perpendicular to both **v** and **B**. (i) If **v** and **B** are parallel **F**=0

(ii) When v is perpendicular to B, i.e. $\theta = 90^0$, F = qvB i.e F is maximum

Lorentz force -The total force on a charged particle moving in co-existing electric field → and magnetic field → is given by $\vec{F} = q\,[\vec{E} + (\vec{v} \times \vec{B})]$

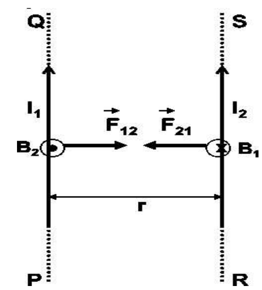
This is called the Lorentz force equation.

The direction of this force is determined by using Fleming's left hand rule

Fleming's Left Hand Rule- Stretch out the fingers in left hand such that the fore-finger, the central finger and thumb are mutually perpendicular to each other. When the fore-finger points in the direction of the magnetic field and the central finger points in the direction ofcurrent then thumb gives the direction of the force acting on the conductor.

Force between two long straight parallel current carrying conductors-

Two parallel current carrying conductors attract while they repel if current in them is anti-parallel. The magnetic forceper unit length on either current carrying conductor at separation a is given by

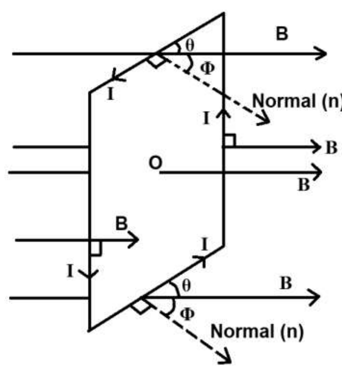


$$\frac{F}{l} = \frac{\mu_0}{4\pi}\frac{2I_1I_2}{r}\ N/m$$

Definition of ampere: - *1 ampere is the current which when flowing in each ofthe two parallel wires in vacuum separated by 1 m from each other exert a forceof 2 X 10^{-7}N/m on each other.*

Torque experienced by a current loop in uniform magnetic field-

A coil of N turns and area A is carrying current I is kept in a magnetic field as shown in figure as shown in figure. Force on it will be zero and torque on it will be



τ = NIBA cosθ

θ = angle between coil and magnetic field

If Φ = angle between Normal ($\hat{n}$) to coil and magnetic field (**B**)

, Φ + θ = 90° so i.e. θ = 90° - Φ

So τ = *N I A B cos (90° - Φ) = N I A B sin Φ*

τ = *N I A B sin Φ*

As τ = ***M*** *B sin Φ* *so* ***M = NIA***

In vector form $\vec{\tau} = NI(\vec{A} \times \vec{B})$

The unit of magnetic moment in SI system is Am^2.

The torque is *maximum* when the plane of the coil is *parallel to the magnetic field* and *zero*when the plane of the coil is *perpendicular to the magnetic field*.

Potential energy of a current loop in a magnetic field- When a current loopof magnetic moment **M** is placed in a magnetic field (**B**), then potential energy of magnetic dipole is

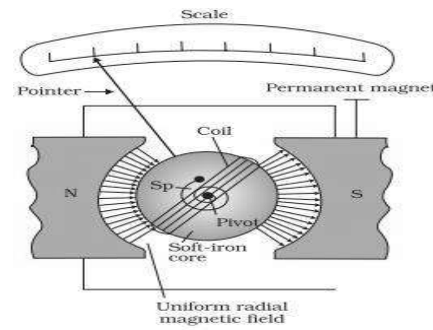
$$U = -MB\cos\theta = -\vec{M}\cdot\vec{B}$$

When θ = 0, U = - MB (minimum or stable equilibrium position)

When θ = 180^0, U = +MB (maximum or unstable equilibrium position)

When θ = 90^0, potential energy is zero

Moving coil galvanometer- A moving coil galvanometer is a device used to detect flowof current in a circuit. A moving coil galvanometer consists of a rectangular coil placed in an uniform radial magnetic field produced by cylindrical poles pieces.Torque on coil due to current



$$\tau = NIBA \sin\Phi$$

for a radial magnetic field sinΦ=1 so $\tau = NIBA$

where **N** is the number of turns, **A** is the area of coil. If *C* is torsional rigidity of material of suspension wire.

For deflection Φ, restoring torque $\tau = C\,\theta$. For equilibrium

$$NIAB = C\,\Phi \quad \text{or} \quad I = C\,\Phi/(NBA)$$

Clearly, deflection in galvanometer is directly proportional to current, so the scale of galvanometer is linear.

Use of radial magnetic field- when radial magnetic field is used the angle between the normal to the plane of loop (**A)** and magnetic field (**B**) $\Phi = 90^0$ for any orientation of loop, in a radial magnetic field the angular deflection of coil is proportional to the current flowing through it. Hence a linear scale can be used to determine the deflection of coil i.e. measurement of current.

Uses of galvanometer: (i) Used to detect electric current and direction of its flow in given branch of circuit. (ii) Usedto convert the ammeter by putting a low resistor in parellel. (iii) Used to convert voltmeterby putting a high resistor in series. (iv) Used as ohmmeter by making special arrangement

Current sensitivity: It is defined as the deflection of coil per unit current flowing in it.

$$\Phi/I = NBA/C$$

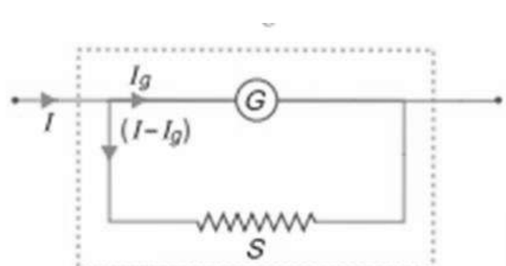
Voltage sensitivity: It is defined as the deflection of coil per unit potential

$$\Phi/V = NBA/RC$$

Conversion of Galvanometer into Ammeter: **-** A galvanometer can be converted into an ammeter by using a suitably small resistance in parallel with the galvanometer coil. The small resistance connected in parallel is called a shunt.If *G* is resistance of galvanometer, *Ig* is current in galvanometer for full scale deflection, then for conversion of galvanometer into ammeter of range *I* ampere,the shunt required can be found as

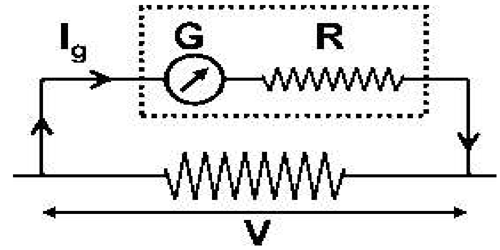
$I_g G = (I - I_g)S$ (As 'S' and 'G' are parallel combination)

So $\boldsymbol{S = \frac{I_g G}{(I - I_g)}}$



Ammeter

Conversion of Galvanometer into Voltmeter: - A galvanometer may be converted into voltmeter by connecting high resistance (R) in series with the coil of the galvanometer. If V volt is the range of voltmeter formed, then series resistance is given by



$V = I_g(R + G)$ So $\boldsymbol{R = \frac{V}{I_g} - G}$

Magnetic moment due to a revolving charge or electron-
A current loop or a revolving charge can be considered as a magnet. The magnetic moment of such a loop is M= qvr/2.
The face from which current flow appears **anticlockwise** is the **north pole** of equivalent magnet with magnetic moment **M**. I.e magnetic moment is outward
If we have a coil having N turns carrying current I having A as area of cross-section the magnetic moment is given by *M= NIA*

For an electron moving in Hydrogen atom
M=evr/2
As per Bohr's theory of Hydrogen atom L= mvr = nh/2π n= 0,1,2,3,4………. Where n is principal quantum number
M= -e**L**/2m

MULTIPLE CHOICE QUESTIONS

1 A proton and an alpha particle with same kinetic energy enters normally into a uniform magnetic field (**B**), the ratio of their radii of curvature of their path respectively will be

(a) More than 1 (b) 1 (c)Lesser than 1 (d) Dependent on the |**B**|

2 If a galvanometer of resistance R_g is connected with a shunt of resistance 'S' such that

R_g=n.S the ratio of power consumed by R_g and S respectively will be

(a) n^2 (b) n (c) 1/n (d) $1/n^2$

3 A galvanometer of can measure current up to 200μA. if a resistor of 10Ω is connected across it the range of it enhances to 1mA.If a resistor of 20Ω is connected in place of 10Ω the range will be

(a) 2mA (b) 0.4mA (c) 0.5mA (d) 0.6mA

4 A charge enters into a uniform magnetic field with a K.E. 'E' and leaves it after some time. The K.E. of the charge while leaving the field will be

(a) Lesser than E (b) More than E (c) Equal to E (d) Lesser than or equal

5 An electric field is applied along positive Y-axis and a magnetic field along negative Z-axis. An electron moving through this region along positive X-axis will

(a) Move undeflected (b) Deflect towards B (c) Deflect along E (d) Deflect against E

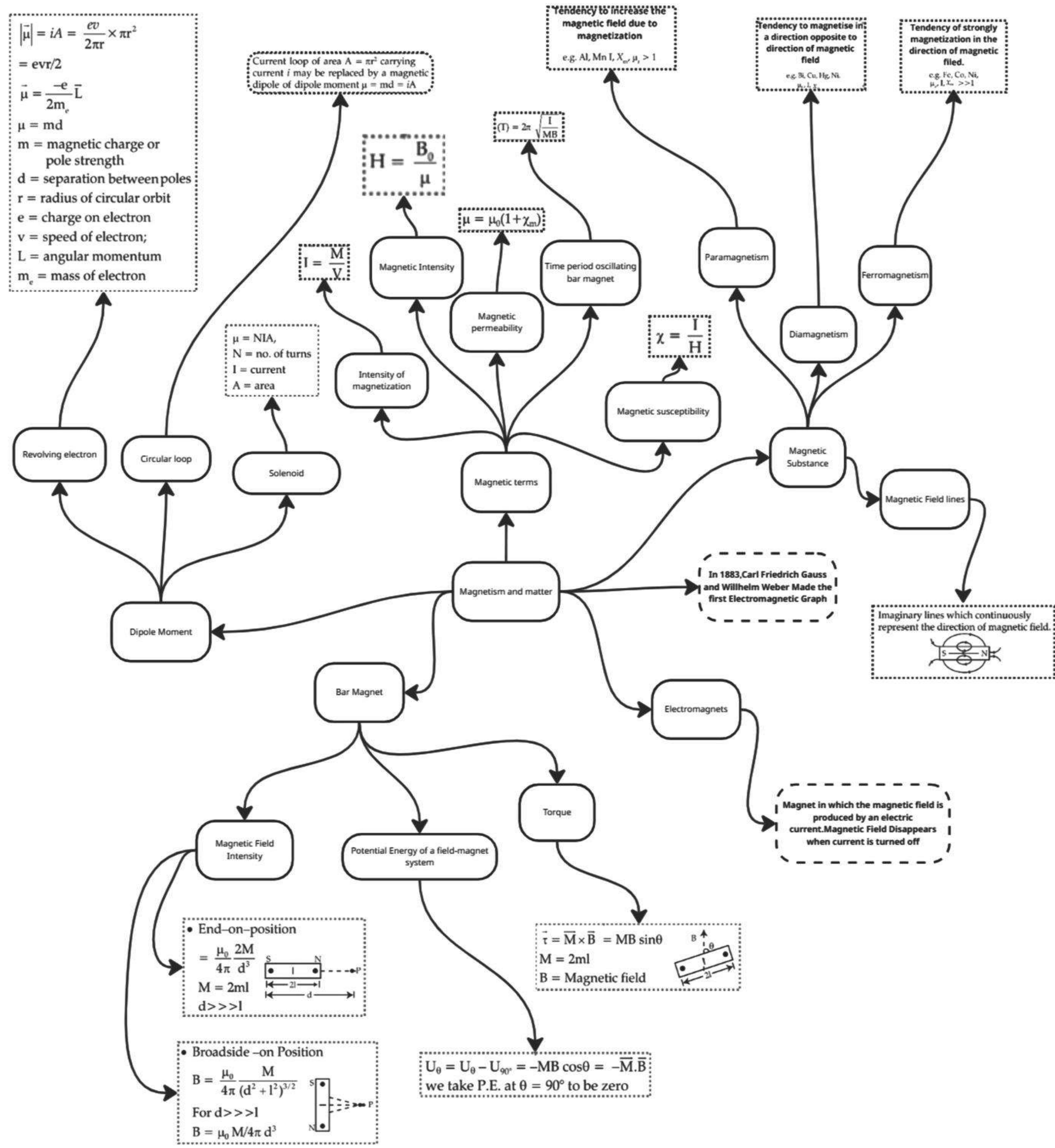
6 A positive charge moves parallel to flow of current in a long straight wire the charge will be

(a) Repelled by the wire (b) Attracted by the wire

(c) Unaffected by the wire (d) Oscillating

CHAPTER 5: MAGNETISM AND MATTER

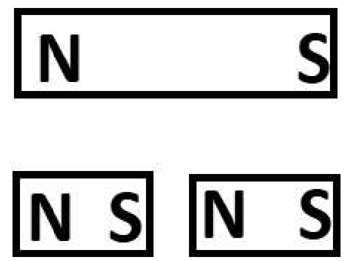
Magnetism- Magnetism is the study of with the properties magnets and magnetic materials along with their behavior and properties. The Earth itself acts like a giant magnet.With the development of atomic sciences we have come to know that magnetic effects are due to moving charges or electrons.It was discovered that some materials in nature has a natural ability to attract iron towards it. These materials are called natural magnets. These were used mainly for navigation in earlier times.



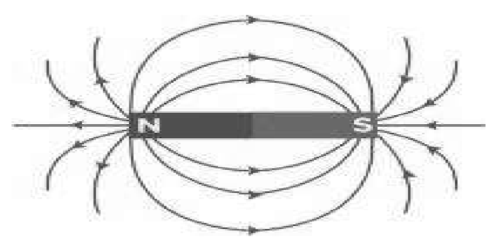
GIST OF THE CHAPTER

Magnetism- Magnetism is the study of the properties of magnets and magnetic materials along with their behavior and properties. The Earth itself acts like a giant magnet. With the development of atomic sciences we have come to know that magnetic effects are due to moving charges or electrons. It was discovered that some materials in nature has a natural ability to attract iron towards it. These materials are called natural magnets. These were used mainly for navigation in earlier times.

Bar magnet- Natural magnets can be mould into various shapes like bars, cylinder, horse-shoe etc.for different purposes. Bar is just one such shape. Such magnets are called bar magnets. So we can say that a bar magnet is a rectangular piece of an object, made of ferromagnetic substances, that shows permanent magnetic properties. It has two poles - North and South. These poles are always in pairs even if we keep splitting the magnet into smaller and smaller parts



Magnetic field- The region of space around a magnet in which it can influence other magnets is called its magnetic field. Magnetic field is represented by closed continuous curves called magnetic field lines.



A tangent at any point on magnetic field line gives the direction of magnetic field at that point. These curves are called magnetic field lines.

Magnetic field lines of a bar magnet appear to emanate from North pole and enter into its south pole but forms complete loop (considering them inside the magnet too).Inside the magnet their direction is from S pole to N- pole while outside its N-pole to S-pole

<u>The properties of magnetic lines of force are as follows</u>:

Magnetic field lines emerge from the north pole and merge at the south pole.

As the distance between the poles increases, the density of magnetic lines decreases.

The direction of field lines inside the magnet is from the South Pole to the NorthPole. Magnetic lines do not intersect with each other. The strength of the magnetic lines is the same throughout and is proportionalto how close are the lines.

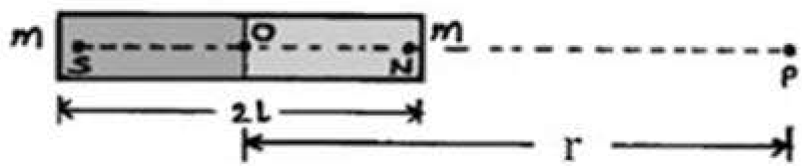
Magnetic dipole- A magnetic system like a bar magnet is essentially a magnetic dipole as its poles are not separable.

Magnetic dipole moment- It is a vector quantity having magnitude m x *l* where m is pole strength of each pole of magnet and *l* is effective length of the magnet. It is directed from South pole towards North pole of magnet

$|\mathbf{M}| = m \times l$, SI unit of **M** and m are Am^{-2} and Am^{-1} respectively

Key Points:

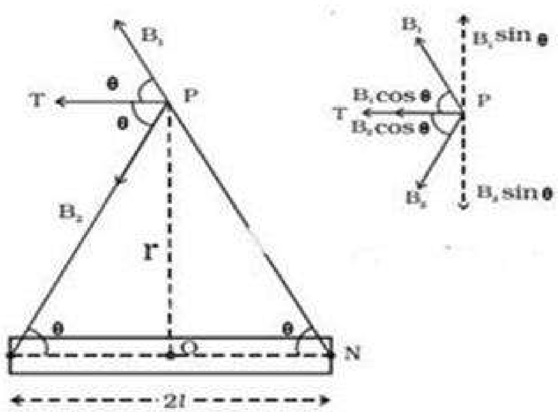
- **B** it is magnetic induction or magnetic flux density
- **H** = magnetizing force or intensity of magnetizing field
- **B** = μH for a material medium for vacuum $B_0 = \mu_0 H$
- **B/B_0** $= \mu/\mu_0 = \mu_r$ is called relative magnetic permeability
- 'I' is called intensity of magnetization it is equal to magnetic moment developed per unit volume in the sample. **I** = **M**/V SI unit of I is A/m
- Magnetic susceptibility (χ_m) – Ratio of intensity of magnetization (I) and intensity of magnetizing field (H) is called magnetic susceptibility. It has no units
- $\mu = \mu_0 (1 + \chi_m)$
- Magnetic field lines emerge from the North pole and enter the South pole. But they completes their loop inside the magnet.
- Magnetic dipole moment (**M**): M = m × 2l (direction is from S pole to N pole)
- Magnetic field on axial line:



B = $(\mu_0 / 4\pi) \times (2\mathbf{M} / r^3)$

B and **M** are parallel

- Magnetic field on equatorial line:
  B = $(\mu_0 / 4\pi) \times (\mathbf{M} / r^3)$
  B and **M** are anti-parallel

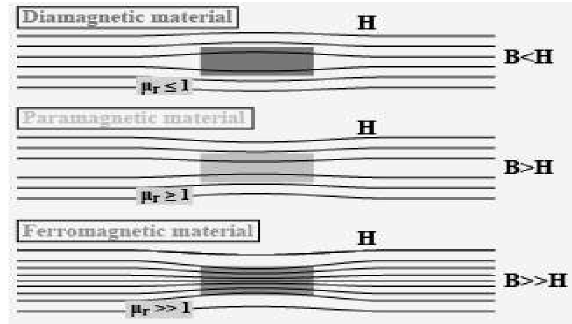


Torque on a Magnetic Dipole: $\boldsymbol{\tau} = \mathbf{M} \times \mathbf{B}$ such that $\tau = MB \sin\theta$

- Potential Energy: $U = -\mathbf{M} \cdot \mathbf{B}$ or $U = -MB\cos\theta$
- Work done to rotate a magnet in magnetic field
  $W = -MB (\cos\theta_2 - \cos\theta_1)$
- Gauss Law of Magnetism essentially states that the magnetic flux through a closed surface/loopis zero. i.e. $\oint \vec{B} . \vec{ds} = 0$ It means magnetic monopoles do not exist in nature
- A bar magnet of magnetic moment **M** is equivalent to a coil of magnetic moment **NIA**
- Magnetic moment of charge moving in a circle is M= qvr/2

Magnetic Properties of Materials

Substances can be divided into three groups based on their magnetic properties i.e. diamagnetic, paramagnetic, and ferromagnetic. They can be classified based on their magnetic susceptibility.



Diamagnetic Materials

The materials that develop temporary magnetization such that the magnetic moment is in the opposite direction to that of the magnetic field in which they are placed are known as

Diamagneticmaterials. In simple words, they are repelled by magnets.

Their magnetic susceptibility is small and negative. They have no unpaired electrons in them so magnetic moment of each atom in them is zero individually. Examples of diamagnetic materials are Bismuth, Copper, Zinc, Lead, etc

Paramagnetic Materials

The materials that develop temporary magnetization such that the magnetic moment is in the same direction as that ofthe magnetic field in which they are placed are known as

Paramagnetic materials. They are slightly attracted by magnets. They have positive but very low susceptibility.They have unpaired electrons in them so each atom has magnetic moment of its own. In an external magnetic field torque acts on tiny atomic magnetic dipoles and align them along applied field. They can be called as poor ferromagnets.

Examples of Paramagnetic materials are Aluminium, Sodium, Calcium, etc

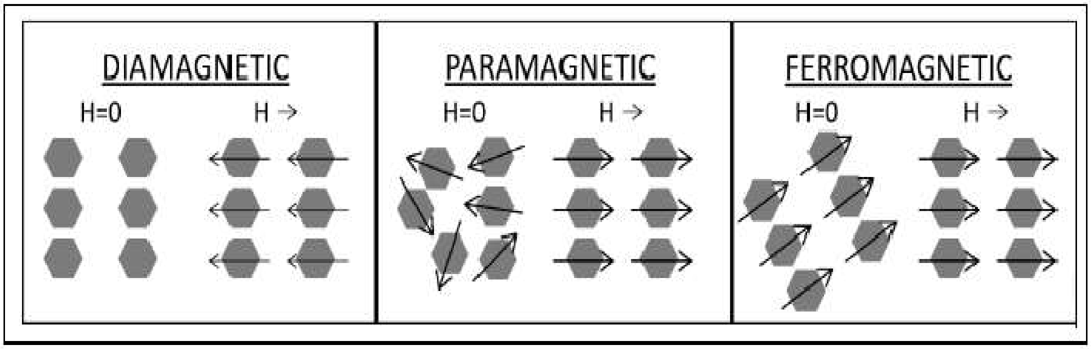
Ferromagnetic Materials

The materials that develop temporary but strong magnetization such that the magnetic moment is in the same direction to that of the magnetic field in which they are placed are known as *ferromagnetic materials*. They are strongly attracted by magnets.

They have positive and high susceptibility. They have unpaired electrons in them. The atoms interact with neighbouring atoms to form 'domains' in them.In a domain all atoms align their magnetic moment in same direction. So a domain has large magnetic moment compared to an atom.in external field these domains get aligned parallel to the field so they get strongly magnetized.

Examples of Ferromagnetic materials are Iron, Nickel, Cobalt, Haematite, etc

	Property	Dia	Para	Ferro
1.	Effect of magnet	They are feebly repelled by magnets.	They are feebly attracted by magnets.	They are strongly attracted by magnets.
2.	Relative magnetic permeability (μ_r).	$0 \leq \mu_r < 1$	$1 < \mu_r$	$\mu_r >> 1$
3.	Susceptibility value (χ)	χ is small and negative $-1 \leq \chi \leq 0$	χ is small and positive. $0 < \chi$	χ is large and positive. $\chi >> 1$



Effect of temperature on magnetic properties

According to Curie's Law, the magnetization in a paramagnetic material is directlyproportional to the applied magnetic field. If the object is heated, the magnetization isviewed to be inversely proportional to the temperature

$$\chi = \frac{I}{H} = \frac{C}{T}$$

I = magnetic moment per unit volume

H= intensity of magnetizing field = B/μ_0

The Curie temperature (T_C) of a ferro-magnetic material is the temperature above which it behaves like a para-magnetic material.

$$\chi = \frac{I}{H} = \frac{C}{(T - T_c}$$

MULTIPLE CHOICE QUESTIONS

1 A ball of a diamagnetic material is heated. The magnetic susceptibility of its material will

(a) increase (b) Decrease (c)Not change
(d) Increases than attains a saturation value

2 A diamagnetic bar is suspended freely between parallel magnetic poles. It will tend to align its length

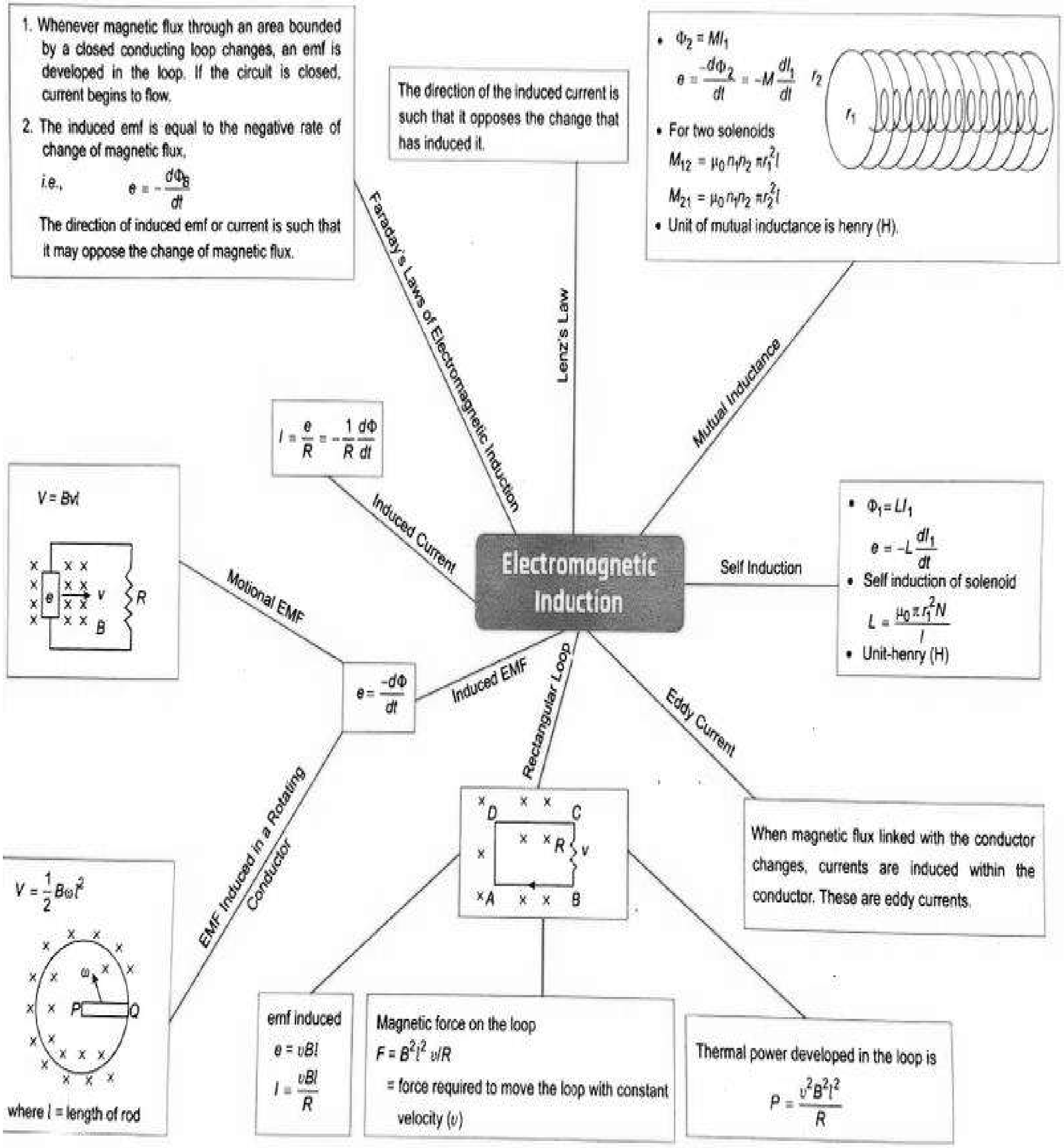
(a) Perpendicular to the poles (c) Parallel to the poles
(b) At 45^0 to the poles (d) In any random direction

3 The magnetic nature of atomic hydrogen is

(a) Diamagnetic (b) Paramagnetic (c) Ferromagnetic (d) Non - magnetic

4 In a bar magnet the distance between its magnetic poles is n times the length of bar magnet where 'n' is nearly

SYLLABUS: Electromagnetic induction; Faraday's laws, induced EMF and current; Lenz's Law, Self and mutual induction.



GIST OF THE CHAPTER

Area Vector($\vec{A}$) :

An area vector is a vector whose magnitude is equal to the area of a plane and direction is normal to the plane of the area.

Magnetic Flux ϕ_B

GIST OF THE CHAPTER

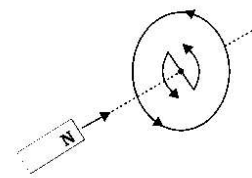
The total number of magnetic lines of force passing normally through an area placed in a magnetic field, is equal to the magnetic flux linked with that area. Net flux through the surface $\phi_B = \boldsymbol{B}.\mathbf{A}$= BAcosθ Magnetic flux is a scalar quantity. S.I. unit: weber (Wb), CGS unit : Maxwell or Gauss × cm^2 (1 Wb = 10^8 Maxwell).

Faraday's laws of EMI

1. **First law** :(**Cause of emf**) The induced emf is due to changing magnetic flux linked with the closed loop/coil.
2. **Second law**: (**magnitude of emf**)

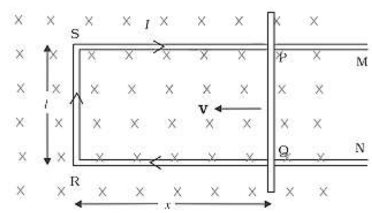
The magnitude of the induced e.m.f. is directly proportional to the rate of change of the magnetic flux. Induced e.m.f., $\varepsilon = -d\phi/dt = -(\phi_2 - \phi_1)/t$ .Negative sign indicates that induced emf (ε) opposes the change of flux

Lenz's Law: - This law gives the direction of induced emf/induced current. According to this law, the direction of induced emf or current in a circuit is such as to oppose the cause that produces it. This law is based upon **law of conservation of energy**



Motional EMF Due to Translatory Motion:-

If the length RQ = x (variable) and RS = l, the magnetic flux Φ enclosed by the loop PQRS will be Φ= B l x Since x is changing with time, the rate of change of flux will induce an emf given by: $\varepsilon = -\frac{d\phi}{dt} = -\frac{d(BL\,X)}{dt}$ = Bl v



The induced emf ε = B l v is called **motional emf**

Motional EMF Due to Rotational Motion:- Emf induces across the ends of the rod where ν = frequency (revolution per sec) And T = Time period.

$$\varepsilon = \frac{B\omega R^2}{2}$$

Inductance is a property of an electrical conductor (like a coil or solenoid) that describes its ability to **oppose changes in electric current** flowing through it by generating a magnetic field.

Self Inductance: Self-inductance (L) of a coil is numerically equal to the magnetic flux (∅) linked with the coil, when a unit current flow through it. $\phi = LI$ $\varepsilon = -L\, dI/dt$, S.I. unit of self-inductance is Henry (H).

Self inductance of a long solenoid : $L = \mu_0 \mu_r N^2 A/l = \mu_0 \mu_r n^2 Al$

Energy stored in an inductor: $U = \frac{1}{2}LI^2$ and energy density is given by $\frac{B^2}{2\mu_0}$

Mutual Inductance: Whenever the current passing through a coil changes, the magnetic flux linked with a neighboring coil will also change. Hence an emf will be induced in the neighboring coil or circuit. This **phenomenon** is called **'mutual induction**'

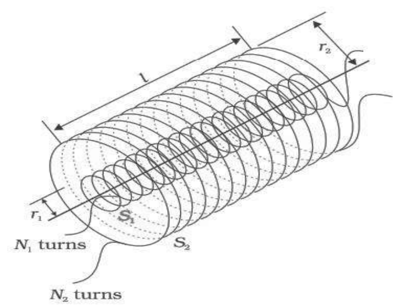
$\phi = MI$ $\varepsilon = -M\, dI/dt$

SI unit is **henry (H).**

Mutual-Inductance between pairs of long Solenoid:-

$M_{12} = (\mu_0 n_1 n_2 L\pi r_1^2)$, $M_{21} = (\mu_0 n_1 n_2 L\pi r_2^2)$

Hence $M_{12} = M_{21}$



AC generator:: It is a device which converts mechanical energy into an electrical energy and generates alternating current.

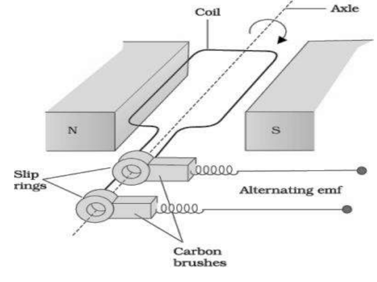
Principle: Works on principle of electro-magnetic induction.

Construction: 1. Armature coil 2. Filed magnet 3. Slip rings 4. Brushes

Theory: When the armature coil rotates between the pole pieces of field magnet, the effective area of the coil is A cos θ, The flux at any time is, $\phi = \boldsymbol{B}.\boldsymbol{A}$ =NBAcosθ=NBA cosωt

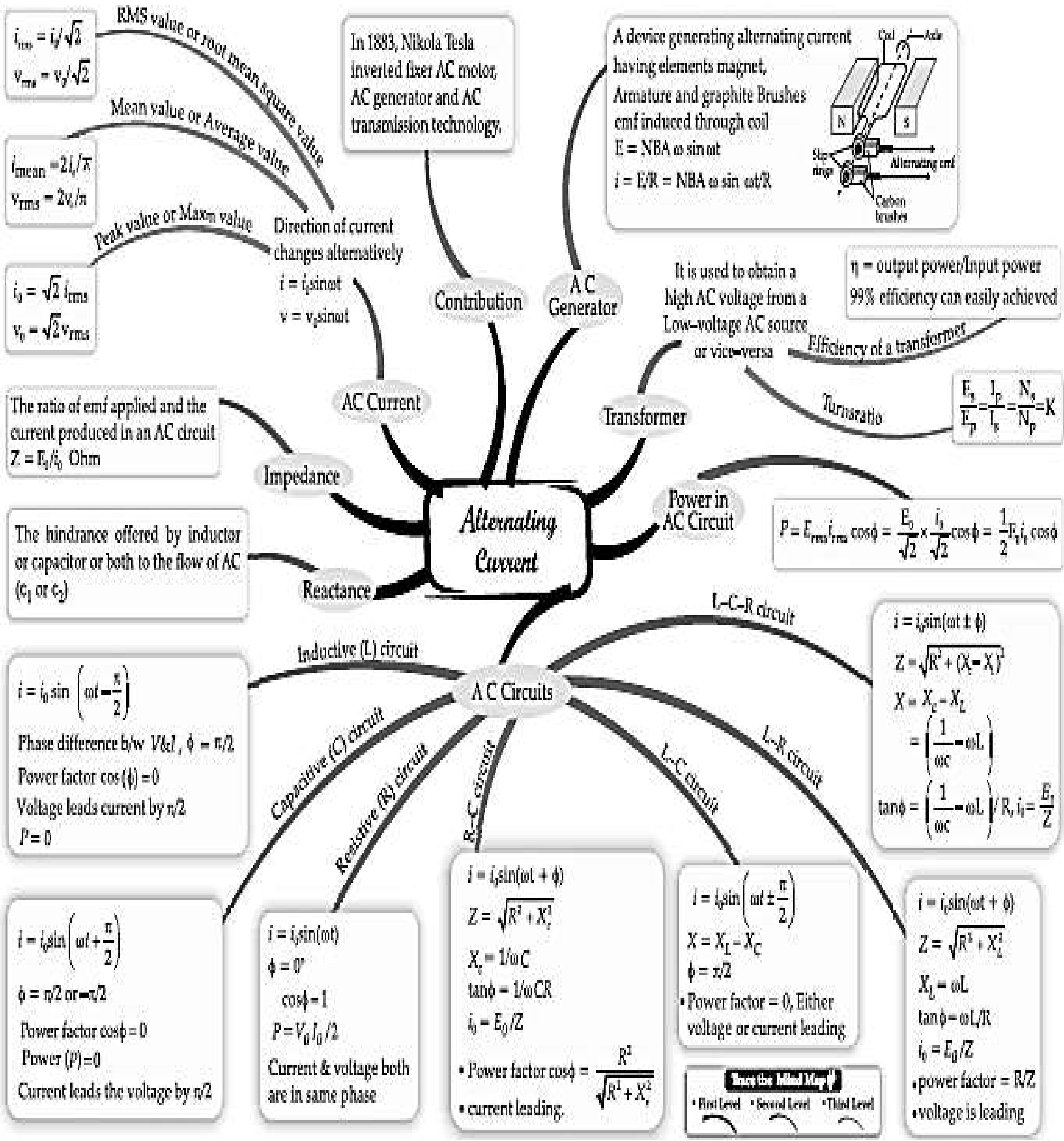
The induced emf is,

$\varepsilon = -d\phi\ dt = -d(NBAcos\omega t)\ dt\ V = \varepsilon = -NBA\omega sin\omega t$



SYLLABUS: Alternating currents, peak and RMS value of alternating current/voltage; reactance and impedance; LCR series circuit (phasors only), resonance, power in AC circuits, power factor, wattless current. AC generator, Transformer.

Mind map



Gist of the chapter

Alternating current and voltage: A signal changing its values periodically is called an alternating signal. & represented as $I = I_0 \sin \omega t$,
alternating voltage (or emf) is $V = V_0 \sin \omega t$

MEAN AND RMS VALUE OF ALTERNATING CURRENTS

The mean or average value of alternating current over complete cycle is zero. For half cycle it's value is given by

(I_{mean})half cycle $= \frac{2I_0}{\pi}$ = 0.636 Io $\qquad$ V_{avg} for half cycle $= \frac{2V_0}{\pi}$ = 0.636 Vo

An ammeter or a voltmeter read its Root Mean Square value as

$I_{rms} = \frac{I_0}{\sqrt{2}}$ = 0.707 I_o $\qquad$ $V_{rms} = \frac{V_o}{\sqrt{2}}$ = 0.707 V_o

V= Vo sin ωt then current is I = Io sin (ωt + Φ) where Φ is the phase difference between voltage and current.

The average power loss over a complete cycle is given by,

$P = E_{rms} I_{rms} \cos \Phi$ where cos Φ is called the power factor

Purely resistive circuit.

(1) Current : $i = i_0 \sin \omega t$

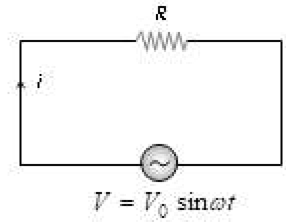
(2) Peak current : $i_0 = \frac{V_0}{R}$

(3) Phase difference between voltage and current : $\phi = 0^o$

(4) Power factor : $\cos \varphi = 1$

(5) Power : $P = V_{rms} i_{rms} = \frac{V_0 i_0}{2}$

(6) Phasor diagram : Both are in same phase



Purely Inductive Circuit (*L*-Circuit)

(1) Current : $i = i_0 \sin\left(\omega t - \frac{\pi}{2}\right)$

(2) Peak current :

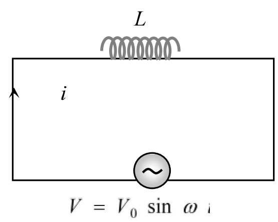
$$i_0 = \frac{V_0}{X_L} = \frac{V_0}{\omega_L} = \frac{V_0}{2\pi\nu L}$$

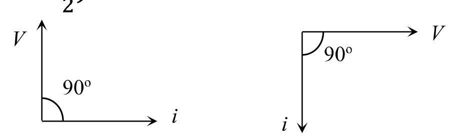
(3) Phase difference between voltage and current $\varphi = 90^o$ (or $+\frac{\pi}{2}$)

(4) Power factor : $\cos \varphi = 0$

(5) Power dissipated : $P = 0$

(6) Phasor diagram : Voltage leads the current by $\frac{\pi}{2}$





Purely capacitive circuit

(1) Current : $i = i_0 \sin\left(\omega t + \frac{\pi}{2}\right)$

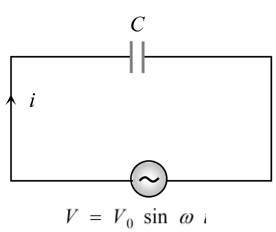
(2) Peak current $i_0 = \frac{V_0}{X_C} = V_0 \omega C = V_0(2\pi\nu C)$

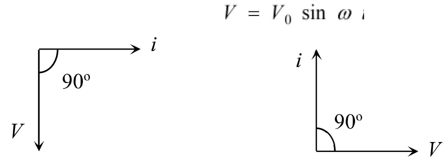
(3) Phase difference between voltage and current :

$\varphi = 90^o$ Power factor : $\cos \varphi = 0$

(4) Average Power : $P_{avg} = 0$

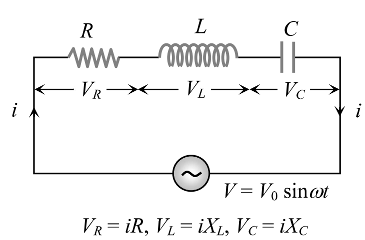
(5) Phasor diagram : Current leads the voltage by $\pi/2$

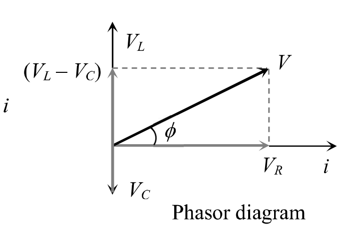




Series LCR circuit

Voltage $V = V_o \sin\omega t$,





Phasor diagram

(1) $I = I_o \sin(\omega t + \Phi)$, where $I_0 = V_o/Z$, and impedance $Z = \sqrt{R^2 + (X_L - X_C)^2}$

(2) $\tan\Phi = (X_L - X_C)/R$

(3) The average power loss over a complete cycle is given by $P = V_{rms} I_{rms} \cos\Phi$
where, the term $\cos\Phi$ is called the power factor

(4) $\cos\Phi = R/\sqrt{R^2 + (X_L - X_C)^2}$)

(5) If net reactance is inductive: Circuit behaves as LR circuit

(6) If net reactance is capacitive: Circuit behave as CR circuit

(7) If net reactance is zero: Means $X_L - X_C = 0$ $X_L = X_C$. This is the condition of electric resonance

(8) **At resonance** (series resonant circuit)

(i) $X_L = X_C \Rightarrow Z_{min} = R$ i.e. circuit behaves as resistive circuit

(ii) $V_L = V_C \Rightarrow V = V_R$ i.e. whole applied voltage appeared across the resistance

(iii) Phase difference : $\phi = 0^o \Rightarrow$power factor = $\cos\phi = 1$

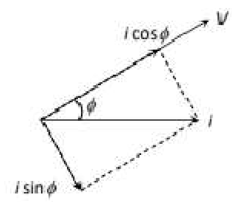
(iv) Power consumption $P = V_{rms} I_{rms}$

(v) These circuits are used for current amplification and as tuning circuits in wireless telegraphy.

(9) **Resonant frequency** (Natural frequency) : At resonance $X_L = X_C \Rightarrow$ $w_0 L = \frac{1}{C\omega_0}$

$\Rightarrow$ $w_0 L = \sqrt{\frac{1}{LC}}$ OR, $w_0 L = \frac{1}{2\pi}\sqrt{\frac{1}{LC}}$ (Resonant frequency doesn't depend upon the resistance of the circuit)

(10) **Watt less Current**

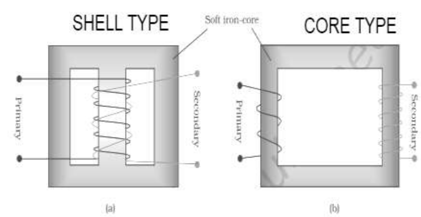


The component of current which does not contribute to the average power dissipation is called watt less current.

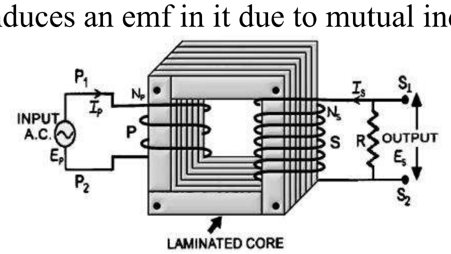
(i) The average of component of watt less component over one cycle is zero

(ii) Amplitude of watt less current = I_0 sin and r.m.s. value of watt less current= $I_{rms} \sin\theta = I_0 \sin\theta/\sqrt{2}$

Transformer:-



It is a device which Increase or decreases the voltage or current in ac circuits through mutual induction.
It does not work in DC circuit.
Principle: It is based on the principle of mutual induction.
Working: When an alternating voltage is applied to the primary coil , magnetic flux linked with it changes which links to the secondary coil and induces an emf in it due to mutual induction.



$$\frac{E_s}{E_P} = \frac{I_P}{I_s} = \frac{N_s}{N_P}$$

$$\eta = \frac{E_s I_s}{E_P I_P} \times 100\ \%$$

Types of transformer: Step-up Transformer: Ns> Np. It increases voltage and decreases current. Transformation Ratio must be greater than 1.

Step-Down Transformer: – Ns< Np; It increases current and decreases voltage. Transformation Ratio must be less than 1.

From Faraday's laws the emf induced in the primary coil

$\varepsilon_p = - N_P \frac{\Delta\phi}{\Delta t}$ ----(i) also for secondary coil $\varepsilon_s = - N_s \frac{\Delta\phi}{\Delta t}$ ---------(ii)

$\frac{\varepsilon_S}{\varepsilon_p} = \frac{N_S}{N_P}$ = k (transformation ratio) -----------(iii)

For ideal transformer input power = output power $\Rightarrow$ $\varepsilon_P I_P = \varepsilon_s I_s$ ------(iv)

By equation (iii) and (iv)

$$\frac{\varepsilon_S}{\varepsilon_p} = \frac{N_S}{N_P} = \frac{I_P}{I_S}$$

Energy losses in a transformer:

(i) Copper loss (ii) Hysteresis loss (iii) Flux leakage (iv) Humming losses (v) Eddy current loss

MULTIPLE CHOICE QUESTIONS

Q1 A resistance 'R' draws power 'P' when connected to an AC source. If an inductance is now placed in series with the resistance, such that the impedance of the circuit becomes 'Z', the power drawn will be :

(a) $P\sqrt{\frac{R}{Z}}$ (b) $P(\frac{R}{Z})$ (c) P (d) $P(\frac{R}{Z})^2$

Q2 To reduce the resonant frequency in an L-C-R series circuit with a generator

(a) the generator frequency should be reduced
(b) another capacitor should be added in parallel to the first
(c) the iron core of the inductor should be removed
(d) dielectric in the capacitor should be removed

Q3 Average value of A.C voltage for positive half cycle is [If V_0 is its peak voltage]

(a) zero (b) $V_0/\sqrt{2}$ (c) $2V_0/\pi$ (d) V_0

Q4 An alternating current in a circuit is given by $I = 20\sin(100\pi t + 10.05\pi)$A . The r.m.s value of current & its frequency respectively are

(A) 10A & 100 Hz (B) 10 A & 50 Hz (C) $10\sqrt{2}$A & 50Hz (D) $20\sqrt{2}$A & 100Hz

Q5 In an ideal transformer, the no. of turns of primary and secondary coil are 500 and 400 respectively. If 220 V is supplied to the primary coil, then ratio of currents in primary and secondary coils is

(A) 4 : 5 (B) 5 : 4 (C) 5 : 9 (D) 9 : 5

Q6 The power factor of LCR circuit at resonance is

(A) 0.707 (B) 1 (C) Zero (D) 0.5

Q7 At resonance frequency in an A.C circuit containing L, C and R in series

(A) The voltage and current will be in same phase.
(B) The voltage will lead the current
(C) The voltage will lag behind the current.
(D) Phase difference depends on peak voltage of source

Q8 A voltage $v = v_o \sin wt$ applied to a circuit drives a current $i = i_o \sin(wt + \varphi)$ in the circuit. The average power consumed in the circuit over a cycle is

a) Zero b) $i_o v_o \cos\varphi$ c) $i_o v_o /2$ d) $(i_o v_o \cos\varphi)/2$

Q9 In the case of an inductor

(a) voltage lags the current by $\pi/2$ (b) voltage leads the current by $\pi/2$
(c) voltage lags the current by $\pi/3$ (d) voltage lags the current by $\pi/4$

Q10 A power transformer is used to step up an alternating e.m.f. of 220 V to 11 kV to transmit 4.4 kW of power. If the primary coil has 1000 turns, what is the current rating of the secondary? Assume 100% efficiency for the transformer

(a) 4 A (b) 0.4 A (c) 0.04 A (d) 0.2 A

Q11 An inductor, a capacitor and a resistor are connected in series across an ac source of voltage. If the frequency of the source is decreased gradually, the reactance of :

(a) both the inductor and the capacitor decreases.
(b) inductor decreases and the capacitor increases.
(c) both the inductor and the capacitor increases.
(d) inductor increases and the capacitor decreases.

CHAPTER-8: ELECTROMAGNETIC WAVES

SYLLABUS: Basic idea of displacement current, Electromagnetic waves, their characteristics, their transverse nature (qualitative idea only). Electromagnetic spectrum (radio waves, microwaves, infrared, visible, ultraviolet, X-rays, gamma rays) including elementary facts about their uses.

MIND MAP

DISPLACEMENT CURRENT

Produced by changing electric field

$$\varepsilon_0\left(\frac{d\Phi}{dt}\right)=i$$

Modified Ampere's law:
The source of magnetic field is: conduction current due to flowing charge.
Time rate of change of electric field

$$i=i_c+i_d=i_c+\varepsilon_0\left(\frac{d\Phi_E}{dt}\right)$$

ELECTROMAGNETIC WAVES

Maxwell's equations

$$\oint \vec{E}.d\vec{A}=\frac{Q}{\varepsilon_0}$$

$$\oint \vec{B}.d\vec{A}=0$$

$$\oint \vec{E}.d\vec{l}=-\frac{d\Phi_B}{dt}$$

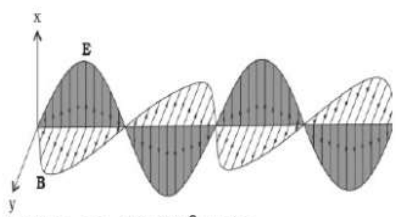
$$\oint \vec{B}.d\vec{l}=\mu_0 i_c+\mu_0\varepsilon_0\frac{d\Phi_E}{dt}$$

How are EM waves produced?

Produced by accelerating or oscillating charges only.

Properties of EM waves

1. Does not require a medium for their propagation
2. Does not get deflected by electric or magnetic field
3. E and B has zero phase difference but are mutually perpendicular to each other.
4. Momentum delivered when wave is completely absorbed by the surface : p=U/c ,where U is the total energy transferred to the surface
5. momentum transferred is p=2U/c when wave is completely reflected by the surface.



$E_o/B_o=c = 3\times10^8$ m/s .

Travels with speed(c) = $\frac{1}{\sqrt{\mu_0\varepsilon_0}}$ in free space.

Both E and B are also perpendicular to the direction of wave propagation

EM spectrum and its order

The classification of EM waves according to frequency is the electromagnetic spectrum.
EM spectrum in order of increasing frequency and decreasing wavelength.

1. Radio Waves
2. Micro Waves
3. Infrared
4. Visible
5. Ultraviolet
6. X-rays
7. Gamma Rays

GIST OF THE CHAPTER

Displacement Current: -If there exists an electric current as well as changing electric field, results magnetic field & cause displacement current

$$\varepsilon_0\left(\frac{d\varphi_E}{dt}\right)=i$$

So, Ampere-Circuital Law was modified called as Ampere-Maxwell Law.

$$\oint B.dl=\mu_0 i_C+\mu_0\varepsilon_0\left(\frac{d\varphi_E}{dt}\right)$$

Electromagnetic Waves: - The electromagnetic waves are those waves in which there are sinusoidal variations of electric and magnetic field vectors to right angles to each other as well as at right angles to the direction of wave propagation. (i.e., electric current and magnetic fields vary with space and time.)

Transverse nature of electromagnetic waves: - Electric and magnetic fields oscillate sinusoidally in space and time in an electromagnetic wave. The oscillating electric and magnetic fields, E and B are perpendicular to each other, and to the direction of propagation of the electromagnetic wave.

- Conduction current & displacement current are the same.
- Conduction current arises due to flow of electrons in the conductor.
- Displacement current arises due to electric flux changing with time.

$$I_D=\varepsilon_O\, d\phi_E/dt$$

- **Maxwell's equations**

Gauss's Law in Electrostatics $\oint E.dS = Q/\varepsilon_O$

Gauss's Law in Magnetism $\oint \vec{B}.dS=0$

• Ampere's – Maxwell law $\int \vec{B}.dl = \mu_O I + \mu_O\varepsilon_O\, d\phi_E/dt$

- Electromagnetic Wave :- The wave in which there are sinusoidal variation of electric and magnetic fields at right angles to each other as well as right angles to the direction of wave propagation. • Velocity of EM waves in free space: $c = 1/\sqrt{\mu_o\varepsilon_o} = 3\text{x}10^8$ m/s
- The Scientists associated with the study of EM waves are Hertz, Jagdish Chandra Bose & Marconi.
- EM wave is a transverse wave because of which it undergoes polarization effect.
- Electric vectors are only responsible for optical effects of EM waves.
- The amplitude of electric & magnetic fields are related by $E/B = c$
- Oscillating or accelerating charged particle produces EM waves.
- Orderly arrangement of electromagnetic radiation according to its frequency or wavelength is electromagnetic spectrum.
- A self made easy Acronym to memorize the electromagnetic spectrum in decreasing order of its frequency.

Gandhiji's X-rays Used Vigorously In Medical Research

Here the first of each word indicates: G- gamma rays , X- rays , Ultraviolet rays ,Visible rays , I- Infrared radiations , M- Microwaves and R- Radio waves

- EM waves also carry energy, momentum.

The Electromagnetic Spectrum					
Type	**Frequency Range (Hz)**	**Wavelength Range**	**Production**	**Detection**	**Uses**
Radio waves	5×10^5 Hz to 10^8 Hz	>0.1m	Rapid acceleration and de-accelerations of electrons in aerials/antenna.	Receiver's aerials	In radio and television communication system. In radio astronomy.
Micro waves	10^9 Hz to 10^{12} Hz	0.1m to 1mm	Klystron value or magnetron value.	Point contact diodes.	In radar Systems. In long distance communication systems. In microwave ovens.
Infrared	10^{11} Hz to 5×10^{14} Hz	1mm to 700nm	Vibration of atoms and molecules.	Thermopiles Bolometer, Infrared photographic film.	In remote control of TV or VCR. In Green House. In haze Photography. Treatment of muscular complaints.
Visible Light	4×10^{14} Hz to 7×10^{14} Hz	7000nm to 400nm	Electron in atoms emit light when they move from one energy level to a lower energy level.	Human eye photocells, photographic film.	It Provides us the information of the world around us. It can cause Chemical Reactions.
Ultra-violet	10^{16} Hz to 10^{17}	400nm to 1nm	Inner shell electrons in atoms moving from one energy level to a lower level.	Photocells, photographic film.	In food Preservation. In the study of invisible writings, forged documents and finger prints. In the study of molecular structure.
X-rays	10^{16} Hz to 10^{19}	1nm to 10^{-3} nm	X-ray tubes or inner shell electrons.	Photographic film, Geiger tubes, Ionization chamber.	In medical diagnosis. In the study of crystals structure. In engineering. In detective departments. In radio therapies.
Gamma rays	10^{18} Hz to 10^{22} Hz	$<10^{-3}$ nm	Radioactive decay of the nucleus.	Photographic film, Geiger tubes, Ionization Chamber	In radio Therapy. In manufacture of polyethylene from ethylene. To initiate some nuclear reactions. To preserve food stuff.

CHAPTER-9: RAY OPTICS

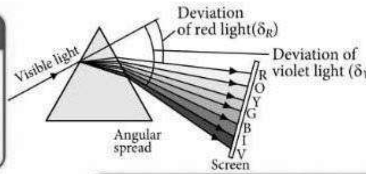
Syllabus-Reflection of light, spherical mirrors, mirror formula, refraction of light, total internal reflection and optical fibers, refraction at spherical surfaces, lenses, thin lens formula, lens maker's formula, magnification, power of a lens, combination of thin lenses in contact, refraction of light through a prism. **Optical Instruments**: Microscopes and astronomical telescopes (reflecting and refracting) and their magnifying powers.

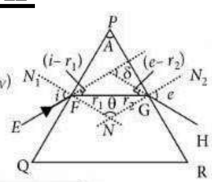
MIND MAP

RAY OPTICS

APPLICATIONS OF TIR

- Fiber optics communication
- Medical endoscopy
- Periscope (Using prism)
- Sparkling of diamond





POWER OF LENSES

Power of lens: $P = \frac{1}{f\text{ (in m)}}$

Combination of lenses:

Power: $P = P_1 + P_2 - dP_1P_2$

(d = small separation between the lenses)

For $d = 0$ (lenses in contact)

Power: $P = P_1 + P_2 + P_3 + \ldots$

TOTAL INTERNAL REFLECTION

TIR conditions

- Light must travel from denser to rarer.
- Incident angle $i >$ critical angle i_c

Relation between μ and i_c: $\mu = \frac{1}{\sin i_c}$

REFRACTION THROUGH PRISM

Relation between μ and δ_m

$$\mu = \frac{\sin\frac{A+\delta_m}{2}}{\sin\frac{A}{2}}$$

where, δ_m = angle of minimum deviation, A = angle of prism

or $\delta = (\mu - 1)A$ (Prism of small angle)

Angular dispersion

$= \delta_V - \delta_R = (\mu_V - \mu_R)A$

Dispersive power,

$$\omega = \frac{\delta_V - \delta_R}{\delta} = \frac{\mu_V - \mu_R}{\mu - 1}$$

Mean deviation, $\delta = \frac{\delta_V + \delta_R}{2}$

THIN SPHERICAL LENS

Thin lens formula: $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

Magnification: $m = \frac{v}{u} = \frac{h_i}{h_o}$

REFRACTION OF LIGHT

Snell's law: When light travels from medium a to medium b, ${}^a\mu_b = \frac{\mu_b}{\mu_a} = \frac{\sin i}{\sin r}$

Refractive index,

$$\mu = \frac{\text{velocity of light in vacuum}}{\text{velocity of light in medium}} = \frac{c}{v}$$

Real and apparent depth

$$\mu = \frac{\text{real depth}(x)}{\text{apparent depth }(y)}$$

REFRACTION BY SPHERICAL SURFACE

Relation between object distance (u), image distance (v) and refractive index (μ)

$$\frac{\mu_{denser}}{v} - \frac{\mu_{rarer}}{u} = \frac{\mu_{denser} - \mu_{rarer}}{R}$$

(Holds for any curved spherical surface.)

Lens maker's formula

$$\frac{1}{f} = (\mu - 1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$$

REFLECTION OF LIGHT

According to the laws of reflection, $\angle i = \angle r$

If a plane mirror is rotated by an angle θ, the reflected rays rotates by an angle 2θ.

REFLECTION BY SPHERICAL MIRRORS

Mirror formula, $\frac{1}{u} + \frac{1}{v} = \frac{1}{f} = \frac{2}{R}$

Magnification, $m = -\frac{v}{u} = \frac{h_i}{h_o}$

OPTICAL INSTRUMENTS

SIMPLE MICROSCOPE

Magnifying power

For final image is formed at D (least distance) $M = 1 + \frac{D}{f}$

For final image formed at infinity

$$M = \frac{D}{f}$$

COMPOUND MICROSCOPE

Magnifying power, $M = m_o \times m_e$

For final image formed at D (least distance) $M = \frac{L}{f_o}\left(1 + \frac{D}{f_e}\right)$

For final image formed at infinity

$$M = \frac{L}{f_o} \cdot \frac{D}{f_e}$$

REFLECTING TELESCOPE

Magnifying power

$$M = \frac{f_o}{f_e} = \frac{R/2}{f_e}$$

TELESCOPE

Astronomical telescope

For final image formed at D (least distance) $M = \frac{f_o}{f_e}\left(1 + \frac{f_e}{D}\right)$

In normal adjustment, image formed at infinity $M = f_o / f_e$

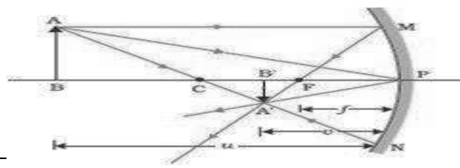
TERRESTRIAL TELESCOPE

For normal adjustment $M = \frac{f_o}{f_e}$

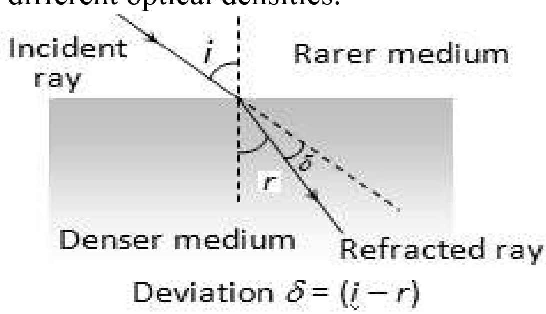
Distance between objective and eyepiece $d = f_o + 4f + f_e$

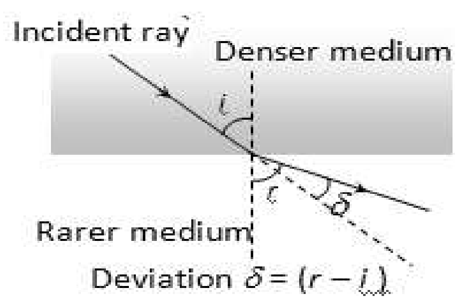
GIST OF THE CHAPTER

Reflection of light: - The bouncing of light back into the same medium from a surface is called reflection of light.
Laws of reflection: - i) Angle of incidence is equal to the angle of incidence.
ii) The incidence ray, the reflected ray and normal to the surface at the point of incidence all lie in the same plane.
Types of spherical mirrors: Concave and Convex. The relation between object distance, image distance and the focal length of a mirror is called mirror formula. The ratio of size of image to the size of object is called the magnification produced by the mirror.

Derivation of mirror formula: ΔABC and $\Delta A'B'C$ are similar A'B'/AB = B'C/CB= PC-PB')/ (PB-PC) …..(1) ΔABP and $\Delta A'B'P$ are also similar 	A'B'/AB =PB'/PB …..(2) Compare eqn (1) and (2) … PB'/PB = (PC-PB')/ (PB-PC) -v/-u = (2f + v)/ (-u+2f) or $2uv$=$2v$f+$2u$f Dividing by$2uv$f on both sides we get, $\frac{1}{f}= \frac{-1}{u}\ \frac{-}{v}$

Refraction of light: - Bending of light from its actual path, when it passes obliquely from one medium to another having different optical densities.



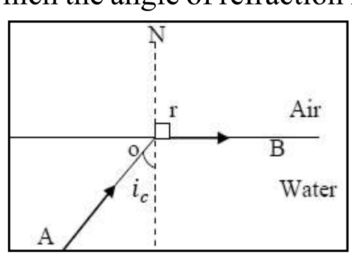


Snell's Law: -The ratio of the sine of the incident angle to the sine of the refracted angle is a constant. $\frac{\sin i}{\sin r} = \frac{n_2}{n_1} = n_{21}$ $n_1 \sin i = n_2 \sin r$ OR$v_2 \sin i = v_1 \sin r$ Examples :- 1.Sun can be seen before actual sunrise	2. An object under water (any medium) appears to be raised due to refraction when observed inclined n = (Real depth / Apparent depth) and Shift in the position (apparent) of object is $x = t\left(1 - \frac{1}{n}\right)$ Where t is the actual depth of the medium

Critical angle (ic): - The angle of incidence in denser medium for which the angle of refraction in rarer medium is 90° is called the critical angle.

$$sini_c = n_{aw} = \frac{1}{n_{wa}}$$

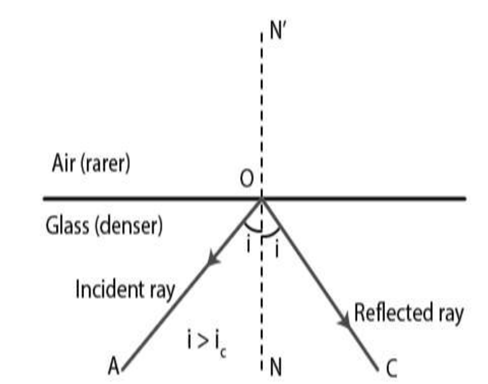
Note:- If rarer medium is not air then $sini_c = \frac{n_r}{n_d}$



<u>Total internal reflection</u>: - When angle of incidence of the ray incident on rarer medium from denser medium, is greater than the critical angle, the incident ray does not refract into rarer medium but is reflected back into denser medium. This phenomenon is called total internal reflection

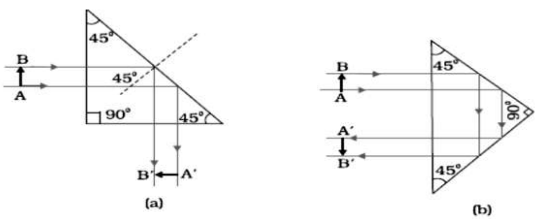
Mathematically: $$n_{21} = \frac{1}{\sin C}$$

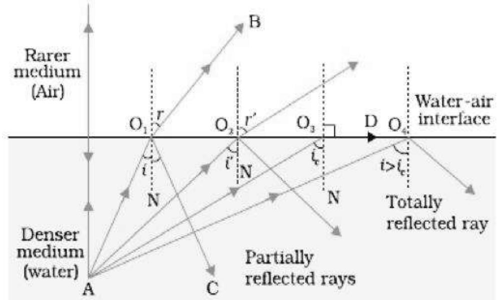
Here, n_{21} is the refractive index of the denser medium 2 w.r.t. the rarer medium 1 and C is the critical angle.



Applications of Total internal reflection:

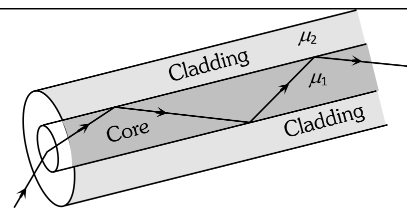
Totally reflecting prisms:- Bend the light at either 90^0 fig (a) or 180^0 fig (b)





Fiber-optic: -Fine fiber of glass or quartz in which light enter from one end and comes out from another end due to total internal reflection is called optical fiber.

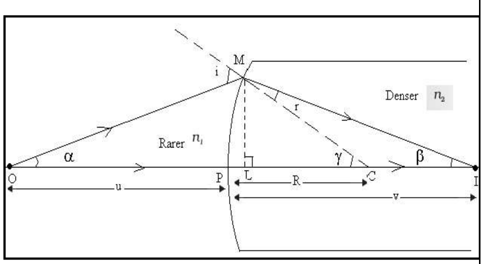
Used in endoscopy and communication



Here $n_{core} > n_{cladding}$

<u>Refraction through Spherical surface</u>:

From fig, in ΔMOC, $i = \alpha + \gamma$ -----(1) and in Δ MCI,



$\gamma = r + \beta \Rightarrow r = \gamma - \beta$------(2)

From laws of refraction, $\frac{\sin i}{\sin r} = \frac{n_2}{n_1}$ --------(3)

For small angles, $\frac{i}{r} = \frac{n_2}{n_1} \Rightarrow n_1 i = n_2 r$------(4)

Using (1) and (2) in (4),

$n_1(\alpha + \gamma) = n_2(\gamma - \beta)$ -----------(5)

$$n_1\left(\frac{ML}{PO} + \frac{ML}{PC}\right) = n_2\left(\frac{ML}{PC} - \frac{ML}{PI}\right)$$

$\Rightarrow \frac{n_2}{PI} + \frac{n_1}{PO} = \frac{(n_2 - n_1)}{PC}$ -----------(6)

Using sign convention, $\frac{n_2}{v} - \frac{n_1}{u} = \frac{(n_2 - n_1)}{R}$

Spherical refracting surface. The portion of a refracting medium, whose curved surface forms the part of a sphere, is called a spherical refracting surface.

When object is situated in the rarer medium, the relation between n_1 (refractive index of the rarer medium), n_2 (refractive index of the spherical refracting surface) and R (the radius of curvature) with the object and image distances (u and v) is given by

$$\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}$$

When object is situated in the denser medium, the relation between n_1 (refractive index of the rarer medium), n_2 (refractive index of the spherical refracting surface) and R (the radius of curvature) with the object and image distances (u and v) can be obtained by interchanging n_1 and n_2. In that case, the relation becomes

$$\frac{n_1}{v} - \frac{n_2}{u} = \frac{n_1 - n_2}{R}$$

Lens maker's formula. The relation connecting the focal length of the lens with the radii of curvature of its two surfaces and the refractive index of the material of the lens is called lens maker's formula. Mathematically:

$$\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

Lens equation. The relation between the focal length, the object and image distances is called lens equation. Mathematically:

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$$

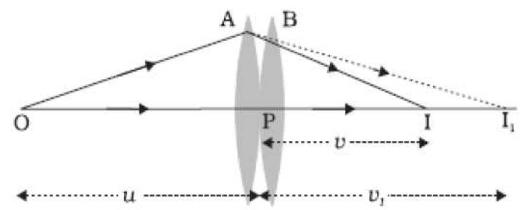
Linear Magnification. The ratio of the size of the image (formed by the lens) to the size of the object is called linear magnification produced by the lens.

Mathematically, $$m = \frac{I}{O} = \frac{v}{u} = \frac{f}{f+u} = \frac{f-v}{f}$$

Power of a lens. It is defined as the reciprocal of the focal length of the lens in metre.

Mathematically, $$P = \frac{1}{f}$$ or $$P = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

In the above two formulae, f, R_1 and R_2 are measured in metre.

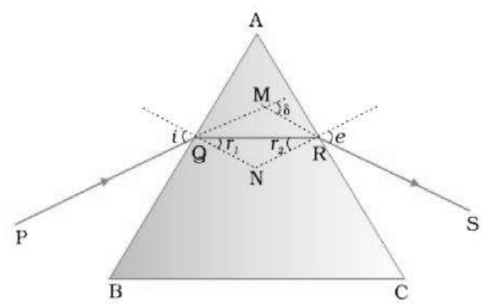


Two thin lenses placed in contact. When two lenses of focal lengths f_1 and f_2 are placed in contact, the focal length of the combination is given by

$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$$

Power of equivalent lens: $P = P_1 + P_2$

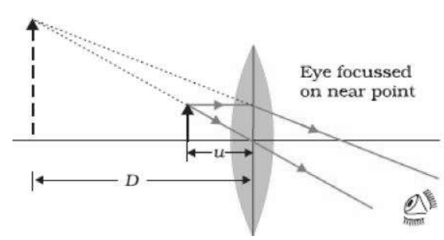
Magnification produced by equivalent lens: $m = m_1 \times m_2$



Refraction through a prism A ray of light incident on one face of the prism suffers refraction successively at the two surfaces and then emerges out of it. Mathematically,

$A = r_1 + r_2$, $A + \delta = i + e$

Prism formula: $\mu = \dfrac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin\left(\frac{A}{2}\right)}$

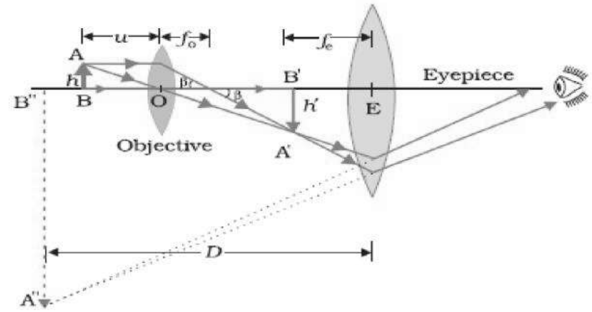


Simple microscope. A convex lens of small focal length is called a simple microscope or a magnifying glass.

The magnifying power of a microscope is defined as the ratio of the angle subtended by the image at the eye to the angle subtended by the object seen directly, when both lie at the least distance of distinct vision.

Mathematically: $$M = \left(1 + \frac{D}{f}\right)$$

Here, D is the least distance of distinct vision



Compound microscope. A compound microscope is a two-lens system (object lens and eye lens of focal lengths f_o and f_e). Its magnifying power is very large, as compared to the simple microscope.

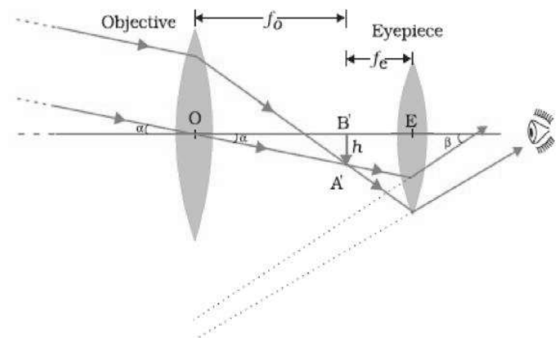
Mathematically:

$$M = \frac{v_o}{u_o}\left(1 + \frac{D}{f_e}\right) = -\frac{L}{f_o}\left(1 + \frac{D}{f_e}\right)$$

Here, u_o is distance of the object from the object lens and $v_o \approx L$, (L is the length of the tube of the microscope) is the distance at which the object lens forms the image of the object.

Astronomical telescope. It is a two-lens system and is used to observe distant heavenly objects. It is called refracting type astronomical telescope.

Normal adjustment- When the final image is formed at infinity, the telescope is said to be in normal adjustment.



The magnifying power of a telescope in normal adjustment is defined as the ratio of the angle subtended by the image at the eye as seen through the telescope to the angle subtended by the object seen directly, when both the object and the image lie at infinity.

Magnifying power in normal adjustment,

$$M = -\frac{f_o}{f_e}$$

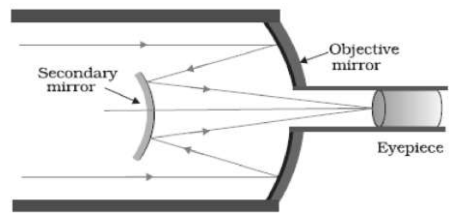
When the final image is formed at the least distance of distinct vision,

Magnifying power of the telescope,

$$M = -\frac{f_o}{f_e}\left(1 + \frac{f_e}{D}\right)$$

Reflecting type telescope. In a reflecting type telescope, the objective is a concave spherical mirror of large aperture in place of a convex lens.

The expression for magnifying power of a reflecting type telescope is same as that for refracting type astronomical telescope.



MULTIPLE CHOICE QUESTIONS

1. A beam of light is incident at 60° to a plane surface. The reflected and refracted rays are perpendicular to each other. What is the refractive index of the surface?

(a) 1√3 (b) √3 (c) 1/3 (d) 3

2. A concave mirror of focal length f produces a real and virtual image of an object of magnification m (m> 1) when placed at two different positions. The distance between the positions of the object is :

(a) $(m-1)f$ (b) $(1-m)f$ (c) $\frac{2f}{m}$ (d) zero

3. The refractive index of the material of a prism is √2 and its refracting angle is 30°. One of the refracting surfaces of the prism is made a mirror. A beam of monochromatic light entering the prism from the other face retraces its path, after reflection from mirror surface. The angle of incidence on prism is:

(a) 0° (b) 30° (c) 45° (d) 60°

4. An astronomical refractive telescope has an objective of focal length 20 m and an eyepiece of focal length 2 cm. Then in normal adjustment:

(a) the magnification is 1000
(b) the length of the telescope tube is 20.02 m
(c) the image formed is of inverted nature.
(d) all of these

5. A particle moves towards a concave mirror of focal length 30 cm along its axis and with a constant speed of 4 cm/ sec. What is the speed of its image when the particle is at 90 cm from the mirror?

(a) 16 cm/ sec. (b) 1 cm/sec. (c) 8 cm/sec.(d) 4 cm/sec.

6. You are given four sources of light each one providing a light of a single colour – red, blue, green and yellow. Suppose the angle of refraction for a beam of yellow light corresponding to a particular angle of incidence at the interface of two media is 90°. Which of the following statements is correct if the source

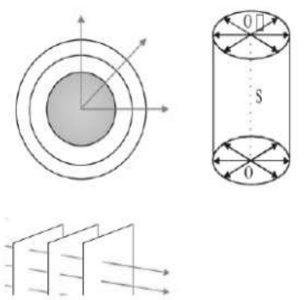
CHAPTER- 10 : WAVE OPTICS

Chapter–10: Wave optics: Wave front and Huygen's principle, reflection and refraction of plane wave at a plane surface using wave fronts. Proof of laws of reflection and refraction using Huygen's principle. Interference, Young's double slit experiment and expression for fringe width (No derivation final expression only), coherent sources and sustained interference of light, diffraction due to a single slit, width of central maxima (qualitative treatment only).

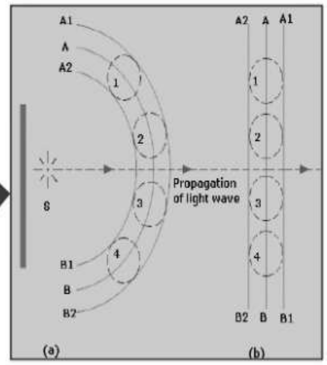
WAVE OPTICS

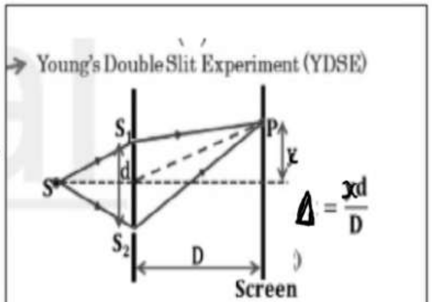
A wavefront is a surface of constant phase

Shape of Wave front



Huygen's principle of the secondary wavelets-Each point on the wavefront is the source **of a secondary wavelets.**





d is distance between slits S_1 and S_2

D is distance between slit and screen

y	0	$\frac{\lambda D}{2d}$	$\frac{\lambda D}{d}$	$\frac{3\lambda D}{2d}$	$\frac{2\lambda D}{2d}$
Max /Mina	Central Maxima	1st Minima	1st Maxima	2nd Minima	2nd Maxima

Path difference $\triangle = \frac{xd}{D}$

Position of nth bright fringe $x_n = \frac{nD\lambda}{d}$ (where **n=0,1,2,3...)**

Position of nth dark fringe $x_n = \frac{(2n-1)D\lambda}{2d}$(where **n=1,2,3...**

Fringe width $\beta = x_n - x_{n-1} = \beta_{bright} = \beta_{dark} = \frac{\lambda D}{d}$

Fringe width in medium $\beta_{med} = \frac{\beta_{vac}}{\mu}$

Angular width of fringe $\theta = \frac{\beta}{D} = \frac{\lambda}{d}$

Interference of light

- Phase difference does not change with time – coherent sources
- $A^2 = A_1^2 + A_2^2 + 2A_1A_2 \cos\phi$
- $I = I_1 + I_2 + 2\sqrt{I_1 I_2} \cos\phi$

YDSE

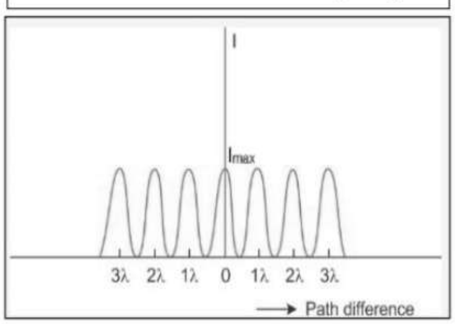
- Fringe width, $\beta = \frac{\lambda D}{d}$
- Position of n_{th} bright fringe,

$y_{bright} = \frac{n\lambda D}{d}$

- Position of n_{th} dark fringe,

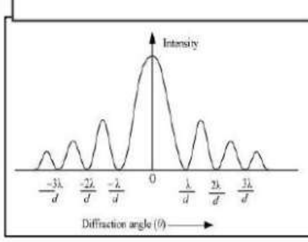
$y_{bright} = \frac{(2n-1)\lambda D}{2d}$

- For bright fringe, $\Delta x = n\lambda$
- For dark fringe, $\Delta x = \left(n + \frac{1}{2}\right)\lambda$



Diffraction

1.Path difference△**= BP-AP = BE =a sin ɵ**2. **Position of minima-** Position of nth dark fringe **a sin** θ_n **= nλ** (where **n =1,2,3...)**
3.**Position of secondary maxima- a sin** θ_n'**= (2n+1) λ/2** where **n =1,2,3...4.angular width of central maxima = 2ɵ =2λ/a5. Linear width of central maxima= 2x or D(2ɵ) = 2λD/a**

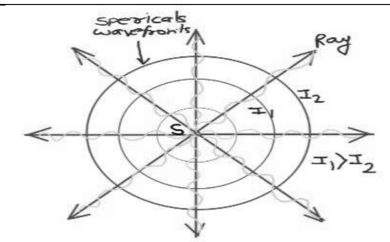
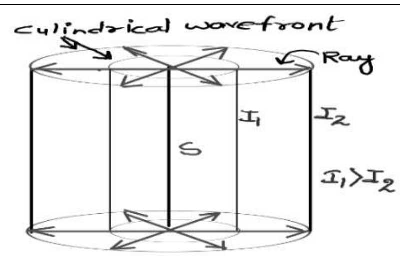
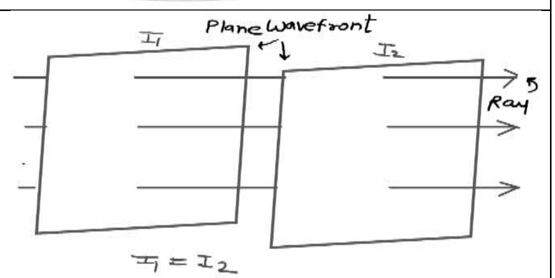


WAVE OPTICS: CONCEPT OF WAVEFRONT.

1.Nature of light-The phenomena like interference, diffraction and polarization establish the wave nature of light. Whereas the phenomena like photo electric effect, Raman effect, Compton effect establish the particle nature of light.

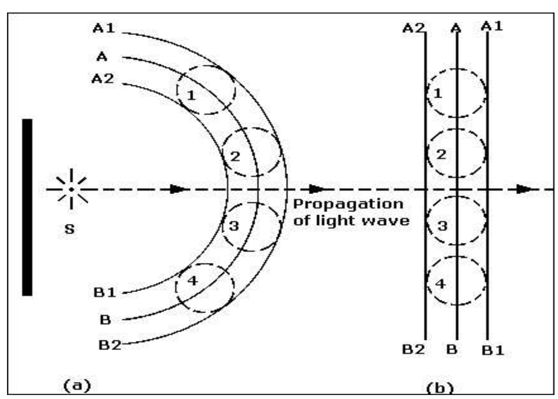
2.Wavefront-It is defined as the continuous locus of all the particles of the medium vibrating in the same phase at any instant. A wavefront is a surface of constant phase. The speed with which the wavefront moves outwards from the source is called the phase speed (wave speed).Note-1. Rays are perpendicular to wavefronts. .2. No backward wavefront is possible.

3.Types of wavefront-It is depends on the source of disturbance.

Spherical wavefront	Wavefront formed by the point source	
Cylindrical wavefront	Wavefront formed by linear or cylindrical shape source	
Plane wavefront	As a spherical or cylindrical wavefront advances, its curvature decreases, so small portion of such a wavefront at a large distance from the source will be a plane wavefront	

4. Huygen's principle of the secondary Wavelets-It is the basis of wave theory of light. It tells how a wavefront propagates through a medium. It is based on the following assumptions

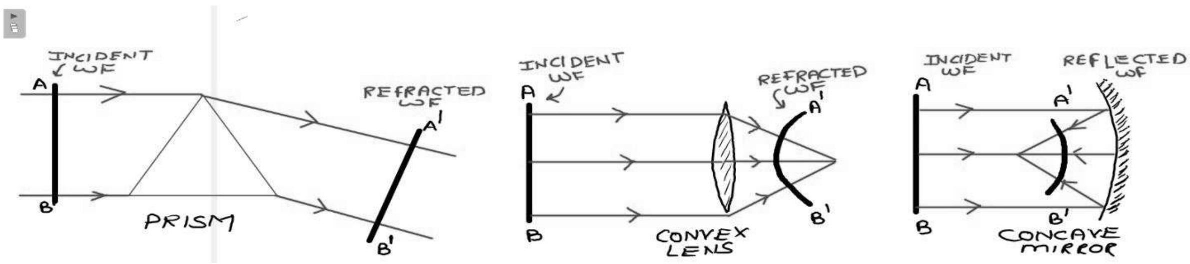
i)Each point on a wavefront acts as a source of new disturbance called secondary wavelets. These secondary wavelets spread out in all directions with the speed of light in the given medium ii)The wavefront at any later time is given by the forward envelope of the secondary wavelets at that time.

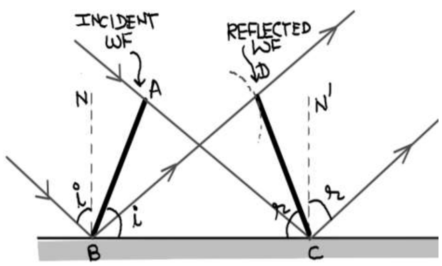
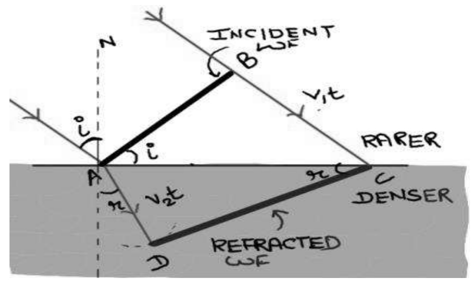
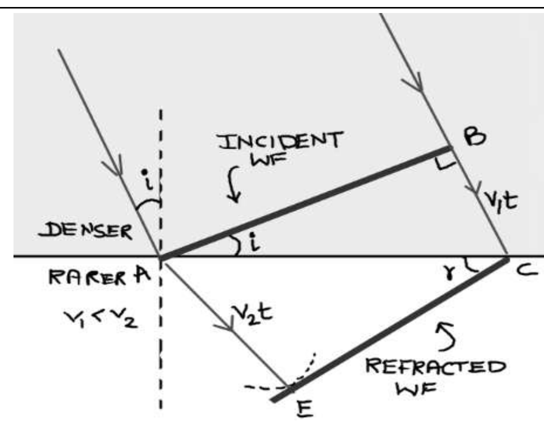


5.During refraction- Frequency of light remains constant, wavelength and speed of light get changed depending on the refractive index. ($\lambda' = \lambda/\mu$ and $v' = v/\mu$) (here μ is the refractive index)

6.Behaviour of a prism, lens and mirror-

7.



	Reflection on the basis of wave theory	Refraction on the basis of wave theory
i)		
ii)	In triangle △ABC and △DCB ∠BAC=∠CDB (Each 90°) BC=BC AC=BD (each equal to ct) ∴△ABC ≅ △DCB Hence ∠i=∠r	From △ABC, sin i =BC/AC From △ADC, sin r = AD/AC $\therefore \frac{\sin i}{\sin r} = \frac{BC}{AD} = \frac{v_1 t}{v_2 t}$ Or $\frac{\sin i}{\sin r} = \frac{v_1}{v_2} = \mu_{21}$(refractive index of second medium wrt first medium)
	Note-for denser to rarer medium	

8.Coherent and Incoherent Sources-Two sources are coherent if they have the same frequency and with a constant phase difference. They are incoherent if phase difference is not constant.

9.Interference of light-When two light waves of the same frequency and having constant phase difference(coherent), travelling in the same direction superpose each other, the intensity gets redistributed, becoming maximum at some points and minimum at others, this phenomenon is called interference of light.

Let two waves from two coherent source of light be $y_1 = a \sin \omega t$ and $y_2 = b \sin (\omega t + \emptyset)$

Where a and b are amplitudes and ∅ is the phase difference

So y = $y_1 + y_2$ after solving we get $\mathbf{y = A\sin(\omega t + \theta)}$

- Where A is the resultant amplitude so $\mathbf{A_{net} = \sqrt{(a^2 + b^2 + 2ab\cos\emptyset}}$
- And Resultant intensity is $\mathbf{I_{net} = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\emptyset}$

- Resultant amplitude when a =b $\quad A_{net} = 2a\cos\frac{\emptyset}{2}$
- Resultant intensity when $I_1=I_2=I$ $\quad I_{net} = 4I\cos^2\frac{\emptyset}{2}$

NOTE- Ratio of maximum intensity to minimum intensity

$$\frac{I_{max}}{I_{min}} = \left(\frac{a+b}{a-b}\right)^2 = \left(\frac{\sqrt{I_1}+\sqrt{I_2}}{\sqrt{I_1}+\sqrt{I_2}}\right)^2$$

10.Types of Interference-

s.no	**Constructive interference**	**Destructive interference**
1	Point where resultant intensity is max	Point where resultant intensity is minimum
2	• For $I_{max} \rightarrow \cos\phi = +1$ • Phase difference $\phi = 0, 2\pi, 4\pi, \ldots 2n\pi$ where $n = 0, 1, 2, \ldots$ • Path difference $\Delta = 0, \lambda, 2\lambda, \ldots, n\lambda$ • $A_{max} = a+b$ • $I_{max} = (\sqrt{I_1}+\sqrt{I_2})^2$	• For $I_{min} \rightarrow \cos\phi = -1$ • Phase difference $\phi = \pi, 3\pi, 5\pi, \ldots (2n-1)\pi$ where $n = 1, 2, 3, \ldots$ • Path difference $\Delta = \frac{\lambda}{2}, \frac{3\lambda}{2}, \frac{5\lambda}{2}, \ldots, (2n-1)\frac{\lambda}{2}$ • $A_{min} = a-b$ • $I_{min} = (\sqrt{I_1}-\sqrt{I_2})^2$
3	Resultant intensity at a point is maximum when the phase difference is even multiple of π or path difference is an integral multiple of wavelength λ	Resultant intensity at a point is minimum when the phase difference is odd multiple of π or path difference is an odd multiple of wavelength λ/2

11.Young's Double Slit Experiment-It is the practical verification of interference. In this we get two coherent source by dividing wavefront. We always get bright fringe at the center of the screen and both side alternately bright and dark fringes are made.

a) Fringe width in YDSE-

In$\triangle S_1S_2L$ $\quad \sin\theta = \frac{S_2L}{S_1S_2} = \frac{\triangle}{d}$

Now in $\triangle DOP$ $\tan\theta = \frac{x}{D}$

If θ is small $\sin\theta \approx \tan\theta \approx \theta$

So $\frac{\triangle}{d} = \frac{x}{D}$

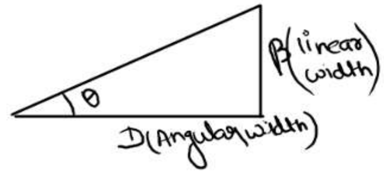
b)Path difference $\quad \triangle = \frac{xd}{D}$

c)Position of n^th^ bright fringe $\quad x_n = \frac{nD\lambda}{d}$ where **n=0,1,2,3…**

d)Position of n^th^ dark fringe $\quad x_n = \frac{(2n-1)D\lambda}{2d}$ where **n=1,2,3…**

e) Fringe width –Separation between position two consecutive maxima or minima. Width of bright and dark fringe will be same.

$$\boldsymbol{\beta = x_n - x_{n-1} = \beta_{bright} = \beta_{dark} = \frac{\lambda D}{d}}$$



f)Fringe width in medium $\boldsymbol{\beta_{med} = \frac{\beta_{vac}}{\mu}}$

g)Angular width of fringe $\boldsymbol{\theta = \frac{\beta}{D} = \frac{\lambda}{d}}$

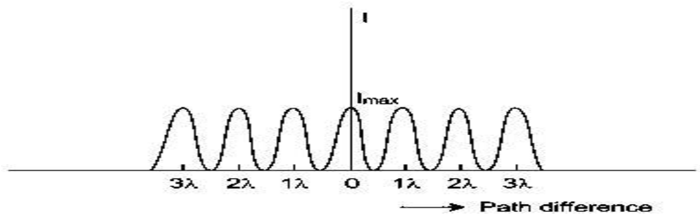
h) overlapping of fringes

if n_1^{th} bright fringe overlapped on n_2^{th} bright fringe then $n_1\lambda_1 = n_2\lambda_2$

if bright overlapped dark $n_1\lambda_1 = (2n_2 - 1)\lambda_2/2$

i)Dependence of fringe width $\beta = \frac{\lambda D}{d}$ ($\beta \propto \lambda$, $\beta \propto D$, $\beta \propto 1/d$)

j) Intensity distribution curve-

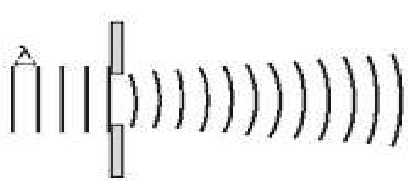


k) Condition for sustained interference-

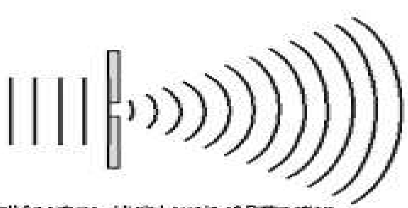
i)Two source of light must be coherent(ii) Having same frequency (iii)source should be monochromatic (iv)wave must travel in same direction(v) for a better contrast amplitude of waves should be approximately equal

12.Diffraction

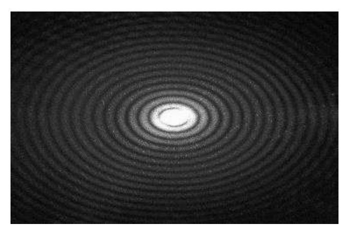
It is the phenomena of bending of light around corners of an obstacle or aperture in the path of light. Due to this bending, light goes into the geometrical shadow region of the obstacle or aperture.This bending becomes more when the dimensions of the aperture or the obstacle are comparable of the wavelength of light.



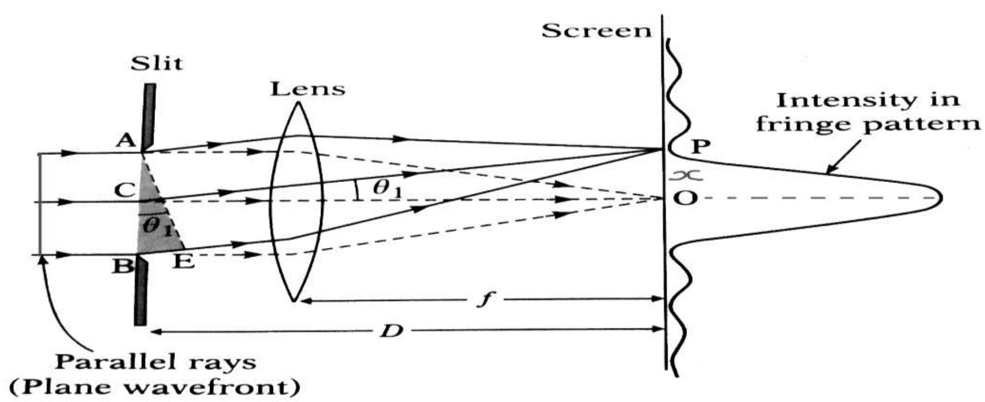
Large Aperture - Low Levels of Diffraction



Small Aperture - High Levels of Diffraction



13.Diffraction of light from a single slit-



a) Central maxima-maximum intensity at point o because path difference at o is zero.

b) Path difference $\triangle$**=BP-AP = BE =a sin θ**

c)Position of minima- Position of n^{th} dark fringe

a sin θ_n = nλ where **n =1,2,3…**

d)Position of secondary maxima-

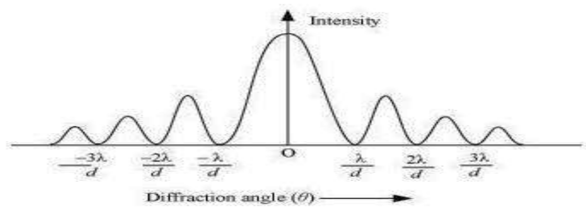
a sin θ_n'= (2n+1) λ/2 where **n =1,2,3…**

Note-width of secondary maxima α $\frac{1}{slit\ width}$

e) width of central maxima- the direction of first minima **θ=λ/a,** this angle is called half angular width of central maxima **angular width of central maxima = 2θ =2λ/a**

f) Linear width of central maxima= 2x or D(2θ) = 2λD/a

g) Graph



MULTIPLE CHOICE QUESTIONS

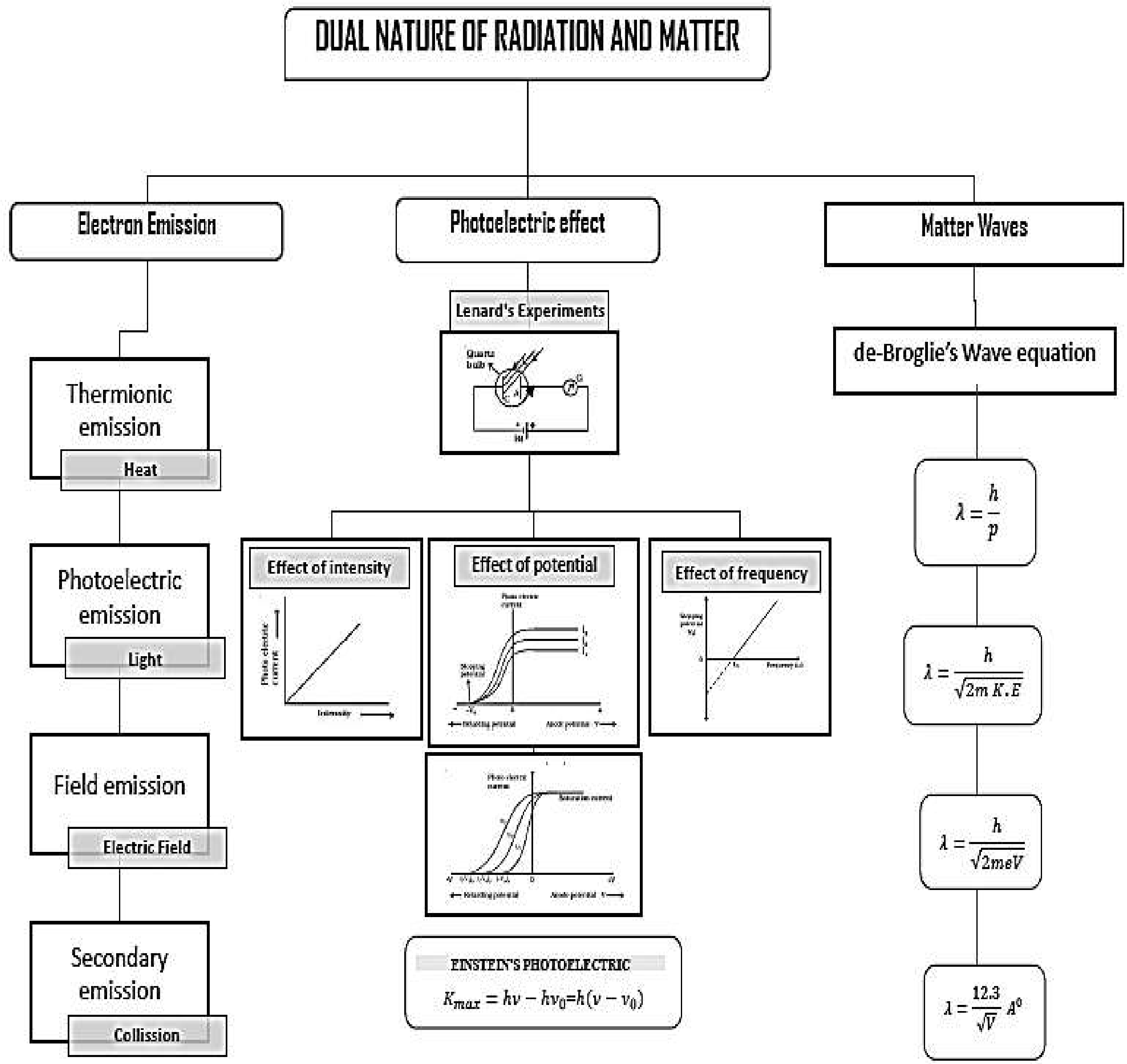
1. The resultant amplitude of a vibrating particle by the superposition of the two waves
   y_1 = a sin(ωt + π / 3) and y_2 = a sin ωt is :-
   a) a b) √2 a c)2a d)√3 a
2. A double slit experiment is performed with light of wavelength 500 nm. A thin film of thickness 2μm and refractive index 1.5 is introduced in the path of the upper beam. The location of the central maximum will

   a) Remain unshifted b)Shift downward by nearly two fringes
   c) Shift upward by nearly two fringe d)Shift downward by 10 fringes
3. Which of following is a true statement, if in Young's experiment, separation between the slits is gradually increased :
   a) fringe width increases and fringes disappear
   b) fringe width decreases and fringes disappear
   c) fringes become blurred
   d) fringe width remains constant and fringes are more bright
4. In an interference of yellow light derived from two slit apertures, if at some point on the screen, yellow light has a path difference of 3 λ / 2, then the fringe at that point will be :
   a) yellow in colour b) white in colour c)dark d)bright
5. Two beams of light having intensities I and 4I interfere to produce a fringe pattern on a screen. The phase difference between the beam is π/2 at point A and 2π at point B. Then find out the difference between the resultant intensities at A and B.
   a) 2I b)5I c)I d)4I
6. In an interference pattern of two waves fringe width is β . If the frequency of source is doubled then fringe width will become :
   a) (1/2) β b)β c)2β d)(3/2) β
7. Find the half angular width of the central bright maximum in the Fraunhofer diffraction pattern of a slit of width 12 × 10^{-5} cm when the slit is illuminated by monochromatic light of wavelength 6000 Å.
   a) 40° b)45° c)30° d)60°
8. A light source of 5000Å wave length produces a single slit diffraction. The first minima in diffraction pattern is seen, at a distance of 5mm from central maxima. The distance between screen and slit is 2metre. The width of slit in mm will be :
   a) 0.1 b)0.4 c)0.2 d)2

CHAPTER-11: DUAL NATURE OF RADIATION AND MATTER

Dual nature of radiation, Photoelectric effect, Hertz and Lenard's observations; Einstein's photoelectric equation-particle nature of light. Experimental study of photoelectric effect Matter waves-wave nature of particles, de-Broglie relation.

MINDMAP



GIST OF THE CHAPTER

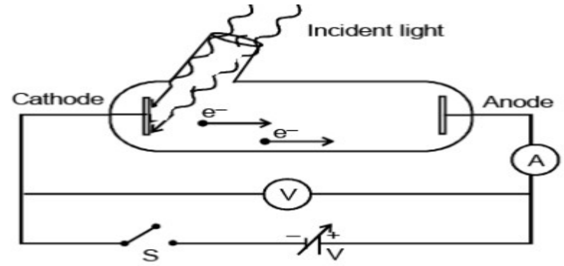
▪ **Electron Emission:** The phenomenon of emission of electron from a metal surface.

1. Thermionic emission (when metal is heated)
2. Field emission: (by applying very strong electric field to a metal)
3. Photo-electric emission (when light of suitable frequency illuminates a metal surface)

- **Work Function**: The minimum amount of energy required to be given to an electron to escape from the metal surface. It is generally denoted by ϕ_0 and unit is electron volt (eV).

1 eV = 1.602×10^{-19} J
Work function of platinum is 5.65 eV (metal having highest work function)
Work function of caesium is 2.14 eV (lowest work function)

- **Photoelectric Effect:** The phenomenon of emission of electrons from the metal surface, when light of suitable frequency illuminates it. (Discovered by Heinrich Hertz)
- **Lenard's Experimental setup:**



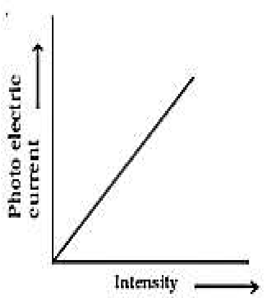
- **Effects on Photoelectric Current**

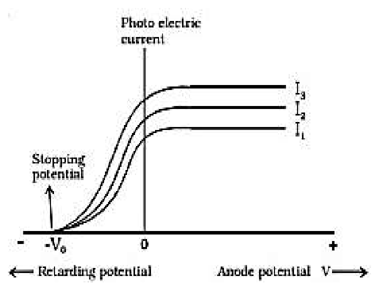
1. Effect of intensity: Photoelectric current increases linearly with intensity of incident light, keeping frequency and voltage constant.
2. Effect of potential.

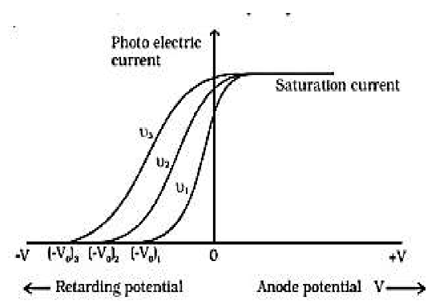
▪ Increasing positive potential increases current until saturation.
▪ Negative retarding potential decreases current. At a certain negative voltage (stopping potential), current becomes zero.
▪ Stopping Potential (V_0): Minimum negative potential to stop photoelectric current for a given frequency. - Independent of intensity, depends only on frequency. - Kinetic energy and stopping potential: $K_{max} = eV_0$

3. Effect of frequency:

▪ Greater frequency → greater stopping potential → greater K_{max}
▪ Saturation current remains same (constant intensity)







Laws of Photoelectric Effect

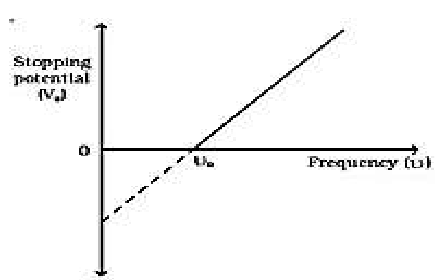
1. Photoelectric current ∝ intensity of radiation (fixed frequency)
2. Saturation current ∝ intensity; stopping potential is independent of intensity.
3. No emission occurs below threshold frequency (ν_0).
4. K_{max} ∝ frequency of incident radiation (ν); independent of intensity.
5. Photoelectric emission is instantaneous (delay ≈ 10^{-9} s)

• **Failure of Classical Theory:** Wave theory predicts electron absorbs energy continuously.
Contradictions: a. K_{max} should depend on intensity (observed: depends on frequency)
b. Any frequency should cause emission (observed: only above threshold frequency)
c. Should be delayed process (observed: instantaneous)

• **Einstein's Photoelectric Equation**: Photon energy = $h\nu = K_{max} + \phi_0 \Rightarrow K_{max} = h(\nu - \nu_0)$

▪ Explanation Laws of Photoelectric Effect:
- Intensity increases photon number → increases current. - $\nu < \nu_0$ →negative K which is impossible → no emission. - Photon-electron interaction is instantaneous → no time lag.

▪ Graph (freq vs Stopping potential) : $V_0 = (h/e)\nu - \phi_0/e$ → straight line. Slope = h/e, y-intercept = $-\phi_0/e$



Particle Nature of Light

▪ Light interacts with matter as photons.

- Photon energy: hν, momentum: hν/c
- Photon: no charge, not deflected by E or B fields
- Photon collisions conserve energy and momentum, but number of photons may change.
- Compton scattering confirmed particle nature of light.

• **Dual Nature of Radiation**

- Wave nature: Interference, diffraction, polarisation. - Particle nature: Photoelectric effect, Compton scattering. ⇒ Light shows wave-particle duality

• **Dual Nature of Matter:** Louis de Broglie (1924) proposed particles have wave nature.

- de-Broglie Equation: $\lambda = h/p = h/mv = h/\sqrt{2mK} = h/\sqrt{2meV}$
- Davisson-Germer experiment confirmed electron wave nature experimentally.

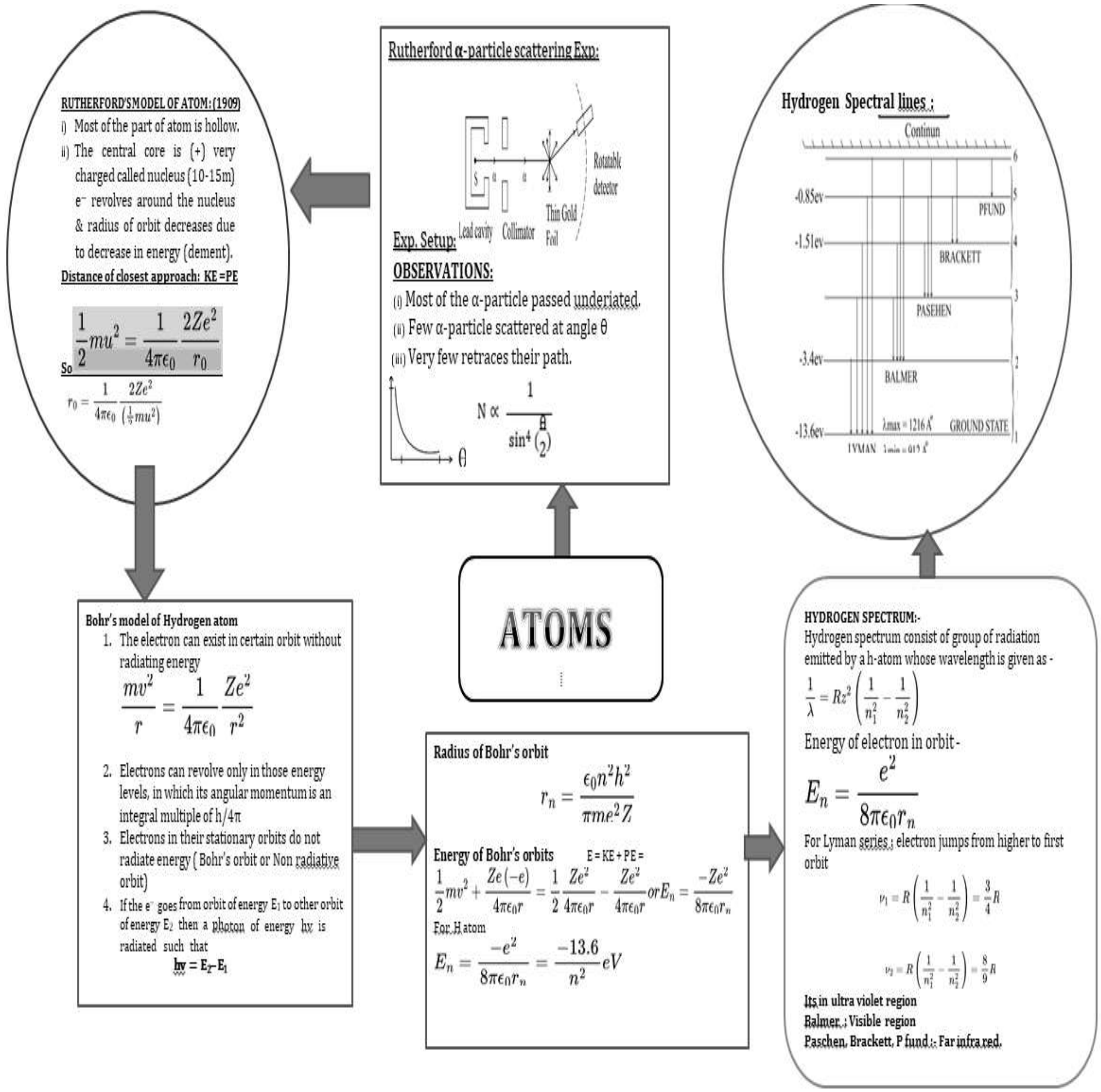
MULTIPLE CHOICE QUESTIONS

1. Which of the following cannot be observed by an increase in the intensity of light alone?
   (A) Increase in photocurrent (B) Increase in stopping potential
   (C) Increase in number of emitted electrons (D) Increase in rate of emission
2. In an experiment, intensity of light is increased but photoelectric current remains constant after sometime. This is due to:
   (A) saturation current has been reached
   (B) frequency of light is below threshold
   (C) work function is larger than incident photon energy
   (D) electrons are absorbed back
3. The photoelectric current becomes zero when:
   (A) The intensity of light is zero (B) Frequency is below the threshold
   (C) Work function is very high (D) Any of the above
4. In a photoelectric experiment with light of intensity I, the current is I_0. When light is filtered to allow only 50% photons through, the current becomes:
   (A) $2\ I_0$ (B) $I_0/2$ (C) $\sqrt{2}\ I_0$ (D) Remains same
5. Consider a photoelectric tube where magnitude of negative anode potential is gradually increased. The photoelectric current decreases to zero because:
   (A) Kinetic energy of electrons is reduced
   (B) All photons are absorbed
   (C) Potential suppresses even fastest electrons
   (D) Frequency becomes less than threshold
6. In an experiment, when frequency is increased, the stopping potential increases linearly. This verifies:
   (A) Planck's quantization (B) de Broglie relation
   (C) Einstein's photoelectric equation (D) Wave-particle duality
7. Which observation supports the quantum nature of light?
   (A) Instantaneous emission (B) KE ∝ frequency
   (C) Threshold frequency exists (D) All of the above
8. In photoelectric emission, a radiation whose frequency is 2 times threshold frequency of a certain metal is incident on the metal. Then the maximum possible velocity of the emitted electron will be:
   (A) $\sqrt{\frac{h\nu_0}{m}}$ (B) $\sqrt{\frac{2h\nu_0}{m}}$ (C) $2\sqrt{\frac{h\nu_0}{m}}$ (D) $\sqrt{\frac{6h\nu_0}{m}}$
9. For two particles with equal momenta, which of the following is true regarding their de Broglie wavelengths?
   (A) The heavier particle has smaller wavelength (B) Both have same wavelength
   (C) The faster particle has smaller wavelength (D) Depends on nature of the particles

CHAPTER–12: ATOMS

Content: Alpha-particle scattering experiment; Rutherford's model of atom; Bohr model of hydrogen atom, Expression for radius of nth possible orbit, velocity and energy of electron in nth orbit, hydrogen line spectra (qualitative treatment only).

MIND MAP:



GIST OF CHAPTER: ATOMS

Rutherford's Atomic Model

On the basis of this experiment, Rutherford made following observations

(i)The entire positive charge and almost entire mass of the atom is concentrated at its centre in a very tiny region of the order of 10-15 m, called nucleus.

(ii)The negatively charged electrons revolve around the nucleus in different orbits.

(iii)The total positive charge 011 nucleus is equal to the total negative charge on electron. Therefore atom as a overall is neutral.

(iv)The centripetal force required by electron for revolution is provided by the electrostatic force of attraction between the electrons and the nucleus.

Distance of Closest Approach

$r_o = 1 / 4\pi \varepsilon o . 2Ze2 / E_k$ where, E_k = kinetic energy of the cc-particle.

Impact Parameter

The perpendicular distance of the velocity vector of a-particle from the central line of the nucleus, when the particle is far away from the nucleus is called impact parameter.

Impact parameter

where, Z = atomic number of the nucleus, E_k = kinetic energy of the c- particle and θ = angle of scattering.

Rutherford's Scattering Formula

where, N(θ) =number of c-particles, Ni = total number of α-particles reach the screen. n = number of atoms per unit volume in the foil, Z = atoms number, E = kinetic energy of the alpha particles and t = foil thickness

Limitations of Rutherford Atomic Model

(i)About the Stability of Atom According to Maxwell's electromagnetic wave theory electron should emit energy in the form of electromagnetic wave during its orbital motion. Therefore. radius of orbit of electron will decrease gradually and ultimately it will fall in the nucleus. (ii) About the Line Spectrum Rutherford atomic model cannot explain atomic line spectrum.

Bohr's Atomic Model

Electron can revolve in certain non-radiating orbits called stationary or bits for which the angular momentum of electron is an integer multiple of (h / 2π)

$mvr = nh / 2\pi$

where n = I, 2. 3,… called principle quantum number.The radiation of energy occurs only when any electron jumps from one permitted orbit to another permitted orbit. Energy of emitted photon

$hv = E_2 – E_1$ where E1 and E2are energies of electron in orbits.

Radius of orbit of electron is given by $r = n^2h^2 / 4\pi^2 mK Ze2 \Rightarrow r \propto n^2 / Z$

where, n = principle quantum number, h = Planck's constant, m = mass of an electron,

K = 1 / 4 π ε, Z = atomic number and e = electronic charge.

Velocity of electron in any orbit is given by $v = 2\pi KZe^2 / nh \Rightarrow v \propto Z / n$

Frequency of electron in any orbit is given by $v = KZe^2 / nhr = 4\pi^2Z^2e^4mK^2 / n3\ h^3$

$\Rightarrow$ v prop; $Z3 / n^3$

Kinetic energy of electron in any orbit is given by $E_k = 2\pi^2me^4Z^2K2 / n^2\ h2 = 13.6\ Z^2 / n^2$ eV

Potential energy of electron in any orbit is given by

$E_p = – 4\pi^2me^4Z^2K^2 / n^2\ h^2 = 27.2\ Z^2 / n^2 \quad \Rightarrow Ep = \propto Z^2 / n^2$

Total energy of electron in any orbit is given by $E = – 2\pi^2me^4Z2K^2 / n^2\ h^2 = – 13.6\ Z2 / n^2$ eV

$\Rightarrow Ep = \propto Z^2 / n^2$ In quantum mechanics, the energies of a system are discrete or quantized. The energy of a particle of mass m is confined to a box of length L can have discrete values of energy given by the relation $En = n^2\ h2 / 8mL2$; n < 1, 2, 3,…

Hydrogen Spectrum Series

Each element emits a spectrum of radiation, which is characteristic of the element itself. The spectrum consists of a set of isolated parallel lines and is called the line spectrum.

Hydrogen spectrum contains five series **(i) Lyman Series** When electron jumps from n = 2, 3,4, …orbit to n = 1 orbit, then a line of Lyman series is obtained. This series lies in ultra violet region.

(ii)Balmer Series When electron jumps from n = 3, 4, 5,… orbit to n = 2 orbit, then a line of Balmer series is obtained. This series lies in visual region.

(iii)Paschen Series When electron jumps from n = 4, 5, 6,… orbit to n = 3 orbit, then a line of Paschen series is obtained. This series lies in infrared region

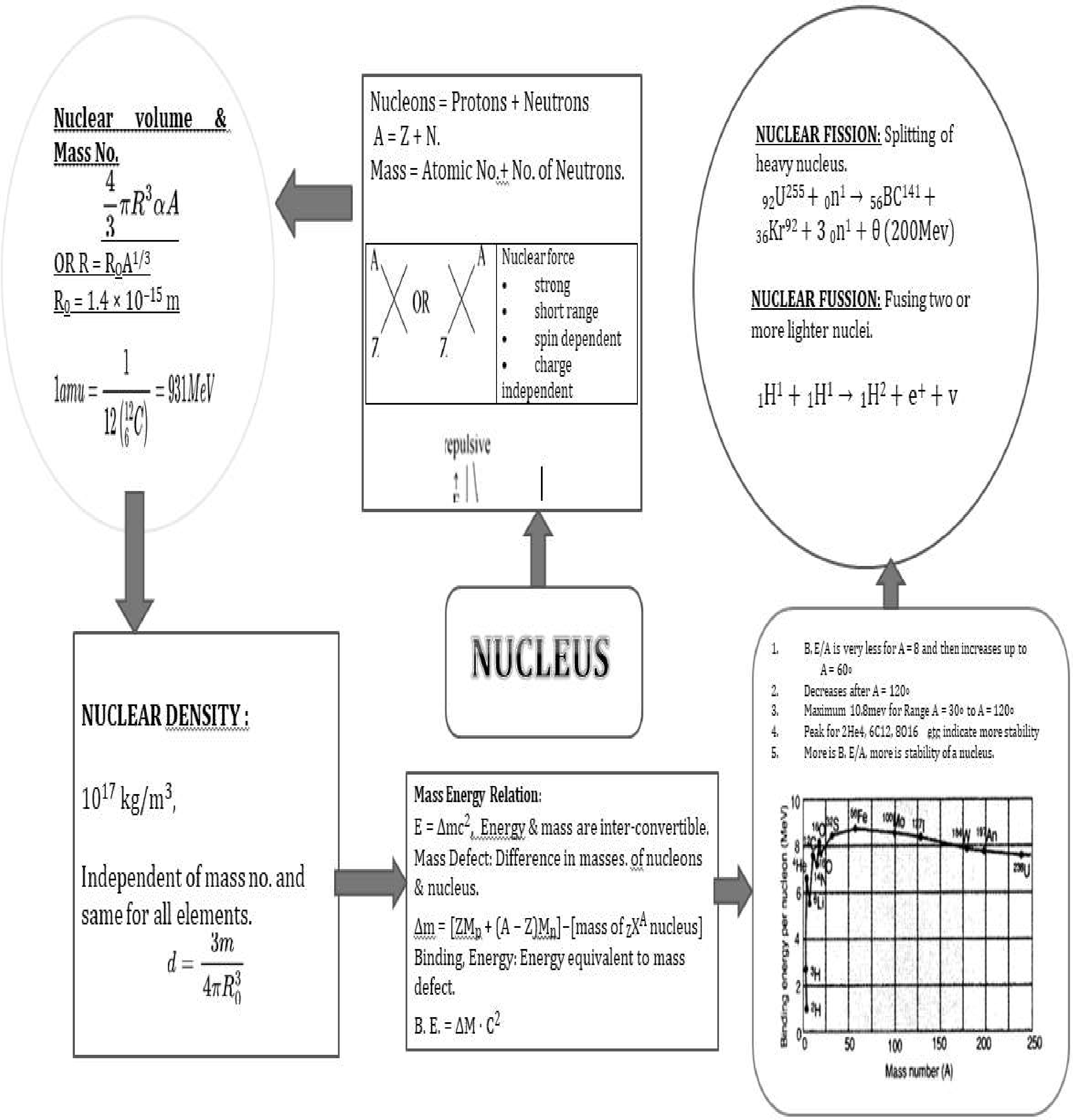
(iv)Brackett Series When electron jumps from n = 5,6, 7…. orbit to n = 4 orbit, then a line of Brackett series is obtained. This series lies in infrared region.

(v)Pfund Series When electron jumps from n = 6,7,8, … orbit to n = 5 orbit, then a line of Pfund series is obtained. This series lies in infrared region.

CHAPTER–13: NUCLEI

Syllabus:-Composition and size of nucleus, nuclear force Mass-energy relation, mass defect; binding energy per nucleon and its variation with mass number; nuclear fission, nuclear fusion.

MIND MAP :



GIST – NUCLEUS

Nucleus: The small, dense region consisting of protons and neutrons at the center of an atom is the atomic nucleus. In every atom, the positive charge and mass are densely concentrated at the central core of the atom, which forms its nucleus. More than 99.9% mass of the atom is concentrated in the nucleus.

Nucleons: The nucleus of an atom consists of protons and neutrons. They are collectively called nucleons.

Atomic Mass Unit (amu) :The unit of mass used to express mass of an atom is called atomic mass unit.

Atomic mass unit is defined as 1/12th of the mass of carbon (126C) atom.
1 amu or 1 u=1.660539 x10-27 kg (1) Mass of proton (m_p)=1.00727 u
(2) Mass of neutron (m_n)=1.00866 u (3) Mass of electron (m_e) =0.000549 u Relation between amu and MeV 1 amu=931 Mev
Composition of Nucleus
The composition of a nucleus can be described by using the following.
Atomic Number (Z) :Atomic number of an element is the number of protons present inside the nucleus of an atom of the element.
Atomic number (Z) = Number of protons = Number of electrons (in a neutral atom)
Mass Number (A): Mass number of an element is the total number of protons and neutrons inside the atomic nucleus of the element.
Mass number (A)= Number of protons(Z) +Number of neutrons(N)
= Number of electrons +Number of neutrons A=Z+N
Size of Nucleus: According to the scattering experiments, nuclear sizes of different elements are assumed to be spherical, so the volume of a nucleus is directly proportional to its mass number. If R is the radius of the nucleus having mass number A, then
$R \propto A^{1/3}$ $R=R_0 A^{1/3}$
Where, R_0= 1.2x10 $^{-15}$ m is the range of nuclear size. It is also known as nuclear radius.

Nuclear Density Density of nuclear matter is the ratio of mass of nucleus and its volume. $\rho=m/(4/3\pi R_0^3)$ => ρ = 2.38×10^{17} kg/m³ where, m = average mass of one nucleon and R_o=1.2 fm = 1.2×10^{-15}**m =>The nuclear density (ρ) does not depend on A (mass number). Mass Defect** The sum of the masses of neutrons and protons forming a nucleus is more than the actual mass of the nucleus. This difference of masses is known as mass defect.

$\Delta m=Zm_p+(A-Z)m_n - M$ where, Z= atomic number, A= mass number, m_p = mass of one proton, m_n= mass of one neutron and M= mass of nucleus.

Mass-Energy Relation Einstein's mass-energy equivalence equation is given by $E = mc^2$, (where E is the energy and c is the speed of light =3×10^8 m/s and m = mass of nucleus)
Nuclear Forces Short ranged (2-3 fm) strong attractive forces which hold protons and neutrons together in against of Colombian repulsive forces between positively charged particle is called nuclear force. The nuclear force between neutron-neutron, proton-neutron and proton-proton is approximately the same. The nuclear force does not depend on the electric charge.
Nuclear Energy When nucleons form a nucleus, the mass of nucleus is slightly less than the sum of individual masses of nucleons. This mass is stored as nuclear energy in the form of mass defect. Also, transmutation of less stable nuclei into more tightly bound nuclei provides an excellent possibility of releasing nuclear energy. Two distinct ways of obtaining energy from nucleus are Number of nucleons given below
The phenomenon of splitting of heavy nuclei (usually A>230) into lighter nuclei of nearly equal masses is known as nuclear fission, e.g.

$$_{92}U^{235} + {}_0n^1 \text{ --------> } {}_{56}Ba^{141} + {}_{36}Kr^{92} + 3\ {}_0n^1 + Q$$

Nuclear Fusion
The phenomenon of fusing or combining of two lighter nuclei into a single heavy nucleus is called nuclear fusion, e.g.

$$_1H^1 + {}_1H^1 \text{ ----------> } {}_1H^2 + e^1 + v + 0.42 \text{ MeV}$$

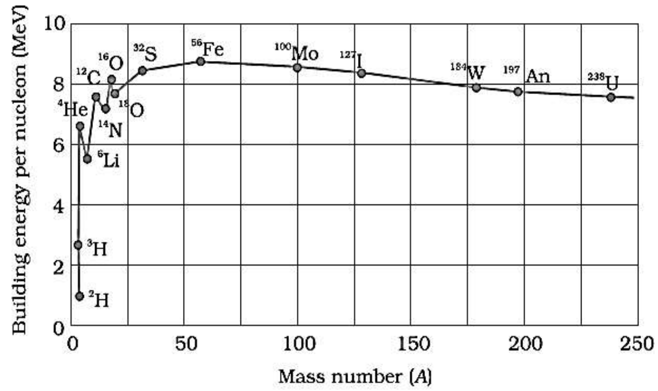
[The energy released during nuclear fusion is known as thermonuclear energy.]
Binding Energy
The binding energy of a nucleus is defined as the minimum energy required to separate its nucleons and place them at rest at infinite distance apart. Using Einstein's mass-energy relation, $\Delta E= (\Delta mc^2)$, the binding energy of the nucleus is$\Delta E =[Zm_p + (A-Z)m_n - M]c^2$

Average Binding Energy Per Nucleon of a Nucleus

It is the average energy required to extract a nucleon from the nucleus to infinite distance. It is given by total binding energy divided by the mass number of the nucleus.

Binding energy curve:

It is a plot of the binding energy per nucleon versus the mass number A for a large number of nuclei as shown below:



The binding energy per nucleon as a function of mass number.

Binding energy per nucleon as a function of mass number :It is used to explain phenomena of nuclear fission and fusion.

Nuclear Stability

The stability of a nucleus is determined by the value of its binding energy per nucleon. The constancy of the binding energy in the range $30 < A < 170$ is a consequence of the fact that the nuclear force is short-ranged.

MCQ - QUESTIONS : NUCLEI)

1.The binding energy per nucleon of a nucleus is a measure of its:

a) Stability b) Instability c) Radioactivity d) Mass defect

2. The binding energy per nucleon is maximum for nuclei with a mass number around:

a) 50 b) 100 c) 150 d) 200

3. The binding energies per nucleon for a deutron and an α- particle are x_1 and x_2 respectively. The energy Q released in reaction $_1H^2 + _1H^2 \rightarrow {}^4_2He + Q$ is

(a) $4 (x_1 + x_2)$ (b) $4 (x_1 – x_2)$ (c) $2 (x_1 + x_2)$ (d) $2 (X_1 – x_2)$.

4. Let m_n and m_p be the masses of a neutron and a proton respectively. M_1 and M_2 are the masses of a ${}^{20}_{10}Ne$ nucleus and a ${}^{40}_{20}Ca$ nucleus respectively. Then

(a) $M_2 < 2M_1$ (b) $M_2 > 2M_1$ (c) $M_2 = 2M_1$ (d) $M_1 < 10 (m_n + m_p)$.

5. One requires an energy E_n to remove a nucleon from a nucleus and an energy E_e to remove an electron from an atom. Then

(a) $E_n = E_e$ (b) $E_n > E_e$ (c) $E_n < E_e$ (d) $E_n > E_e$.

3. When the number of nucleons in nuclei increases, the binding energy per nucleon numerically

(a) increases continuously with mass number.

(b) decreases continuously with mass number. (c) First increases and then decreases with increase of mass number.

(d) Remains constant with mass number.

7. Consider the fission reaction : ${}^{236}_{92}U \rightarrow x^{117} + Y^{117} + {}_0n^1 + {}_0n^1$i.e., two nuclei of same mass numbers 117 are formed plus two neutrons. The binding energy per nuclear of X and Y is 8.5 MeV whereas U^{236} is 7.6 MeV. The total energy liberated will be about:

(a) 2 MeV (b) 20 MeV (c) 2,000 MeV (d) 200 MeV

8. Fusion takes place at high temperature because:

(a) Atom are ionised at high temperature

(b) Molecules break up at high temperature

(c) Nuclei break up at high temp.

(d) Kinetic energy is high enough to overcome repulsion between nuclei

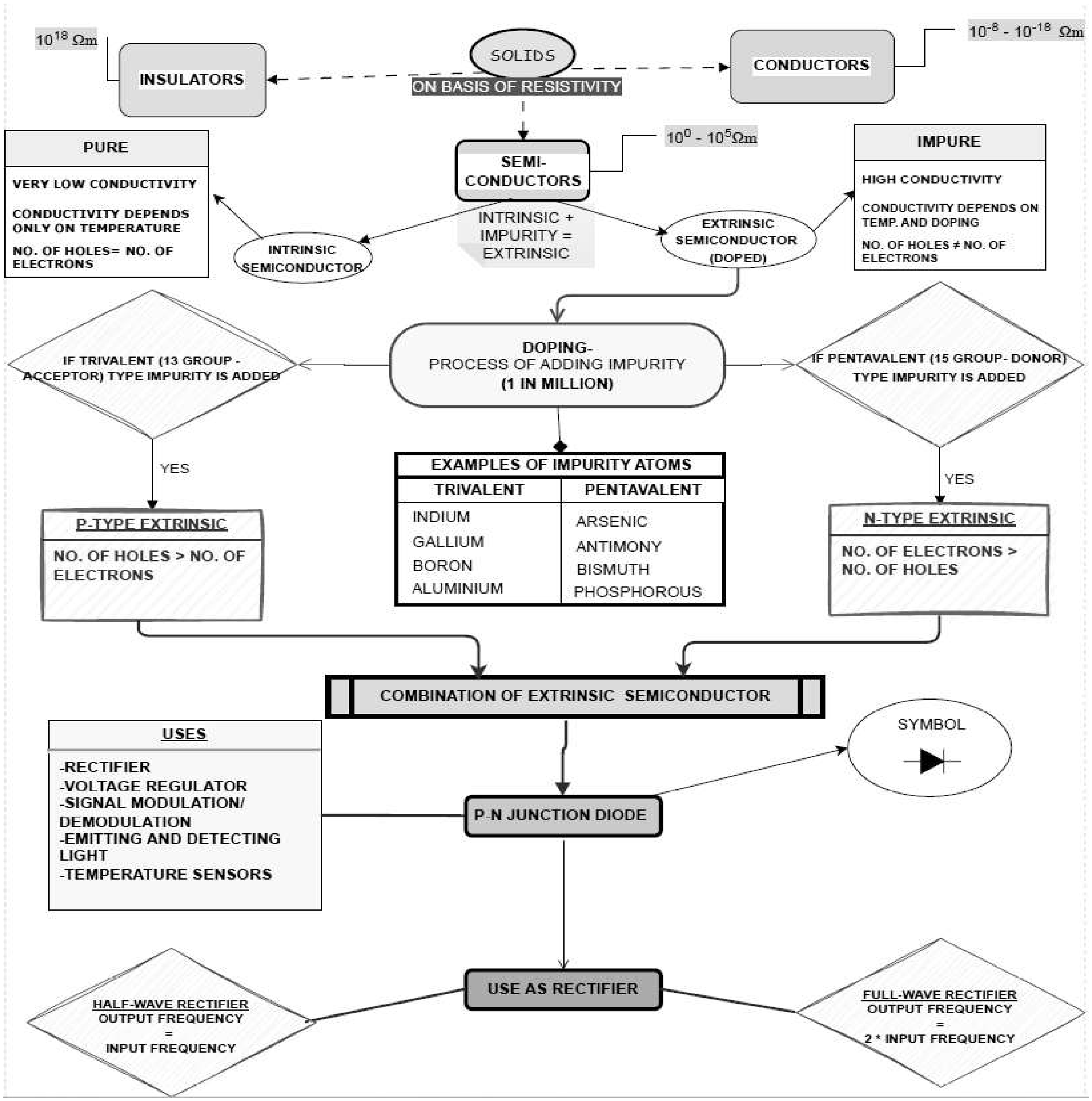
9. The binding energy per nucleon for the parent nucleus is E1 and that for the daughter nuclei is E2. Then

(a) E1 > E2 (b) E2 > E1 (c) E1 = 2E2 (d) E2 = 2E1

CHAPTER–14: SEMICONDUCTOR ELECTRONICS

Syllabus:- Materials, Devices and Simple Circuits Energy bands in conductors, semiconductors and insulators (qualitative ideas only) Intrinsic and extrinsic semiconductors- p and n type, p-n junction Semiconductor diode - I-V characteristics in forward and reverse bias, application of junction diode -diode as a rectifier.

Mindmap



GIST OF CHAPTER

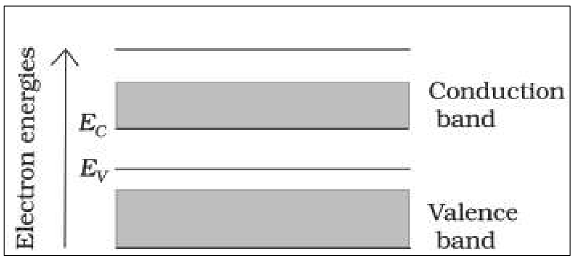
Semiconductor Electronics were discovered as a part of experiments in the **1930s**. This led to the realization that certain solid-state semiconductors and their junctions **had the capacity to control the number and direction of flow of charge carriers** through them.

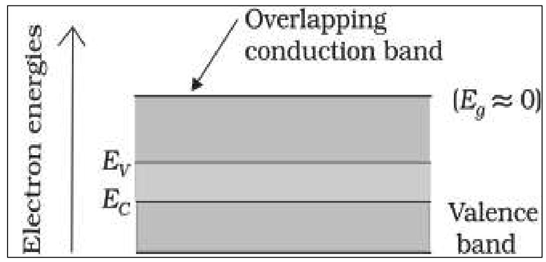
A semiconductor is a type of material whose resistivity is between a conductor (silver, copper, etc.) and insulator (glass, diamond) which is

$$\rho = 10^0 - 10^5 \quad \Omega - m$$

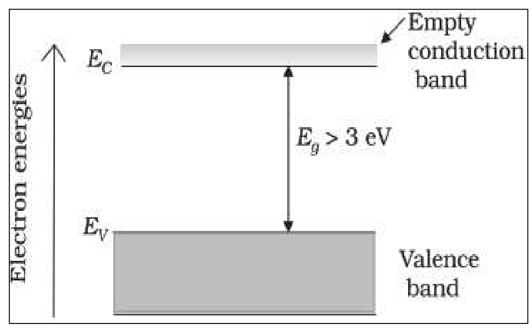
Insulators, conductors and semiconductors can be differentiated based on their energy bands.

- **Metals:-** In metals, the valence and conduction **band lie very close to each other** and **sometimes even overlap** which allows free movement of electrons.



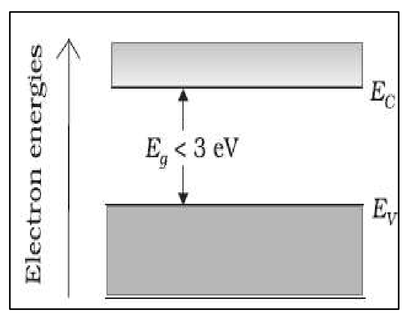


- **Insulators:-** In case of insulators, the conduction band and valence band is separated by a **large gap** which discourages movement of electrons.



- **Semiconductors:-** The **energy band gap is smaller in semiconductors** which encourages some electrons to enter the conduction band by crossing the gap.

  E_g-Si = 1.1 eV E_g-Ge = 0.74 eV



Types of Semiconductors

Semiconductors are classified into two types **based on the number of electrons and holes**.

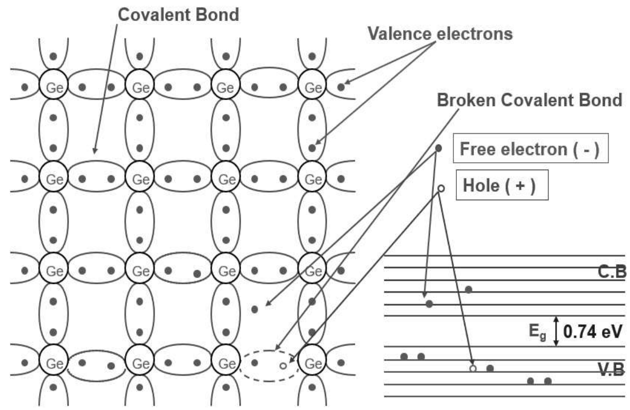
- **Intrinsic**
- **Extrinsic**

Intrinsic or Pure Semiconductor:

Intrinsic semiconductors **are free from impurities**. Examples: **Germanium and silicon**

- for **Pure Si (Z=14)** and for **Pure Ge (Z=32).** Both have 4 valence electrons.
- All 4 valence electrons are involved in covalent bond formation in Si or Ge crystal.
- It has an **equal number of holes and free electrons**.

  Thus, $n_e = n_h = n_i$



Here, **n_i = intrinsic carrier concentration, n_e = number of electrons, n_h = number of holes**

Extrinsic or impure Semiconductor:

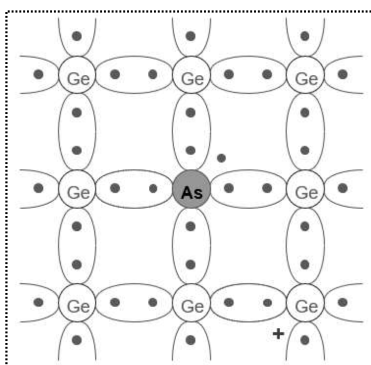
The electrical conductivity of **intrinsic (pure) semiconductor** is dependent **on its temperature.** However, **at room temperature**, its conductivity is very **poor**.

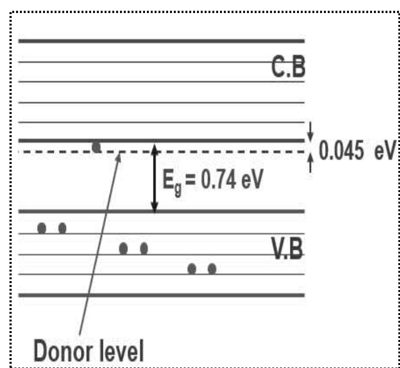
- The addition of certain impurities (very small amount-in part per million ppm) **can increase the conductivity** of the intrinsic (natural) semiconductors.
- The process of addition of impurity is called **doping** and the impurity atoms are called **dopants**.
- The impure semiconductor thus formed is called a **"doped" semiconductor** or **Extrinsic Semiconductor**.

An Extrinsic Semiconductor can be of two types based on the type of doping.

- **n-type semiconductor doped with Pentavalent impurity atom**. Examples include **Phosphorus (P), Antimony (Sb), Arsenic (As).**

Here $n_e >> n_h$, that is the number of electrons is greater than the number of holes.

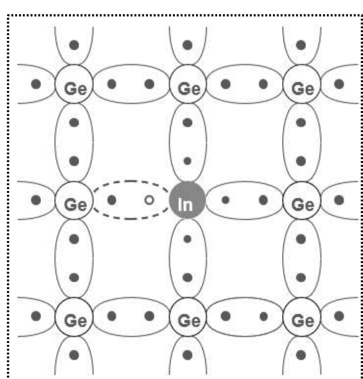


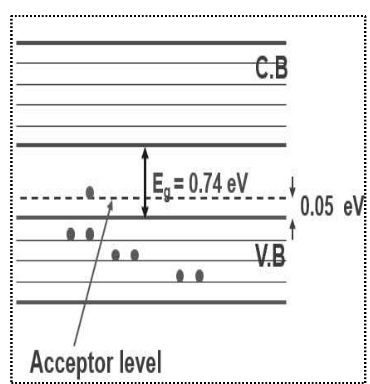


- **p-type semiconductor doped with Trivalent impurities atom.** Examples include **Boron (B), Aluminium (Al), Indium (In).**

Here $n_h >> n_e$, that is the number of holes is greater than the number of electrons.

The electron and hole concentration in a semiconductor *in thermal equilibrium* is given by $n_e \cdot n_h = n_i^2$



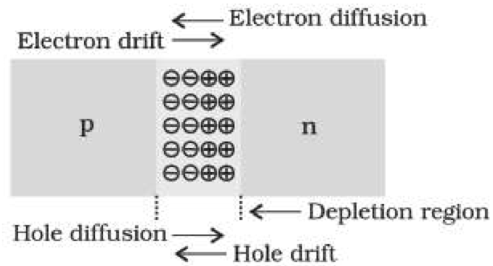


P-N Junction

By Considering a thin p-type silicon (p-Si) semiconductor wafer and adding precisely, a small quantity of pentavalent impurity, part of the p-Si wafer can be converted into n-Si. The wafer now contains p-region and n-region and a metallurgical junction between p-, and n-region.

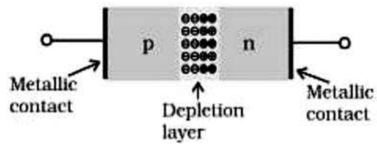
Two important processes occur during the formation of a p-n junction are **diffusion and drift**.

Initially, diffusion current is large and drift current is small. As the diffusion process continues, the space- charge regions on either side of the junction extend, thus increasing the electric field strength and hence drift current. This process continues until the diffusion current equals the drift current.



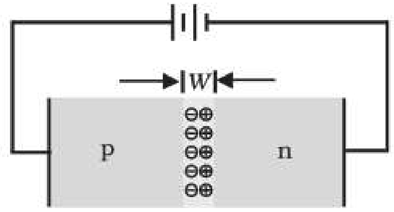
Semiconductor Diode

A semiconductor diode is basically a p-n junction with metallic contacts provided at the ends for the application of an external voltage. It is a two-terminal device.

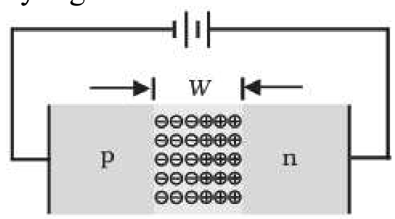


Symbol- 

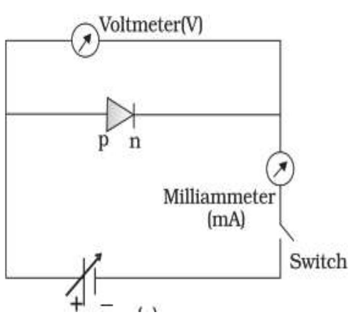
- When an external voltage *V* is applied across a semiconductor diode such that p-side is connected to the positive terminal of the battery and n-side to the negative terminal , it is said to be *forward biased*. In forward bias, it offers very low resistance.

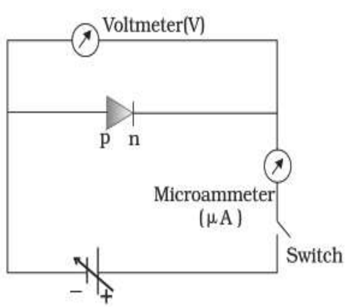


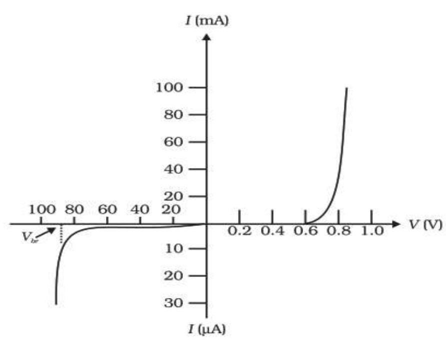
- When an external voltage (*V*) is applied across the diode such that n-side is positive and p-side is negative, it is said to be *reverse biased*. In reverse bias, it offers very high resistance.
- The ratio of forward biased to reverse biased resistance for p-n junction diode is 10^{-4}:1.



Characteristic curve study for p-n junction diode in forward and reverse bias:-







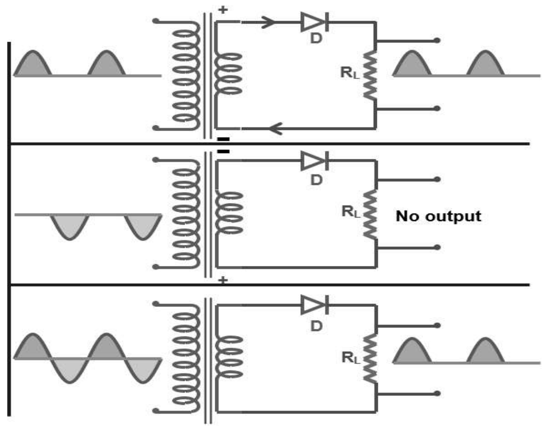
Application of Junction Diode as a Rectifier

An electrical device **that converts alternating current into direct current** with the help of a diode is called **a Rectifier**. There are two types of rectifiers:

1. **Half-Wave Rectifier**
2. **Full-Wave Rectifier**

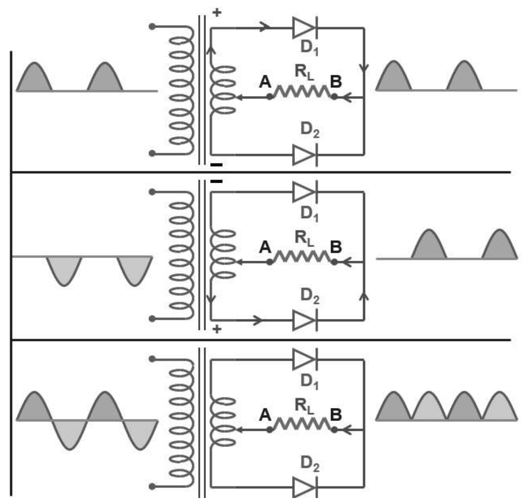
Half Wave Rectifier

A half-wave rectifier is defined as a type of rectifier **that only allows the one-half cycle of an AC voltage** and gives the pulsating DC voltage.
There is only one diode in the half-wave rectifier, which helps to rectify the AC voltage to DC voltage.
The average value of output direct current in a half wave rectifier is I_0/π.



Full Wave Rectifier

Full-wave rectifiers have **two diodes** where the **first diode will conduct in the positive half cycle** and **other diode will conduct in the negative half cycle**. It **will give full pulsating DC.**
The average value of output direct current in a full wave rectifier is $2I_0/\pi$
The sinusoidal wave is complete and with the help of the capacitor or inductor we can filter and convert pulsating DC into constant DC.



Application of Full Wave Rectifier and Half Wave Rectifier

The use of a half-wave rectifier can help us achieve the desired dc voltage by using step-
down or step-up transformers. Moreover, to power up the motor and LED that works on DC voltage, full wave rectifiers are used.

MULTIPLE CHOICE QUESTIONS

1. Carbon, silicon and Germanium have four valence electrons each. At room temperature which one of the following statements is most appropriate ?
(a) The number of free electrons for conduction is significant only in Si and Ge but small in C.
(b) The number of free conduction electrons is significant in C but small in Si and Ge.
(c) The number of free conduction electrons is negligibly small in all the three.
(d) The number of free electrons for conduction is significant in all the three.

2. In the energy band diagram of a semiconductor, if more charge carriers are seen near valence band. It would be
(a) an intrinsic semiconductor (b) a metal may be n-type or p-type semiconductor
(c) an n-type semiconductor (d) a p-type semiconductor

3. The peak voltage in the output of a half wave diode rectifier fed with a sinusoidal signal without filter is 10 V. The d.c. component of the output voltage is
(a) $10/\sqrt{2}$ V (b) $10/\pi$ V (c) 10 V (d) $20/\pi$ V