
Physics
KARNATAKA
2ND PUC
EXAM PATTERN

Preface

This material is prepared for those students who cannot read all the concepts in Physics. This material prepared only to get minimum marks or passing marks in the subject. This is only a guide to get self confidence in the minds of the students who were below average or who think that it is very difficult to get passing marks. This material prepared as per the revised syllabus and for II PUC main examination of March - 2020. The students can read this material first and after getting self-confidence, they can read further concepts for scoring more and more marks in Physics.

In this material concepts related all the chapters were provided except the numerical problems. The student may study this material by selecting some the chapters whichever he/she feels very easy so that he/she can get passing marks. For example One student may study chapter1, 2, 3 and 4 along with chapter 14. This material is prepared on the basis of the questions asked in Previous question papers till July 2019.

At last three model Questions papers are given as per the blue print suggested by Pre University Board, Bangalore for the march 2020 exam. You cannot get/find the answers for all the questions from this material only, because it prepared to get passing marks.

This material is prepared for the betterment of students and to improve the results but not for commercial purpose. This material is not for sale.

Please provide suggestions to improve this material further. You can also download and comment on http://swamyphysics.blogspot.com/

All the best.

Ugranarasimhaswamy
Lecturer in Physics
Govt P U College, Aranakatte.
Hiriyur Taluk, Chitradurga Dist
Mob-9902856985

CHAPTER – 1 ELECTRIC CHARGES AND FIELDS

Methods of charging a body: The process of charging a body is known as electrification.

1) Charging by friction
2) Charging by conduction
3) Charging by Induction

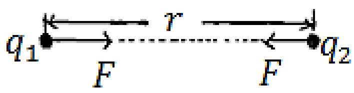
Properties of Electric charge:

(i) Additivity of charges
(ii) Conservation of charge
(iii) Quantization of charge

The smallest amount of free charge e that has been discovered is the charge on an electron or a proton having magnitude $1.602192 \times 10^{-19}\ C$.

Coulomb's law: The magnitude of the force between any two point charges is directly proportional to the product of their magnitudes and inversely proportional to the square of the distance between them and the force always acted along the line joining the two charges.

Explanation: Let q_1 and q_2 are two point charges separated by a distance r in vacuum.



$$F \propto \frac{|q_1 q_2|}{r^2}$$

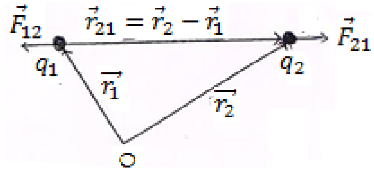
$$F = K\frac{|q_1 q_2|}{r^2}$$

SI system, $K = \dfrac{1}{4\pi\,\varepsilon_0} = 9 \times 10^9\ N\,m^2 C^{-2}$

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

Coulomb's law in vector form:

Let the position vectors of charges q_1 and q_2 be $\vec{r_1}$ and $\vec{r_2}$ respectively.



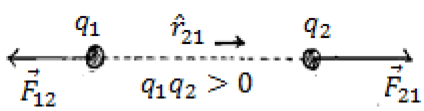
In Vector form: $\boldsymbol{\vec{F}_{21} = \dfrac{1}{4\pi\,\varepsilon_0}\dfrac{q_1 q_2}{r^2{}_{21}}\,\hat{r}_{21}}$

Where, $r_{21} = |\vec{r}_{21}| = |\vec{r}_2 - \vec{r}_1|$

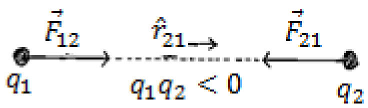
and $\hat{r}_{21} = \dfrac{\vec{r}_{21}}{|\vec{r}_{21}|}$ = Unit vector in the direction from q_1 to q_2

Diagrammatical representation of direction of force:

(1) When the two charges are of same sign, then $q_1 q_2 > 0$, the electric force is repulsive, as shown.



(2) When two charges are of opposite sign, then $q_1 q_2 < 0$, the force is attractive, as shown.



Unit of charge: The SI unit of charge is ***coulomb* (*C*).**

coulomb: One coulomb is that charge when placed at a distance of $1m$ from another charge of same magnitude in *vacuum* experiences an electrical force of repulsion of magnitude $9 \times 10^9\ N$.

Number of electrons present in one coulomb:

Number of electrons in one coulomb is given by, $\boldsymbol{n = \frac{q}{e}} = \frac{1}{1.60 \times 10^{-19}} = 6.25 \times 10^{18}$

$\therefore$ 6.25×10^{18} Electrons constitute 1 *coulomb* of charge.

To determine the electric force on a charge due to other charges we need the **Principle of superposition**.

Principle of Superposition: The force on any charge due to a number of other charges is the vector sum of all the forces on that charge due to the other charges, taken one at a time. The individual forces are unaffected due to the presence of other charges.

Electric field: **T**he force that a unit positive charge would experience if placed at that point.
SI unit of electric field is $N\,C^{-1}$ or $V\,m^{-1}$.

Electric field due to a point charge:

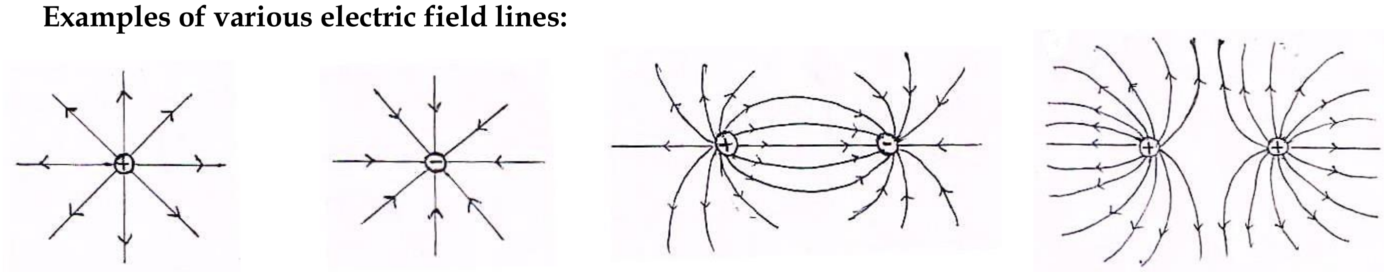
$$\boldsymbol{\vec{E} = \frac{1}{4\pi\,\varepsilon_0}\frac{Q}{r^2}\,\hat{r}}$$

Electric field lines: An electric field line is a path in an electric field, straight or curved, such that the tangent to it any point gives the direction of electric field at that point.

Properties of Electric field lines:

1. Electric field lines start from positive charges and end on negative charges.
2. Field lines can never intersect
3. Electric field lines do not form any closed loops.
4. Electric field lines are always normal at every point on the surface of a charged conductor.
5. Tangent drawn to the electric field line at any point gives the direction of the electric field at that point.

Examples of various electric field lines:



Electric dipole: A pair of equal and opposite point charges separated by a distance is called an electric dipole.

Dipole moment: The electric dipole moment equal to the charge q times the distance 2a between the charges.

$$\boldsymbol{\vec{p} = 2aq\,\hat{p}}$$

Dipole moment is a vector and SI unit is $C\,m$ $(coulomb - metre)$

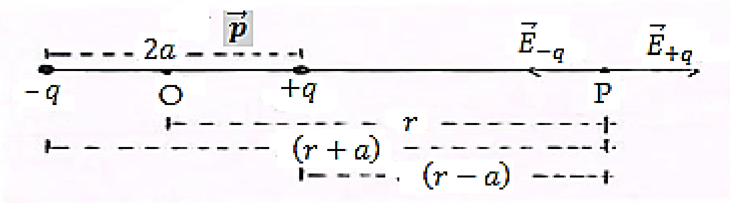
Polar molecules: The molecules with non-zero intrinsic dipole moments are called polar molecules.
Ex: H_2O, HCl and CO.

Non-Polar molecules: Molecules with zero intrinsic dipole moment are called non-polar molecules.

Ex: H_2, CO_2 and O_2.

The Electric field of an electric dipole:

(i) Field at a point on the axis:



Let P be a point on the axis of a dipole at a distance r from its centre O.

$$\vec{E}_{+q} = \frac{q}{4\pi\varepsilon_0 (r-a)^2}\,\hat{p}$$

$$\vec{E}_{-q} = \frac{q}{4\pi\varepsilon_0 (r+a)^2}\,(-\hat{p}) = -\frac{q}{4\pi\varepsilon_0 (r+a)^2}\,(\hat{p})$$

$$\vec{E} = \vec{E}_{+q} + \vec{E}_{-q}$$

$$\vec{E} = \left[\frac{q}{4\pi\varepsilon_0 (r-a)^2} - \frac{q}{4\pi\varepsilon_0 (r+a)^2}\right]\hat{p}$$

$$\vec{E} = \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{(r-a)^2} - \frac{1}{(r+a)^2}\right]\hat{p}$$

$$\vec{E} = \frac{q}{4\pi\varepsilon_0}\left[\frac{(r+a)^2 - (r-a)^2}{(r^2-a^2)^2}\right]\hat{p}$$

$$\vec{E} = \frac{q}{4\pi\varepsilon_0}\left[\frac{r^2 + a^2 + 2ra - r^2 - a^2 + 2ra}{(r^2-a^2)^2}\right]\hat{p}$$

$$\vec{E} = \frac{q}{4\pi\varepsilon_0}\frac{4ra}{(r^2-a^2)^2}\,\hat{p} = \frac{1}{4\pi\varepsilon_0}\frac{2r\,(2a\,q\,\hat{p})}{(r^2-a^2)^2}$$

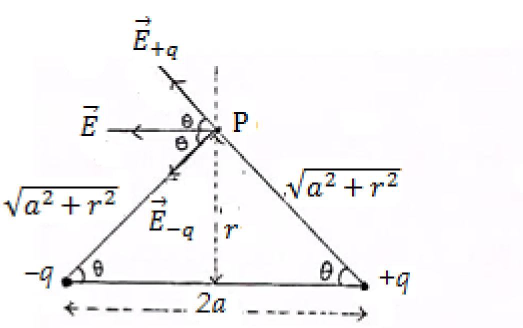
$$\boldsymbol{\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{2r\vec{p}}{(r^2-a^2)^2}}$$

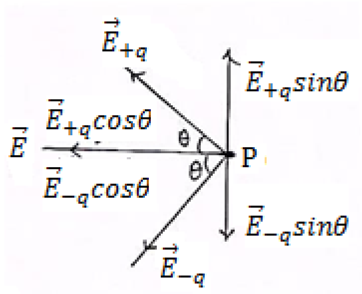
Further, for $r >> a$, $a^2 \approx 0$ and $(r^2-a^2)^2 \approx 0$ $(r^2)^2 = r^4$

$$\boldsymbol{\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{2\,\vec{p}}{r^3}}$$

(ii) Field at a point on the equatorial line:

Consider a point P at a distance r from the centre of the dipole and lying in the equatorial plane.





$$\vec{E}_{+q} = \frac{1}{4\pi\epsilon_0}\frac{q}{\left(\sqrt{a^2+r^2}\right)^2} = \frac{1}{4\pi\epsilon_0}\frac{q}{a^2+r^2}$$

$$\vec{E}_{-q} = \frac{1}{4\pi\epsilon_0}\frac{q}{a^2+r^2}$$

The resultant field at P is obtained by resolving the fields.

The components $\vec{E}_{+q}sin\theta$ and $\vec{E}_{-q}sin\theta$ are perpendicular to the dipole axis cancel each other.

The components $\vec{E}_{+q}cos\theta$ and $\vec{E}_{-q}cos\theta$ along the dipole axis add up.

$$\vec{E} = \vec{E}_{+q}cos\theta + \vec{E}_{-q}cos\,\theta$$

$$\vec{E} = [\vec{E}_{+q} + \vec{E}_{-q}]cos\,\theta(-\hat{p})$$

$$\vec{E} = \left[\frac{1}{4\pi\varepsilon_0}\frac{q}{r^2+a^2} + \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2+a^2}\right]\frac{a}{\sqrt{a^2+r^2}}(-\hat{p})$$

$$\vec{E} = \left[\frac{1}{4\pi\varepsilon_0}\frac{2q}{r^2+a^2}\right]\frac{a}{(a^2+r^2)^{\frac{1}{2}}}(-\hat{p})$$

$$\vec{E} = \frac{-1}{4\pi\varepsilon_0}\frac{2\,q\,a}{(r^2+a^2)^{\frac{3}{2}}}\,\hat{p}$$

$$\boldsymbol{\vec{E} = -\frac{1}{4\pi\varepsilon_0}\frac{\vec{p}}{(r^2+a^2)^{\frac{3}{2}}}}$$

Further, For $r >> a$, $a^2 \approx 0$ and $(r^2+a^2)^{\frac{3}{2}} \approx (r^2)^{\frac{3}{2}} = r^3$

$$\boldsymbol{\vec{E} = -\frac{\vec{p}}{4\pi\varepsilon_0 r^3}}$$

Dipole in a Uniform external field (Torque on a dipole): $\boldsymbol{\tau = pEsin\theta}$

In vector form $\boldsymbol{\vec{\tau} = \vec{p} \times \vec{E}}$

Maximum and Minimum values of Torque:

(i) When $\vec{p}$ is perpendicular to $\vec{E}$, θ = 90⁰ and $\tau = pEsin90^0 = pE$.
This is the maximum value of torque.

(ii) When $\vec{p}$ is along $\vec{E}$, θ = 0, and $\tau = pEsin0^0 = 0$.
The dipole is in stable equilibrium and has minimum value.

Linear charge density (λ): The charge per unit length of the line. Its SI unit is Cm^{-1}.

$$\boldsymbol{\lambda = \frac{\Delta Q}{\Delta l}}$$

Surface charge density (σ): The charge per unit area of that surface. Its SI unit is Cm^{-2}.

$$\boldsymbol{\sigma = \frac{\Delta Q}{\Delta S}}$$

Volume charge density (ρ): The charge per unit volume of the region. Its SI unit is Cm^{-3}.

$$\boldsymbol{\rho = \frac{\Delta Q}{\Delta V}}$$

Gauss's law: The Electric flux through any closed surface S is $(1/\epsilon_0)$ times the total charge enclosed by S.

Mathematically, $\boldsymbol{\phi = \frac{q}{\varepsilon_0}}$

Applications of Gauss's law:

(1) Electric field due to an infinitely long straight uniformly charged wire:

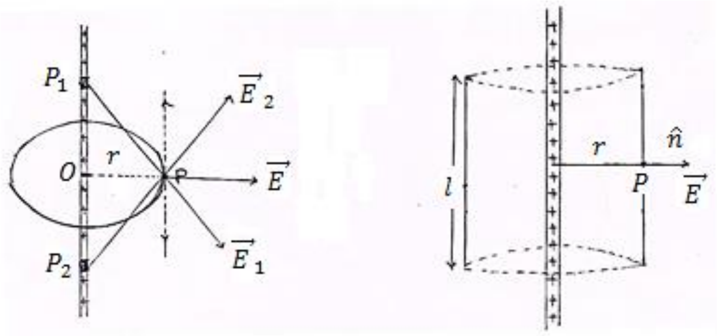
Consider an infinitely long thin straight wire with uniform linear charge density λ.

Let P be a point at a radial distance r from O.

Imagine a cylindrical Gaussian surface of radius r and height l.

Flux through the Gaussian surface, $\phi = E(2\pi r l)$

Charge on the surface, $q = \lambda l$



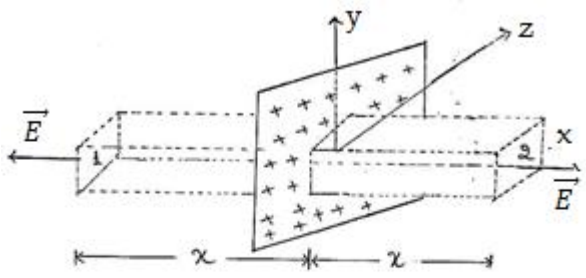
From Gauss law, $\phi = \dfrac{q}{\varepsilon_0}$

$$E\,(2\pi r l) = \frac{\lambda\, l}{\varepsilon_0}$$

$$E = \frac{\lambda}{2\pi\varepsilon_0 r}$$

Vectorically, $\boldsymbol{\vec{E} = \dfrac{\lambda}{2\pi\varepsilon_0 r}\,\hat{n}}$

(2) Electric field due to a uniformly charged infinite plane sheet:



Consider an infinite sheet of positive charge with uniform surface charge density σ.

Consider a Gaussian surface in the form of a parallel piped of cross sectional area A.

Then the flux through the each end face $= EA$.

Total flux $\phi = EA + EA = 2EA$

Charge enclosed by the Gaussian surface, $q = A\,\sigma$

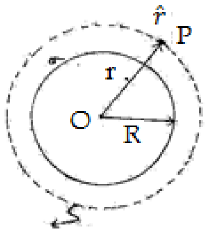
By Gauss law, $\phi = \dfrac{q}{\varepsilon_0}$

$$2EA = \frac{A\,\sigma}{\varepsilon_0}$$

$$E = \frac{\sigma}{2\epsilon_0}$$

Vectorically, $\boldsymbol{\vec{E} = \dfrac{\sigma}{2\varepsilon_0}\,\hat{n}}$

3) Field due to a uniformly charged thin spherical shell:



(a) Electric field outside the shell:

Consider a spherical shell of radius R with centre O.

Consider a point P outside the shell at a distance r from O.

Choose a Gaussian surface of radius r, concentric with the shell and passing through P.

The electrical flux through the Gaussian surface, $\phi = E \times 4\pi r^2$

The charge enclosed by the Gaussian surface $= q$

By Gauss law, $\phi = \dfrac{q}{\varepsilon_0}$

$$E \times 4\pi r^2 = \frac{q}{\varepsilon_0}$$

$$E = \frac{q}{4\pi\varepsilon_0 r^2}$$

Vectorically, $\boldsymbol{\vec{E} = \dfrac{q}{4\pi\varepsilon_0 r^2}\,\hat{r}}$

(b) Electric field inside the shell: $\boldsymbol{E = 0}$

Chapter – 2 ELECTROSTATIC POTENTIAL AND CAPACITANCE

Electrostatic (Electric) Potential energy: The potential energy of a charge q at a point is the work done by the external force in bringing the charge q from infinity to that point.

Electrostatic (Electric) potential: The electrostatic potential at any point in an electrostatic field is defined as the work done in carrying a unit positive charge from infinity to that point against the electrostatic force of the field.

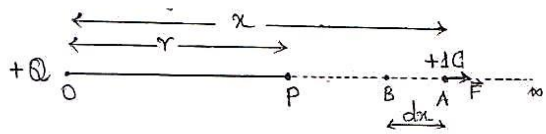
$$\boldsymbol{V = \frac{W}{q}}$$

Electrostatic potential is a scalar quantity; its SI unit is *volt (V)*

Volt: The electrostatic potential at a point is said to be one volt if one joule of work is done in moving one coulomb positive change from infinity to that point in an electrostatic field.

Electrostatic potential difference: The electrostatic potential difference between two points in an electrostatic field is defined as the work done in bringing unit positive change from one point to the other point against the electrostatic field.
The S.I unit of electrostatic potential difference is *volt (V)* and dimensions are $ML^2T^{-3}A^{-1}$.

Potential due to a point charge:



Consider a point Charge $+Q$ at O.
Let P be a point at a distance r from O.
Consider a point A at a distance x from O.
The magnitude of force on unit positive change at A is,

$$F = \frac{1}{4\pi\varepsilon_0}\frac{Q \times 1}{x^2} = \frac{Q}{4\pi\varepsilon_0\, x^2} \qquad \text{along } OP$$

Work done in moving a unit positive change from A to B

$$\Delta W = \vec{F}\cdot d\vec{x} = F dx \cos 180^0$$

$$\Delta W = -F\, dx = \frac{-Q}{4\pi\varepsilon_0\, x^2} dx$$

$$\text{Total work done, } W = \int_\infty^r \frac{-1}{4\pi\varepsilon_0}\frac{Q}{x^2}\, dx = -\frac{Q}{4\pi\varepsilon_0}\int_\infty^r \frac{1}{x^2} dx$$

$$W = -\frac{Q}{4\pi\varepsilon_0}\left[-\frac{1}{x}\right]_\infty^r = \frac{Q}{4\pi\varepsilon_0}\left[\frac{1}{r} - \frac{1}{\infty}\right]$$

$$W = \frac{Q}{4\pi\varepsilon_0 r}$$

By definition, this work done is equal to the electrostatic potential *(V)* at that point due to Q.

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

Electric Potential due to an electric dipole:

Let P be a point whose position vector $\overrightarrow{OP} = \vec{r}$ and it is at a distance r_1 from A and r_2 from B.

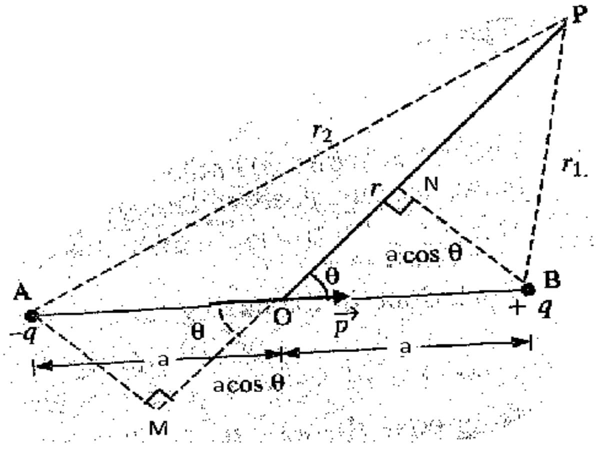
The potential at P due to positive charge $+q$ is, $V_+ = \dfrac{q}{4\,\pi\varepsilon_0\, r_1}$

Similarly, potential at P due to $-q$ is, $V_- = \dfrac{-q}{4\,\pi\varepsilon_0\, r_2}$

The net potential at P due to the dipole is,

$$V = V_+ + V_- = \frac{q}{4\,\pi\varepsilon_0\, r_1} + \frac{-q}{4\,\pi\varepsilon_0\, r_2}$$

$$V = \frac{q}{4\,\pi\varepsilon_0}\left(\frac{1}{r_1} - \frac{1}{r_2}\right) = \frac{q}{4\,\pi\varepsilon_0}\left(\frac{r_2 - r_1}{r_1 r_2}\right)$$



When $r >> 2a$

$$r_1 = r - OB\cos\theta = r - a\cos\theta$$
$$r_2 \cong r + OA\,\cos\theta = r + a\cos\theta$$

$$V = \frac{q}{4\,\pi\varepsilon_0}\left[\frac{r\, +\, a\cos\theta - (r - a\cos\theta)}{(r - a\cos\theta)(r + a\cos\theta)}\right]$$

$$V = \frac{q}{4\,\pi\varepsilon_0}\,\frac{2a\,\cos\theta}{(r^2 - a^2\cos^2\theta)}$$

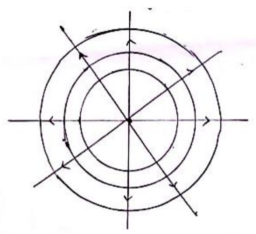
Since $2a$ is very small compared to r, $a^2\cos^2\theta$ can be ignored compared to r^2

$$V = \frac{2aq\,\cos\theta}{4\,\pi\varepsilon_0\, r^2}$$

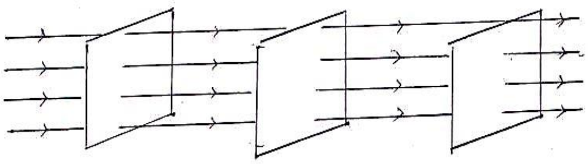
$$\boldsymbol{V = \frac{p\,\cos\theta}{4\,\pi\varepsilon_0\, r^2}}$$

Equipotential surface: An equipotential surface is a surface with a constant value of potential at all points on the surface.

(i) Equipotential surface of a single point charge are concentric spherical surfaces with a charge at its centre.



(ii) For uniform electric field $\vec{E}$, say along x-axis the equipotential surfaces are planes parallel to the y-z plane.



Properties of equipotential surfaces:

(i) No work is done in moving a test charge from one point to another point on an equipotential surface. (Because, potential difference between any two points is Zero)

(ii) The electric field is normal to the equipotential surface.

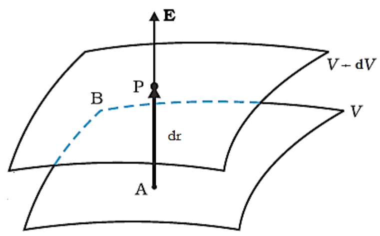
(iii) Two equipotential surfaces cannot intersect.

(iv) Equipotential surfaces indicate regions of strong or weak electric fields.

Relation between electric field and potential:

Consider two closely spaced equipotential surfaces A and B with potential values V and $V - dV$ respectively.

A ***unit*** positive charge is taken along perpendicular distance dr from the surface B to A against the electric field.



$$dW = \vec{F}\cdot d\vec{r} = q\vec{E}\cdot d\vec{r}$$
$$dW = \vec{E}\cdot d\vec{r} = E\; dr\cos 180^0$$
$$dW = -Edr$$

This work done is equal to the potential difference between the surfaces A and B,

$$dW = V_A - V_B = V - (V - dV) = V - V + dV = dV$$

$-Edr = dV$

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

(i) Potential energy of a system of two charges: (in the absence of External field)

Consider a charge q_1 being moved from infinity to A.

Since there is no field initially, $dW_1 = 0$

Let q_2 be moved from infinity to B.

Potential at B due to q_1 is, $V_1 = \frac{1}{4\,\pi\varepsilon_0}\frac{q_1}{r_{12}}$

Work done is, $dW_2 = V_1 q_2$

$$dW_2 = \left(\frac{1}{4\,\pi\varepsilon_0}\frac{q_1}{r_{12}}\right) q_2 = \frac{q_1\, q_2}{4\,\pi\,\varepsilon_0\, r_{12}}$$

Net work done, $W = dW_1 + dW_2 = 0 + \frac{q_1\, q_2}{4\,\pi\,\varepsilon_0\, r_{12}} = \frac{q_1\, q_2}{4\,\pi\,\varepsilon_0\, r_{12}}$

This work done is the Potential energy stored, $\boldsymbol{U = \frac{1}{4\,\pi\,\varepsilon_0}\frac{q_1\, q_2}{r_{12}}}$

(ii) Potential energy of a system of three charges: (in the absence of External field)

$$\boldsymbol{U = \frac{1}{4\,\pi\varepsilon_0}\left(\frac{q_1 q_2}{r_{12}} + \frac{q_1 q_3}{r_{13}} + \frac{q_2 q_3}{r_{23}}\right)}$$

Potential energy in an electric field:

(i) Potential energy of a single charge:

$$\boldsymbol{U = qV}$$

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

$$\boldsymbol{U = q_A V_A + q_B V_B + \frac{1}{4\,\pi\varepsilon_0}\frac{q_A q_B}{r_{ab}}}$$

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

$$\boldsymbol{U = -\,pE\cos\theta = -\,\vec{p}\cdot\vec{E}}$$

Maximum and minimum values of potential energy:

(i) Potential energy is minimum when $\theta = 0$, $U_{min} = -pE$

(ii) Potential energy is maximum when , $\theta = 180^0$ $U_{max} = +pE$

Electrostatic Shielding: Electrostatic shielding is the phenomenon of protecting a certain region of space or objects from the influence of external electric field and charges.

Use: This effect of electrostatic shielding can be used in *protecting sensitive instrument from outside electrical influence.*

Dielectrics: Dielectrics are non-conducting substances and they have no charge carriers

Non-polar dielectrics: Non–polar dielectrics are those in which the centre of positive charge coincides with the centre of negative charge in the molecule.

Ex : Hydrogen (H_2). Oxygen (CO_2), Carbon dioxide (CO_2)

Polar dielectrics: Polar dielectrics are those in which the centre of the positive charge and centre of the negative charge do not coincide in the molecule.
Ex: Water (H_2O), CO and HCl.

Capacitor: A capacitor is a system of two conductors separated by an insulator.

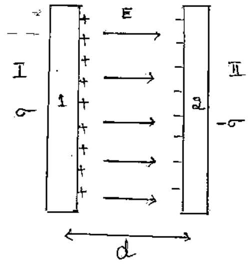
Capacitance: The capacitance of a capacitor is defined as the ratio of the charge Q on either conductor to the potential difference V between the conductors.
SI unit is $farad\ (F)$.

$$\boldsymbol{C = \frac{Q}{V}}$$

Factors on which capacitance depends: The capacitance C depends on the *shape*, *size* and *separation of the system of two conductors* and on the *nature of the dielectric*.

The parallel plate capacitor: A parallel plate capacitor consists of two large conducting plates held parallel to each other and separated by a small distance.

Expression for Capacitance of a parallel plate capacitor:



Let the two plates have charges Q and $-Q$.

Plate 1 has surface charge density, $\sigma = \frac{Q}{A}$

Plate 2 has surface charge density, $-\sigma = \frac{-Q}{A}$

In outer region I $E = \frac{\sigma}{2\varepsilon_0} - \frac{\sigma}{2\varepsilon_0} = 0$

In outer region II $E = \frac{\sigma}{2\varepsilon_0} - \frac{\sigma}{2\varepsilon_0} = 0$

In the inner region, $E = \frac{\sigma}{2\varepsilon_0} + \frac{\sigma}{2\varepsilon_0} = \frac{2\sigma}{2\varepsilon_0} = \frac{\sigma}{\varepsilon_0}$

We have, $V = E\, d$

$$V = \left(\frac{\sigma}{\varepsilon_0}\right) d$$

The capacitance of the parallel plate capacitor is, $C = \frac{Q}{V} = \frac{\sigma A}{\left(\frac{\sigma}{\varepsilon_0}\right) d}$

$$\boldsymbol{C = \frac{\varepsilon_0 A}{d}}$$

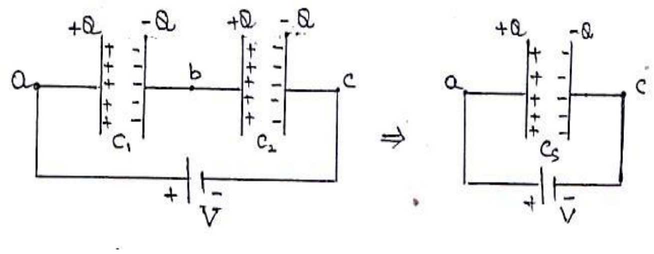
Note: (1) The capacitance of a parallel plate capacitor with air between the plates is,
(i) directly proportional to the area of each plate and
(ii) inversely proportional to the distance between the plates.
(2) The capacitance of a parallel plate capacitor depends on *area of each plate* and *distance between the plates.*

Effect of dielectric on capacitance:
When the dielectric is inserted fully between the plates of the capacitor, the *capacitance of the capacitor increases* from its vacuum value.

Equivalent Capacitance: It is the total Capacitance of the system of capacitors in the combination.

Capacitors in series:

Expression for equivalent capacitance:



When capacitors are connected in series,

$$Q_1 = Q_2 = Q$$
$$V = V_1 + V_2$$

Potential difference across C_1 is, $V_{ab} = V_1 = \frac{Q}{C_1}$

Potential difference across C_2 is, $V_{bc} = V_2 = \frac{Q}{C_2}$

Total voltage, $V = V_1 + V_2$

$$V = \frac{Q}{C_1} + \frac{Q}{C_2}$$
$$V = Q\left(\frac{1}{C_1} + \frac{1}{C_2}\right)$$
$$\frac{V}{Q} = \frac{1}{C_1} + \frac{1}{C_2}$$

If C_s is the equivalent capacitance of the series combination, $C_s = \frac{Q}{V}$

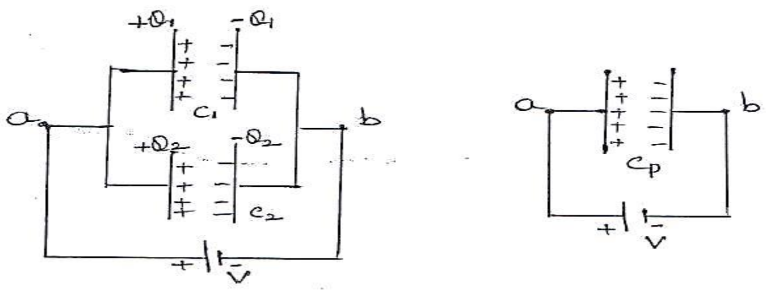
$$\frac{V}{Q} = \frac{1}{C_S}$$

Hence $\boldsymbol{\frac{1}{C_S} = \frac{1}{C_1} + \frac{1}{C_2}}$

In general for any number of capacitors in series, $\boldsymbol{\frac{1}{C_S} = \frac{1}{C_1} + \frac{1}{C_2} + \ldots\ldots\ldots + \frac{1}{C_n}}$

Capacitors in parallel:

Expression for equivalent capacitance:



When capacitors are connected in parallel,

$$V_1 = V_2 = V$$
$$Q = Q_1 + Q_2$$

Charge stored by the capacitor C_1 is, $Q_1 = C_1 V$

Charge stored by the capacitor C_2 is, $Q_2 = C_2 V$

Total charge stored is, $Q = Q_1 + Q_2$

$$Q = C_1 V + C_2 V$$
$$Q = V(C_1 + C_2)$$
$$\frac{Q}{V} = C_1 + C_2$$

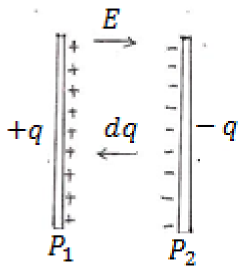
If C_p is the equivalent capacitance of the parallel combination, then

$$C_p = \frac{Q}{V}$$

Hence, $\boldsymbol{C_p = C_1 + C_2}$

In general, for any number of capacitors in parallel, $\boldsymbol{C_p = C_1 + C_2 + C_3 + \ldots\ldots + C_n}$

Expression for energy stored in in a capacitor:



The potential difference between the plates V' is given by, $V' = \frac{q}{C}$

The work done in transferring a small charge dq from P_2 to P_1 is,

$$dW = V'\,dq = \frac{q}{C}\,dq$$

Total work done in charging the capacitor from zero to Q is,

$$W = \int dW = \int_0^Q \frac{q}{C}\,dq = \frac{1}{C}\int_0^Q q\,dq$$

$$W = \frac{1}{C}\left[\frac{q^2}{2}\right]_0^Q = \frac{1}{C}\left(\frac{Q^2}{2}\right) = \frac{Q^2}{2C}$$

This work done is stored as Potential Energy , $U = \frac{Q^2}{2C}$

Chapter – 3 **CURRENT ELECTRICITY**

Electric current: Electric Current is the net charge passing per unit time through the area.

$$I = \frac{dQ}{dt}$$

SI unit of current is *ampere* (*A*

Electric current in conductors:

In solid conductors such as metals valence or free electrons are the current carriers.

In liquid conductors the current carriers are *positively and negatively charged ions*.

In gaseous conductors the current carriers are *positive ions and electrons*.

Ohm's law: The Electric current *I* through a conductor is directly proportional to the potential difference *V* across the ends of the conductor provided the temperature remain constant.

Explanation: $V \propto I$

$$\frac{V}{I} = \text{Constant}$$

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

$$\boldsymbol{V = I\,R}$$

The Constant of proportionality *R* is called electrical Resistance of the conductor.

Electrical resistance(R): It is defined as the ratio of the potential difference *V* across the ends of the conductor to the electrical current *I* through it.

The SI unit of resistance is *ohm*(Ω).

ohm: The resistance of a conductor is one ohm if one ampere current flows through it when the potential difference across its ends is one volt.

Factors affecting resistance of a conductor: The resistance R of a conductor of material varies,

(i) Directly proportional to its length, *l*

(ii) Inversely proportional to its area of cross section, *A*

(iii) Directly proportional to the temperature, provided temperature change is small.

Current density: The electrical current per unit area taken normal to the direction of the current is known as current density, and is denoted by ***j***.

$$\boldsymbol{j = \frac{I}{A}}$$

Current density *(j)* is a vector quantity and its SI unit is *ampere per square metre* (Am^{-2}).

Ohm's law in vector form

(Relation between current density and conductivity of a conductor)

If *E* is the magnitude of the uniform electric field in the conductor whose length is *l* and *V* is the potential difference across its ends then,

$$V = E\,l$$

But we have $V = \frac{I\,\rho\,l}{A}$

$$El = \frac{I\,\rho\,l}{A}$$

$$E = \rho\left(\frac{I}{A}\right)$$

$$E = \rho\, j$$

Since the direction of E and j are same, $\vec{E} = \rho\,\vec{j}$

$$\vec{j} = \frac{1}{\rho}\,\vec{E}$$

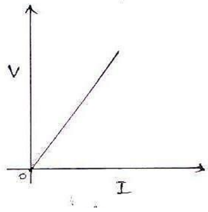
$$\boldsymbol{\vec{j} = \sigma\,\vec{E}}$$

This is the vector form of ohm's law.

Ohmic device: Device which obey ohm's law and in which current varies linearly with voltage are called an Ohmic device.

V-I graph is linear for those devices as shown in figure.

Ex: Voltmeter, ammeter, metallic conductors.

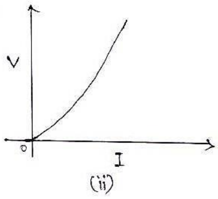


Non-ohmic device: The devices which do not obey ohms law are called non-ohmic devices.

V-I graph is non-linear for those devices as shown in figure.

Ex: Diodes, transistors, LED etc.

The V-I graph for Diode, transistor and Ga-As materials are non-linear, these devices are non-ohmic which do not obey Ohm's law.



Limitations of Ohm's law:

Ohm's law **cannot** be applied,

(i) to devices where the relation between V and I is not unique.
Ex: Ga-As material used in LED.

(ii) to devices such as diodes and transistors.
The relation between V and I depends on the sign of V as shown in the graph.

(iii) to conductors maintained at very high temperatures or very low temperatures.

(iv) to conductors across which very high pd or very low pd is applied.

(v) to electrolytic conductors and sources of emf's.

Drift velocity: The average velocity with which free electrons get drifted towards the positive end of a conductor under the influence of an external electric field.

Expression for drift velocity:

If we consider all the electrons, their average velocity will be zero.

If there are N electrons, $\frac{\sum_{i=1}^{n} \vec{v}_i}{N} = 0$

When an electric field is applied, electrons will be accelerated and is given by,

$$\vec{a} = \frac{F}{m} = \frac{-e\,\vec{E}}{m}$$ where $-\,e$ is the charge on electron and mass is m.

At any given time, the velocity of i^{th} electron is, $\vec{V}_i = \vec{v}_i + \vec{a}\,t_i$

The average velocity of all electrons is the drift velocity, $\vec{v_d} = \frac{\sum \vec{V}_i}{N}$

$$\vec{v_d} = \frac{\sum \vec{V}_i}{N} = \frac{\sum \vec{v}_i}{N} + \frac{\sum \vec{a} t_i}{N}$$

$$\vec{v_d} = \frac{\sum \vec{v}_i}{N} + \vec{a}\,\frac{\sum t_i}{N}$$

But $\frac{\sum \vec{v}_i}{N} = 0,$

$$\vec{v}_d = 0 + \vec{a}\,\tau$$

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

Hence the magnitude of drift velocity is, $v_d = \frac{e\,E}{m}\tau$

Mobility: Mobility (μ) is defined as the magnitude of drift velocity per unit electric field.

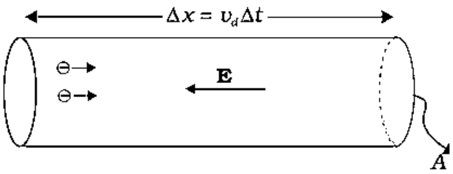
$\mu = \frac{e\,\tau}{m}$ $\qquad$ $S.I$ unit of mobility is $m^2\,/\,Vs$

Relation between current and drift velocity (Expression for conductivity):

Consider a metallic conductor of length l and uniform Cross-sectional area A.

Let n be the number of free electron per unit volume in the metal.

The free electrons drift with a drift velocity v_d.



The distance travelled by the free electrons $= v_d\Delta t$

The volume of the conductor is $= Av_d\Delta t$

Total charge transported = $-enAv_d\Delta t$

The amount of charge transported ***in the direction*** of the electric field is, $\Delta Q = enAv_d\Delta t$

$$\frac{\Delta Q}{\Delta t} = enAv_d$$

$$I = enAv_d$$

This is the relation between current and drift velocity.

Further $\quad \frac{I}{A} = env_d$

$$j = env_d$$

$$j = e\,n\left(\frac{e\,E}{m}\tau\right)$$

$$j = \frac{n\,e^2}{m}\tau\,E$$

But we have, $j = \sigma E,$ where σ is the conductivity of the material.

Comparing both the equations we get, $\sigma = \frac{ne^2}{m}\tau$

This is the expression for conductivity.

Resistivity is given by, $\quad \rho = \frac{1}{\sigma} = \frac{m}{ne^2\,\tau}$

$\rho = \frac{m}{ne^2\,\tau}$ $\qquad$ This is the expression for resistivity.

Resistivity of various materials:

Resistivity: Resistance per unit length of the conductor having unit area of cross section.

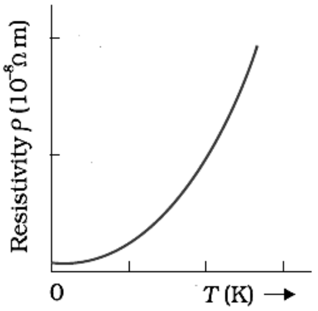
It's SI unit is Ω m.

Temperature dependence of resistivity:

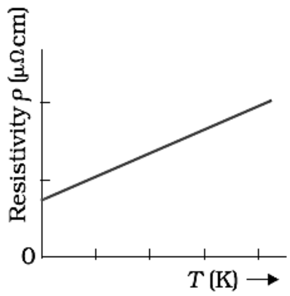
$$\alpha = \frac{R - R_0}{R_0(T - T_0)}$$

S.I unit of α is K^{-1}. For metals α is positive and for semiconductors it is negative.

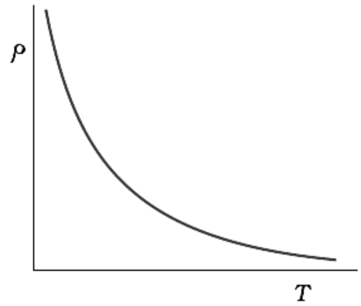
The variation of resistivity with temperature is indicated by graph as shown below.



Resistivity of copper (Metals)



Resistivity of Alloys

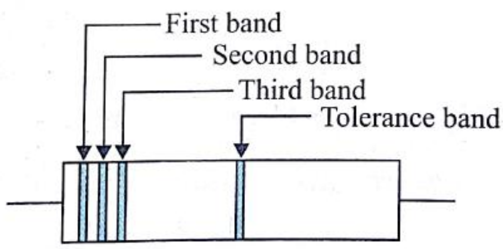


Resistivity of Semiconductors

Resistors: A resistor is a device, which offers electrical resistance to the flow of current through it. Materials whose resistivity has very small dependence on temperature are used to make resistors.

Colour code for resistors: Carbon resistors are small in size; their values are given in colour code. These resistors have a set of co-axial coloured rings on them.

- The first and the second bands indicate the first and the second significant digits.
- The third band indicates the multiplier.
- The last band stands for tolerance or the possible variation in percentage about the indicated values.
- Sometimes, the last band is absent. Then tolerance is 20%.



Colour	Number	Multiplier	Tolerance (%)
Black	0	1 or 10^0	
Brown	1	10^1	
Red	2	10^2	
Orange	3	10^3	
Yellow	4	10^4	
Green	5	10^5	
Blue	6	10^6	
Violet	7	10^7	
Gray	8	10^8	
White	9	10^9	
Gold		10^{-1}	5
Silver		10^{-2}	10

Note : *Memory tip : **B.B ROY** of **G**reat **B**ritain had a **V**ery **G**ood **W**ife.* The letters in bold indicate the first letters of the colours in the sequence 0, 1, 2, 3, 4, 5, 6, 7, 8 and 9.

Combination of resistors: Resistor can be combined in series, parallel or in a mixed fashion to obtain the desired values of resistance.

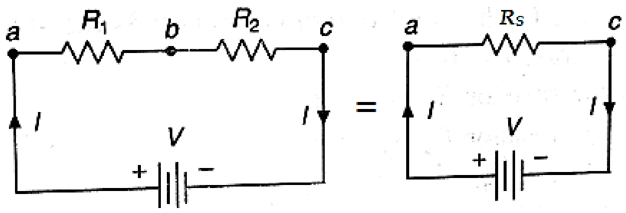
Equivalent resistance: The resistance of a single resistor which is same as that of the resistance of the combination (series/parallel) is called equivalent resistance *or*
It is the total (effective) resistance produced by the combination of resistors.

Resistors in series: A number of resistors are said to be in series if they are connected end to end such that same current flows through each of them.

Expression for effective resistance of two resistors connected in Series:
When resistors connected in series,

$I_1 = I_2 = I$

$V = V_1 + V_2$



Potential drop across R_1 is, $V_1 = I R_1$
Potential drop across R_2 is, $V_2 = I R_2$
Potential across the combination $V = V_1 + V_2$

$V = I R_1 + I R_2$

$V = I (R_1 + R_2)$

$$\frac{V}{I} = R_1 + R_2$$

If R_S is the equivalent resistance of the series combination, then $V = I R_S$

$$R_s = \frac{V}{I}$$

$\mathbf{R_S = R_1 + R_2}$

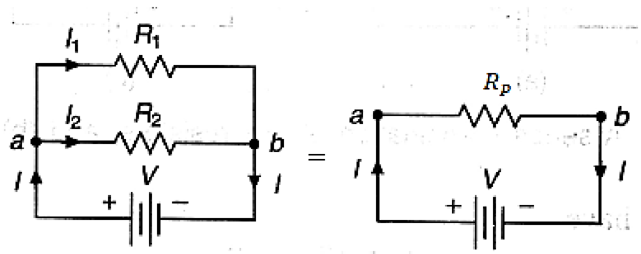
In general, for any number of resistors in series, $R_S = R_1 + R_2 + R_3 + \ldots\ldots\ldots\ldots + R_n$

Resistors in parallel: A number of resistors are said to be in parallel if they are connected between two common points such that the potential difference remains same across each resistor.

Expression for effective resistance of two resistors connected in Parallel:
When Resistors are connected in Parallel

$V_1 = V_2 = V$

$I = I_1 + I_2$



Current through R_1 is, $I_1 = \dfrac{V}{R_1}$

Current through R_2 is, $I_2 = \dfrac{V}{R_2}$

Total Current, $I = I_1 + I_2$

$$I = \frac{V}{R_1} + \frac{V}{R_2}$$

$$I = V\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$$

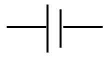
$$\frac{I}{V} = \frac{1}{R_1} + \frac{1}{R_2}$$

If R_P is the equivalent resistance of the parallel combination, then, $V = I R_P$

$$\frac{I}{V} = \frac{1}{R_P}$$

Hence, $\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2}$

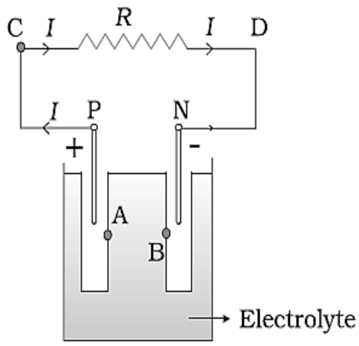
In general for any number of resistors in parallel, $\frac{I}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots\dots\dots\dots\dots + \frac{1}{R_n}$

Cell: A Cell is a device which provides the necessary potential difference to an electric circuit to maintain a continuous flow of current in it.The Pictorial symbol of a cell is 

Electromotive force (emf): Potential difference between its terminals when no current is drawn from the cell. S.I unit of emf is *Volt (V)*

Internal resistance: The resistance of the electrolyte of the cell and SI unit is *ohm(Ω)*.

Current in a simple circuit (Current drawn by external resistor):



Consider a simple circuit in which a resistance R is connected to a cell of emf ε and internal resistance r.
If R has a finite value, a steady current I flows in the circuit.
If V is the potential difference across P and N of the cell, then,
V = P.d between P and A + P.d between A and B + P.d between B and N

$V = V_+ - Ir + V_-$

$V = V_+ + V_- - Ir$

$\boldsymbol{V = \varepsilon - Ir}$

But we have $V = I\,R$

$\therefore IR = \varepsilon - Ir$

$IR + Ir = \varepsilon$

$$\boldsymbol{I = \frac{\varepsilon}{R + r}}$$

This is the expression for current in circuit.

For $R = 0$ (short circuit). I is maximum, $\boldsymbol{I_{max} = \frac{\varepsilon}{r}}$

Now $V = I\,R$

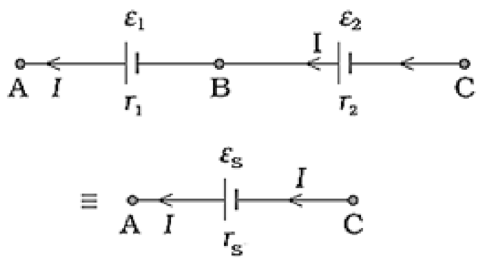
$\boldsymbol{V = \left(\frac{\varepsilon}{R + r}\right) R}$ Since r is not zero. V is always less than ε. V is called terminal potential difference

Terminal potential difference: The Potential difference across the terminals of a cell when the cell is in a closed circuit or when a current flows through the circuit.

Grouping of cells:

Cells in series: Cells are said to be connected in series if they are connected end to end such that the same current flows through each cell.

Expression for effective emf and effective internal resistance of two cells connected in Series:



Let ε_1, ε_2 be the emfs of two cells and r_1, r_2 be their internal resistances respectively.
The cells be sending a current I as shown in the figure.
V_A, V_B and V_C be their potentials at A, B and C respectively.

P.d between A and B is $V_{AB} = \varepsilon_1 - Ir_1$

P.d between B and C is $V_{BC} = \varepsilon_2 - Ir_2$

The P.d between A and C is , $V_{AC} = V_{AB} + V_{BC}$

$$V_{AC} = \varepsilon_1 - Ir_1 + \varepsilon_2 - Ir_2$$

$$V_{AC} = (\varepsilon_1 + \varepsilon_2) - I(r_1 + r_2)$$

But we have, $V_{AC} = \varepsilon_S - Ir_S$

Comparing the eqns. we get, $\varepsilon_S = \varepsilon_1 + \varepsilon_2$

and $r_S = r_1 + r_2$

In general, $\varepsilon_S = \varepsilon_1 + \varepsilon_2 + \varepsilon_3 + \dots\dots\dots + \varepsilon_n$ $\quad r_S = r_1 + r_2 + r_3 + \dots\dots\dots\dots\dots + r_n$

Cells in parallel: Cells are said to be connected in parallel if positive terminals of all the cells are connected together at one point and negative terminals of all cells are connected together at another point.

Expression for effective emf and effective internal resistance of two cells connected in parallel:

Let ε_1 and ε_2 be the emfs of the two cells connected in parallel.

Let r_1, r_2 be their internal resistances respectively.

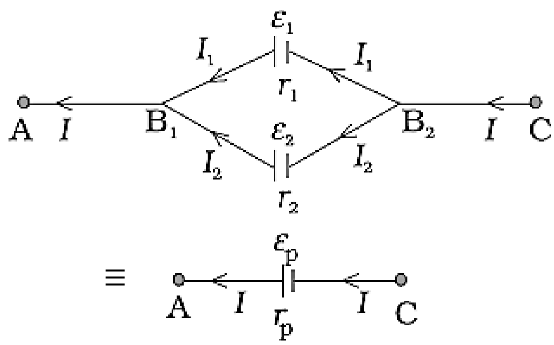
I_1 and I_2 are the currents leaving the positive electrodes of the cells.

We have $I = I_1 + I_2$

P.d across the first cell is $V_1 - V_2 = V = \varepsilon_1 - I_1 r_1$

P.d across the second cell is also $V_1 - V_2 = V = \varepsilon_2 - I_2 r_2$

Hence $I_1 = \dfrac{\varepsilon_1 - V}{r_1}$ and $I_2 = \dfrac{\varepsilon_2 - V}{r_2}$



$$I = I_1 + I_2 = \frac{\varepsilon_1 - V}{r_1} + \frac{\varepsilon_2 - V}{r_2}$$

$$I = \frac{\varepsilon_1}{r_1} - \frac{V}{r_1} + \frac{\varepsilon_2}{r_2} - \frac{V}{r_2}$$

$$I = \left(\frac{\varepsilon_1}{r_1} + \frac{\varepsilon_2}{r_2}\right) - V\left(\frac{1}{r_1} + \frac{1}{r_2}\right)$$

$$I = \frac{\varepsilon_1 r_2 + \varepsilon_2 r_1}{r_1 r_2} - V\left(\frac{r_1 + r_2}{r_1 r_2}\right)$$

$$V\left(\frac{r_1 + r_2}{r_1 r_2}\right) = \frac{\varepsilon_1 r_2 + \varepsilon_2 r_1}{r_1 r_2} - I$$

$$V(r_1 + r_2) = \varepsilon_1 r_2 + \varepsilon_2 r_1 - I r_1 r_2$$

$$V = \frac{\varepsilon_1 r_2 + \varepsilon_2 r_1}{r_1 + r_2} - I\left(\frac{r_1 r_2}{r_1 + r_2}\right)$$

We have, $V = \varepsilon_P - I\, r_P$

Comparing the above equations,

$$\varepsilon_p = \frac{\varepsilon_1 r_2 + \varepsilon_2 r_1}{r_1 + r_2} \quad \text{and} \quad r_P = \frac{r_1 r_2}{r_1 + r_2} \quad \text{or} \quad \frac{1}{r_P} = \frac{1}{r_1} + \frac{1}{r_2}$$

Kirchhoff's 1st law (Current law or Junction rule): At any Junction, the sum of the currents entering the Junction is equal to the sum of currents leaving the Junction.

The first law is simply the expression of conservation of charge.

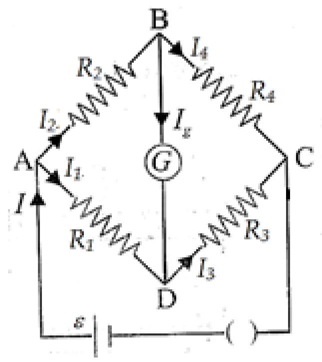
Kirchhoff's Second law (Voltage law or Loop rule):

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

The second law is a statement of conservation of energy.

Wheatstone bridge: Wheatstone bridge or Wheatstone network is used to find the ratio of two resistance values or to determine the value of an unknown resistance.

Expression for balancing condition:



Using Kirchhoff's first law,

(i) At node B, $I_2 = I_g + I_4$ -----(1)

(ii) At node D, $I_1 + I_g = I_3$ -----(2)

Applying Kirchhoff's second law to the

(i) Mesh $ABDA$, $-I_2R_2 - I_gG + I_1R_1 = 0$ ----(3)

(ii) Mesh $BCDB$, $-I_4R_4 + I_3R_3 + I_gG = 0$ ----(4)

When the network is balanced the current through the galvanometer is zero. i.e. $I_g = 0$

Substituting for I_g in eqn.(1), (2), (3) and (4) we get

$I_2 = I_4$

$I_1 = I_3$

$-I_2R_2 + I_1R_1 = 0$ or $I_1R_1 = I_2R_2$ ----(5)

$-I_4R_4 + I_3R_3 = 0$ or $I_3R_3 = I_4R_4$ -----(6)

Taking equation (5) ÷ equation (6)

$$\frac{I_1R_1}{I_3R_3} = \frac{I_2R_2}{I_4R_4}$$

As $I_2 = I_4$ and $I_1 = I_3$ we get

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

Meter Bridge: It is an instrument that works on the principle of balancing Wheatstone bridge. It is used to determine the value of unknown Resistance.

Potentiometer: A Potentiometer is a device that can be used to measure the emf of a source (say a cell) without drawing any current from the source.

Principle: It works on the principle that potential difference across any part of a uniform wire is directly proportional to the length of the portion, when a constant current flows through the wire.

Practical applications /uses of Potentiometer :

(i) It is used to compare the emf's of two primary cells and

(ii) It is used to determine the internal resistance of a cell.

Chapter – 4 **MOVING CHARGES AND MAGNETISM**

Magnetic force on a moving charge:

Force given by, $\vec{F}_m = q(\vec{v} \times \vec{B})$.

The magnitude of this force is given by, $F_m = qvBsin\theta$

Magnetic field: The force acting on a unit positive charge moving with a unit velocity perpendicular to the direction of magnetic field.

S I unit of magnetic field is **tesla**(T).

tesla: The magnetic field at a point is one tesla if a unit positive charge moving with a velocity of $1ms^{-1}$ perpendicular to the magnetic field experiences a force of 1N.

Lorentz Force: When a charged particle having charge q moves with a velocity $\vec{v}$ in the presence of both electric field ($\vec{E}$) and magnetic field ($\vec{B}$) it experiences a net force called Lorentz Force ($\vec{F}$).

Thus Lorentz force $\vec{F} = q\vec{E} + q(\vec{v} \times \vec{B})$

$$\vec{F} = q[\vec{E} + (\vec{v} \times \vec{B})]$$

Magnetic force on a current carrying Conductor:

Consider a conductor of length l carrying a current I placed in a uniform magnetic field $\vec{B}$.

Let n be the number of charge carriers per unit volume and

Let A be the area of cross-section of the conductor.

In length l number of charge carriers = n × volume of the element = nAl

If q is the charge on each carrier, total charge = $qnAl$

Let $\vec{v}_d$ be the drift velocity of the charge carrier.

Magnetic Lorentz force acting is $\vec{F}_m = q(nAl)(\vec{v}_d \times \vec{B})$

$$\vec{F}_m = q(nAl\vec{v}_d) \times \vec{B}$$

$$\vec{F}_m = q(nA\vec{v}_d l) \times \vec{B}$$

But, $q(nA\vec{v}_d) = I$

$$\vec{F}_m = I(\vec{l} \times \vec{B})$$

Magnitude of $\vec{F}_m$ is $F_m = BIl\ sin\theta$ where θ is the angle between $\vec{l}$ and $\vec{B}$

Special cases:

(1) If $\theta = 0^0$ or $\theta = 180^0$, $\vec{F}_m = 0$, because $\sin\theta = 0$, It means the conductor experiences no force when placed parallel or anti-parallel to the direction of the magnetic field.

(2) If $\theta = 90^0$, $F_m = BIl$, the conductor experiences a maximum force when the conductor is placed at right angles to the magnetic field.

Motion in a magnetic field

Path of the moving charge:

This force is always perpendicular to the direction of motion of the particle as well as the magnetic field thus the *path of the charged particle is Circular*.

Radius of the path:

Radius of the circular path, $r = \dfrac{mv}{qB}$

Time period: Time period of the charged particle to complete a circle is given by,

$$T = \frac{2\,\pi\,m}{q\,B}$$

If the velocity $\vec{v}$ of the particle makes an arbitrary angle ($\theta \neq 90^0$) with the magnetic field $\vec{B}$.
Due to the combined effect of two components of velocity, the path of the particle in space is *helix or spiral*.

Motion in Combined Electric and magnetic field:
Crossed fields: Mutually perpendicular electric and magnetic fields are called crossed fields.

Velocity Selector: It is a setup to select charged particles of a particular velocity from a beam passed through a space having crossed fields.

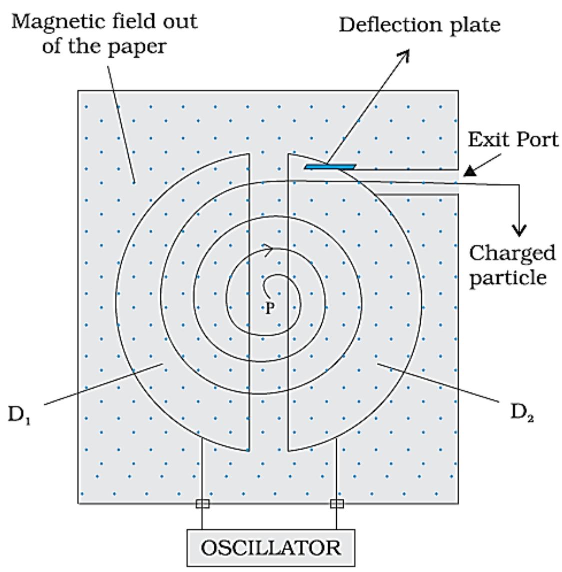
Expression for velocity of charged particle in velocity selector:

$$v = \frac{E}{B}$$

Uses of velocity selector:
(i) This method is used to measure specific charge (e/m)
(ii) Mass spectroscope works on the principle of velocity selector. It is a device used to separate ions according to their charge to mass ratio.

Cyclotron: Cyclotron is a machine to accelerate (positively) charged ions or particles to high energies. It was invented by Lawrence and Livingston in 1934 to investigate nuclear structure.

Principle: (1) When a positively charged particle is made to move in both electric and magnetic fields which are perpendicular to each other, the magnetic field makes the charged particles to move along circular paths and the electric field accelerates the charged particles.



(2) Cyclotron uses the fact that the frequency of revolution of the charged particle in a magnetic field is independent of its energy.

(3) The operation of the cyclotron is based on the fact that the time for one revolution of an ion is independent of its speed or radius of its orbit.

Cyclotron frequency

$$\nu_C = \frac{qB}{2\pi m}$$

The maximum energy E_{max} attained by the ion depends on the radius R of the dees:

$$E_{max} = \frac{1}{2}\frac{B^2R^2q^2}{m}$$

Application of Cyclotron: Accelerate positively charged ions or particles like protons, deuterons alpha particles etc.

Uses of a Cyclotron:

1) It is used to produce radioactive material for medical purpose ex : for the purpose of diagnostics and treatment of chronic disease.
2) It is used to synthesize fresh materials.
3) It is used to improve the quality of solids by adding ions.
4) It is used to bombard the atomic nuclei with highly accelerated particles to study the nuclear reactions.

Limitations of Cyclotron:

1) Cyclotron cannot accelerate uncharged particles like neutrons.
2) Cyclotron cannot accelerate electrons because they have very small mass.

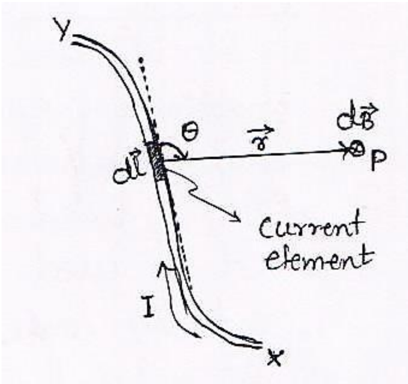
Biot–Savart's Law: The magnitude of the magnetic field $d\vec{B}$ is

(i) Proportional to current I

(ii) Proportional to the length dl of the current element.

(iii) Proportional to $\sin\theta$, where θ is the angle between $\vec{r}$ and $d\vec{l}$ and

(iv) Inversely proportional to the square of the distance r of the point P from the current element.



Explanation:

$$dB \propto \frac{I\,dl\,sin\theta}{r^2}$$

$$dB = k\frac{I\,dl\,sin\theta}{r^2}$$ where k is a constant of proportionality.

In SI units, $k = (\mu_0/4\pi)$

Hence $$\boldsymbol{dB = \frac{\mu_0}{4\pi}\frac{I\,dl\sin\theta}{r^2}}$$

Biot–Savart's Law in Vector form: If we consider length of element as $d\vec{l}$, distance of P as displacement vector $\vec{r}$ and unit vector as $\hat{r}$ then,

$$d\vec{B} = \frac{\mu_0}{4\pi}\frac{I\,d\vec{l}\times\hat{r}}{r^2} \qquad (\because\ d\vec{l}\times\hat{r} = dlsin\theta)$$

Now, $$\hat{r} = \frac{\vec{r}}{|\vec{r}|} = \frac{\vec{r}}{r}$$

$$\boldsymbol{d\vec{B} = \frac{\mu_0}{4\pi}\frac{I\,(d\vec{l}\times\vec{r})}{r^3}}$$

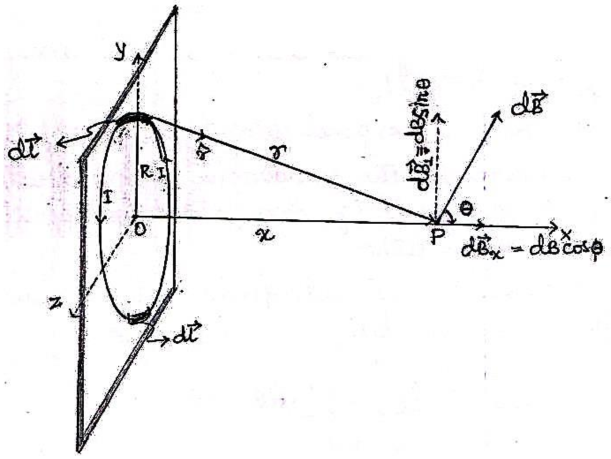
Magnetic field at a point on the axis of a Circular Current loop:

Consider a circular loop in the $Y - Z$ Plane with its center at the origin O.

Let R be the radius of the loop.

Let I is the steady current through the loop in anti-clock wise direction.

Consider a point P on the axis of the loop coinciding with $X - axis$ at a distance x from O.



The magnitude of magnetic field at P due to current element dl is given by,

$$dB = \frac{\mu_0}{4\pi}\frac{I\,dl\sin\theta}{r^2}$$

The element $d\vec{l}$ is in $Y-Z$ plane. Unit vector $\hat{r}$ is in the x-y plane, Hence $sin90^0 = 1$

$$dB = \frac{\mu_0}{4\pi}\frac{I\,dl}{r^2}$$

The direction of dB is perpendicular to the plane formed by $d\vec{l}$ and $\vec{r}$

Resolving dB into two components,

(i) $dB\,cos\theta$ which along the axis of the coil away from the centre of the coil.

(ii) $dB\,sin\theta$ which is perpendicular to the axis of the coil.

By symmetry, the components perpendicular to x-axis cancel each other.

The net field at P is along x-axis it is given by,

$$B = \sum dB_x = \sum dB\,cos\theta$$

$$B = \sum \frac{\mu_0}{4\pi}\frac{I\,dl}{r^2}\,cos\theta$$

$$B = \frac{\mu_0}{4\pi}\frac{I\,cos\theta}{r^2}\sum dl$$

$$B = \frac{\mu_0}{4\pi}\frac{I\,cos\theta}{r^2}\,2\pi R \qquad \left(\sum dl = 2\pi R\right)$$

$$B = \frac{\mu_0}{4\pi}\frac{I}{r^2}\frac{R}{r}\,2\pi R \qquad \left(cos\theta = \frac{R}{r}\right)$$

$$B = \frac{\mu_0}{4\pi}\frac{2\pi\,IR^2}{r^3}$$

But $r = (x^2+R^2)^{\frac{1}{2}}, \quad r^3 = (x^2+R^2)^{\frac{3}{2}}$

$$B = \frac{\mu_0}{4\pi}\frac{2\,\pi I\,R^2}{(x^2+R^2)^{\frac{3}{2}}}$$

$$\boldsymbol{\vec{B} = \frac{\mu_0}{4\pi}\frac{2\pi\,I\,R^2}{(x^2+R^2)^{\frac{3}{2}}}\,\hat{\imath}}$$

where $\hat{\imath}$ is the unit vector along x − axis

Note: At the centre of the loop $x = 0$, $\therefore\ B_0 = \frac{\mu_0}{4\pi}\frac{2\pi\,I\,R^2}{(R^2)^{\frac{3}{2}}} = \frac{\mu_0}{4\pi}\frac{2\pi\,I\,R^2}{R^3}$

$$\boldsymbol{B_0 = \frac{\mu_0}{4\pi}\frac{2\pi I}{R}}$$

Ampere's Circuital law: The line integral of $\vec{B}\cdot d\vec{l}$ around any closed path enclosing a surface is μ_0 times the total steady current passing through the surface.

$$\oint \vec{B}.d\vec{l} = \mu_0 I$$

where I is the total steady current passing through the surface bounded by the closed path and μ_0 is permeability of free space.

Magnetic field due to straight conductor of infinite length carrying current:

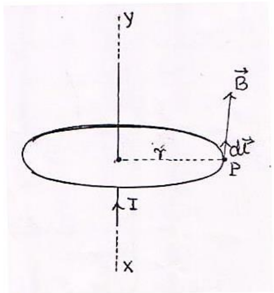
Consider a straight conductor of infinite length.

Let I be the current through it from X to Y.

Let P be a point at a perpendicular distance r from the straight wire.

Consider a circle of radius r around the wire passing through P as an *amperian loop.*

$\oint \vec{B}\cdot d\vec{l} = \oint B\, dl \cos 0 = B \oint dl = B(2\pi r)$



According to Ampere's circuital law, $\oint \vec{B}\cdot d\vec{l} = \mu_0 I$

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

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

$$\boldsymbol{B = \frac{\mu_0}{4\pi}\frac{2\,I}{r}}$$

The Solenoid: A Solenoid consists of a long insulated wire wound in the form of a helix where the neighboring turns are closely spaced.

Magnetic field inside an ideal solenoid: $\boldsymbol{B = \mu_0\, n\, I}$

Toroid: The toroid is a hollow circular ring on which a large number of turns of a wire are closely wound.

Magnetic field due to a Toroid: $\boldsymbol{B = \mu_0 n I}$

or $\quad \boldsymbol{B = \frac{\mu_0 N\, I}{2\pi r}}$

Force between two parallel conductors carrying current:

Consider two long parallel conductors a and b separated by a distance d.

Let I_a and I_b be current passing through conductors a and b respectively.

The magnetic field B_a due to conductor a at the site of the conductor b is given by,

$$B_a = \frac{\mu_0\, I_a}{2\pi d}$$

The direction of B_a is perpendicular to the plane containing the conductors and into it.

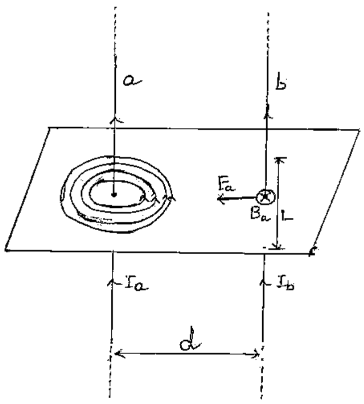
The force on a length L of the conductor b is given by,

$$F_a = B_a I_b L\, sin\theta$$

$$F_a = B_a I_b L \qquad (\because \sin 90^0 = 1)$$

$$F_a = \left(\frac{\mu_0\, I_a}{2\pi d}\right) I_b L$$

$$\boldsymbol{F_a = \left(\frac{\mu_0\, I_a\, I_b}{2\pi d}\right) L}$$



According to Fleming's left hand rule, the direction of force F on b is towards the conductor a.

Force per unit length of conductor b is, $\quad f_a = \frac{F_a}{L}$

$$\boldsymbol{f_a = \frac{\mu_0\, I_a\, I_b}{2\pi d}}$$

Conclusion: Hence we conclude that, two long parallel conductors carrying currents in the ***same*** direction ***attract*** each other.
Similarly, it can also be shown that two long parallel conductors carrying currents in the ***opposite*** direction ***repel*** each other.

Definition of Ampere: **O**ne ampere is that constant current which, when maintained in each of the two infinitely long straight parallel conductors of negligible cross-section, placed 1m apart in vacuum, will cause each conductor to experience a force equal to 2×10^{-7} Newton per meter.

Torque on a rectangular current loop in a uniform magnetic field:

$$\vec{\boldsymbol{\tau}} = \boldsymbol{I}\,\vec{\boldsymbol{A}} \times \vec{\boldsymbol{B}}$$

$$\vec{\boldsymbol{\tau}} = \vec{\boldsymbol{m}} \times \vec{\boldsymbol{B}}$$

Magnetic moment: The quantity $I\vec{A}$ is defined as magnetic moment of the loop, denoted by $\vec{m}$.

Thus, $\vec{m} = I\vec{A}$

It is a vector, its direction is that of $\vec{A}$. The S I unit of $\vec{m}$ is Am^2

Maximum and minimum values of Torque:

(1) Torque on the loop is maximum when $\theta = 90^0$ $\hat{\tau} = mBsin\theta \Rightarrow \hat{\tau} = mB$

(2) The loop will be in equilibrium when for stable equilibrium $\theta = 0^0$ and for unstable equilibrium $\theta = 180^0$

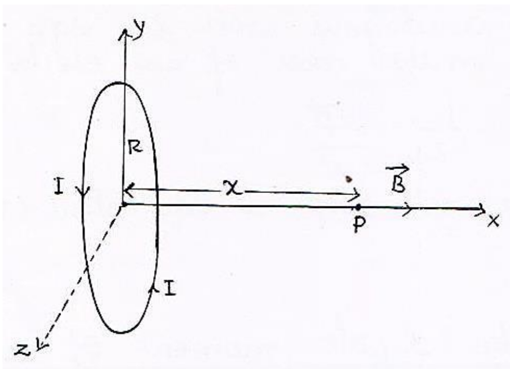
(3) If the coil has N turns then $\vec{m} = NI\vec{A}$, where $\vec{A}$ is mean area.

Circular current loop as a magnetic dipole:

Consider a circular current loop of Radius R carrying a current I.
The magnitude of magnetic field at a distance x on the axis of the loop is given by,

$$B = \frac{\mu_0}{4\pi}\frac{2\pi I\,R^2}{(x^2 + R^2)^{\frac{3}{2}}} \qquad \text{(along the axis of the coil)}$$

At large distances, i.e, $x >> R$, we may drop R^2 then,



$$B = \frac{\mu_0}{4\pi}\frac{2\pi\,IR^2}{(x^2)^{\frac{3}{2}}}$$

$$B = \frac{\mu_0}{4\pi}\frac{2\pi IR^2}{x^3}$$

Now the area of the loop $A = \pi R^2$

$$B = \frac{\mu_0}{4\pi}\frac{2\,I(\pi\,R^2)}{x^3}$$

$$B = \frac{\mu_0}{4\pi}\frac{2\,I\,A}{x^3}$$

$$B = \frac{\mu_0}{4\,\pi}\frac{2m}{x^3}$$

Vectorically, $\vec{\boldsymbol{B}} = \frac{\boldsymbol{\mu_0}}{\boldsymbol{4\,\pi}}\frac{\boldsymbol{2\vec{m}}}{\boldsymbol{x^3}}$

This equation is analogous with the equation for the electric field on the axis of an electric dipole.

i. e. $\vec{E} = \frac{1}{4\pi\epsilon_0}\frac{2\,\vec{p}}{x^3}$, Hence a current loop is equivalent to a magnetic dipole.

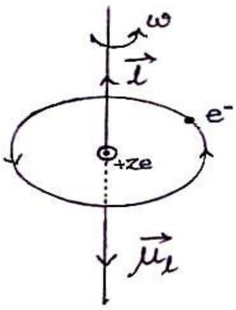
The magnetic dipole moment of a revolving electron:

Consider an electron revolving in a circular path of radius r.

Let magnitude of charge on the electron be e and T be its period of revolution.

The current due to motion of election is $I = {}^{e}/_{T}$

If v is the velocity of the electron, then



$$v = \frac{2\,\pi\,r}{T}$$

$$T = \frac{2\,\pi\,r}{v}$$

Now, $I = \dfrac{e}{\left(\frac{2\pi r}{v}\right)}$

$$I = \frac{ev}{2\pi r}$$

The magnetic moment produced by the revolving electron is given by, $\mu_l = IA$

$$\mu_l = \frac{e\,v}{2\,\pi\,r}\,\pi r^2$$

$$\boldsymbol{\mu_l = \frac{e\,v\,r}{2}}$$

The direction of this magnetic moment is into the plane of the paper, as if it is due to a clockwise current I.

Bohr Magneton: The minimum angular magnetic moment associated with the revolving electron in first orbit of the hydrogen atom is called Bohr magneton.

The minimum value of magnetic moment is obtained when n = 1

$$\boldsymbol{(\mu_l)_{min} = \frac{e\,h}{4\,\pi\,m_e}}$$

This minimum value of μ_l is called Bohr magneton.

The value of Bohr magneton is $9.27 \times 10^{-24} Am^2$

The moving coil galvanometer (MCG): A galvanometer is a basic instrument used to detect the presence of current (low current) in a circuit.

In a modified form, it is employed to measure current or to measure potential difference.

Principle: It is based on the principle that a coil carrying current when placed in a magnetic field experience a torque and deflects, if free to move.

Moving coil galvanometer as Ammeter:

Ammeter: An Ammeter is an instrument used for measurement of current in ampere. It is always connected in series in the circuit.

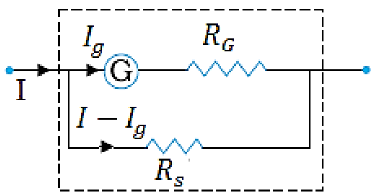
The resistance of ammeter must be zero; such an ammeter is an ideal ammeter.

The moving coil galvanometer cannot be used directly to measure the current because,

(i) The resistance of the galvanometer is high.

(ii) The instrument is very sensitive and gives full scale deflection for very small currents.

Conversion: To use a MCG as ammeter, a low resistance called shunt resistance is connected in parallel with galvanometer coil.



Ammeter

Expression for Shunt resistance: If R_s be the required shunt Resistance, then

$$R_s = \frac{I_g R_G}{(I - I_g)}$$

where I_g → Current for full scale deflection. I → Current to be measured.
R_G → Galvanometer resistance.

Moving coil galvanometer as Voltmeter:

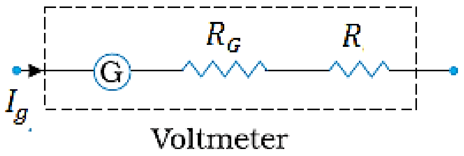
Voltmeter: A voltmeter is an instrument used for measurement of voltage across a given section of the circuit. It is always connected in parallel to the component.

The resistance of voltmeter must be infinite; such a voltmeter is an ideal voltmeter.

The moving coil galvanometer cannot be used directly to measure the voltage because,

The resistance of moving coil galvanometer is not high enough to make the current drawn by it negligible, when connected in parallel.

Conversion: To use a MCG as a voltmeter, a high resistance R is connected is series with the galvanometer.



Expression for Series resistance:

$$R = \frac{V}{I_g} - R_G$$

where I_g → current for full scale deflection. V → Potential difference to be measured.
R_G → Galvanometer resistance.

Current Sensitivity: Current sensitivity of a moving coil galvanometer is defined as the deflection per unit current. It is expressed as divisions per microampere.

$$\frac{\phi}{I} = \frac{NAB}{K}$$

Thus current sensitivity of a MCG is directly proportional to number of turns in the coil.

Voltage sensitivity: Voltage sensitivity of a MCG is defined as the deflection per unit voltage. It is expressed as divisions per volt.

$$\therefore \frac{\phi}{V} = \left(\frac{NAB}{k}\right)\frac{1}{R}$$

As N increases, R also increases. Hence $\left(\frac{\phi}{V}\right)$ will not increase.

To increase the voltage sensitivity the series Resistance should be reduced.

To increase the range of the voltmeter the series Resistance should be increased.

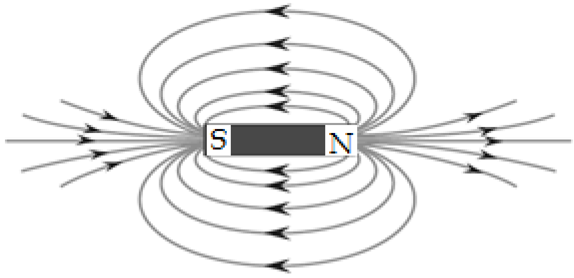
Comparison between Voltmeter and Ammeter:

Voltmeter	Ammeter
It is used to measure potential difference	It is used to measure current
It is connected in parallel with the components	It is connected in series with the circuit
The resistance is very high	The resistance is very low
The resistance of ideal voltmeter is infinite	The resistance of ideal ammeter is zero
The effective resistance of the voltmeter is, $R_V = R + R_G$	The effective resistance of the ammeter is $R_A = \frac{R_g R_s}{R_G + R_s}$

Chapter – 5 **MAGNETISM AND MATTER**

The Bar magnet: A bar magnet is generally a rectangular shaped small piece of a rod having two pole of same strength separated by a small distance.

Magnetic field lines around a Bar magnet:
To visualise the magnetic field graphically, the concept of magnetic field lines was introduced which is as shown.

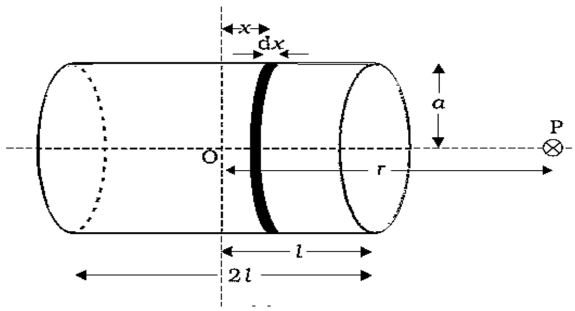


Properties of magnetic field lines:

- ∗ Magnetic field lines are directed away from the N-pole and towards the S-pole in the region outside the magnet.
- ∗ Magnetic field lines ***form continuous closed loops.***
- ∗ Magnetic field lines do not intersect. (If they do so, at the point of intersection the magnetic field would have two different directions.)
- ∗ Magnetic field lines are crowded in the region where the magnitude of magnetic field is stronger.
- ∗ The tangent at any point on the magnetic field line gives the direction of strength of the magnetic field $\vec{B}$ at that point.

Bar magnet as an equivalent solenoid
(A solenoid is equivalent to a bar magnet):

Consider a solenoid with O as centre.
Let a be its radius, $2l$ be its length.
Let n be the number of turns per unit length.
Consider a small element of thickness dx of the solenoid at a distance x from O.
Number of turns in this element is ndx.
When current I flows through it, the magnetic field at P is given by,



$$dB = \frac{\mu_0}{4\pi}\frac{2\pi(ndxI)a^2}{[(r-x)^2+a^2]^{3/2}}$$

When r is very large compared to a and x, then $[(r-x)^2+a^2]^{3/2} \approx r^3$

$$dB = \frac{\mu_0}{4\pi}\frac{2\pi(ndxI)a^2}{r^3} = \frac{\mu_0}{4\pi}\frac{2\pi nIa^2}{r^3}\,dx$$

Total magnetic field at P due to the solenoid is, $B = \int_{-l}^{+l} dB$

$$B = \int_{-l}^{+l}\frac{\mu_0}{4\pi}\frac{2\pi nIa^2}{r^3}\,dx = \frac{\mu_0}{4\pi}\frac{2\pi nIa^2}{r^3}\int_{-l}^{+l}dx$$

$$B = \frac{\mu_0}{4\pi}\frac{2\pi nIa^2}{r^3}\,[x]_{-l}^{+l}$$

$$B = \frac{\mu_0}{4\pi}\frac{2\pi nIa^2}{r^3}\,[l-(-l)] = \frac{\mu_0}{4\pi}\frac{2\pi nIa^2}{r^3}\,(2l)$$

$$B = \left(\frac{\mu_0}{4\pi}\right)\,2\,\frac{2\pi nIa^2 l}{r^3}$$

But, we have Magnetic moment of the solenoid is, $m = IA$

$$m = (2lnI)(\pi a^2) = 2\pi nIa^2 l$$

Then, $\boldsymbol{B = \left(\frac{\mu_0}{4\pi}\right) 2\,\frac{m}{r^3}}$

This expression is similar to the magnetic field on the axial line of a short bar magnet.
Hence, for all practical purpose, a finite solenoid carrying current is equivalent to a bar magnet.

Torque on a bar magnet in magnetic field:

$$\boldsymbol{\tau = mB\sin\theta}$$

Vectorically, $\boldsymbol{\vec{\tau} = \vec{m} \times \vec{B}}$

Maximum and minimum values of torque:

1) If $\theta = 0$, $\tau = 0$. Torque is Minimum if magnetic dipole is along the magnetic field.
2) If $\theta = 90^0$, $\tau = mB$. Torque is Maximum if magnetic dipole is perpendicular to the applied magnetic field.

Potential energy of the bar magnet:

$$\boldsymbol{U = -\vec{m} \cdot \vec{B}}$$

Maximum and minimum values of Potential:

1)When $\theta = 0$, $U = -mB$.
Potential is minimum when dipole is aligned along the magnetic field.
2) When $\theta = 180$, $U = mB$.
Potential is maximum when dipole is aligned opposite to the direction of the field.
3) When $\theta = 90$, $U = 0$. Potential is zeor when dipole is perpendicular to the magnetic field.

Time period:

$$\boldsymbol{T} = 2\pi\sqrt{\frac{\boldsymbol{I}}{\boldsymbol{mB}}}$$

Gauss's law in magnetism:
Statement: The net magnetic flux through any closed surface is zero.

Significance of Gauss law in magnetism: *It indicates that monopole does not exist.*

Magnetic Elements of the earth: The Magnitude and direction of the magnetic field of the earth at a place are completely given by three quantities known as magnetic elements.

They are 1) Magnetic Declination (θ)
2) Magnetic Inclination or Angle of Dip (I)
3) Horizontal component of magnetic field of earth (H_E)

Magnetic Declination ($\boldsymbol{\theta}$): The angle between the magnetic meridian and geographic meridian at a place is called Magnetic Declination at that place.

Magnetic Inclination or Angle of Dip ($\boldsymbol{I}$): It is the angle between the direction of total magnetic field of earth and a horizontal line in magnetic meridian.

Horizontal component of earth's magnetic field (H_E): The component of total magnetic field of earth in the horizontal direction in magnetic meridian is called Horizontal component of earth's magnetic field.

$$\text{Magnitude, } B_E = \sqrt{{H_E}^2 + {Z_E}^2}$$

$$\text{Direction} \quad \tan I = \frac{Z_E}{H_E}$$

Note: If $Z_E = H_E$, then $\tan I = 45^0$

Various terms related to magnetism.

Magnetisation ($\overrightarrow{M}$): The magnetization M of the sample is defined as the net magnetic moment per unit volume.

$$\overrightarrow{\boldsymbol{M}} = \frac{\overrightarrow{\boldsymbol{m}}_{\boldsymbol{net}}}{\boldsymbol{V}}$$

M is a vector and is measured in a units of $A\,m^{-1}$

Magnetic Intensity ($\vec{H}$): Magnetic intensity is defined as the ratio of the magnetic field ($\overrightarrow{B_0}$) in space to the permeability of free space (μ_0).

$$\vec{H} = \frac{\overrightarrow{B_0}}{\mu_0} \quad \text{OR} \quad \overrightarrow{B_0} = \mu_0 \vec{H}$$

If the medium is other than free space then $\vec{H} = \frac{\vec{B}}{\mu}$ OR $\vec{B} = \mu\vec{H}$

H is a vector; SI unit of H is $A\,m^{-1}$

Magnetic permeability (μ): Magnetic permeability of a substance is defined as the ratio of the magnitude of the magnetic induction to the magnetic intensity.

$\mu = \frac{B}{H}$ OR $B = \mu H$ and SI unit of μ is $T\,m\,A^{-1}$

Magnetic susceptibility (χ): Magnetic susceptibility is equal to the ratio of the Magnetisation to the magnetic intensity.

$$\chi = \frac{M}{H}$$

χ has no unit. It is just a number.

Relation between μ and χ :

$\therefore \boldsymbol{\mu = \mu_0 (1 + \chi)}$ $\qquad \because \frac{M}{H} = \chi$

Also, $\boldsymbol{\mu_r = \frac{\mu}{\mu_0} = 1 + \chi}$

Magnetic Properties of Materials: Faraday classified the materials on the basis of their magnetic properties into the fallowing three categories.

(i) Diamagnetic substances

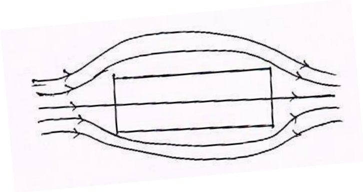
(ii) Paramagnetic substances

(iii) Ferromagnetic substances

Diamagnetic substances: Diamagnetic substances are those which have a tendency to move from stronger to weaker part of the external magnetic fields. This property of the substances is called Diamagnetism.

Ex : Gold, Silver, Copper, Zinc, lead, bismuth, mercury, diamond, marble, glass, silicon, quartz, water, alcohol, air, helium, argon, hydrogen, nitrogen sodium chloride etc.,

Properties of Diamagnetic substance:



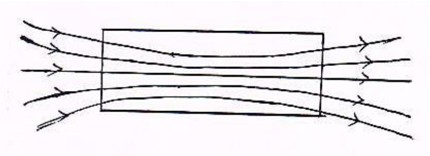
* A magnet repels a diamagnetic substance.
* When a bar of diamagnetic substance is placed in an external field the field, **the field lines are repelled by the substance.**
* In diamagnetic substance the magnetic dipole moment of the atom is zero.
* When a magnetic field is applied, a small value of magnetic dipole moment is induced in a direction opposite to the magnetic field. Hence they repelled by a magnet.
* It is very difficult to magnetise a diamagnetic substance. They require very strong magnetic field to show magnetic properties.
* Their magnetic behaviour normally does not depend upon change in temperature.
* The susceptibility of diamagnetic substance has a **small negative** value and $\mu_r < 1$.
* Diamagnetism is present in all the materials.

Paramagnetic substances: Paramagnetic substances are those which are weakly magnetized when placed in an external magnetic field. This property is called Para magnetism.

Ex: Aluminium, chromium, manganese, platinum, calcium, antimony, sodium, lithium, magnesium, tungsten, copper chloride, liquid oxygen.

Properties of Paramagnetic substance:

* They are weakly attracted by magnets.
* When a bar of paramagnetic substance is placed in an external magnetic field, **the field lines gets concentrated inside the material and the field inside the material is slightly increased.**



* The atoms of a paramagnetic material possess a small value of permanent magnetic dipole moment.
* When placed in a strong magnetic field the atomic dipole moments align parallel to the direction of external magnetic field. Hence **they are weakly magnetized, in the direction of magnetic field.**
* The susceptibility of paramagnetic material has a **small positive** value and $\mu_r > 1$
* They obey Curie's law.

Curie's law in Para magnetism: Curie's law states that the magnetization of a paramagnetic material is inversely proportional to absolute temperature T of the material.

OR

Magnetic susceptibility of a paramagnetic material is inversely proportional to absolute temperature of the material.

$$\chi \propto \frac{1}{T}$$

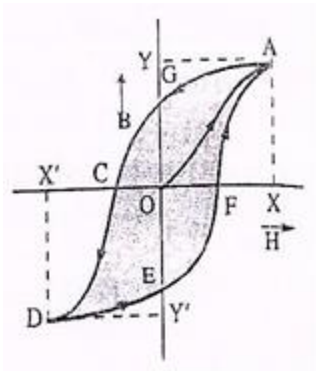
Ferromagnetic Substances: Ferromagnetic materials are those which are strongly magnetized when placed in an external magnetic field.
Ex: Iron, steel, nickel, cobalt, alnico etc.

Properties of Ferro magnetic substances:

* They are strongly attracted by magnetic field.
* They are strongly magnetised in the direction of the external magnetic field.
* The magnetic field lines are highly concentrated inside the substance.
* The susceptibility of ferromagnetic materials has a **large positive value**.
* The relative permeability is also **very high** ($\approx 10^3$)
* Above the Curie temperature, its susceptibility varies inversely as excess of temperature or they obey Curie – Weiss law.
* They exhibit magnetic hysteresis.

Curie's Temperature: The temperature at which the transition from ferromagnetic to Para magnetism takes place is called Curie temperature or Curie point.
Above Curie temperature a ferromagnetic material becomes a Paramagnetic material.

Hysteresis: The phenomenon of logging behind the magnetic induction ($\vec{B}$) with respect to the magnetizing field ($\vec{H}$) is called hysteresis.



Magnetisation curve (hysteresis curve): Magnetisation curve or hysteresis curve is the graph between the magnetic induction $\vec{B}$ and the magnetic intensity ($\vec{H}$).

Definition of Retentivity: The value of magnetic field, B in the sample when magnetic Intensity, $H = 0$ is called retentivity. (The amount magnetism retained even in the absence of the Magnetic intensity is known as retentivity or remanence.)

Definition of Coercivity: The value of magnetic intensity H when magnetic field inside the sample becomes zero is called coercivity. (The reverse magnetic field needed to demagnetize the magnetic material completely is known as coercivity.)

The curve which is the result of a cycle of magnetization and demagnetization of the magnetic material is called **Hysteresis loop**

Energy dissipation due to hysteresis (Hysteresis loss): During the cycle of magnetization and demagnetization of a magnetic substance, energy is spent. This energy appears as the heat energy and the substance is heated. Such energy loss is known as **hysteresis loss**.

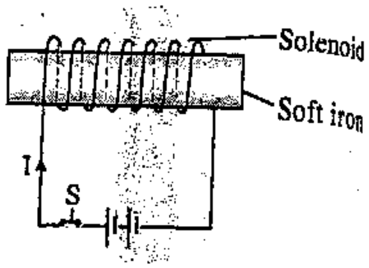
Note: *The loss of energy per unit volume of the substance is equal to the area of B – H curve.*

1. **Permanent Magnets:** The substances which retain their ferromagnetic properties for a long time at room temperature are called permanent magnets.

Material for making permanent magnet should have:

(i) High permeability (ii) high coercivity (iii) high retentivity.

2. Electromagnets: A ferromagnetic material placed inside a current carrying solenoid acts as an electromagnet.



Uses of Electromagnets: They are used in electric bells, loud speakers, telephone diaphragms and magnetic cranes.

Material for making electromagnets should have:

(i) High permeability (ii) Low coercivity (iii) Low retentivity.

Note:

Cores of generators, motors and transformers are magnetized and demagnetized number of times, when current flows through them. Hence *the materials having narrow hysteresis loops should be used to prepare these cores.*

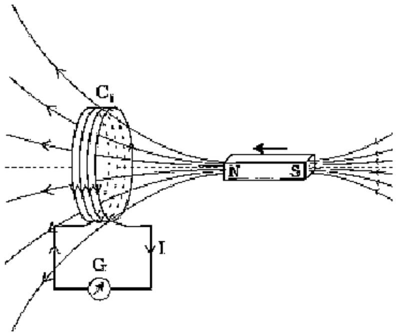
Chapter 6 **ELECTROMAGNETIC INDUCTION**

Electromagnetic Induction (EMI): The phenomenon in which electric current is generated in a closed coil by varying magnetic fields is called Electromagnetic induction.

Faraday and Henry's experiments:

Experiment 1: Coil-magnet experiment

C_1 is a large coil of several turns of a conductor connected to a sensitive galvanometer.

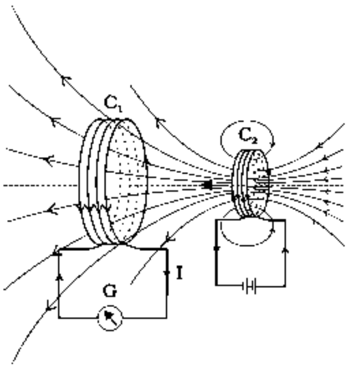


(i) When the bar magnet NS is moved towards the coil, the galvanometer shows a deflection.
(ii) The galvanometer shows an opposite deflection when the magnet is moved away.
(iii) The galvanometer shows a deflection if the coil moves and the magnet is stationary. That is, there must be relative motion between them.
(iv) No deflection is observed if neither the coil nor the magnet moves or if there is no relative motion.
(v) If the relative motion is brought about faster, the deflection is larger.

Conclusion: A relative motion between a magnet and a coil induces an emf and if it is closed circuit, induces a current.

Experiment 2: Coil-Coil experiment

Bar magnet is replaced by a coil C_2. The coil C_1 and C_2 are not connected physically with one another. C_1 is connected to sensitive galvanometer and C_2 is connected to a battery.



(i) The galvanometer showed a deflection when coil C_2 is moved towards C_1.
(ii) When coil C_2 is moved away from coil C_1, the galvanometer showed a deflection but in opposite direction.
(iii) When the coil C_2 is held fixed and C_1 is moved, the same effects are observed.

Conclusion: Induced emf and thus current is produced in a nearby conducting coil C_1, when there is a relative motion between current carrying coil C_2 and the Conducting coil C_1.

Faraday's law of induction: The magnitude of induced emf is directly proportional to the rate of change of magnetic flux linked with the coil.

Explanation:

According to Faraday's law of induction, $\varepsilon \propto \frac{\phi_2 - \phi_1}{t_2 - t_1}$

$$\varepsilon = -k\,\frac{\phi_2 - \phi_1}{t_2 - t_1}$$

$k \rightarrow$ proportionality constant. In SI, $k = 1$

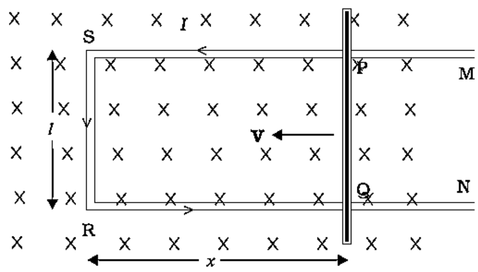
$$\boldsymbol{\varepsilon = -\frac{d\phi_B}{dt}}$$

Lenz's Law: The polarity of induced emf is such that it tends to produce a current which opposes the change in magnetic flux that produced it. This law **gives the polarity of induced emf.**

Lenz's Law and Energy conservation (Significance of Lenz's law):
Significance: *Lenz's law is in accordance with the law of conservation of energy.*

Motional emf: Induced emf produced by changing the area of a closed circuit by the movement of the circuit or part of it through a uniform magnetic field is known as motional emf.

Expression for Motional emf:



Consider a rectangular conductor $PQRS$ in which the conductor PQ is free to move with a velocity $\vec{v}$.

Let $\vec{B}$ is the magnetic field which is perpendicular to the plane of this system.

Magnetic flux through $PQRS$ is, $\phi_B = BA$

$$\phi_B = Blx$$

since x is changing with time, the rate change of flux ϕ_B will induce an emf in the circuit given by,

$$\varepsilon = -\frac{d\phi_B}{dt} = -\frac{d(Blx)}{dt}$$

$$\varepsilon = -Bl\frac{dx}{dt} = -Bl(-v)$$

$$\boldsymbol{\varepsilon = Blv}$$

Eddy currents (Foucault currents): The induced circulating currents produced in a conductor due to change in magnetic flux linked with the conductor are called eddy currents.

Advantages or Applications of eddy currents:
(i) Magnetic braking in electric trains
(ii) Electromagnetic damping
(iii) Induction furnace
(iv) Analogue energy power metres
(v) Induction cooking

Disadvantages or undesirable effects of eddy currents:
(i) The production of eddy currents in a metallic block leads to the loss of electric energy in the form of heat.
(ii) The heat produced due to eddy currents breaks the insulation used in the electrical machines.
(iii) Eddy currents may cause unwanted damping effect.

Mutual Induction: It is the phenomenon in which an emf is induced in one coil due to the variation of current in the neighbouring coil.

$$\boldsymbol{\varepsilon = -M\frac{dI}{dt}}$$

The SI unit of mutual inductance is $henry(H)$.

Self-Induction: It is the phenomenon in which an emf is induced in a coil due to the change in magnetic flux through the coil as a result of variation of current in the same coil.

$$\boldsymbol{\varepsilon = -L\frac{dI}{dt}}$$

The SI unit of Self-inductance is $henry(H)$.

Self-Inductance of a solenoid (Co-efficient of Self-Induction of a solenoid):

$$\boldsymbol{L = \mu_0 n^2 A\, l}$$

Factors affecting self-inductance of a coil: self-inductance of a solenoid depends on,

(i) Total number of turns of the solenoid.

(ii) Area of cross-section of the solenoid.

(iii) Material of the core.

Inductor: A tightly wound coil of insulated wire which opposes the change in current flowing through it is called an inductor. It is a current element and its circuit symbol is 

Energy stored in an Inductor:

Consider an inductor of inductance L, connected across a battery.

Let I be the current through the inductor.

The emf of external battery, $\varepsilon = L\dfrac{dI}{dt}$

Let an infinitesimal charge dq be driven through the inductor.

Then work done by the external voltage is given by, $dW = \varepsilon\, dq$

$$dW = L\frac{dI}{dt}\, dq$$

$$dW = L\, dI\left(\frac{dq}{dt}\right) = L\, I\, dI$$

Total work done to maintain the maximum value of current I through the inductor is,

$$W = \int dW = \int_0^I L\, I\, dI$$

$$W = L\left[\frac{I^2}{2}\right]_0^I = \frac{LI^2}{2}$$

This work done is stored as potential energy (U) in the inductor.

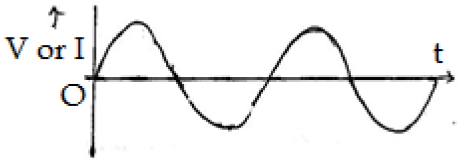
$$\boldsymbol{U = \frac{1}{2}LI^2}$$

AC Generator: The Alternating current generator is a device that *operates on the principle of electromagnetic induction* and converts mechanical energy to electrical energy.

Note: ***Working principle of AC generator***: *Whenever a current carrying coil (conductor) rotates in the magnetic field, an emf is induced in the coil due to variation of effective area of the coil.*

CHAPTER – 7 ALTERNATING CURRENT

Alternating current (AC): An electric current in which the magnitude changes with time and polarity reverses periodically is called alternating current.



Advantages of AC over Direct current (DC)

* Generation, transmission and distribution ac AC is more economical(less costly)
* AC voltage can be stepped down or stepped up easily.
* AC can reach distant places without much lass of electric power.
* Alternating voltage can be better controlled without any loss of electric power.
* AC is easily convertible in to DC
* AC machines are small sized, stronger and easy to use.

AC parameters:

1. **Period of AC (T):** It is the time taken by the ac to complete one cycle.

2. **Frequency of AC($\boldsymbol{\nu}$) :** It is the number of cycles completed by the AC in one second.

   It follows that, $\nu = \frac{1}{T}$ or $T = \frac{1}{\boldsymbol{\nu}}$

3. **Instantaneous value of AC**: It is the value of alternating voltage or current at the given instant.

   The instantaneous values are given by (i) Voltage: $v = v_m \sin \omega t$
   (ii) Current: $i = i_m \sin \omega t$

4. **Peak value:** It is the maximum value attained by AC voltage or current during a cycle.

5. **Mean or Average value of AC**: It is the mean or average of the Instantaneous value of AC taken over one ***half*** cycle. Mean value of a sinusoidal AC over ***a complete cycle is zero***

   Expression for mean value of AC: Let I_{av} be the mean or average value of ac over positive half cycle, then

   $$\boldsymbol{I_{av} = \frac{2}{\pi} i_m} \quad \text{or} \quad \boldsymbol{I_{av} = 0.637\, i_m}$$

   Similarly $$\boldsymbol{v_{av} = \frac{2}{\pi} v_m} \quad \text{or} \quad \boldsymbol{v_{av} = 0.637 v_m}$$

   The mean value of alternate current or voltage is 63.7% of its peak value.

6. **Root mean square value or effective value of alternating current :**
   The root mean square value of alternating current is equal to the square root of the mean of the squares of instantaneous currents in one cycle. It is also known as effective or virtual value.

   Expression for R.M.S value of ac ($\boldsymbol{I_{rms}}$ *or* $\boldsymbol{I}$): Let I_{rms} be the *rms* value of ac, then

   $$\boldsymbol{I_{rms} = \frac{i_m}{\sqrt{2}}} \quad \text{or} \quad \boldsymbol{I_{rms} = 0.707\, i_m}$$

   Similarly $$\boldsymbol{V_{rms} = \frac{v_m}{\sqrt{2}}} \quad \text{or} \quad \boldsymbol{v_{rms} = 0.707\, v_m}$$

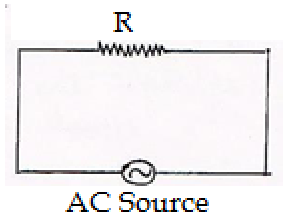
   The RMS value of ac is 70.7% of its peak value.

Phasors: A phasor is a vector rotating about the origin in anticlockwise direction with an angular speed of ω. It represents a scalar quantity which is sinusoidally varying with time. The length of the phasor represents the peak value or amplitude of sinusoidally varying quantity.

AC voltage applied to a Resistor:

Consider a pure resistor of resistance R connected to an ac source, which gives ac voltage,

$$\boldsymbol{v = v_m \sin \omega t} \quad \text{--- (1)}$$



The current through the resistor at any instant t is, $i = \frac{v}{R} = \frac{v_m \sin \omega t}{R}$

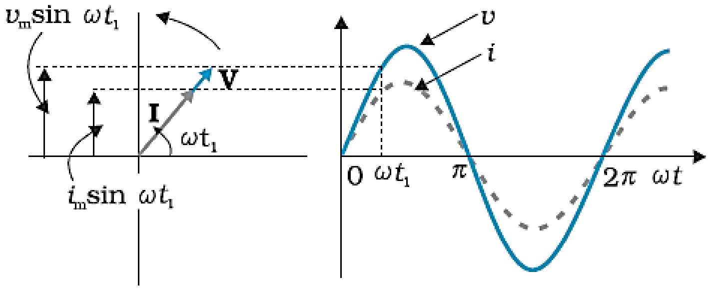
$$i = \frac{v_m}{R} \sin \omega t$$

$$\boldsymbol{i = i_m \sin \omega t} \quad \text{----- (2)}$$

Where $i_m = \frac{v_m}{R}$ is the peak current.

Phasor diagram for purely resistive circuit:

It is found that current is in **phase** with applied voltage when the load is purely resistive, this can be shown in following diagrams.



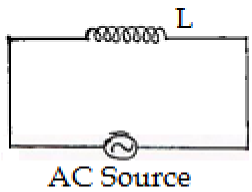
AC voltage applied to an Inductor:

The circuit shows an inductor of self-inductance L connected to an ac voltage source.

Let the ac voltage across the inductor at an instant of time t be $\boldsymbol{v = v_m \sin \omega t}$

The induced emf at the instant t is given by, $\varepsilon = -L\frac{di}{dt}$

According to Kirchhoff's law, $v + \varepsilon = 0$



$$v_m \sin \omega t - L\frac{di}{dt} = 0$$

$$L\frac{di}{dt} = v_m \sin \omega t$$

$$di = \frac{v_m}{L} \sin \omega t \ dt$$

The instantaneous current i is obtained by integrating above equation, $i = \int di$

$$i = \int \frac{v_m}{L} \sin \omega t \, dt$$

$$i = \frac{v_m}{L} \int \sin \omega t \, dt$$

$$i = \frac{v_m}{L}\left(\frac{-\cos \omega t}{\omega}\right) + \text{constant of integration}$$

It can be shown that the constant of integration is zero and

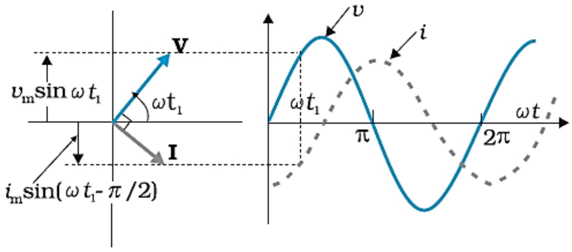
We know that, $\quad -\cos \omega t = \sin\left(\omega t - \frac{\pi}{2}\right)$

$$i = \frac{v_m}{L\omega} \sin\left(\omega t - \frac{\pi}{2}\right)$$

$$\boldsymbol{i = i_m \sin\left(\omega t - \frac{\pi}{2}\right)} \qquad \text{where} \quad i_m = \frac{v_m}{\omega L}$$

Phasor diagram for purely inductive circuit:

It is found that *the current* ***lags*** *behind the applied voltage* by $\frac{\pi}{2}$ or 90^0



Inductive reactance: Inductive reactance (X_L) is the opposition offered by an inductance to alternating current, through it. $\boldsymbol{X_L = \omega L = 2\pi\nu L}$

For direct current, $\nu = 0, X_L = 0$. Thus a pure inductor offers no opposition to direct current.

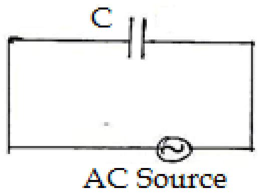
Ac voltage applied to a capacitor:

Consider an ideal capacitor connected to an ac source.

The instantaneous voltage is $\boldsymbol{v = v_m \sin \omega t}$

Let q be the charge on the capacitor at an instant of time t, then potential difference across capacitor is, $v = \frac{q}{C}$

$$q = vC$$



The instantaneous current is given by, $i = \frac{dq}{dt}$

$$i = \frac{d}{dt}(vC) = C\frac{d}{dt}(v_m \sin \omega t)$$

$$i = \omega C\, v_m \cos \omega t$$

But $\cos \omega t = \sin\left(\omega t + \frac{\pi}{2}\right)$

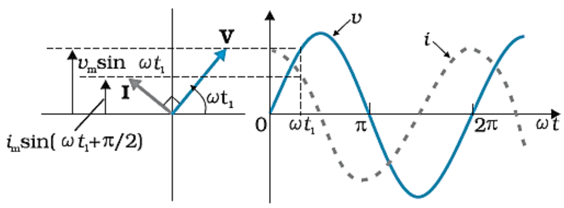
$$i = \omega C v_m \sin\left(\omega t + \frac{\pi}{2}\right)$$

$$i = \frac{v_m}{\left(\frac{1}{\omega C}\right)} \sin\left(\omega t + \frac{\pi}{2}\right)$$

$$\boldsymbol{i = i_m \sin\left(\omega t + \frac{\pi}{2}\right)} \qquad \text{where} \quad i_m = \frac{v_m}{\left(\frac{1}{\omega C}\right)}$$

Phasor diagram for Purely Capacitive circuit:

It is found that *the current* ***leads*** *the applied voltage by* $\frac{\pi}{2}$ or 90^0.



Capacitive reactance: Capacitive reactance is the effective opposition offered by capacitance to alternating current in the circuit.

$$X_C = \frac{\mathbf{1}}{\boldsymbol{\omega C}} = \frac{\mathbf{1}}{\boldsymbol{2\pi\nu C}}$$

A *capacitor offerers infinit opposition to the flow of direct current through it.* That is capacitor blocks DC.

Impendence: In a series LCR circuit with ac source, the combined opposition offered by resistance and reactance to the flow of ac is called the impedance and is denoted by Z.

$$Z = \frac{v_m}{i_m}$$

Electrical Resonance: The phenomenon of impedance of the series LCR circuit becoming minimum and current in the circuit becoming maximum at a particular frequency of the applied alternating voltage is called electrical resonance.

Condition for resonance: $X_C = X_L$ **or** capacitive reactance is equal to inductive reactance **or** Impedance Z will have minimum value and current i_m will have a maximum value.

Resonant frequency ($\boldsymbol{\omega_0}$): The frequency at which the electrical resonance occurs is called resonant frequency.

Expression for resonant frequency:

At resonance, $X_C = X_L$

$$\frac{1}{\omega_0 C} = \omega_0 L$$

$$\omega_0^2 = \frac{1}{LC}$$

$$\boldsymbol{\omega_0 = \frac{1}{\sqrt{LC}}}$$

This is the expression for resonant frequency.

Application of Resonant circuit: Series resonant circuits are used in the tuning mechanism of radio or TV set.

Wattless current: In an ac circuit, if the voltage and current differ in phase by $\frac{\pi}{2}$ or 90^0. Then power factor $\cos\phi = 0$ and no power is dissipated even though a current is flowing in the circuit such a current is called wattless current or Idle current.

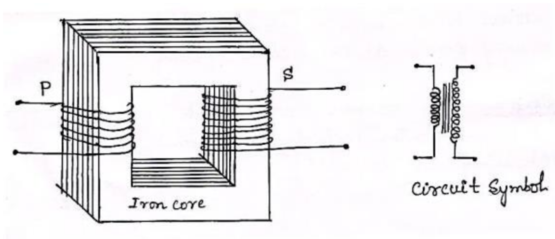
Such a current flows only in purely capacitive or in purely inductive circuits.

Transformer: A transformer is a device to step up or step down ac voltages

Principle: It works on the Principle of mutual induction.

$$\boldsymbol{\frac{v_s}{v_P} = \frac{N_s}{N_P}}$$ This is known as Turn ratio.

Thus, $$\boldsymbol{\frac{i_p}{i_s} = \frac{v_s}{v_P} = \frac{N_s}{N_P}}$$



Energy loss in a transformer:

Loss due to heatin.

Loss due to flux linkage.

Loss due to eddy currents.

Hysteresis loss.

Chapter 8 ELECTROMAGNETIC WAVES

Displacement current(i_d): The current through the gap between the plates of the capacitor due to the changing electric field is known as displacement current **or**
The current due to changing electric field is called displacement current.

Expression for Displacement current:

$$i_d = \varepsilon_0 \left(\frac{d\phi_E}{dt}\right)$$

i_d = Displacement current, ε_0 = Permitivity of free space , $\frac{d\phi_E}{dt}$ = Rate of change of electric field

Ampere's–Maxwell's law:

$$\oint \vec{B} \cdot d\vec{l} = \mu_0 i_c + \mu_0 \varepsilon_0 \left(\frac{d\phi_E}{dt}\right)$$

Importance (Need) of displacement current: Concept of displacement current is used to understand the generation and propagation of electromagnetic waves.

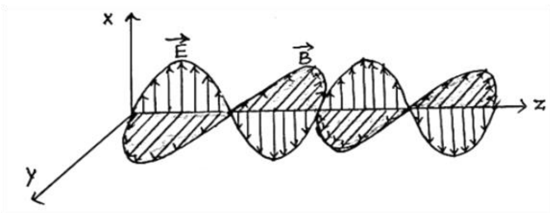
Electromagnetic wave: Waves radiated by accelerated charges and consists of time varying transverse electric and magnetic fields are called Electromagnetic waves.
Maxwell predicted the existence of electromagnetic waves.

Source of electromagnetic waves: A charge oscillating harmonically is a source of electromagnetic wave of same frequency.

Nature of electromagnetic waves: It can be shown from Maxwell's equations that electromagnetic waves are ***transverse in nature***.

From Maxwell's equation we can show that, $C = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$

Properties of electromagnetic waves:



- Electromagnetic waves are transverse in nature. The electric and magnetic fields are at right angles to one another and also at right to the direction of propagation.
- Electromagnetic waves can propagate through vacuum as well as material medium.
- A single electromagnetic wave is plane polarised.
- The velocity of the electromagnetic waves in space is equal to the speed of light.
  $c = 2.99792456 \times 10^8 ms^{-1} \approx 3 \times 10^8 ms^{-1}$
- Electromagnetic waves undergo interference, diffraction and polarisation.

Electromagnetic spectrum: The orderly arrangement of electromagnetic radiation according to their wavelength or frequency is called electromagnetic spectrum.

Radio waves: Wavelength range: $Greater\ than\ 0.1m$

Microwaves: Wavelength range: $0.1m$ to $1mm$

Uses: Microwaves are used

* in radar system for air craft navigation
* for cooking in microwave ovens.
* in radar for detecting speed of ball, automobiles etc.
* for communication system

Infrared (IR) rays: Wavelength range: $1mm$ to $700nm$

Uses: IR rays are used

* in muscular therapy, to treat muscular strain.
* for taking photographs during conditions of fog and smoke.
* in green house to keep the plant warm.
* for producing dehydrated fruits.
* in remote switches and remote controls.
* in solar water heaters and cookers.

Visible light: Wavelength range: $700nm$ to $400nm$

Ultraviolet (UV) rays:

Wavelength range: 400 nm to 1nm **or** 4×10^{-7} m (400 nm) down to 6×10^{-10}m (0.6 nm)

Uses: UV rays are used

* to preserve food stuffs as they kill germs.
* to sterilize milk and drinking water.
* to cause photo electric current in burglar alarm.
* in the detection of finger prints.
* for checking the mineral samples through fluorescence.
* to sterilize surgical equipment.
* to detect forged documents.

X-rays: Wavelength range: 1nm to 10^{-3} nm **or** 10^{-8} m (10 nm) down to 10^{-13} m(10^{-4} nm)

Uses: X-rays are used

* as a diagnostic tool in medicine to detect fracture of bones, foreign bodies like bullets and stones in body.
* in the treatment of certain cancer.
* for detecting faults, cracks and flaws in metal casting.
* in the investigation of structure of crystals.
* to cause photoelectric effect.

Gamma rays:

Frequency range: More than $3 \times 10^{20} H$

CHAPTER - 9 RAY OPTICS AND OPTICAL INSTRUMENTS

Reflection of light: The phenomenon of returning of light in the same medium when if falls on a surface is known as reflection of light.

Laws of Reflection

1. Angle of reflection is equal to the angle of incidence.
2. The incident ray, the reflected ray and normal at the point of incidence lie in the same plane.

Reflection at spherical mirrors:

Spherical mirror: A spherical mirror is a part of hollow sphere whose one side is reflecting and the other side is opaque.

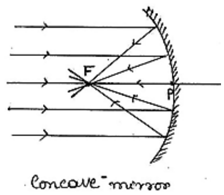
Pole: The geometric centre of the reflecting surface is called its pole (P).

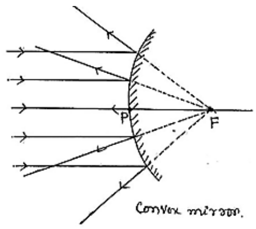
Centre of curvature (C): The centre of the sphere of which the mirror is a part is called its centre of curvature.

Radius of curvature (R): The radius of the sphere of which the mirror is a part is called it radius of curvature.

Principle axis: A straight line passing through the pole and centre of curvature of a mirror is called the principal axis.

Normal: The Normal to the spherical mirror at any point is the line joining that point to the centre of curvature.



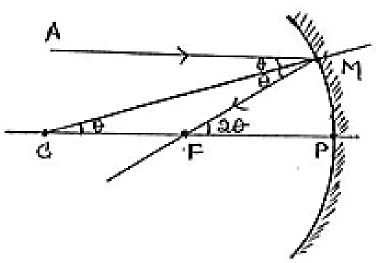


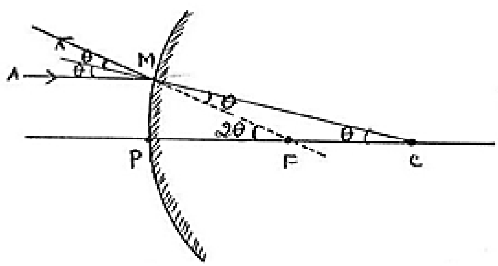
Principal focus: When a narrow parallel beam of light is incident along the principal axis, the reflected rays either converge to a point on the principal axis in the case of concave mirror or appear to diverge from a point on the principal axis of a convex mirror. This point is called the principal focus (F).

In the case of concave mirror F is real point and in the case of convex mirror F is virtual point.

Focal length (f): The distance between the principal focus (F) and pole (P) of a mirror is called focal length of the spherical mirror.

Relation between focal length and Radius of curvature:





Consider a concave mirror of focal length f and Radius of curvature R.

Let P represent pole, F represent principal focus and C its centre of curvature.

A ray AM parallel to the principal axis of a concave mirror is incident at M and reflected along MF.
By the law of Reflection, $\angle CMF = \angle AMC = \theta$
From figure, $\angle MCF = \angle AMC = \theta$ (alternative angles)
and $\angle MFP = 2\theta$
As the aperture is small and angle θ is small, arc PM may be considered as a straight segment.

From Δ^{le} PMC, $\tan\theta \approx \theta = \frac{PM}{PC}$

and Δ^{le} MFP, $\tan 2\theta \approx 2\theta = \frac{PM}{PF}$

$$2\theta = \frac{PM}{PF}$$

$$2\left(\frac{PM}{PC}\right) = \frac{PM}{PF}$$

$$\frac{2}{PC} = \frac{1}{PF}$$

$$PF = \frac{PC}{2}$$

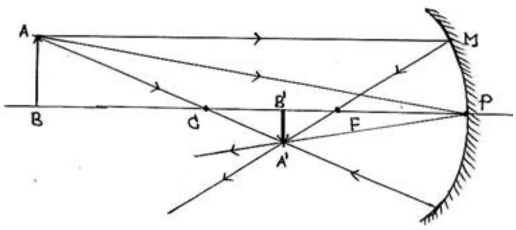
But $PF = f$ and $PC = R$

$$\boldsymbol{f = \frac{R}{2}}$$

Sign convention:
1. All the distances are measured from the pole of the spherical mirror along the principal axis.
2. The distances measured in the same direction as the incident light, are taken as positive.
3. The distances measured opposite to the direction of incident light are taken as negative.
4. The height measured upwards and perpendicular to the principal axis of the mirror is taken as positive, the height measured downwards is taken as negative.

The mirror equation: The equation relating the object distance (u), image distance (v) and focal length (f) in the case of spherical mirror is called mirror equation.

Derivation of Mirror equation:
Consider an object AB placed in front of a concave mirror of focal length f.
It forms a real image $A'B'$.
For paraxial rays MP can be considered to be a straight line and perpendicular to CP.
The right angled triangles $A'B'F$ and MPF are similar.



$$\frac{A'B'}{PM} = \frac{B'F}{FP}$$

$$\frac{A'B'}{AB} = \frac{B'F}{FP} \qquad \because PM = AB$$

Also the right angled triangles $A'B'P$ and ABP are similar,

Then, $\frac{A'B'}{AB} = \frac{B'P}{BP}$

From the above equations we get, $\frac{B'F}{FP} = \frac{B'P}{BP}$

$$\frac{B'P - FP}{FP} = \frac{B'P}{BP}$$

According to sign convention, $B'P = -v$, $FP = -f$ and $BP = -u$

$$\frac{-v-(-f)}{-f} = \frac{-v}{-u}$$

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

$$-vf = -uv + uf$$

On rearranging, $uv = uf + vf$

Dividing throughout by uvf, $\frac{uv}{uvf} = \frac{uf}{uvf} + \frac{vf}{uvf}$

$$\mathbf{\frac{1}{f} = \frac{1}{v} + \frac{1}{u}}$$

This relation is called mirror equation

Linear Magnification (m): The linear magnification produced by a spherical mirror is defined as the ratio of height of image to the height of the object.

$$m = \frac{height\ of\ image}{height\ of\ object} = \frac{h'}{h}$$

$$\mathbf{m = \frac{-v}{u}}$$

The magnitude of linear magnification is $|m| = \frac{h'}{h} = \frac{v}{u}$

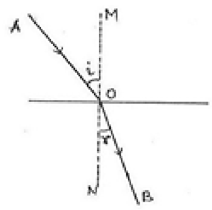
If $|m| > 1$, image formed is enlarged, if $|m| < 1$, image formed is diminished

Refraction: The phenomenon of the change in direction of light when it enters from one medium to another medium obliquely is called Refraction.

$AO \rightarrow$ incident ray

$OB \rightarrow$ refracted ray

$NM \rightarrow$ normal to the surface



Angle of incidence: The angle between the incident ray and normal is called angle of incidence (i).

Angle of refraction: The angle between the refracted ray and the normal is called angle of refraction (r).

Laws of Refraction:

1. The incident ray, the refracted ray and the normal to refracting surface at the point of incidence lie in the same plane.
2. The ratio of the sine of the angle of incidence to the sine of the angle of refraction is a constant for given pair of media and for a given wavelength of light.

$$\mathbf{\frac{\sin i}{\sin r} = n_{21}}$$

This is known as Snell's law, where n_{21} is a constant, called refractive index of second medium with respect to the first medium when a ray of light travels from medium-1 to medium-2

Consequences due to Refraction

1. Lateral shift:
2. Apparent depth :
3. Delayed sunset and advanced sunrise

Total internal reflection: It is the phenomenon, in which a ray of light travelling at an angle of incidence greater than the critical angle from denser medium to a rarer medium is totally reflected back into the denser medium, obeying the laws of reflection.

Critical angle(i_c): It is the angle of incidence in the denser medium for which the angle of refraction in the rarer medium is 90^0.

Condition for total internal reflection:

1) The ray of light must travel from a denser medium into a rarer medium.
2) The angle of incidence in the denser medium must be greater than the critical angle for the given pair of media.

Relation between critical angle and refractive index:

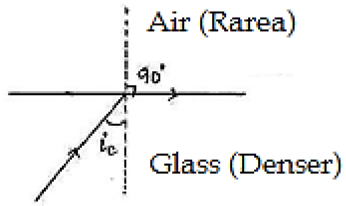
Consider the refraction of light from denser medium of RI n_1 into a rarer medium of RI n_2.

$$\frac{\sin i}{\sin r} = n_{21} = \frac{n_2}{n_1}$$

When $i = i_c$, then $r = 90^0$

$$\frac{\sin i_c}{\sin 90^0} = n_{21}$$

$$\boldsymbol{\sin i_c = n_{21}} \quad \text{or} \quad \boldsymbol{\sin i_c = \frac{1}{n_{12}}}$$



Application of Total internal reflection

1) Brilliance of Diamond
2) Mirage
3) Totally reflecting prisms
4) Optical fibres:

Uses of optical fibre cable:

- Optical fibres are used to transmit light without any loss in its intensity over distances of several km.
- Optical fibres are used in the manufacture of endoscopes.
- They are used in telecommunication for transmitting audio and video signals.
- They are used to transmit the images of the objects.

Refraction at a convex surface:

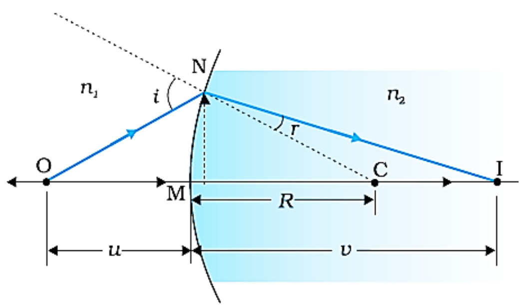
Figure shows the formation of image I of an object O on the principal axis of a convex surface with centre of curvature C.

For small angles (assuming paraxial rays) we have,

$$\tan(\angle NOM) \approx \angle NOM = \frac{MN}{OM}$$

$$\tan(\angle NCM) \approx \angle NCM = \frac{MN}{MC}$$

$$\tan(\angle NIM) \approx \angle NIM = \frac{MN}{MI}$$



Here $i = \angle NOM + \angle NCM = \frac{MN}{OM} + \frac{MN}{MC}$

and $r = \angle NCM - \angle NIM = \frac{MN}{MC} - \frac{MN}{MI}$

For small angles, Snell's law, $n_1 \sin i = n_2 \sin r$ can be written as,

$$n_1 i = n_2 r$$

$$n_1\left(\frac{MN}{OM} + \frac{MN}{MC}\right) = n_2\left(\frac{MN}{MC} - \frac{MN}{MI}\right)$$

$$n_1 MN\left(\frac{1}{OM}+\frac{1}{MC}\right)=n_2 MN\left(\frac{1}{MC}-\frac{1}{MI}\right)$$
$$\frac{n_1}{OM}+\frac{n_1}{MC}=\frac{n_2}{MC}-\frac{n_2}{MI}$$
$$\frac{n_1}{OM}+\frac{n_2}{MI}=\frac{n_2}{MC}-\frac{n_1}{MC}$$
$$\frac{n_1}{OM}+\frac{n_2}{MI}=\frac{n_2-n_1}{MC}$$

Applying the Cartesian sign convention, $OM=-u, MI=+v, MC=+R$

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

This relation relates u and v to n and R and this equation holds good for any spherical surface.

Lens: A lens is an optical medium bounded by two surfaces of which at least one is spherical or cylindrical.

Principal axis: It is a straight line passing through the centers of curvature of the two spherical surface of the lens.

Optic centre: Optic centre of a lens is a point on the principal axis inside the lens such that all rays passing through this point will have the emergent ray parallel to the corresponding incident ray.

Principal focus: A beam of light, close and parallel to the principal axis incident on the lens, after refraction, the rays converge to a fixed point in the case of a convex lens and appear to diverge from a fixed point in the case of a concave lens. This fixed point is called Principal focus.

Focal length: It is the distance between the optic centre and principal focus of the lens.

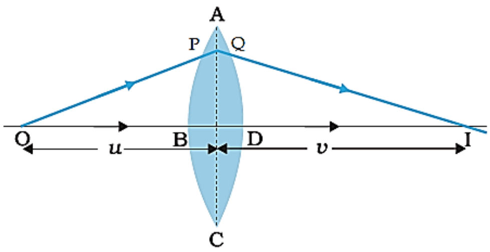
Lens Maker's formula:

Consider a thin lens of small aperture placed in a medium of Refractive index n_1.

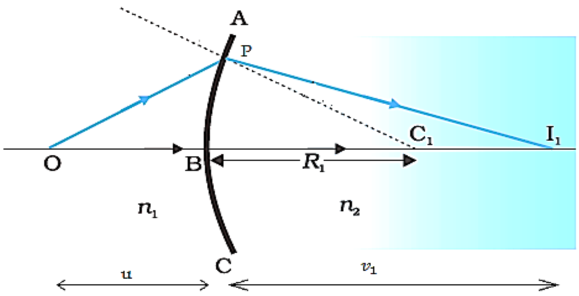
Let n_2 be the Refractive index of the material of the lens.

Let f be the focal length of the lens.

Let R_1 and R_2 be the radii of curvature of its two surfaces.



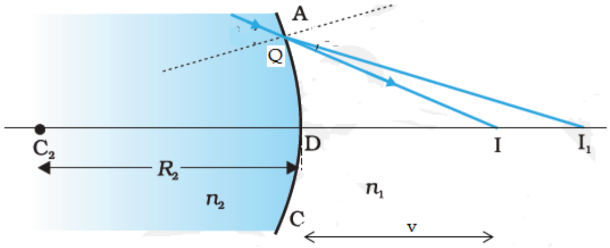
(i) The first refracting surface ABC forms the image I_1 of the object O at a distance v_1 from the lens.



Using the relation for refraction at a spherical surface,

$$\frac{n_2}{v_1}-\frac{n_1}{u}=\frac{n_2-n_1}{R_1} \qquad \rightarrow (1)$$

(ii) The image I_1 acts as a virtual object for the second surface ADC and the refraction at the second surface forms the image I.



Using the relation for refraction at a spherical surface,

$$\frac{n_1}{v} - \frac{n_2}{v_1} = \frac{n_1 - n_2}{R_2}$$

$$\frac{n_1}{v} - \frac{n_2}{v_1} = \frac{-(n_2 - n_1)}{R_2} \qquad \rightarrow (2)$$

Adding the equation (1) and (2)

$$\frac{n_2}{v_1} - \frac{n_1}{u} + \frac{n_1}{v} - \frac{n_2}{v_1} = \frac{n_2 - n_1}{R_1} + \frac{-(n_2 - n_1)}{R_2}$$

$$-\frac{n_1}{u} + \frac{n_1}{v} = (n_2 - n_1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\frac{1}{v} - \frac{1}{u} = \left(\frac{n_2}{n_1} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\frac{1}{v} - \frac{1}{u} = (n_{21} - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

If the object is at infinity then $u = \infty$ and $\frac{1}{u} = 0$, $\frac{1}{v} = \frac{1}{f}$

$$\boldsymbol{\frac{1}{f} = (n_{21} - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)}$$

This equation is known as lens maker's formula and this is true for both convex and concave lens.

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

$$\boldsymbol{P = \frac{1}{f_{(in\,m)}} = \frac{100}{f_{(in\,cm)}}}$$

$$P = \frac{1}{f} = (n_{21} - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

Power of the lens is measured in *dioptre* (D).

Note: (1) While calculating power in dioptre - focal length should be metre.

(2) *Power of a lens varies inversely as the focal length or vice versa.*

Thin lens formula:

Consider a convex lens of focal length f.

Let AB be the object. $A'B'$ is image formed after refraction through the convex lens.

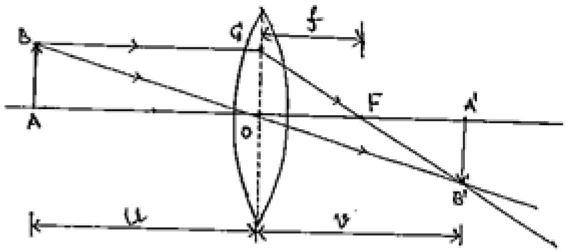
$\Delta\, ABO$ and $OA'B'$ are similar

$$\frac{AB}{A'B'} = \frac{AO}{A'O} \qquad \rightarrow (1)$$

Similarly, ΔCOF and $\Delta\, A'B'F$ are similar

$$\frac{CO}{A'B'} = \frac{OF}{FA'}$$

But $CO = AB$, $\quad \frac{AB}{A'B'} = \frac{OF}{FA'} \qquad \rightarrow (2)$



From equation (1)and (2), we have $\frac{AO}{A'O} = \frac{OF}{FA'}$

$$\frac{AO}{A'O} = \frac{OF}{OA' - OF}$$

Applying sign convention, $AO = -u, OA' = v$ and $OF = f$

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

$$-uv + uf = vf$$

Dividing both sides by uvf, $\frac{-uv}{uvf} + \frac{uf}{uvf} = \frac{vf}{uvf}$

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

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

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

This is the thin lens this formula is applicable to both convex and concave lenses.

Linear Magnification:

Magnification produced by a lens is defined as the ratio of the size of the image to that of the object. Thus magnification for convex lens is negative for real image,

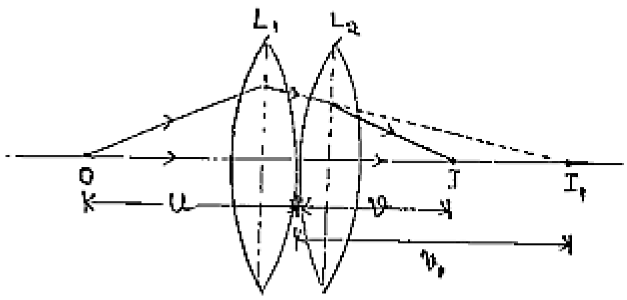
For convex lens, virtual image : $m = \frac{h'}{h} = \frac{v}{u}$

For convex lens $m = \frac{h'}{h} = \frac{-v}{-u} = \frac{v}{u}$

Combination of thin lenses in contact:

L_1 and $L_2$are the two thin lenses of focal lengths f_1 and f_2 kept in contact.

Let O is the point object placed on the principal axis of the lens at a distance u from the lens system.



The lens L_1 forms an image I_1 of the object at a distance v_1 from it.

$$\frac{1}{v_1} - \frac{1}{u} = \frac{1}{f_1}$$

I_1 acts as an object for the lens L_2 which forms the image I at a distance v from it.

$$\frac{1}{v} - \frac{1}{v_1} = \frac{1}{f_2}$$

Adding both the equations,

$$\frac{1}{v_1} - \frac{1}{u} + \frac{1}{v} - \frac{1}{v_1} = \frac{1}{f_1} + \frac{1}{f_2}$$

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f_1} + \frac{1}{f_2}$$

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

where $\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$ called *equivalent focal length*.

Thus, the two thin lenses in contact behave as a single lens of focal length *f*.

For more than two lenses, $\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} + \frac{1}{f_3} + \cdots\cdots$

Prism: Prism is an optical medium bounded by three rectangular faces and two triangular faces which are parallel to each other.

Refraction through a prism (Expression for refractive index of the material of prism):

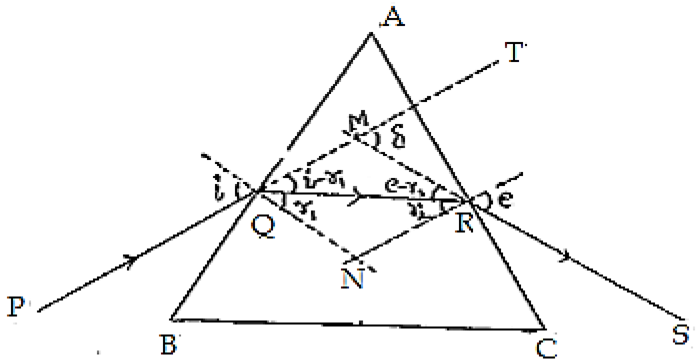
ABC is a principal section of a prism of Refractive Index n.

A ray of light PQ incident on the refracting face AB refracts along QR and emerges along RS.

Let i and r_1 be the angle of incidence and refraction respectively at AB.

Let r_2 and e be the angle of incidence and emergence respectively at AC.

QN and RN are the normal at Q and R to AB and AC respectively.



In the quadrilateral $AQNR$, $\angle Q + \angle R = 180^0$

Therefore, $\angle A + \angle N = 180^0$

In the triangle QNR, $r_1 + r_2 + \angle N = 180^0$

From above equation, we get, $\boldsymbol{A = r_1 + r_2}$

The Angle δ between the incident ray PMT and the direction of emergence MRS is the angle of deviation.

From the Δ^{le} MQR, $\angle TMR = \angle MQR + \angle MRQ$

$$\delta = (i - r_1) + (e - r_2)$$
$$\delta = i + e - r_1 - r_2$$
$$\delta = i + e - (r_1 + r_2)$$
$$\delta = i + e - A$$
$$A + \delta = i + e$$

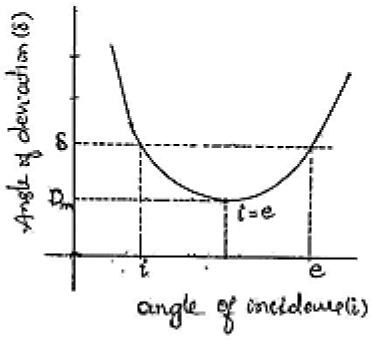
From the graph, for a given value of deviation there are two values of angle of incidence i and e

At minimum deviation position,

$i = e$

then $r_1 = r_2 = r$

and $\delta = D_m$



Now we have , $A = r_1 + r_2$

$A = r + r = 2r$

$r = \frac{A}{2}$

and $A + D_m = i + e$

$$A + D_m = i + i = 2i$$

$$i = \frac{A + D_m}{2}$$

From Snell's law, $n = \frac{\sin i}{\sin r}$

$$\boldsymbol{n = \frac{\sin\left(\frac{A + D_m}{2}\right)}{\sin\left(\frac{A}{2}\right)}}$$

This is the expression for RI of the material of the prism.

Natural phenomena Due to sunlight

(i) Rainbow

(ii) Scattering of light.

Rayleigh's scattering law: Amount of scattering is inversely proportion to the fourth power of the wavelength.

Light of shorter wave length is scattered much more than light of longer wave lengths.

(iii) Blue colour of the sky

(iv) White colour of clouds

(v) Reddish sun at sunset or sunrise

Chapter – 10 **WAVE THEORY**

Wave front: A wave front is defined as the locus of points which have the same phase of oscillation.

Huygens Principle:

(i) Each point of the wave front is the source of a secondary disturbance.

(ii) The wavelets emanating from these points spread out in all directions with the speed of the wave.

(iii) These wavelets emanating from the wave front are usually referred to as secondary wavelets and if we draw a common tangent to all these spheres, we obtain the new position of the wave front at a later time.

Refraction of a plane wave using Huygens principle:

Consider a plane wave front AB incident in medium-I at an angle i.

Let the secondary wavelet from B strike the surface XY at C in a time t, then $BC = v_1 t$

Secondary wavelet from A will travel a distance $v_2 t$ in medium-II in the same time t.

Therefore with A as centre and $v_2 t$ as radius draw an arc in the medium II.

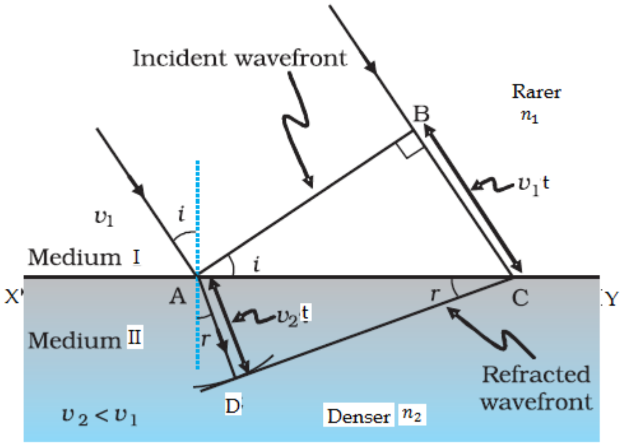
The tangent from C touches the arc at D.

Let r be the angle of refraction.

From $\Delta^{le} ABC$, $\sin i = \frac{BC}{AC} = \frac{v_1 t}{AC}$

$\Delta^{le} ACD$, $\sin r = \frac{AD}{AC} = \frac{v_2 t}{AC}$

$$\frac{\sin i}{\sin r} = \frac{v_1 t}{AC} \times \frac{AC}{v_2 t} = \frac{v_1}{v_2}$$



If C represents the speed of light in vacuum then,

$$n_1 = \frac{C}{v_1} \quad \text{and} \quad n_2 = \frac{C}{v_2}$$

$$\frac{n_2}{n_1} = \frac{C}{v_2} \times \frac{v_1}{C} = \frac{v_1}{v_2}$$

$$\frac{\sin i}{\sin r} = \frac{n_2}{n_1}$$

$$\boldsymbol{n_1 \sin i = n_2 \sin r}$$

This is the Snell's law of refraction

Reflection of a plane wave by a plane surface:

Consider a wave front AB incident at an angle i on a reflecting surface XY.

Let v be the speed of light wave in the medium.

Let the secondary wavelets from B strike the surface XY at C in time t then $BC = vt$.

The secondary wavelet from A will travel the same distance vt in the same time t.

Therefore A as Centre, vt as radius draw an arc. The tangent from C touches the arc at D.

Then $AD = vt$ and CD is the Reflected wave front

In the figure from triangles, ABC and DCA

$$\angle ABC = \angle ADC = 90^0$$

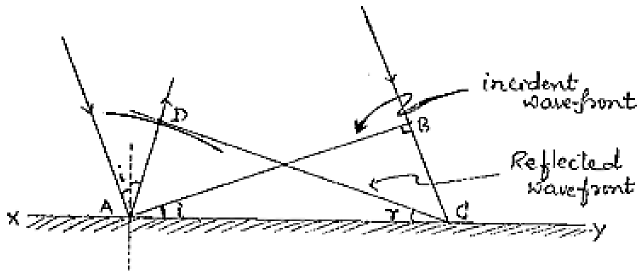
$$BC = AD = vt$$

and $AC =$ common side

$$\therefore \quad \Delta ABC \cong \Delta ADC$$

Hence $\angle BAC = \angle DCA$

$$\boldsymbol{i = r}$$



Doppler Effect: The apparent change in frequency of waves from a source due to the relative motion between an observer and the source is called Doppler Effect.

Interference of light: The modification in the distribution of light energy due to the superposition of two or more waves of light is called Interference of light.

Theory of Interference:

Let a_1 and a_2 be the amplitudes of the two waves.

The displacements of any particle in the medium due to those waves at any instant of time t are,

$$y_1 = a_1 \sin \omega t$$

and $$y_2 = a_2 \sin(\omega t + \phi)$$

Where $\omega \rightarrow$ angular frequency of the waves

$\phi \rightarrow$ phase difference between the two waves.

By the principle of super position, the resultant displacement is,

$$y = y_1 + y_2$$
$$y = a_1 \sin \omega t + a_2 \sin(\omega t + \phi)$$
$$y = a_1 \sin \omega t + a_2 \sin \omega t \cos \phi + a_2 \cos \omega t \sin \phi$$
$$y = (a_1 + a_2 \cos \phi) \sin \omega t + a_2 \cos \omega t \sin \phi$$

Let $R \cos \theta = a_1 + a_2 \cos \phi$ and $R \sin \theta = a_2 \sin \phi$

Then $y = R \cos \theta \sin \omega t + R \sin \theta \cos \omega t$

$$y = R[\sin \omega t \cos \theta + \cos \omega t \sin \theta]$$
$$\boldsymbol{y = R \sin(\omega t + \theta)}$$

Amplitude of the resultant wave: The amplitudes of the resulting wave is R.

We have, $R \cos \theta = a_1 + a_2 \cos \phi$

$R \sin \theta = a_2 \sin \phi$

Squaring the above equations and adding them,

$$R^2 cos^2\theta + R^2 sin^2\theta = (a_1 + a_2 \cos \phi)^2 + a_2^2 \, sin^2\phi$$
$$R^2(cos^2\theta + sin^2\theta) = a_1^2 + a_2^2 \, cos^2\phi + 2a_1a_2 \cos \phi + a_2^2 \, sin^2\phi$$
$$R^2 = a_1^2 + a_2^2(cos^2\phi + sin^2\phi) + 2a_1a_2 \cos \phi$$
$$R^2 = a_1^2 + a_2^2 + 2a_1a_2 \cos \phi$$
$$\boldsymbol{R = \sqrt{a_1^2 + a_2^2 + 2a_1a_2 \cos \phi}}$$

Phase angle: θ is the phase angle of the resultant wave.

The phase angle θ is given by, $\tan \theta = \frac{R \sin \theta}{R \cos \theta}$

$$\boldsymbol{tan\ \theta = \frac{a_2 \sin \phi}{a_1 + a_2 \cos \phi}}$$

Condition for constructive interference:

(a) In terms of Phase difference:

Thus *for constructive interference, the phase difference is even multiple of* π.

(b) In terms of path difference:

∴ *For constructive interference, the path difference must be equal to the even multiple* $\frac{\lambda}{2}$ *where* λ *is the wave length of light.*

Condition for Destructive interference:

(a) In terms of Phase difference:

Thus *for destructive interference, the phase difference is odd multiple of* π.

(b) In terms of path difference:

For destructive interference the path difference must be equal to the odd multiple of $\frac{\lambda}{2}$

Fringe width: Distance between two successive bright or dark fringes is called fringe width (β)

Expression for fringe width:

In the figure S_1 and S_2 represents two coherent sources separated by a distance *d*.

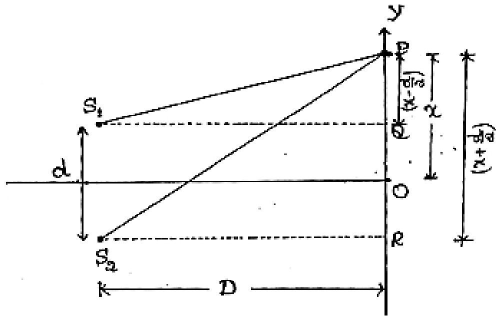
Let a screen be placed at a distance *D* from the coherent sources.

The point *O* on the screen is equidistant from S_1 and S_2 so that the path difference between the two light waves from A and B reaching is zero.

Consider a point P at a distance x from O.

The path difference between the light waves from S_1 and S_2 reaching the point P is given by,

Path difference $= S_2P - S_1P$



From figure, $(S_2P)^2 = (S_2R)^2 + PR^2 = D^2 + \left(x + \frac{d}{2}\right)^2$

and $(S_1P)^2 = (S_1Q)^2 + PQ^2 = D^2 + \left(x - \frac{d}{2}\right)^2$

$$(S_2P)^2 - (SP)^2 = \left[D^2 + \left(x + \frac{d}{2}\right)^2\right] - \left[D^2 + \left(x - \frac{d}{2}\right)^2\right]$$

$$(S_2P)^2 - (SP)^2 = D^2 + \left(x + \frac{d}{2}\right)^2 - D^2 - \left(x - \frac{d}{2}\right)^2$$

$$(S_2P)^2 - (SP)^2 = D^2 + x^2 + \left(\frac{d}{2}\right)^2 + \frac{2xd}{2} - D^2 - x^2 - \left(\frac{d}{2}\right)^2 + 2\frac{xd}{2}$$

$$(S_2P)^2 - (S_1P)^2 = 2xd$$

$$(S_2P + S_1P)(S_2P - S_1P) = 2xd$$

$$S_2P - S_1P = \frac{2xd}{S_2P + S_1P}$$

Since P is very close to O, $(S_2P + S_1P) \approx 2D$

$$\textbf{Path difference} = \frac{2xd}{2D} = \frac{xd}{D}$$

<u>For Bright fringe or maximum intensity at P,</u>

Path difference must be equal to $2n\frac{\lambda}{2}$ where λ is the wave length.

$$\frac{xd}{D} = \lambda n$$

$$x = n\frac{xD}{d}$$

The distance of the nth bright fringe from the centre O of the screen is, $x_n = n\frac{\lambda D}{d}$

The distance of (n + 1)th bright fringe from the centre of the screen is, $x_{n+1} = (n+1)\frac{\lambda D}{d}$

Fringe width is given by, $\beta = x_{n+1} - x_n = (n+1)\frac{\lambda D}{d} - n\frac{\lambda D}{d}$

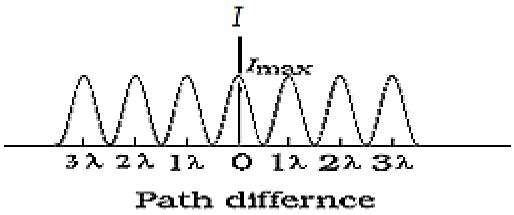
$$\boldsymbol{\beta = \frac{\lambda D}{d}}$$

Similarly for Dark fringe or minimum intensity at P, we can obtain the same expression.

Factors on which fringe width depends.

- β is directly propositional to wave length (λ) of light used and slit-screen separation (D).
- β is inversely proportional to the shit separation (d).

Intensity distribution curve:



Characteristics of interference pattern:

- Alternate dark and bright fringes are present.
- Central fringe is bright fringe.
- The width of each bright fringe is equal to the width of each dark fringe.
- All bright fringes have equal intensity
- All the dark fringes ideally have zero intensity

Conditions for sustained interference:

- Two sources must coherent.
- The two sources should be close to each other.
- The two waves must have equal or nearly equal amplitude.
- Two sources must be narrow.
- Light should be monochromatic
- Two sources should emit light waves continuously.

Diffraction: The phenomenon of bending of light waves around the edges of obstacles and entering into the geometrical shadow of the obstacle is called diffraction of light.

Condition for minima:

In general for minima, $a\theta = n\lambda$

$$\boldsymbol{\theta = \frac{n\lambda}{a}} \qquad \text{where } n = 1, 2, 3 \ldots\ldots$$

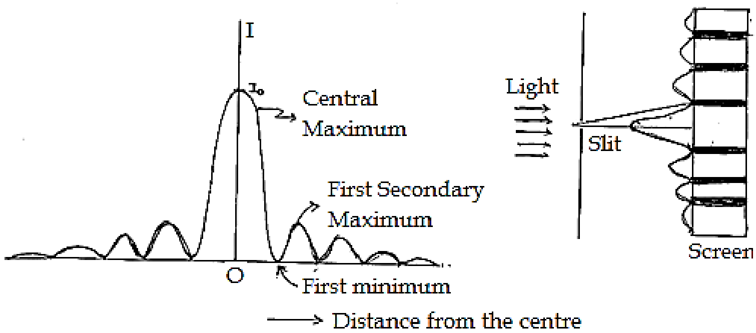
This is the condition for minima.

Condition for secondary maxima:

$$\boldsymbol{\theta = (2n+1)\frac{\lambda}{2a}} \qquad \text{where } n = 1, 2, 3, 4 \ldots\ldots$$

This is the condition for secondary maxima.

Intensity Distribution Curve:



Difference between Interference and diffraction

Interference	Diffraction
Interference is the modification in the intensity of light due to superposition to two or more coherent waves	Diffraction is bending of light around the edges of obstacles.
Interference pattern is a superposition of two waves originating from two narrow slits.	This pattern is a superposition of a continuous family of waves originating from each point of the single slit.
This pattern has a number of equally spaced bright & dank fringes	It has the brightest bound at its centre with alternate dark bands and bright bands on either side.
Fringe width is same	Fringe width is not same
Intensity of bright bounds is same	Intensity of centre band is maximum and intensity goes decreasing on either side.
Contrast between bright & dark bands is good	Contrast in this pattern is poor

Resolving power: Resolving power of an optical instrument is its ability to produce separate images of two closely lying point objects distinctly.

Limit of resolution of a telescope: The limit of resolution of a telescope is the angle subtended at the objective of the telescope by two distant objects whose images are just resolved.

Resolving power of a telescope: The Reciprocal of limit of resolution of telescope is called Resolving power of a telescope.

$$\mathbf{R.P} = \frac{\boldsymbol{D}}{\mathbf{1.22}\boldsymbol{\lambda}}$$

Thus, *the resolving power of a telescope is increased by using objectives of large diameter*.

Limit of Resolution of a microscope: The limit of resolution of a microscope is the minimum distance between two point objects whose images appear just resolved.

Resolving power of a microscope: The resolving power of the microscope is the reciprocal of the limit of resolution of microscope.

$$\boldsymbol{R.P} = \frac{\mathbf{2}\boldsymbol{n}\sin\boldsymbol{\beta}}{\mathbf{1.22}\boldsymbol{\lambda}}$$

(i) *Resolving power can be increased by increasing* n and decreasing λ.

(ii) In an oil immersion microscope oil of high refractive index is used to increase the resolving power.

Polarization: The phenomenon by which the vibration of the waves in a beam is restricted to a particular plane is called polarization.

Polaroid: Polaroid is the thin sheets of plastic, which are used to produce the plane polarized light. A Polaroid consists of long chain of molecules aligned in a particular direction.

Pass - axis (transmission axis): The direction perpendicular to the direction of the alignment of the molecules of the Polaroid is known as pass - axis.

Malus' Law: This law states that, the intensity of the polarized light transmitted through analyser varies as the square of the cosine of the angle between the plane of transmission of the analyser and the plane of the polarizer.

$$I \propto cos^2\theta$$

$$\boldsymbol{I = I_0 \, cos^2\theta}$$

Where I_0 → Intensity of the light entering the analyser

θ → angle between pass axes of polarizer & Analyser.

Use of Polaroids:

1. Polaroids are used as sunglasses.
2. Automobile head light are covered with Polaroids to minimize glare.
3. Polaoids are used in cameras, microscope objectives to eliminate glare of reflected light.
4. Polaroids are used as sun films in window panes of aero planes.
5. Polaroids are used to view 3-D pictures & movies.
6. Polaroids are used to improve colour contrast in old oil paintings.
7. Polaroids are used in Laboratory to study plane polarized light.

Brewster's angle (Polarising angle): Brewster's angle for a surface is the angle of incidence for which the reflected light is completely polarized.

Brewster's law: The refractive index of the material of the reflector is numerically equal to tangent of the Brewster's angle. Mathematically, $n = \tan i_B$

Proof for Brewster's law: When the angle of incidence on a surface is equal to the Brewster's angle the reflected and refracted rays are perpendicular to each other.

When $i = i_B$

From figure, $\angle BOY + \angle COY = 90^0$

$$(90 - i_B) + (90 - r) = 90^0$$

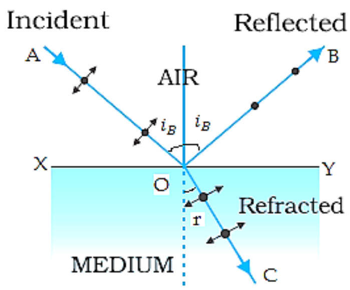
$$90 - i_B + 90 - r = 90^0$$

$$r = 90 - i_B$$

Using, $n = \dfrac{\sin i_B}{\sin r}$

$$n = \frac{\sin i_B}{\sin(90 - i_B)} = \frac{\sin i_B}{\cos i_B}$$

$$\boldsymbol{n = \tan i_B}$$



Chapter 11 DUAL NATURE OF RADIATION AND MATER

Electron Emission: The liberation of electron from a metal surface is called electron emission.

Work function: The minimum energy required by the free electron to just leave the metal surface is known as work function of the metal.

electron-volt: One electron-volt is the energy gained by an electron when it is accelerated through a potential difference of one volt. $1eV = 1.6 \times 10^{-19}C \times 1V = 1.6 \times 10^{-19}J$

Types of electron emission:

(i) Thermionic emission

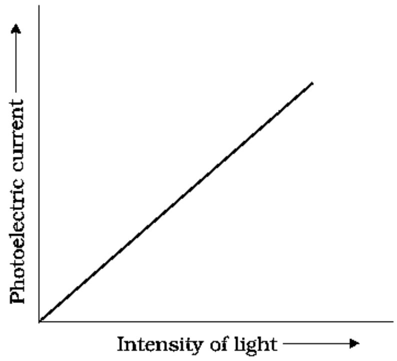
(ii) Field emission

(iii) Photo-Electric emission

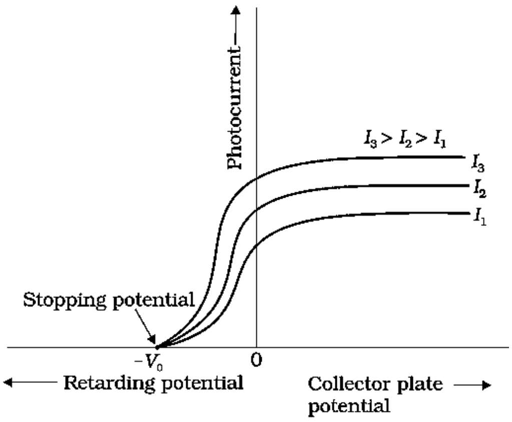
Photo Electric effect: It is the phenomenon of emission of electron from the surface of the metal when radiation of suitable frequency falls on it.

Threshold frequency: The minimum frequency of incident light required to emit electrons from a metal surface is known as threshold frequency.

(i) Effect of intensity of light on photo current:

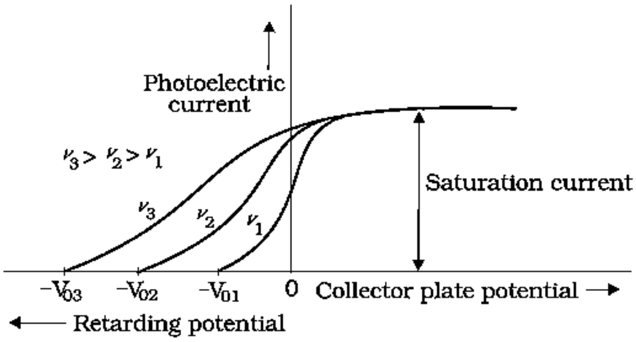


(ii) Effect of potential on the photoelectric current:

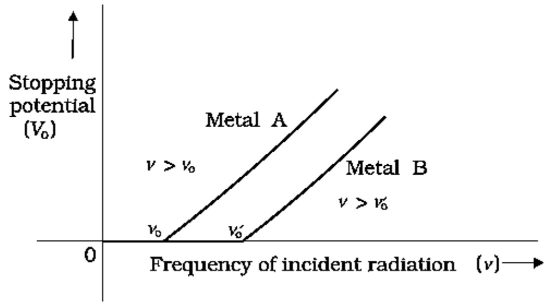


<u>Stopping (Retarding) Potential:</u> It is the minimum negative voltage on the collector plate at which the photo electric current becomes zero.

(iii) Effect of frequency of the incident radiation:



(iv) Variation of stopping potential V_0 with frequency ν of incident radiation:



Experimental observations or Laws of Photo electric effect:

- The photoelectric emission is an instantaneous process.
- There exists a certain minimum frequency below which no emission of photoelectrons takes place.
- The number of photo electrons emitted per second is proportional to the intensity of incident radiation.
- Kinetic energy of the emitted photo electrons increases linearly with the frequency.
- The photoelectric current increases with increase in collector plate voltage and reaches a saturation value.
- The photocurrent decreases with increase in negative potential and reaches zero at a negative potential known as stopping potential.
- The stopping potential V_0 varies linearly with the frequency of incident radiation.

Photo electric equation:

$$E = \phi_0 + K_{max}$$

$$\boldsymbol{h\nu = \phi_0 + K_{max}}$$

Where $\phi_0 = h\nu_0 \rightarrow$ work function of the metal.

$\nu \rightarrow$ Frequency of incident radiation.

$h \rightarrow$ Planck's Constant.

Properties of Photon:

- Photon travel at a speed of $3 \times 10^8 ms^{-1}$ in vacuum.
- The rest mass of the photon is zero.
- The energy of photon is given by, $E = h\nu$, where ν is the frequency of light.
- Photons are electrically neutral.

Matter waves(de-Broglie wave): The waves associated with ***moving*** material particle are known as matter waves or de Broglie waves. Matter waves are ***not*** electromagnetic waves.

de-Broglie wavelength: The wavelength associated with the matter wave is called de Broglie wavelength.

Expression for de Broglie wavelength of a particle in motion or de Broglie relation:

$$\boldsymbol{p = \frac{h\nu}{C} = \frac{h}{\lambda}} \qquad \text{(where } C = \nu\lambda\text{)}$$

Instead of photon, if we have a material particle of mass m, moving with velocity v,

Then, $p = mv$

$$mv = \frac{h}{\lambda}$$

$$\boldsymbol{\lambda = \frac{h}{mv} = \frac{h}{p}}$$ Where λ is the wave length of the matter wave.

de-Broglie wavelength of electron in motion:

The de Broglie wavelength of the electron is, $\lambda = \frac{h}{p} = \frac{h}{\sqrt{2meV}}$

$$\boldsymbol{\lambda = \frac{h}{\sqrt{2meV}} = \frac{h}{\sqrt{2mK}}}$$

Substituting, $h = 6.625 \times 10^{-34} Js,\ m = 9.1 \times 10^{-31} kg,\ e = 1.6 \times 10^{-19} C,$ we get

$$\boldsymbol{\lambda = \frac{1.227}{\sqrt{V}}}\ nm$$

Note: As the accelerating potential increases the de Broglie wavelength decreases.

Davisson and Germer Experiment:

Aim: To study wave nature of electrons.

Principle: Davisson and Germer used the diffraction pattern effects of electron radiations scattered by crystals.

Result or Conclusion or Significance: Davisson and Germer experiment confirms the wave nature of electrons and the de Broglie relation.

CHAPTER – 12 **ATOMS**

Thomson's Plum-pudding model of atom: J J Thomson, himself proposed the first model, called Plum-pudding model.

Hypothesis of the model:

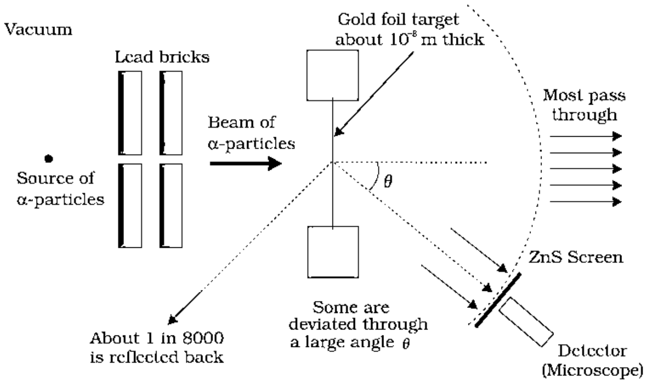
* An atom consists of an elastic sphere over which positive charges are distributed uniformly.
* Most of the mass of the atom is carried by this positive elastic sphere.
* Size of the elastic sphere is equal to the size of the atom.
* Electrons are embedded in this positive sphere like plums in a pudding.

Success of this model:

* It explained the electrical neutrality.
* Stability of atom was explained, by proposing that electrostatic repulsion between the electrons is balanced by attractive force between electrons and positively charged sphere.
* Size and mass of the atom were explained satisfactorily.

Failure of this model: This model failed to explain the large number of spectral lines of simplest element hydrogen.

Alpha particle scattering experiment



Rutherford's nuclear model of atom: Following are the essential features of the Rutherford nuclear atom model.

* An atom has a central core called nucleus, which contain the entire positive charge of the atom and nearly complete mass.
* Number of positive charge inside the nucleus is equal to number of electrons outside the nucleus to make the atom electrically neutral.
* The electron revolves in a *circular orbit*, around the nucleus so that Coulombian force of attraction provides the necessary centripetal force.
* The size of the nucleus to be about $10^{-15}m$ to $10^{-14}m$. The size of the atom is about $10^{-10}m$. Therefore most of an atom is empty space in which electrons revolve around the nucleus.

Impact parameter(b): It is the perpendicular distance of the initial velocity vector of the alpha particle from the centre of the nucleus when it is far away from the atom.

Success of Rutherford's model:

* Large angle scattering of alpha particle through thin metal foils could be explained.

* The existence of nucleus and also the size of a nucleus could be estimated.
* The classification of the elements in periodic table on the basis of atomic number was accumulated.

Drawbacks of Rutherford model:

* It failed to explain the stability of atom.
* It failed to explain the complex spectrum emitted by an atom.

Postulates of Bohr's atomic model:

First Postulate: Electron revolves round the nucleus in discrete circular orbits called stationary orbits without emission of radiant energy. These orbits are called stable orbits or non-radiating orbits.

Second postulate: Electrons revolve around nucleus only in such orbits for which the angular momentum is some integral multiple of $\left(h/_{2\pi}\right)$.

$$\boldsymbol{mv_n r_n = n\frac{h}{2\pi}}$$

Third Postulate: When an electron makes a transition from one of its non-radiating orbits to another of lower energy, a photon is emitted having energy equal to the energy difference between the two states. The frequency of the emitted photon is then given by, $\boldsymbol{E = E_i - E_f}$.

Expression for radius of the Orbit (Bohr's radius):

Consider an electron of mass m and charge e revolving round the nucleus of charge Ze.
Let r be the radius of the n^{th} orbit and v be the liner velocity of the electron.
For an electron in circular orbit, the centripetal force is provided by electrostatic force of attraction.

$$\frac{mv_n^2}{r_n} = \frac{1}{4\pi\varepsilon_0}\frac{(Ze)\,e}{r_n^2}$$

$$m\,v_n^2\,r_n = \frac{1}{4\pi\varepsilon_0}Ze^2 \quad \rightarrow (1)$$

Form Bohr's second postulate, $$mv_n r_n = n\frac{h}{2\pi}$$

$$v_n = \frac{nh}{2\pi m r_n}$$

Substituting for v in equation (1), $$m\left(\frac{nh}{2\pi m r_n}\right)^2 r_n = \frac{1}{4\pi\varepsilon_0}Ze^2$$

$$m\frac{n^2h^2}{4\pi^2m^2r_n^2}r_n = \frac{1}{4\pi\varepsilon_0}Ze^2$$

$$\frac{n^2h^2}{\pi m r_n} = \frac{1}{\varepsilon_0}Ze^2$$

$$\boldsymbol{r_n = \frac{n^2h^2\varepsilon_0}{\pi m Z e^2}} \qquad \text{where n} = 1,2,3,\ldots\ldots\ldots$$

This equation gives the radius of n^{th} stationary orbit.

For Hydrogen atom $Z = 1$, then $$\boldsymbol{r_n = \frac{n^2h^2\varepsilon_0}{\pi m e^2}}$$

For the innermost orbit, $n = 1$, $$r = \frac{h^2\varepsilon_0}{\pi m e^2}$$

The radius of the innermost orbit of hydrogen atom is called **Bohr's radius**, denoted by a_0.

Therefore, $$\boldsymbol{a_0 = \frac{h^2\varepsilon_0}{\pi m e^2}}$$

Note: $a_0 = 5.29 \times 10^{-11} m = 0.529$Å

Expression for linear velocity (orbital speed) of the electron:

$$\boldsymbol{v_n = \frac{Ze^2}{2nh\varepsilon_0}}$$

For hydrogen atom $Z = 1$ and $n = 1$,

Velocity of the first orbit is given by, $$\boldsymbol{v_n = \frac{e^2}{2h\varepsilon_0}}$$

Expression for the total energy of the electron in a stationary orbit (of an hydrogen atom):

Consider an electron of mass m and charge e revolving round the nucleus of charge, Ze.

Let r_n be the radius of the n^{th} orbit.

The potential energy of the electron is , $$U = -\frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{r_n}$$

For uniform circular motion, $$F_c = F_e$$

$$\frac{mv_n^2}{r_n} = \frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{r_n^2}$$

$$m\,v_n^2 = \frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{r_n}$$

The kinetic energy of the electron is, $$K = \frac{1}{2}mv_n^2 = \frac{1}{2}\left(\frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{r_n}\right)$$

The total energy, $E_n = K + U$

$$E_n = \frac{1}{2}\left(\frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{r_n}\right) - \frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{r_n}$$

$$E_n = \frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{r_n}\left(\frac{1}{2} - 1\right)$$

$$E_n = -\frac{1}{2}\left(\frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{r_n}\right)$$

Now substituting the valve of $r_n = \frac{n^2h^2\varepsilon_0}{\pi m Z e^2}$ in the above equation, we get

$$E_n = -\frac{1}{2}\left[\frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{\left(\frac{n^2h^2\varepsilon_0}{\pi m Z e^2}\right)}\right]$$

$$E_n = -\frac{1}{2}\left[\frac{1}{4\varepsilon_0^2}\frac{Z^2e^4m}{n^2h^2}\right]$$

$$\boldsymbol{E_n = -\left[\frac{Z^2me^4}{8n^2\varepsilon_0^2h^2}\right]}$$

For hydrogen atom, $Z = 1$, $$\boldsymbol{E_n = -\frac{me^4}{8n^2\varepsilon_0^2h^2}}$$

$$E_n = -\frac{13.6}{n^2}\ eV$$

Expression for Frequency of emitted radiation in hydrogen:

For hydrogen, $$\boldsymbol{\nu = \frac{me^4}{8\varepsilon_0^2h^3}\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]}$$

Wave number of emitted radiation in hydrogen: Wave number of a spectral line is the reciprocal of its wavelength. It gives the number of waves per unit length.

$$\bar{\nu} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

Where $R = \frac{me^4}{8\varepsilon_0^2 h^3 C}$ and is called *Rydberg constant*, $R = 1.097 \times 10^7 m^{-1}$

Spectral series of Hydrogen:

(i) Lyman series: The spectral lines emitted because of the transition of the electron from higher orbits to the first orbit form a spectral series known as Lyman series.
These spectral lines lie in the ***Ultraviolet region***. These spectral lines have shortest wavelengths.

(ii) Balmer series: The spectral lines emitted due to transition of an electron from any outer orbit to the second orbit form a spectral series known as Balmer series.
The different visible lines in the Balmer series are designated as $H_\alpha, H_\beta, H_\gamma$ and H_δ.
The transition for H_α line is from 3^{rd} orbit to 2^{nd} orbit.
The transition for H_β line is from 4^{th} orbit to 2^{nd} orbit.
The transition for H_γ line is from 5^{th} orbit to 2^{nd} orbit.
The transition for H_δ line is from 6^{th} orbit to 2^{nd} orbit.
These spectral lines lie in the ***visible region***.

(iii) Paschen series: The spectral lines emitted due to the transition of ta electron from any outer orbit to the third orbit form a spectral series known as Paschen series.
These spectral lines lie in the ***infrared region***.

(iv) Bracket series: The spectral lines emitted due to the transition of an electron from any outer orbit to the fourth orbit form a spectral series known as Bracket series.
These spectral lines lie in the ***infrared region***.

(v) Pfund series: The spectral lines emitted due to the transition of an electron from any outer orbit to the fifth orbit form a spectral series known as Bracket series.
These spectral lines lie in the ***far-infrared region***. These spectral lines have longest wavelengths.

Success of Bohr's Theory:

* This theory was first satisfactory theory of atomic structure and atomic spectra.
* This theory explains both emission and absorption spectra.
* This theory was first to introduce quantum number.
* This theory was the first theory to predict the size of electron orbit and hence size of an atom.

Limitations/Drawbacks/Demerits of Bohr's theory:

* This theory can be applied only to hydrogen and hydrogen like atoms.
* This theory cannot explain the structure of all atoms.
* This theory not give any idea about the relative intensities of spectral lines.
* This model does not give any indication regarding the arrangement and distribution of electrons in an atom.
* This model could not explain the wave nature of the electrons.
* There was no theoretical basis for the existence of stationary waves.

CHAPTER – 13 NUCLEI

atomic mass unit (u): It is defined as $\left(\frac{1}{12}\right)^{th}$ of the mass of the corbon-12 atom.

$$1u = \frac{1.992647 \times 10^{-26}}{12}\ kg = 1.660539 \times 10^{-27}\ kg$$

Facts about or Properties of neutron:

(i) It is a constituent of nucleus.
(ii) It is electrically neutral.
(iii) The mass of the neutron is $m_n = 1.6749 \times 10^{-27}\ kg = 1.008666\ u$.
(iv) A neutron is stable inside a nucleus.
(v) A free neutron is unstable. The mean life of a free neutron is around 1000 s and it decays into a proton, an electron and an anti-neutrino.

$$^1_0n \to {}^1_1p + {}^{\ 0}_{-1}e + \overline{\nu}$$

Properties of proton:

(i) Proton is a constituent of nucleus.
(ii) Proton is positively charged particle and charge is $1.6 \times 10^{-19}C$.
(iii) Mass of the proton is $m_p = 1.6726 \times 10^{-27}\ kg = 1.007276\ u$.

Classification of nuclides:

(i) Isotopes: Nuclei having same atomic number but different mass number are called isotopes.

Ex: (i) Hydrogen has three isotopes. $^1_1H \to$ Hydrogen, $^2_1H \to$ deuterium and $^3_1H \to$ tritium
(ii) Nitrogen has two isotopes, $^{14}_{\ 7}N$ and $^{15}_{\ 7}N$

(ii) Isobars: Nuclei having same mass number but different atomic number are called isobars.

Ex: (i) $^{14}_{\ 6}C$, $^{14}_{\ 7}N$ (ii) $^{235}_{\ 92}U$, ^{235}Th (iii) $^{58}_{26}Fe$, $^{58}_{27}Ni$

(iii) Isotones: Nuclei having equal number of neutrons but different atomic number are called isotones.

Ex: (i) ^3_1H , ^4_2He are isotones, they contain 2 neutrons. (ii) $^{14}_{\ 6}C$, $^{16}_{\ 8}O$

Characteristics of a Nucleus:

(i) Radius of the nucleus:

$$\boldsymbol{r = R_0 A^{\frac{1}{3}}}$$ where $R_0 \to$ Constant of proportionality

(ii) Nuclear mass: The mass of a nucleus is due to the masses of protons and neutrons in it. Nuclear mass is found to be less than the sum of masses of protons and neutrons.

$$\textbf{Nuclear mass} < [Zm_p + (A - Z)m_n]$$

(iii) Nuclear density:

$$\rho = \frac{Am_p}{\frac{4}{3}\pi AR_0^3}$$

Substituting the respective values, $\boldsymbol{\rho = 2.3 \times 10^{17} kgm^{-3}}$

It is of the order of $10^{17} kgm^{-3}$.

(iv) Nuclear charge: The positive charge of the nucleus is due to the protons contained in it. Each proton has a charge, $e = 1.6 \times 10^{-19} C$. If Z is the atomic number, then nuclear charge $= Ze$

Mass defect: The difference between the sum of the masses of the constituent nucleons and the actual mass of the nucleus is called mass defect.

$$\Delta M = [Zm_p + (A - Z)m_n] - M$$ where $M \rightarrow$ mass of the nucleus.

Binding energy (E_b): It is the minimum energy required to split the nucleus into its constituent nucleons.

$$E_b = [Zm_p + (A - Z)m_n - M]C^2$$

Specific binding energy (Binding energy per nucleon): The ratio of binding energy of a nucleus to its mass number is called the specific binding energy of the nucleus. It is also referred to as binding energy per nucleon.

$$E_{bn} = \frac{E_b}{A} = \frac{[Zm_p + (A - Z)m_n - M]C^2}{A}$$

Nuclear force: In nucleus, the protons and neutrons are strongly held by attractive force known as nuclear force.

Characteristics of Nuclear force:

* It is the strongest force in nature.
* It is a short range force.
* It is charge independent.
* Nuclear force has the property of Saturation.
* It is spin dependent.
* It is exchange force.
* It has a repulsive core.
* It is a non-central force.

Radioactivity: The phenomenon of spontaneous emission of radiations by heavy elements is called radioactivity. The elements which show this phenomenon are called radioactive element.

Types of radioactive rays: Naturally occurring radioactive substances disintegrate by emitting one or more following types of radiations namely,

(a) Alpha (α) rays: These are the streams of positively charged particles identical with helium nuclei (^4_2He).

(b) Beta (β) rays: These are the streams of electrons or positrons emitted from the *nucleus* of radioactive substance.

(c) Gamma (γ) rays: These are the high energy electromagnetic radiations (or photons) emitted from radioactive *nuclei*.

Law of radioactive decay: In any radioactive sample, the number of nuclei undergoing the decay per unit time is proportional to the total number of nuclei in the sample.

If N is the number of nuclei in the sample and ΔN undergo decay in time Δt then,

$$\frac{\Delta N}{\Delta t} \propto N$$

$$\frac{\Delta N}{\Delta t} = \lambda N$$

where λ is called the radioactive decay constant or disintegration constant.

The change in number of nuclei, $dN = -\Delta N$

The quantity dN represents the decrease in the number of atoms and hence it is taken with a negative sign.

The rate of change of N is, $\quad -\frac{dN}{dt} = \lambda N$

$$\frac{dN}{N} = -\lambda dt$$

Integrating, $\quad \int_{N_0}^{N} \frac{dN}{N} = -\lambda \int_{t_0}^{t} dt$

$\ln N - \ln N_0 = -\lambda(t - t_0)$ $\quad$ where N_0 is the initial number of radioactive atoms

Setting $t_0 = 0$, $\quad \ln N - \ln N_0 = -\lambda t$

$$\ln\left(\frac{N}{N_0}\right) = -\lambda t$$

$$\frac{N}{N_0} = e^{-\lambda t}$$

$$\boldsymbol{N = N_0\, e^{-\lambda t}}$$

This equation shows that, the decay is exponential.

Decay constant of a radioactive element is equal to the reciprocal of the time required for the number of nuclei in a radioactive sample to reduce to $\left(1/e\right)$ times the initial number.
Unit of decay constant is s^{-1} or min^{-1} or day^{-1} or $year^{-1}$

Total decay rate(R) or Activity: It is the number of nuclei disintegrating per unit time.
It is a positive quantity and is given by,

$\boldsymbol{R = R_0\ e^{-\lambda t}}$ $\quad$ where $R_0 = \lambda N_0$

This equation is called alternate form of radioactive decay.

Units of activity: The SI unit of activity is $becquerel\ (Bq)$.
One becquerel is one disintegration per second.

The commonly used units or older units are $curie$ and $rutherford$
(i) One curie is 3.7×10^{10} disintegration per second. $i.e.\ 1\ Ci = 3.7 \times 10^{10}\ Bq$
(ii) One rutherford is 10^{6} disintegration per second. $i.e.\ 1Rd = 10^{6}\ Bq$

Half-life: It is the time at which the number of atoms in a radioactive sample is reduces to half of its original value. It is denoted by $T_{1/2}$ which was introduced by Rutherford.

Expression for half-life <u>or</u> Relation between Half-life and decay constant:
At time t the number of atoms present in a radioactive sample is,

$$N = N_0\, e^{-\lambda t}$$

At $t = T_{1/2}$, $\quad$ we have $\quad N = \frac{N_0}{2}$

$$\frac{N_0}{2} = N_0\, e^{-\lambda\left(T_{1/2}\right)}$$

$$e^{\lambda\left(T_{1/2}\right)} = 2$$

$$\lambda\left(T_{1/2}\right) = \log_e 2$$

$$\lambda\left(T_{1/2}\right) = 2.303 \log_{10} 2$$

$$\lambda\left(T_{1/2}\right) = 2.303 \times 0.3010 = 0.693$$

$$\boldsymbol{T_{1/2} = \frac{0.693}{\lambda}}$$

Mean life (Average life): Mean life of a radioactive substance is given by the sum of total life time of all atoms divided by the total number of atoms present.

Expression for Mean life:

We have, $N = N_0\, e^{-\lambda t}$

$$\frac{dN}{dt} = -\lambda N_0\, e^{-\lambda t}$$

$$dN = -\lambda N_0\, e^{-\lambda t}\, dt$$

It means, dN atoms have lived for time t before decaying.

Total life time of dN atoms $= t\,|dN|$

Now total life of all atoms in the radioactive substance, $T_{tot} = \int_{N_0}^{0} t\,|dN|$

When $N = N_0$, we have $t = 0$ and when $N = 0$, we have $t = \infty$

also $|dN| = \lambda N_0\, e^{-\lambda t}\, dt$

Therefore, $T_{tot} = \int_0^{\infty} t\,\lambda N_0\, e^{-\lambda t}\, dt$

$$T_{tot} = \lambda N_0 \int_0^{\infty} t\, e^{-\lambda t}\, dt$$

Integrating by parts, $T_{tot} = \frac{N_0}{\lambda}$

Now, Mean life, $\tau = \frac{T_{tot}}{N_0} = \frac{\left(N_0/\lambda\right)}{N_0}$

$$\boldsymbol{\tau = \frac{1}{\lambda}}$$

Relation between half-life and mean life:

$$\boldsymbol{T_{1/2} = 0.693\,\tau}$$

or $\boldsymbol{\tau = 1.44\, T_{1/2}}$

Alpha decay: The phenomenon of emission of an alpha particle from a radioactive nucleus is called alpha decay.

When a nucleus emits an alpha particle, its atomic number (proton number) decreases by 2 and mass number decreases by 4. The alpha decay of a nucleus can be represented as,

$${}_{Z}^{A}X \xrightarrow{\alpha} {}_{Z-2}^{A-4}Y + {}_{2}^{4}He + Q$$ where $Q \rightarrow$ Energy released

Ex: ${}_{92}^{238}U \xrightarrow{\alpha} {}_{90}^{234}Th + {}_{2}^{4}He + Q$

Beta decay: It is a process in which a radioactive nucleus emits either an electron or a positron.

(a) Emission of electron ($\boldsymbol{\beta^-}$ *decay*) : During electron emission (β^- *decay*) the atomic number increases by one and the mass number remains unchanged.

$${}_{Z}^{A}X \xrightarrow{\beta^-} {}_{Z+1}^{A}Y + e^- + \overline{\nu}$$

Ex: $^{32}_{15}P \xrightarrow{\beta^-} {}^{32}_{16}S + e^- + \overline{\nu}$

The process of electron emission can be explained as, $n \longrightarrow p + e^- + \overline{\nu}$. Neutron decays into a proton and an electron. Electron is emitted while proton stays inside the nucleus.
Note: Neutron decay is observed in the case of ***free*** neutron when it is outside the nucleus also.

(b) Emission of positron ($\boldsymbol{\beta^+}$ *decay*) : During positron emission (β^+ *decay*) the atomic number decreases by one and the mass number remains unchanged.

$${}^{A}_{Z}X \xrightarrow{\beta^+} {}_{Z-1}^{A}Y + e^+ + \nu$$

Ex: ${}^{22}_{11}N \xrightarrow{\beta^+} {}^{22}_{10}Ne + e^+ + \nu$

The process of positron emission can be explained as, $p \longrightarrow n + e^+ + \nu$. Proton decays into a neutron and a positron. Positron is emitted while neutron stays inside the nucleus.

Note: Proton decay occurs only inside nucleus and it cannot occur in the case of free proton, because energy conservation cannot be satisfied in this case, ***as the proton being lighter than a neutron***.

In β^- *decay*, anti-neutrino ($\overline{\nu}$) is emitted while neutrino (ν) is emitted in β^+ *decay*.

Properties of neutrino, as proposed by Pauli:

(a) It is electrically neutral.
(b) It has zero rest mass.
(c) It has a spin equal to $\frac{1}{2}$

Gamma decay: Gamma decay is the phenomenon of emission of gamma radiation from a radioactive nucleus.

$${}^{A}_{Z}X \xrightarrow{\gamma} {}^{A}_{Z}X + \gamma - ray$$

Ex: The beta decay of ${}^{60}_{27}Co$ transforms into ${}^{60}_{28}Ni$. The ${}^{60}_{28}Ni$ is in the excited state. This reaches the ground state by emission of $\gamma - ray$ of energy 1.17 MeV and 1.33 MeV.

Nuclear energy: The energy obtained from the conversion of nuclear mass is known as nuclear energy.

Nuclear fission: Nuclear fission is a process of splitting a heavy nucleus into two lighter nuclei along with conversion of mass defect into energy.

$${}^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{141}_{56}Ba + {}^{92}_{36}Kr + 3\,{}^{1}_{0}n + Q$$

Here $Q = 200\ MeV$ of energy is released due to the mass defect of about $0.215\ u$.

The other examples are,

$${}^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{140}_{54}Xe + {}^{94}_{38}Sr + 2\,{}^{1}_{0}n + Q$$
$${}^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{135}_{52}Te + {}^{98}_{40}Zr + 3\,{}^{1}_{0}n + Q$$

Nuclear chain reaction: The neutrons released during one fission can cause further fission and the process continues such a self-sustaining reaction is called a chain reaction.

There are two types of chain reactions, (i) Controlled chain reaction
(ii) Uncontrolled chain reaction

(i) Controlled chain reaction: It is a reaction in which the neutrons are built-up to a certain level and there after the number of neutrons producing fission are kept constant.
In this reaction Energy is released at a constant rate and this reaction is the *Principle of nuclear reactor.*

(ii) Uncontrolled chain reaction: It is a reaction in which fission neutrons are allowed to multiply indefinitely which leads to release of enormous energy in a very short interval of time.
This reaction is used in *Atom bombs.*

Critical size: For a chain reaction to be sustained, the size of the fissionable material should have a minimum size. This minimum size is called Critical size.

Multiplication factor or Reproduction factor: The possibility of chain reaction is determined by a factor called multiplication factor or reproduction factor, K.
The multiplication factor measures the growth rate of neutrons in a reactor. It is given by,

$$K = \frac{Number\ of\ neutrons\ in\ any\ ane\ generation}{Number\ of\ neutrons\ in\ the\ preceding\ generation}$$

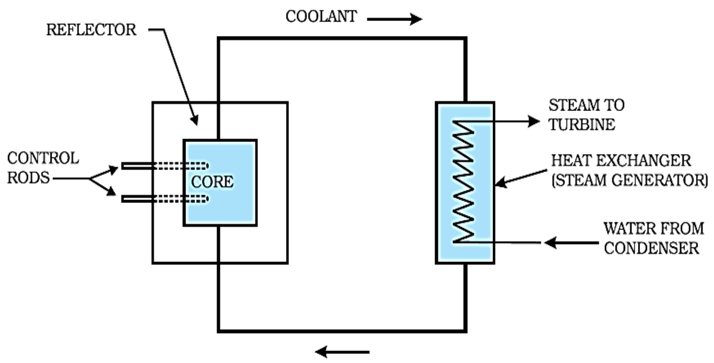
(i) If $K = 1$, the fission chain reaction will be critical and chain reaction is sustained.
(ii) If $K < 1$, the fission chain reaction is sub-critical and the rate of chain reaction decreases until it finally stops.
(iii) If $K > 1$, the fission chain reaction is super-critical and the rate of chain reaction increases exponentially.

Nuclear reactor: Nuclear reactor is an arrangement in which nuclear fission is produced by controlled self-sustaining chain reaction.

Schematic diagram of nuclear reactor:

The essential components of a nuclear reactor are,

(i) Nuclear fuel
(ii) Moderator
(iii) Control rods
(iv) Cooing system
(v) Neutron reflector
(vi) Protective shield



(i) Nuclear fuel: ${}^{235}_{92}U$, ${}^{239}_{94}Pu$ and ${}^{233}_{92}U$. The fissionable material in its pure form is wrapped in aluminium foils and taken in the form of rods.

(ii) Moderator: Moderator is a material used to ***slow down the neutrons*** produced during fission. Heavy water, graphite, paraffin are used as moderators.

(iii) Control rods: These are the devices used for controlling the rate of fission. ***These rods readily absorb the neutrons.*** Cadmium and Boron rods are commonly used as control rods.

Disposal of nuclear waste:

(i) The waste can be buried underground.

(ii) The waste can be stored in unused deep mines.

(iii) The waste is packed in enclosures within thick concrete walls and then buried under sea.

Nuclear fusion: The process in which two or more light nuclei combine to form a single heavy nucleus with the release of large amount of energy is called nuclear fusion.

Ex: (i) ${}_1^2H + {}_1^2H \rightarrow {}_1^3H + {}_1^1H + 4.03\ MeV$

(ii) ${}_1^2H + {}_1^2H \rightarrow {}_2^3He + {}_0^1n + 3.2\ MeV$

(iii) ${}_1^3H + {}_1^2H \rightarrow {}_2^4He + {}_0^1n + 17.6\ MeV$

Thermonuclear reaction: Nuclear fusion reaction achieved at a very high temperature is known as thermonuclear reaction. The temperature of the order of $10^7\ to\ 10^9 K$ is required to trigger nuclear fusion. Thermonuclear reactions were realised in hydrogen bomb.

Stellar energy: Hans Bethe suggested that the source of the stellar energy is thermonuclear reactions. The energy released during these reactions has been supplied to the earth for ages. Thermonuclear reactions in Sun and other stars follow two different series of processes.

(i) Proton-Proton cycle: In this cycle direct collisions of protons result in the formation of heavy nuclei. Total energy released is $18.77\ MeV$

(ii) Carbon-Nitrogen cycle: In this cycle carbon acts as a nuclear catalyst and four hydrogen nuclei fuse to form a helium nucleus with the release of enormous amount of energy.
The total energy released is $24.68\ MeV$.

Controlled thermonuclear fusion: It is very difficult to build a controlled thermo nuclear fusion power source. Many countries of the world including India are trying to build such sources of power.

Chapter-14

SEMICONDUCTOR ELECTRONICS: MATERIALS, DEVICES AND SIMPLE CIRCUITS

Energy Bands in solids:

Energy band: In a solid because of a very large number of close lying atoms (which can interact with one another), the different energy levels with continuous energy variation form a band which are called energy band.

Valence band: The energy band occupied by the valence electrons is called valence band.
Valence band is the highest energy band which is completely or partially filled at zero kelvin.

Conduction band: The energy band above the valence band is called conduction band.
Conduction band is the next higher energy band which may be partially filled at room temperature but completely empty at zero kelvin (in case of semiconductors).

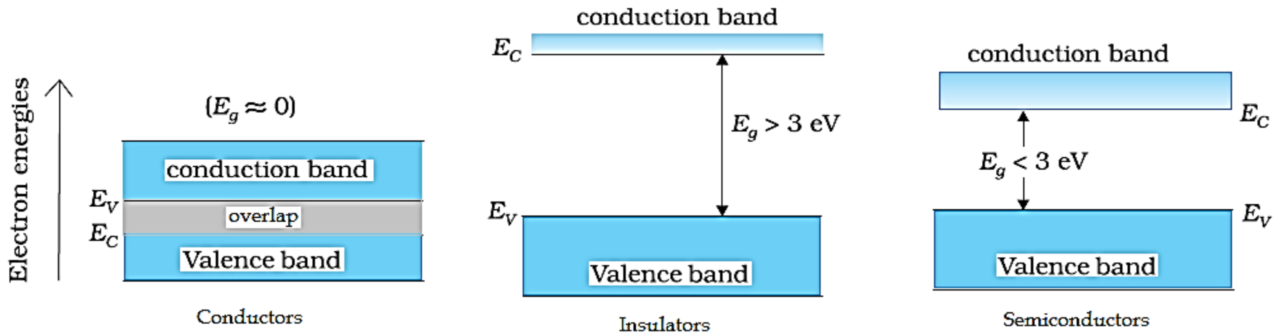
Forbidden energy gap: The gap between the top of the valence band and bottom of the conduction band is called forbidden energy gap or energy band gap or energy gap, denoted by E_g.

Classification of Metals, Insulators and semiconductors based on Energy band or Band theory:

Metals (Conductors): Materials in which there is no physical separation between the valence band and conduction band is called metals (conductors).

Insulators: Materials in which there is a large energy gap ($E_g > 3\ eV$) between the valence band and conduction band are called insulators.
Ex: Diamond has $E_g = 7\ eV$

Semiconductors: Materials in which there is a small energy gap ($E_g < 3\ eV$) between the valence band and conduction band are called semiconductors.



Classification of semiconductors:

There two types, (1) Intrinsic semiconductors and (2) Extrinsic semiconductors.

Intrinsic semiconductors: Semiconductors in pure form are called intrinsic semiconductors.
Ge and Si are most common examples.

Electrical conductivity of intrinsic semiconductor: The conductivity of an intrinsic semiconductor depends on its temperature, but at room temperature its conductivity is very low. As such no important electronic devices can be developed using these semiconductors.

Extrinsic semiconductors: A semiconductor obtained after adding a desirable impurity in the intrinsic (pure) semiconductor is called extrinsic or doped semiconductor.

Doping: The process of adding desirable impurities is the intrinsic(pure) semiconductor is called doping.

Dopants: The materials added in the intrinsic (pure) semiconductor to increase its conductivity are known as dopants.

Types of Dopants or impurities: There are two types of dopants,
(i) Pentavalent dopants: The dopants having five valance electrons are called pentavalent dopants.
Ex: Antimony (Sb), Arsenic (As), Phosphorus (P) etc.

(ii) Trivent dopants: The dopants having three valence electrons are called trivalent dopants.
Ex: Aluminium (Al), Indium (In), Gallium (Ga), Boron (B) etc.

Types of Extrinsic semiconductors: Doping process produces two types of extrinsic semiconductors. They are (i) p - type semiconductors and (ii) n - type semiconductors.

p - type semiconductor: When suitable trivalent impurity is added to pure semiconductor we get extrinsic semiconductor known as p - type semiconductor.

n - type semiconductor: When suitable pentavalent impurity is added to pure semiconductor, we get an extrinsic semiconductor known as n - type semiconductor.

Difference between Intrinsic and extrinsic semiconductors

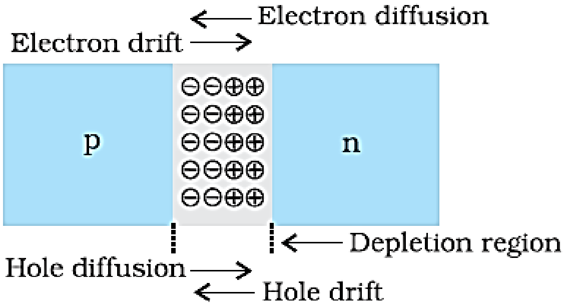
Intrinsic semiconductor	Extrinsic semiconductors
1) It is in pure form.	1) It is not in pure form (some impurities are added)
2) Conductivity less.	2) Conductivity high.
3) Number of electrons is equal to number of holes.	3) Number of electrons is not equal to number of holes.
4) Have no practical applications.	4) Have wide variety of practical applications.

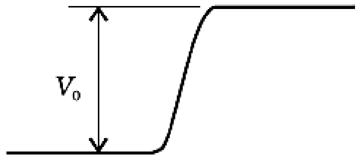
Difference between p - type and n - type semiconductors

p - type semiconductor	n - type semiconductors
1) It is obtained by doping with trivalent impurities.	1) It is obtained by doping with pentavalent impurities.
2) Majority charge carriers are holes.	2) Majority charge carriers are electrons.
3) Minority charge carriers are electrons.	3) Minority charge carriers are holes.
4) At zero kelvin only holes are available conduction.	4) At zero kelvin only electrons are available conduction.
5) Impurity atom is called acceptor impurity.	5) Impurity atom is called donar impurity.
6) Acceptor energy level lies close to the valence band.	6) Donor energy level lies close to the conduction band.
7) $n_h \gg n_e$	7) $n_e \gg n_h$

p - n junction: A p - n junction consists of a p - type semiconductor on one side and n - type semiconductor at the other side of a single crystal of semiconductor.

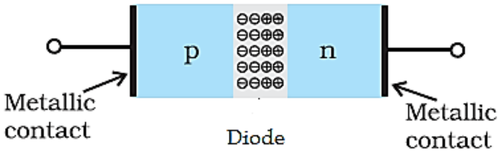
Depletion region: The space-charge region on either side of the junction where there is a depletion of mobile charge carriers is called depletion region.



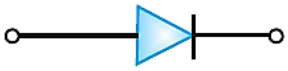


Barrier potential height under no bias

Semiconductor diode: A p - n junction diode with metallic contacts provided at the ends for the application of an external voltage is called a semiconductor diode.

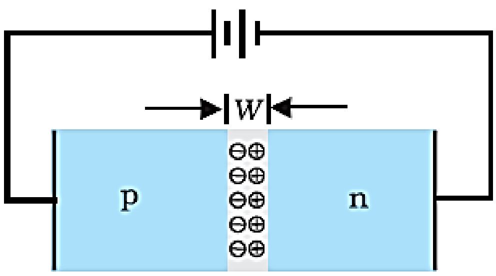


Diode

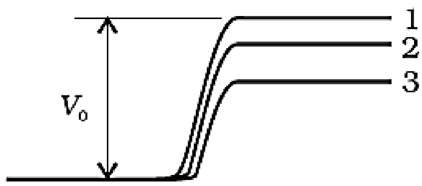

Circuit symbol

Biasing a diode: When external voltage is applied across a semiconductor diode, then the diode is said to be biased. Diode can be biased in two ways; (i) Forward bias and (ii) Reverse bias.

p - n junction diode under forward bias: A p - n junction diode is said to be under forward bias, if n - diode is connected to the negative and p - side to the positive of a battery.



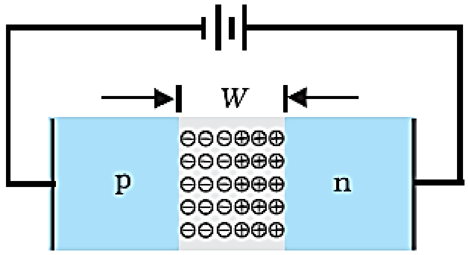
Forward bias



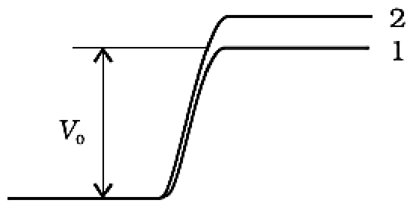
1 - Potential barrier without battery
2 - Potential barrier with low battery voltage
3 - Potential barrier with high battery voltage

Explanation: When the p - n junction diode is forward biased, applied potential difference V reduces the barrier potential (V_0). The effective barrier potential reduces to $(V - V_0)$ and thickness of the depletion layer also decreases. The junction resistance becomes very low. The holes in the p - region and electron in the n - region acquire sufficient energy to cross over the potential barrier across the junction.

p - n junction diode under reverse bias: A p - n junction diode is said to be under reverse bias, if n - diode is connected to the positive and p - side to the negative of a battery.



Reverse bias



1 - Potential barrier without battery
2 - Potential barrier with extaenal battery

Explanation: When p - n junction diode is reverse biased, the applied potential difference V adds to the barrier potential V_0. The effective barrier potential increases to $(V + V_0)$ and thickness of the depletion region also increases. The junction resistance becomes very high. The majority charge carriers in p - region and n - region respectively are attracted by negative and positive terminals of the battery. Thus, both holes and electrons are drifted away from the junction. Therefore, the flow of current in the diode is almost stopped.

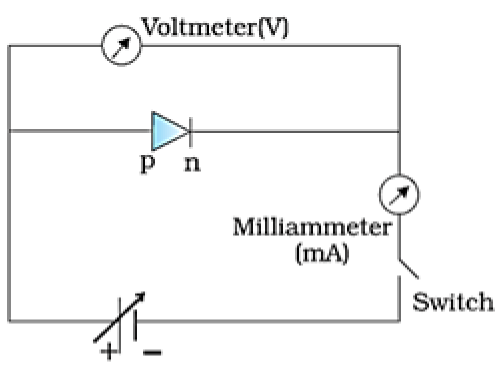
Difference between forward bias and reverse bias of diode

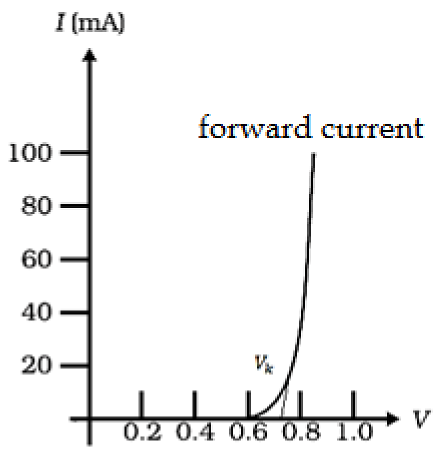
Forward bias of diode	Reverse bias of diode
1) p - side is connected to positive and n - side is connected to negative of a battery.	1) p - side is connected to negative and n - side is connected to positive of a battery.
2) Diode offers low resistance.	2) Diode offers high resistance.
3) Potential barrier reduces.	3) Potential barrier increases.
4) Depletion region decreases.	4) Depletion region increases.
5) Diode allows current through it.	5) Diode does not allow current through it.

I - V characteristics of p - n junction diode: The variation of current with the applied voltage across the junction diode gives the V - I characteristics of p - n junction diode.

(a) Forward bias characteristics: When the battery voltage is zero, diode does not conduct and the diode current is zero. As the forward battery voltage (V) increases, the barrier potential starts decreasing and a small current begins to flow. The forward current increases slowly at first but as soon as the battery voltage increases and reaches to a particular value called cut-in voltage, the forward current increases rapidly.

Circuit diagram and I-V characteristics:





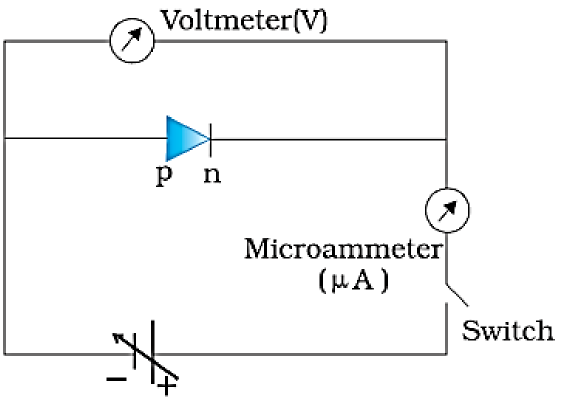
Cut-in voltage (Threshold voltage): The battery voltage at which the forward current starts increasing rapidly is called cut-in voltage or threshold voltage (V_k).

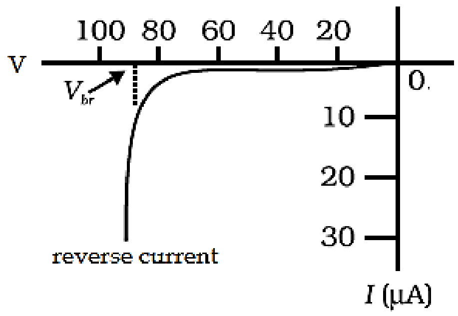
(b) Reverse bias characteristics: When the p - n junction diode is reverse biased, the majority charge carriers in p and n - region are repelled away from the junction. Hence no current flows through the diode. But there is a small current due to the minority charge carriers. As the reverse voltage is increased to a certain value, called break down voltage, this current attains its maximum valve or saturation value immediately and is independent of the applied reverse voltage.

Reverse saturation current: The current which results due to diffusion of minority charge carriers and almost independent of reverse bias voltage is called reverse saturation current.

Break down voltage (V_{br}) : The reverse battery voltage at which the reverse saturation current increase immediately and will become independent of the applied voltage is called break down voltage.

Circuit diagram and I-V characteristics:





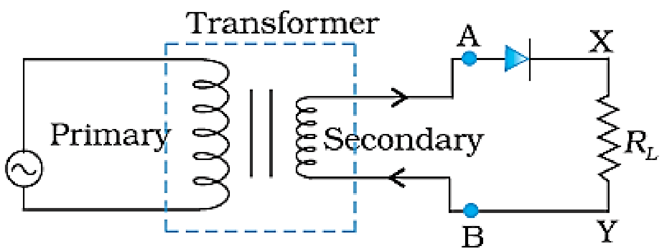
Application of junction diode: A diode allows current through it only in one direction. Hence it can be used as rectifier.

Rectifier: A device which converts alternating current in to direct current is known as rectifier.

Rectification: The process of converting ac in dc is known as rectification.

Principle of reciter: Junction diode conducts only when forward biased and it does not conduct when reverse biased.

Half wave rectifier: The rectifier which converts only one half cycle of ac in to dc is called half wave rectifier.

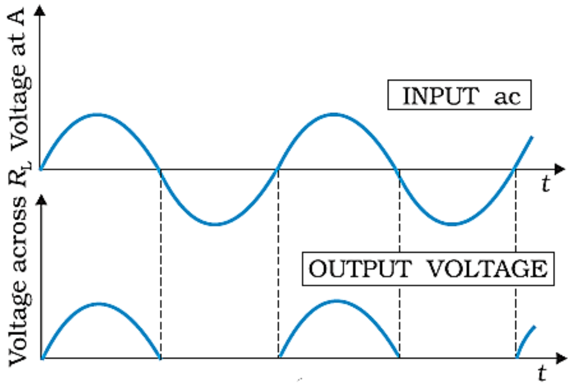


Working:

During positive half cycle of ac, p - type is positive with respect to its n - type. Hence it is forward biased and conducts. A current flows through R_L.

During negative half cycle of ac, p - type is negative with respect to its n - type. Hence it is reverse biased and does not conducts. No current flows through R_L.

Input and output wave forms:



Disadvantages:

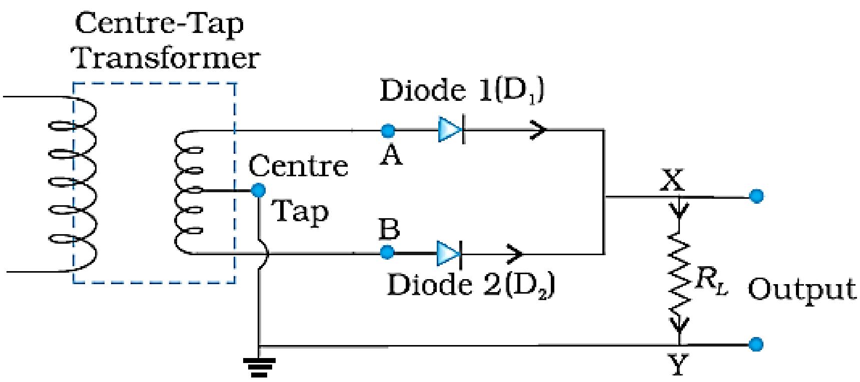
(i) Output signal is discontinuous.

(ii) Efficiency of half wave rectifier is low. (40.6%)

(iii) The output is not pure dc and contains ac components or ripples.

Full wave rectifier: The rectifier which converts both halves of ac into dc is called full wave rectifier.

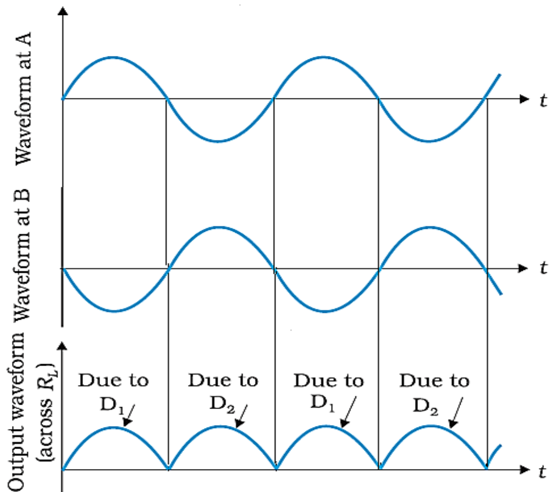
Construction and circuit diagram:



Working: During the positive half cycle appearing at A, the diode D_1 is forward biased. At the same time end B is negative and diode D_2 is reverse biased and does not conduct. The diode D_1 conducts. A current flows through the R_L and output voltage appears at the output terminals.

During the negative half cycle appearing at A, the diode D_1 is reverse biased and does not conduct. End B is positive and diode D_2 is forward biased. The diode D_2 conducts. A current flows through R_L in the same direction and output voltage appears across R_L.

Input and output wave forms:



Advantages: (i) Output is continuous. (ii) Efficiency is more. (81.2%)

Disadvantage: output again contains ac components.

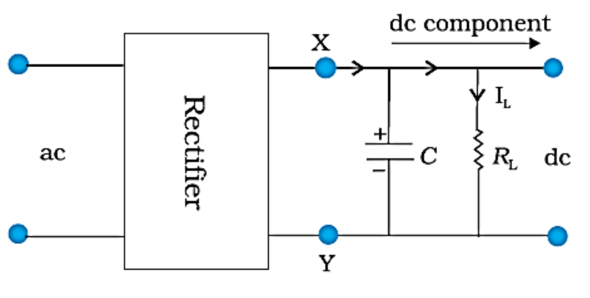
Comparison of half wave rectifier and full wave rectifier

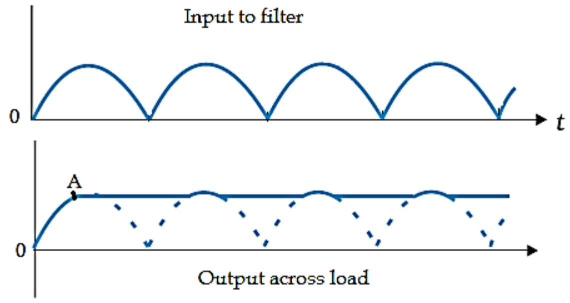
Half wave rectifier	Full wave rectifier
1) One p - n junction diode is used.	1) Two p - n junction diodes are used.
2) Only one half of cycles are converted in output.	2) Both the half cycles are converted into output.
3) Output is discontinuous.	3) Output is continuous.
4) Transformer needs no centre tap.	4) Centre tap transformer is essential.
5) Efficiency is low.	5) Efficiency if more.

Filter circuit: A filter circuit is a device which removes the ac component of rectifier output, but allows the dc components to reach the load.
As a filter circuit normally a capacitor is connected parallel to load resistor.

Principle of filter circuit: A capacitor allows ac but not dc to pass through it.

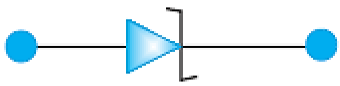
Circuit diagram and input, output waveforms:



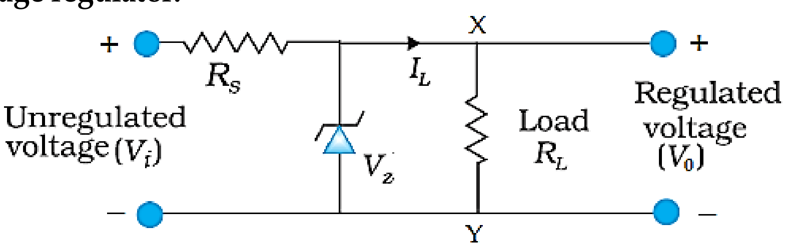


Special purpose p - n junction diodes: Junction diodes can be manufactured for special purposes, that is, other than rectification also. One of them is Zener diode.

Zener diode: A properly doped p - n junction diode which works in the breakdown region without damaging itself is called a Zener diode. Symbolic representation of zener diode is as shown.



Zener diode as voltage regulator:



Working: If the input voltage increases, the current through R_S and Zener diode also increases. This increases the voltage drop across R_S without any change in the voltage across the Zener diode.

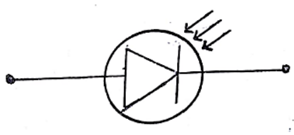
Similarly, if the input voltage decreases, the current through R_s and Zener diode also decreases. The voltage drop across R_s decreases without any change in the voltage across the Zener diode.

Let V_i be the unregulated input voltage, V_0 be the regulated output voltage and V_z be the zener voltage. (i) If $V_i < V_z$ then $V_o = V_i$

(ii) If $V_i > V_z$ then $V_o = V_z$ for any value of V_i.

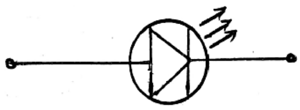
Optoelectronic devices: The junction diode which conducts when charge carriers are generated by the photons (when light incident on it) is known as optoelectronic junction devices.
They are, (i) Photodiodes (ii) Light emitting diodes (LED) and (ii) Photo voltaic devices.

Photo diode: A reverse biased special p - n junction having transparent window is known as photo diode. Symbolically it is represented as shown.



Uses of photo diode:
(i) Photo diodes are used as photo detectors to detect intensity of light.
(ii) They are used as light operated devices.
(iii) They are used in the receivers for remote controls.

Light emitting diode (LED): A special heavily doped p - n junction diode which emits spontaneous radiation when forward biased is known as light emitting diode. Symbolically it is represented as shown in the figure.



Uses of LED:
(i) LED's are used in display devices such as signal lamps, calculators etc.
(ii) LED's are used as indicators in various electronic and electric circuits.
(iii) LED's are used in optical fibre communication.
(iv) LED's emitting IR radiations are used in burglar alarm systems, cd players, remote control units.

Advantages of LED over conventional incandescent lamp:
(i) Low operational voltage and less power.
(ii) Fast action and no warm up time required.
(iii) Long life and ruggedness.
(iv) Light emitted is nearly monochromatic.
(v) Fast on-off switching capability.

Solar cell or Photo-voltaic device: A special p - n junction diode which converts solar energy into electrical energy is known as solar cell or photo voltaic cell. It works on the same principle (photovoltaic effect) as the photodiode, except that no external bias is applied

The important criteria for the selection of a material for solar cell fabrication:
Material used to manufacture a solar cell should have,
(i) Low cost.
(ii) Easy availability.
(iii) Desirable conductivity.
(iv) Optical absorption is as high as $10^4\ cm^{-1}$.
(v) Forbidden energy gap of 1 eV to 1.8 eV.

Uses of solar cell: Solar cells are used,

(i) to charge storage batteries in day time.

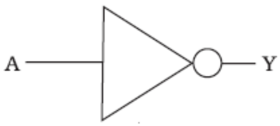
(ii) in calculators for power supply units.

(iii) to supply power in artificial satellites and space vehicles.

Logic gates: A logic gate is a digital circuit that follows certain logical relations between the input and output voltages. The five common logic gates used are NOT, AND, OR, NAND, NOR. Logic gates are building blocks of digital electronics.

Truth table: A table giving the output for different combinations of input is called truth table. It helps to understand the behaviour of the logic gates.

NOT gate: A logic gate whose output is the complement of the input is called a NOT gate. It is also known as Inverter.



Logic symbol

Input	Output
A	Y
0	1
1	0

Trueth table

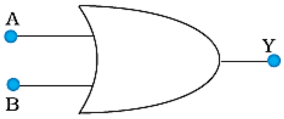
AND gate: A logic gate which has a high output only when all the inputs are high is called an AND gate.

Lgic Symbol

Input		Output
A	B	Y
0	0	0
0	1	0
1	0	0
1	1	1

Truth Table

OR gate: A logic gate which has a high output only when any one of the inputs is high is called an OR gate.



Logic Symbol

Input		Output
A	B	Y
0	0	0
0	1	1
1	0	1
1	1	1

TruthTable

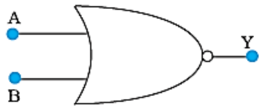
NAND gate: An AND gate followed by a NOT gate is called NAND gate.

Logic Symbol

Input		Output
A	B	Y
0	0	1
0	1	1
1	0	1
1	1	0

Truth Table

NOR gate: An OR gate followed by a NOT gate is called NOR gate.



Logic Synbol

Input		Output
A	B	Y
0	0	1
0	1	0
1	0	0
1	1	0

Truth Table

Blue print -1

Unit	Chapter	Topic	Teaching Hrs	Marks Allotted	1 M (VSA)	2M (SA1)	3M (SA2)	5M (LA)	5M (NP)
1	1	Electric Charges and Fields	10	8	√	√			√
2	2	Electric Potentials and Capacitance	9	8		√	√√		
3	3	Current Electricity	15	13	√	√		√	√
4	4	Moving Charges and Magnetism	12	10		√	√	√	
5	5	Magnetism and Matter	8	7		√		√	
	6	Electromagnetic Induction	7	6	√	√	√		
6	7	Alternating Current	8	7		√			√
	8	Electromagnetic waves	3	3	√	√			
7	9	Ray optics and Optical Instruments	10	9	√		√	√	
8	10	Wave Optics	10	9	√		√		√
9	11	Dual Nature of Radiation and Matter	6	5	√√		√		
	12	Atoms	5	5					√
10	13	Nuclei	7	6	√			√	
	14	Semiconductor Electronics	10	9	√		√	√	
TOTAL			120	105	10	16	24	30	25

MODEL PAPER-1, MARCH-2020

II PUC PHYSICS (33)

Time: 3Hrs 15 Min. Max. Marks:70

General instruction: 1) All parts are compulsory.

2) Answer without relevant diagram/figure/circuit wherever necessary will not carry any marks.

3) Numerical problems solved without writing the relevant formulae carry no marks.

PART A

I Answer all Questions. $\mathbf{1 \times 10 = 10}$

1) How many electrons constitute one Nano coulomb of charge?
2) A wire of resistivity ρ is stretched to double of its length. What will be the new resistivity?
3) Give the expression for the emf induced between the ends of a metal conductor moving perpendicular to uniform magnetic field.
4) Mention the need (importance) of Displacement current.
5) State Rayleigh's law of scattering.
6) What is wave front of light waves?
7) How does the de-Broglie wavelength of a charged particle changes with change in accelerating potential?
8) State Heisenberg's uncertainty principle.
9) In proton – proton cycle, what is the approximate energy (in MeV) released?
10) Draw the circuit symbol of zener diode.

PART B

II Answer any FIVE of the following Questions. $\mathbf{2 \times 5 = 10}$

11) Draw the figure to represent the direction of force between the charges for (i) $q_1q_2 > 0$ and (ii) $q_1q_2 < 0$
12) Two capacitors of capacitance $2pF$ and $4pF$ are connected is series. Find their effective capacitance.
13) Define the terms junction and mesh in an electrical network.
14) The moving coil galvanometer cannot be used directly to measure the current. Why?
15) State Gauss's law in magnetism. What does it indicate?
16) A pair of adjacent coils has a mutual inductance of 1.5 H. If the current in one coil changes from 0 to 20 A in 0.5 s, what is the change of flux linkage with the other coil?
17) Define rms value of an AC. Give its relation with peak value.
18) Find the wavelength of electromagnetic waves of frequency $5 \times 10^{19} Hz$ in free space.

PART C

III Answer any FIVE of the following Questions. $\mathbf{3 \times 5 = 15}$

19) Derive the expression for potential energy of a system of two charges in the absence of the external electric field.
20) Derive the expression for energy stored in a charged capacitor.
21) Derive the expression for the magnetic force experienced by a current carrying conductor.
22) Obtain the expression for the magnetic energy stored in a coil (solenoid).
23) Mention two conditions for total internal reflection. Give the relation between critical angle and refractive index.
24) State and prove Brewster's law.

25) Calculate the kinetic energy of an electron if the de-Broglie wavelength associated with it is 0.123nm. Given mass of the electron= $9.1 \times 10^{-31} kg$ and Planck's constant is $6.63 \times 10^{-34} Js$

26) Distinguish between conductor, insulator and semiconductor on the basis of Band theory of solids.

PART D

IV Answer any TWO of the following Questions. $\mathbf{5 \times 2 = 10}$

27) Define terminal potential of a cell. Derive an expression for current drawn from a cell connected to an external resistance and hence arrive at the relation between terminal potential difference and emf of the cell.

28) Define Magnetic dipole moment. Obtain the expression for magnetic dipole moment of a revolving electron in a hydrogen atom.

29) Show that a current carrying solenoid is equivalent to a bar magnet.

V Answer any TWO of the following Questions. $\mathbf{5 \times 2 = 10}$

30) Derive mirror equation in case of a concave mirror producing a real image.

31) What is mean life of a radioactive element? Obtain the expression for mean life of a radioactive substance.

32) What is diode? Explain the working of p-n junction diode as a half wave rectifier with circuit diagram. Give input and output wave forms.

VI Answer any THREE of the following Questions. $\mathbf{5 \times 3 = 15}$

33) A spherical conductor of radius 12 cm has a charge of $1.6 \times 10^{-7}\ C$ distributed uniformly on its surface. What is the electric field (a) Inside the sphere (b) just outside the sphere and (c) at a point 18 cm from the Centre of the sphere?

34) The number density of free electrons in a copper conductor is $8.5 \times 10^{28}\ \mathrm{m}^{-3}$. How long does an electron take to drift from one end of a wire 3.0 m long to its other end? The area of cross section of the wire is $2.0 \times 10^{-6}\ \mathrm{m}^2$ and it is carrying a current of 3.0A.

35) A $\left(\frac{1}{12\pi}\right) mF$ capacitor in series with a 40Ω resistor is connected to a $110V$, $60Hz$ supply.

(i) What is the maximum current in the circuit?

(ii) What is the phase difference between the current maximum and voltage maximum?

36) In a double-slit experiment the angular width of a fringe is found to be 0.2° on a screen placed 1 m away. The wavelength of light used is 600 nm. What will be the angular width of the fringe if the entire experimental apparatus is immersed in water? Take refractive index of water to be $4/3$.

37) Calculate wave number, wavelength and frequency of the H_α − line of hydrogen spectrum. Given: $R = 1.097 \times 10^7\ m^{-1}$, $C = 3 \times 10^8 ms^{-1}$

Blue print - 2

Unit	Chapter	Topic	Teaching Hrs	Marks Allotted	1 M (VSA)	2M (SA1)	3M (SA2)	5M (LA)	5M (NP)
1	1	Electric Charges and Fields	10	8	√	√		√	
2	2	Electric Potentials and Capacitance	9	8			√		√
3	3	Current Electricity	15	13	√	√√	√	√	
4	4	Moving Charges and Magnetism	12	10		√	√		√
5	5	Magnetism and Matter	8	7	√		√√		
	6	Electromagnetic Induction	7	6	√			√	
6	7	Alternating Current	8	7		√			√
	8	Electromagnetic waves	3	3	√	√			
7	9	Ray optics and Optical Instruments	10	9	√		√		√
8	10	Wave Optics	10	9	√√	√		√	
9	11	Dual Nature of Radiation and Matter	6	5		√	√		
	12	Atoms	5	5				√	
10	13	Nuclei	7	6	√				√
	14	Semiconductor Electronics	10	9	√		√	√	
TOTAL			120	105	10	16	24	30	25

MODEL PAPER-2, MARCH-2020

II PUC PHYSICS (33)

Time: 3Hrs 15 Min. Max. Marks:70

General instruction: 1) All parts are compulsory.

2) Answer without relevant diagram/figure/circuit wherever necessary will not carry any marks.

3) Numerical problems solved without writing the relevant formulae carry no marks.

PART A

I Answer all Questions. **$1 \times 10 = 10$**

1) Define electric dipole moment.
2) On what principle a meter bridge work?
3) What is the angle of dip at a place where the horizontal and vertical components of the earth's magnetic fields are equal?
4) Define the SI unit of self-inductance.
5) What are the sources of electromagnetic waves?
6) Define power of a lens.
7) How resolving power of a microscope can be increased?
8) What are polaroids?
9) Write the relation between curie and becquerel.
10) Write truth table of NOR gate

PART B

II Answer any FIVE of the following Questions. **$2 \times 5 = 10$**

11) Define electric flux through an area element. Mention the SI unit of Electric flux.
12) Write the colour sequence for the resistance value $1.2\ M\Omega \pm 10\%$.
13) What is ohmic device? Give one example.
14) Write down expression for Biot-savart's law in vector form and explain the terms.
15) Write an expression for resonant frequency. Explain the terms.
16) Write Ampere-Maxwell equation and explain the symbols used.
17) What is fringe width? How do you increase the fringe width (Give any one factor)?
18) Define (i) Photoelectric work function (ii) electron volt (eV)

PART C

III Answer any FIVE of the following Questions. **$3 \times 5 = 15$**

19) Write any three properties of equipotential surfaces.
20) Derive an expression for equivalent resistance when two resistors are connected in series.
21) Write three properties of paramagnetic materials.
22) Define magnetic susceptibility, magnetic permeability and magnetic intensity.
23) Mention the expression for torque experienced by a current loop in a magnetic field. Explain the terms. When it will be maximum?
24) Draw ray diagram for image formation in Refracting telescope and mention expression for its magnifying power.
25) What are matter waves? Obtain the expression for de Broglie wavelength of a particle and explain the terms.
26) Write any three differences between half wave and full wave rectifier.

PART D

IV Answer any TWO of the following Questions. $\mathbf{5 \times 2 = 10}$

27) Derive an expression for electric field due electric dipole at a point on an equatorial line.

28) Define emf and internal resistance of a cell. Derive an expression for equivalent emf and equivalent internal resistance when two cells of different emf 's and internal resistances are connected in series.

29) What is an AC generator? Derive an expression for Instantaneous emf in an AC generator.

V Answer any TWO of the following Questions. $\mathbf{5 \times 2 = 10}$

30) What is interference of light? Arrive at the conditions for constructive and destructive interference by assuming the expression for intensity.

31) Assuming the expression for the radius of the electron orbit, obtain the expression for the total energy of the electron in the stationary orbit of hydrogen atom.

32) What is diode? Describe with suitable block diagrams, action of pn-junction diode under forward and reverse bias conditions. Also draw I-V characteristics.

VI Answer any THREE of the following Questions. $\mathbf{5 \times 3 = 15}$

33) The effective capacitance of two capacitors is $7\ \mu F$ when in parallel and $\frac{6}{7}\ \mu F$ when in series. Find the individual capacitance.

34) A galvanometer of resistance 50Ω requires a current of $2\ mA$ for full scale deflection. How do you convert it into, (a) an ammeter of range 0-30A and (b) a voltmeter of range 0-5V?

35) A coil of inductance $0.50H$ and resistance of 100Ω is connected to a $240V, 50Hz$ ac supply.
(a) What is the maximum current in the coil?
(b) What is the time lag between voltage maximum and the current maximum?

36) A prism is made of glass of unknown refractive index. A parallel beam of light is incident on a face of the prism. By rotating the prism, the angle of minimum deviation is measured to be 40^0. What is the refractive index of the material of the prism? If the prism is placed in water ($n_w = 1.33$), calculate the new angle of minimum deviation of a parallel beam of light. The refracting angle of the prism is 60^0.

37) A given coin has a mass 3.0 gram, Calculate the nuclear energy that would be required to separate all the neutrons and protons from each other. Assume that the coin is entirely made of $^{62}_{29}\mathrm{Cu}$ atoms of mass = 62.92960 u. Given Avogadro number = 6.023×10^{23}, mass of proton m_p = 1.00727 u and mass of neutron m_n = 1.00866 u.

Blue print - 3

Unit	Chapter	Topic	Teaching Hrs	Marks Allotted	1 M (VSA)	2M (SA1)	3M (SA2)	5M (LA)	5M (NP)
1	1	Electric Charges and Fields	10	8	√	√			√
2	2	Electric Potentials and Capacitance	9	8			√	√	
3	3	Current Electricity	15	13			√	√	√
4	4	Moving Charges and Magnetism	12	10		√	√	√	
5	5	Magnetism and Matter	8	7	√√	√	√		
	6	Electromagnetic Induction	7	7		√			√
6	7	Alternating Current	8	6	√	√	√		
	8	Electromagnetic waves	3	3	√	√			
7	9	Ray optics and Optical Instruments	10	9	√		√	√	
8	10	Wave Optics	10	9	√		√		√
9	11	Dual Nature of Radiation and Matter	6	5		√	√		
	12	Atoms	5	5					√
10	13	Nuclei	7	6	√			√	
	14	Semiconductor Electronics	10	9	√√	√		√	
TOTAL			120	105	10	16	24	30	25

MODEL PAPER-3, MARCH-2020

II PUC PHYSICS (33)

Time: 3Hrs 15 Min. Max. Marks:70

General instruction: 1) All parts are compulsory.

2) Answer without relevant diagram/figure/circuit wherever necessary will not carry any marks.

3) Numerical problems solved without writing the relevant formulae carry no marks.

PART A

I Answer all Questions. $\mathbf{1 \times 10 = 10}$

1) Which principle is employed in finding the force between multiple charges?
2) What is Curie temperature?
3) Name the material used in making the core of a moving coil galvanometer.
4) What is resonance in series LCR circuit?
5) Mention the expression for displacement current.
6) Define critical angle.
7) What happens to the interference fringes when the distance between the two coherent sources is decreased?
8) Why control rods were used in a nuclear reactor?
9) Write the truth table of OR gate.
10) Under what condition does a junction diode work as open switch?

PART B

II Answer any FIVE of the following Questions. $\mathbf{2 \times 5 = 10}$

11) Write Coulomb's law in vector form. Explain the terms.
12) Write any two uses of cyclotron.
13) Write any two properties of magnetic field lines.
14) Define self-inductance and Mutual inductance.
15) Derive an expression for current, when AC voltage is applied across resistor.
16) Mention any two applications of Infrared radiation.
17) Give two characteristics of photon.
18) Write any two advantages of Light Emitting Diode (LED) over conventional incandescent low power lamp.

PART C

III Answer any FIVE of the following Questions. $\mathbf{3 \times 5 = 15}$

19) Derive the relation between electric field and electric potential due a point charge.
20) What is resistivity? How does the resistivity of (1) Metallic conductor and (2) Semiconductor vary with the increase in temperature?
21) Explain with circuit diagram how to convert galvanometer into an ammeter.
22) Write three differences between diamagnetic and paramagnetic substances.
23) Define power factor. What is its value in pure resistive and reactive circuit?
24) Write the Cartesian sign convention used in spherical mirrors.
25) Write any three differences between interference and diffraction.
26) Define (a) Photo electric effect (b) Threshold frequency (c) Stopping potential.

PART D

IV Answer any TWO of the following Questions. **$5 \times 2 = 10$**

27) Obtain the expression for potential at a point due to an electric dipole.

28) Assuming the expression for drift velocity, derive the expression for conductivity of a material $\sigma = \frac{ne^2\tau}{m}$, where symbols have usual meaning.

29) Obtain the expression for the force between two infinitely long straight parallel conductors carrying current. Hence define "ampere" the SI unit of electric current.

V Answer any TWO of the following Questions. **$5 \times 2 = 10$**

30) Derive the expression for refractive index of the material of the prism in terms of angle of the prism and angle of minimum deviation.

31) State law of radioactive decay. Hence prove $N = N_0 e^{-\lambda t}$.

32) What is energy bands and Forbidden energy gap in solids? On the basis of energy bands distinguish between a metal, a semiconductor and an insulator.

VI Answer any THREE of the following Questions. **$5 \times 3 = 15$**

33) Charges of $+10\mu C$, $+20\mu C$ and $-20\mu C$ are placed in air at the corners of an equilateral triangle having each of side equal to $0.02m$. Determine the force on charge $+10\mu C$.

34) A cell supplies 0.9 A current through 2 Ω resistor and a current of 0.3 A through 7 Ω resistor. Find the internal resistance and emf of the cell.

35) A jet plane is travelling towards west at a speed of 1800 km/h. What is the voltage difference developed between the ends of the wing having a span of 25 m, if the Earth's magnetic field at the location has a magnitude of 5×10^{-4} T and the dip angle is 30°.

36) Calculate the distance between the centers of fourth bright fringe and seventh dark fringe in an interference pattern produced by Young's double slit experiment of slit separation $1.1mm$ and separation between the slit and screen being $1.3m$. Wavelength of the light used is $589.3nm$.

37) The ionization energy of the hydrogen atom is given by -13.6 eV . A photon falls on a hydrogen atom, which is initially in the ground state and excite it to the $n = 4$ state. Calculate the wavelength of photon. Given: $h = 4.14 \times 10^{-15}$ eV − s and $C = 3 \times 10^8 ms^{-1}$.