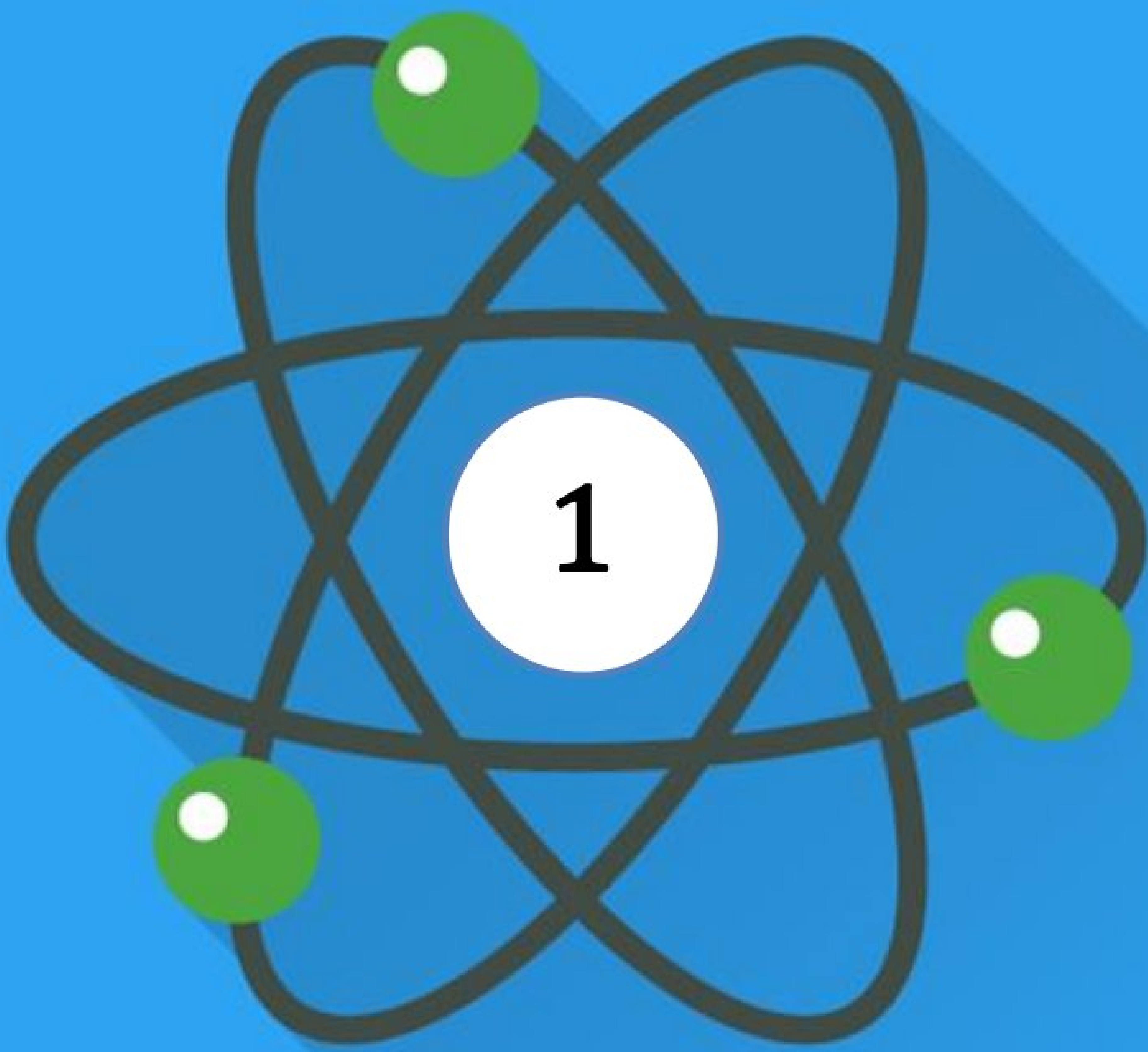
HAND BOOK

II PUC
2023 – 24

L P

Physics



QUESTIONS AND ANSWERS

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FIVE MARK QUESTIONS

QUESTION NO. : 39 [ELECTRIC CHARGES & FIELDS AND ELECTRIC POTENTIAL & CAPACITANCES]

1. **What is electric charge? Mention any four properties of it**

   Ans: It is the property of a body due to which it attracts or repels other charged bodies.

   Properties of charges

   - Charge is a scalar quantity.
   - Like charges repel and unlike charges attract each other.
   - Charges always reside on the surface of conductor.
   - Electric charge is additive.
   - Charge is conserved.
   - Charge is quantized.

   (The last three: **Basic properties**)

2. **What is electric field line/electric line of force? Mention any four properties of it.**

   Ans: Electric line of force in an electric field is the path along which a free positive charge moves.

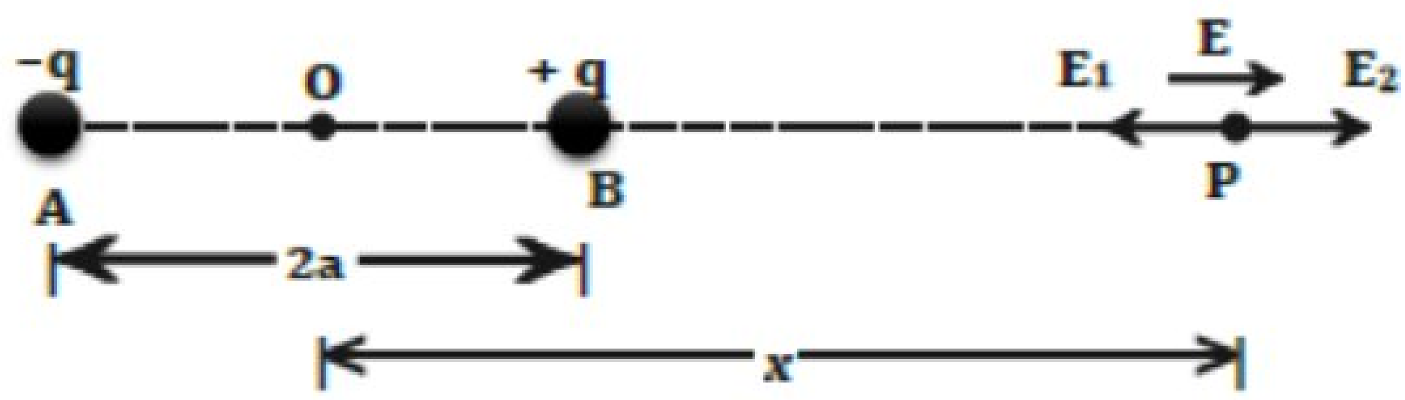
   Properties of lines of force or field lines

   - The field lines start from a positive charge and ends at negative charge
   - No two field lines intersect each other.
   - They do not form closed loops
   - They do not pass through a conductor
   - They can pass through non-conductor [dielectric]
   - The tangent drawn to line of force at any point on it gives the direction of the electric field at the point.

3. **Derive an expression for electric field due to a dipole at a point on the axial line.**

   Ans:

   In the figure
   +q and − q are charges of dipole
   2a is length of dipole
   O is midpoint of dipole
   P is point on the axial line
   x is the distance between O and P



FIG

   Electric field at P due to – q;

   $$E_1 = \frac{q}{4\pi\varepsilon_0 AP^2} = \frac{q}{4\pi\varepsilon_0 (x+a)^2} \quad \text{along PA}$$

   Electric field intensity at P due to + q;

   $$E_2 = \frac{q}{4\pi\varepsilon_0 BP^2} = \frac{q}{4\pi\varepsilon_0 (x-a)^2} \quad \text{along BP}$$

   Resultant field at P;

   $$E = E_2 - E_1$$
   $$= \frac{q}{4\pi\varepsilon_0 (x-a)^2} - \frac{q}{4\pi\varepsilon_0 (x+a)^2}$$

$$= \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{(x-a)^2} - \frac{1}{(x+a)^2}\right]$$
$$= \frac{q}{4\pi\varepsilon_0}\left[\frac{(x+a)^2-(x-a)^2}{(x^2-a^2)^2}\right]$$
$$= \frac{q}{4\pi\varepsilon_0}\frac{4ax}{(x^2-a^2)^2}$$
$$= \frac{1}{4\pi\varepsilon_0}\frac{(q\times 2a)\ 2x}{(x^2-a^2)^2}$$
$\therefore E = \frac{1}{4\pi\varepsilon_0}\frac{2px}{(x^2-a^2)^2}$ along BP [∵ Electric dipole moment, $p = q \times 2a$]

If the dipole is short (i.e., a<< x), then a^2 can be neglected as compared to x^2

$\therefore E = \frac{1}{4\pi\varepsilon_0}\frac{2px}{(x^2)^2}$

$E = \frac{1}{4\pi\varepsilon_0}\frac{2P}{x^3}$ along BP

4. Derive an expression for electric field due to a dipole at a point on an equatorial line.

Ans:

In the figure

+q and − q are charges of dipole

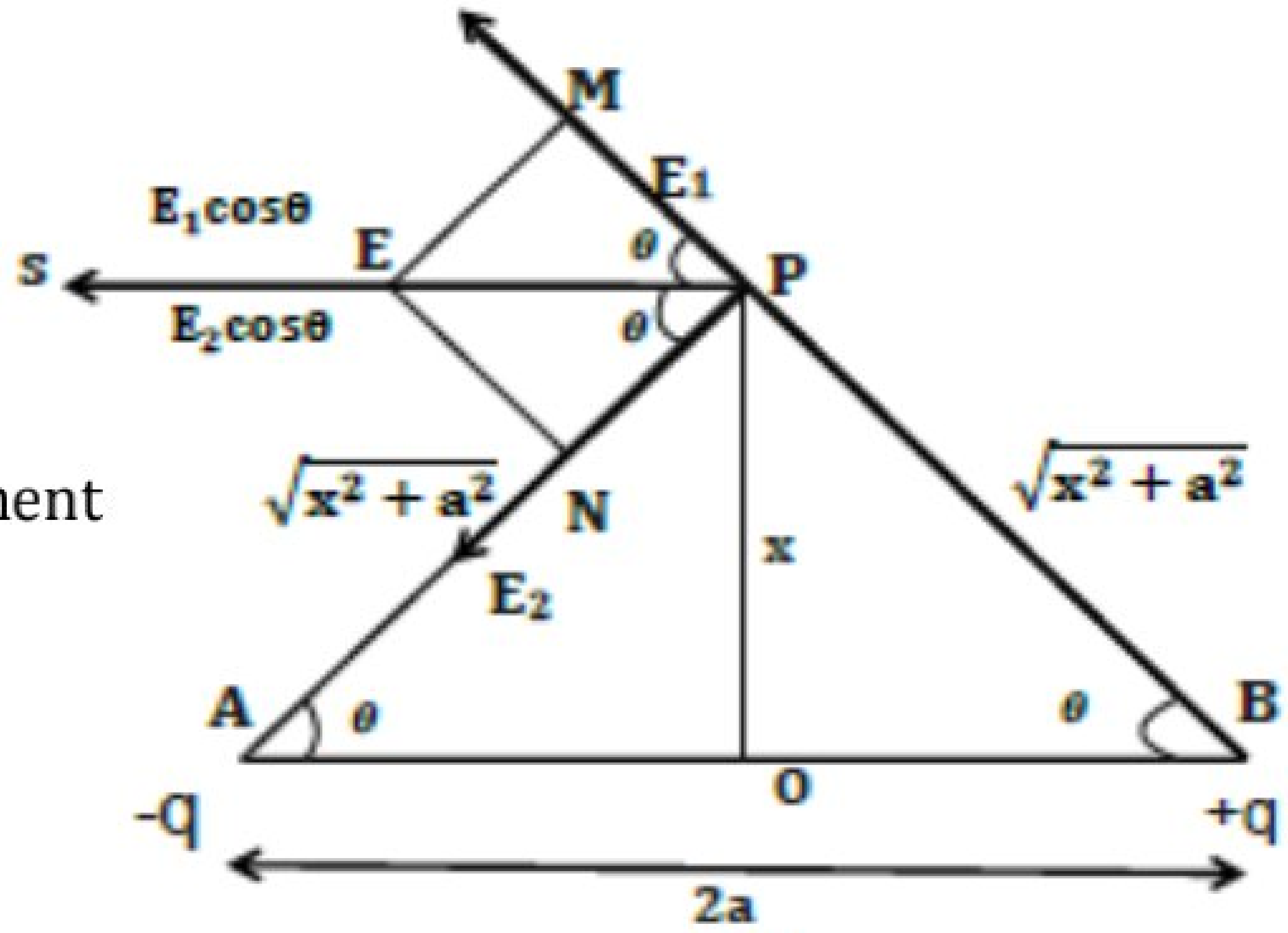
2a is length of dipole

O is midpoint of dipole

P is point on the equatorial line

x is the distance between O and P

θ is the angle between E_1 or E_2 and dipole moment



FIG

Electric field at P due to + q

$E_1 = \frac{1}{4\pi\varepsilon_0}\frac{q}{BP^2}$ along BP

$= \frac{1}{4\pi\varepsilon_0}\frac{q}{(x^2+a^2)}$

Electric field at P due to – q

$E_2 = \frac{1}{4\pi\varepsilon_0}\frac{q}{AP^2}$ along PA

$= \frac{1}{4\pi\varepsilon_0}\frac{q}{(x^2+a^2)}$

Resultant electric field at P;

$E = E_1 \cos\theta + E_2 \cos\theta$

$E = 2E_1 \cos\theta$ [∵ $E_1 = E_2$]

$= \frac{1}{4\pi\varepsilon_0}\frac{2q}{(x^2+a^2)}\cos\theta$

$= \frac{1}{4\pi\varepsilon_0}\frac{2q}{(x^2+a^2)}\cdot\frac{a}{\sqrt{x^2+a^2}}$ [∵ In fig; $\cos\theta = \frac{a}{\sqrt{x^2+a^2}}$]

$= \frac{1}{4\pi\varepsilon_0}\frac{q\times 2a}{(x^2+a^2)^{3/2}}$

$\therefore E = \frac{1}{4\pi\varepsilon_0}\frac{p}{(x^2+a^2)^{3/2}}$ along PS [∵ Electric dipole moment, $p = q \times 2a$]

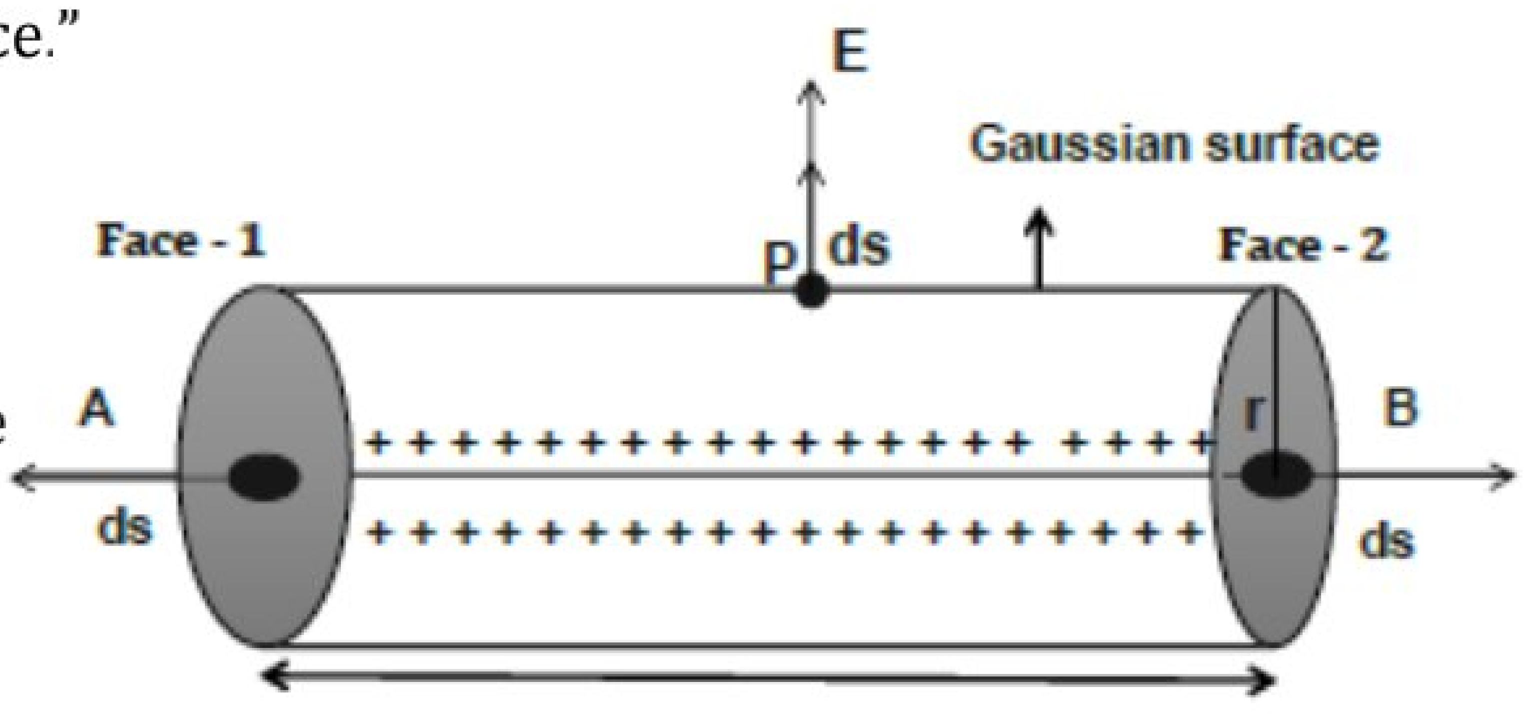
If the dipole is short (i.e., a << x), then a^2 may be neglected as compared to x^2

$\therefore E = \frac{1}{4\pi\varepsilon_0}\frac{p}{x^3}$ along PS

5. State Gauss law in electrostatics. Using the Gauss law, derive an expression for electric field at a point due to an infinitely long charged conductor (wire).

Ans: **Statement:** "The total electric flux through a closed surface in free space is equal to $1/\varepsilon_0$ times the net charge enclosed by the surface."

In the figure;
AB is the infinitely long wire
E is the electric field
P is the point at a distance 'r' from the wire
r is the radius of Gaussian cylinder
l is the length of Gaussian cylinder



FIG

Electric flux is through the Gaussian cylinder is given by,

$\phi = \sum E \cos\theta \, dS$

$= E \sum dS$ [$\because \cos 0^0 = 1$]

$\phi = E \times 2\pi r l$ ....(1)   Where $\sum ds = 2\pi r l$ is the area of the cylinder.

But $\phi = \frac{q}{\varepsilon_0} = \frac{\lambda l}{\varepsilon_0}$ ......(2)   [$\because \lambda l = q$ Where λ is linear charge density]

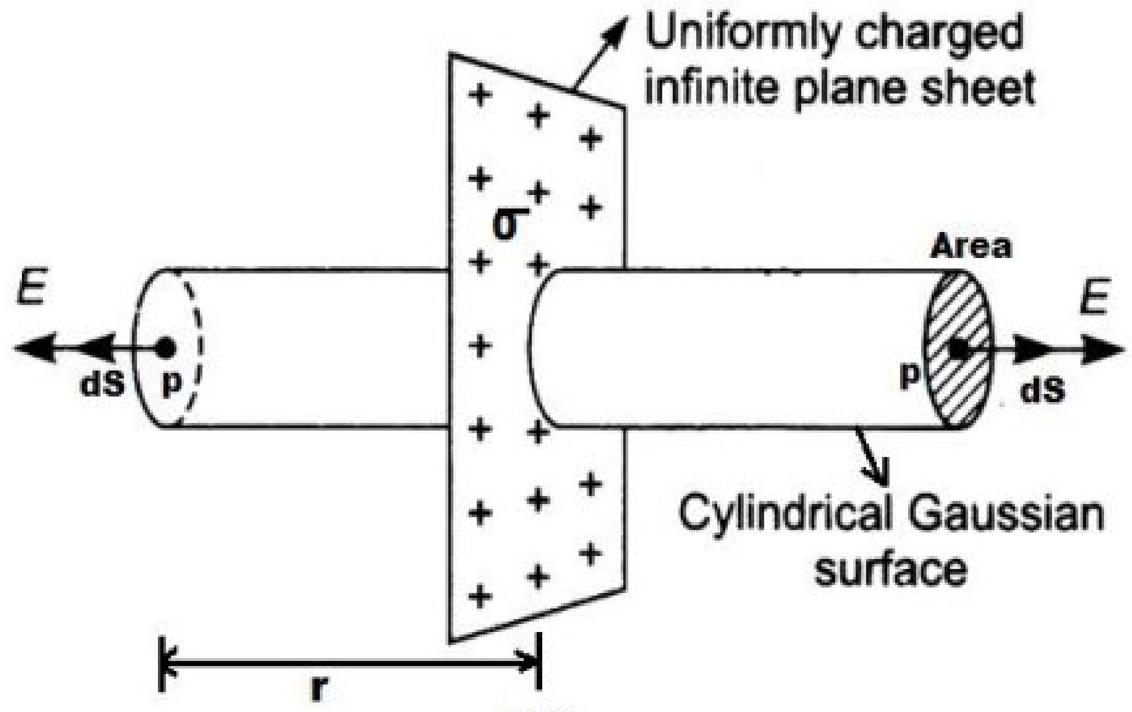
From equation (1) and (2), we get

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

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

6. Obtain an expression for electric field due to uniformly charged infinite plane sheet by using Gauss's law.

Ans: In the figure;
E is the electric field
σ is the surface charge density on the sheet
r is distance between end face of cylinder and the sheet
q is the charge inside the Gaussian cylinder



FIG

Electric flux through the Gaussian cylinder;

$\phi = \sum E \cos\theta \, dS + \sum E \cos\theta \, dS$

$= 2E \sum dS$ [$\because \cos 0^0 = 1$]

$\phi = 2ES$ ...(1)   Where $\sum dS = S$ is the area of each face of the cylinder.

But, $\phi = \frac{q}{\varepsilon_0} = \frac{\sigma S}{\varepsilon_0}$ ...(2)   [$\because \sigma S = q$ Where σ is surface charge density]

From equation (1) and (2), we get

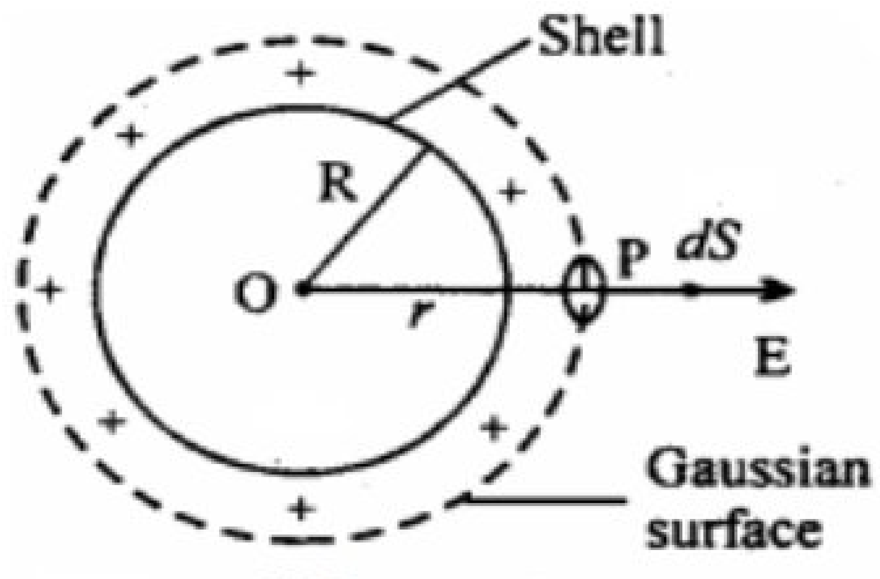
$2ES = \frac{\sigma S}{\varepsilon_0}$

$E = \frac{\sigma}{2\varepsilon_0}$

7. Using the Gauss law, derive an expression for electric field due to a uniformly charged thin spherical shell at a point outside the shell

Ans:
In figure;
E is electric field

R is radius of thin spherical shell of center O
r is radius of Gaussian sphere
P is a point at a distance ‘r’ from O
ds is the area element around the point P
q is the charge on the surface of the shell



FIG

The electric flux through the Gaussian surface is given by

$\phi = \sum E\, ds \cos\theta$

$\phi = \sum E\, ds$ $\quad$ [$\cos 0^0 = 1$]

$\phi = E \sum ds$ $\quad$ [Where $\sum ds = 4\pi r^2$, Area of the Gaussian sphere]

$\therefore \phi = E \times 4\pi r^2$ ....(1)

But, $\phi = \frac{q}{\epsilon_0}$ ....(2)

From equ (1) and (2), we get

$E \times 4\pi r^2 = \frac{q}{\epsilon_0}$

$E = \frac{1}{4\pi\epsilon_0}\frac{q}{r^2}$ $\quad$ along OP

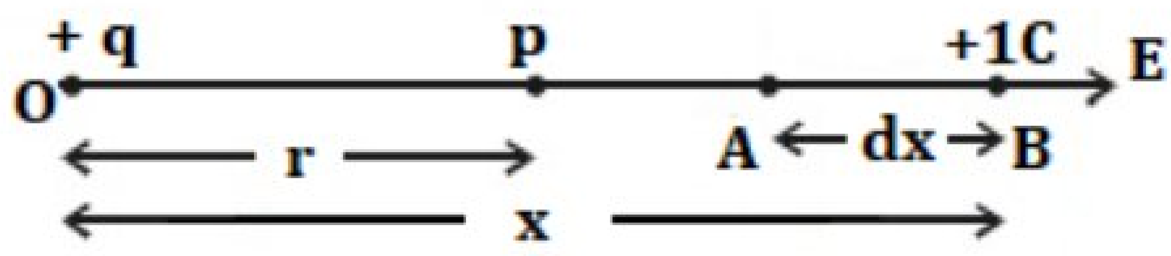
Note:

- If P is just outside the spherical shell [$r \approx R$], Then $E = \frac{1}{4\pi\epsilon_0}\frac{q}{R^2}$
- If P is inside the spherical shell, Then $q = 0$, $\phi = 0$ and $E = 0$

8. Define electric potential and derive an expression for electric potential due to an isolated point charge.

Ans: The electric potential at a point in an electric field is the amount of work done in moving a unit positive charge from infinity to that point against the electric field.

In the figure



FIG

+q is the point charge placed at O in free space
x is the distance between q and +1C
p is the point at a distance r from O
E is the electric field

Work done in bringing a unit positive charge from B to A,

$dW = -F dx$

Negative sign indicates that work is done opposite to the direction of electric field

But $F = \frac{1}{4\pi\varepsilon_0}\left(\frac{q \times 1}{x^2}\right)$ $\quad$ along OB

$\therefore dW = -\frac{1}{4\pi\varepsilon_0}\left(\frac{q}{x^2}\right) dx$

The total work done in bringing a +1C charge from $x = \infty$ to $x = r$;

$W = \int_\infty^r dW$

$W = \int_\infty^r -\frac{1}{4\pi\varepsilon_0}\left(\frac{q}{x^2}\right) dx$

$W = -\frac{q}{4\pi\varepsilon_0}\int_\infty^r \frac{1}{x^2}\, dx = -\frac{q}{4\pi\varepsilon_0}\left[-\frac{1}{x}\right]_\infty^r$

$W = \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{r} - \frac{1}{\infty}\right]$

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

For 1C, V = W

∴ Electric potential at 'p', $V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$

9. Derive an expression for electric potential due to a dipole

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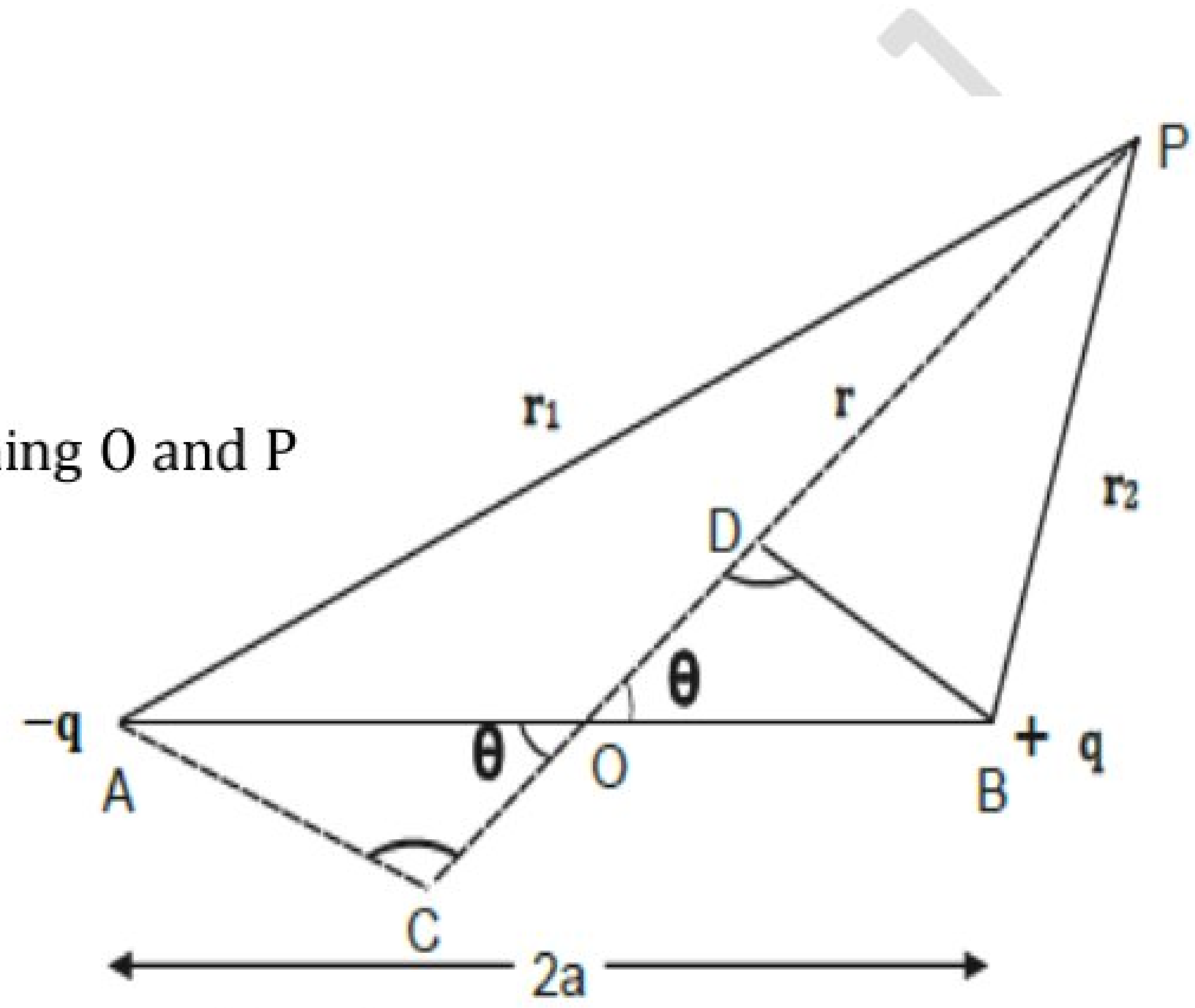
Ans: **In the figure**

+q and − q are charges of dipole
2a is length of dipole
O is midpoint of dipole
P is point at a distance r from O
θ is the angle between dipole axis and line joining O and P



Potential at P due to –q;

$V_1 = \frac{-q}{4\pi\varepsilon_0 r_1}$

Potential at P due to +q;

$V_2 = \frac{q}{4\pi\varepsilon_0 r_2}$

Potential at P due to dipole;

$V = V_1 + V_2$

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

$= \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{r_2} - \frac{1}{r_1}\right]$

Consider right angled triangle ACO; $\cos\theta = \frac{OC}{OA} \Longrightarrow OC = OA\cos\theta = a\cos\theta$

Similarly it can be obtained that $OD = OB\cos\theta = a\cos\theta$

In fig; $r_1 \approx (PO + OC) = (r + a\cos\theta)$ & $r_2 \approx (PO - OD) = (r - a\cos\theta)$

∴ $V = \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{(r - a\cos\theta)} - \frac{1}{(r + a\cos\theta)}\right]$

$= \frac{q}{4\pi\varepsilon_0}\left[\frac{(r + a\cos\theta) - (r - a\cos\theta)}{(r^2 - a^2\cos^2\theta)}\right]$

$= \frac{q}{4\pi\varepsilon_0}\left[\frac{2a\cos\theta}{(r^2 - a^2\cos^2\theta)}\right]$

$V = \frac{1}{4\pi\varepsilon_0}\frac{p\cos\theta}{(r^2 - a^2\cos^2\theta)}$ [∵ Electric dipole moment, p = q × 2a]

10. What is an electric dipole? Derive an expression for potential energy of a dipole placed in uniform electric field.

Ans: A pair of equal and opposite charges separated by a small distance is called electric dipole

In the figure

+q and − q are charges of dipole
2a is length of dipole
p is electric dipole moment

E is electric field.

θ is angle between p and E

The torque acts on the dipole is given by

$\tau = pE\sin\theta$.

Work is done to rotate the dipole through an angle $d\theta$;

$dW = \tau\, d\theta = pE\sin\theta\, d\theta$

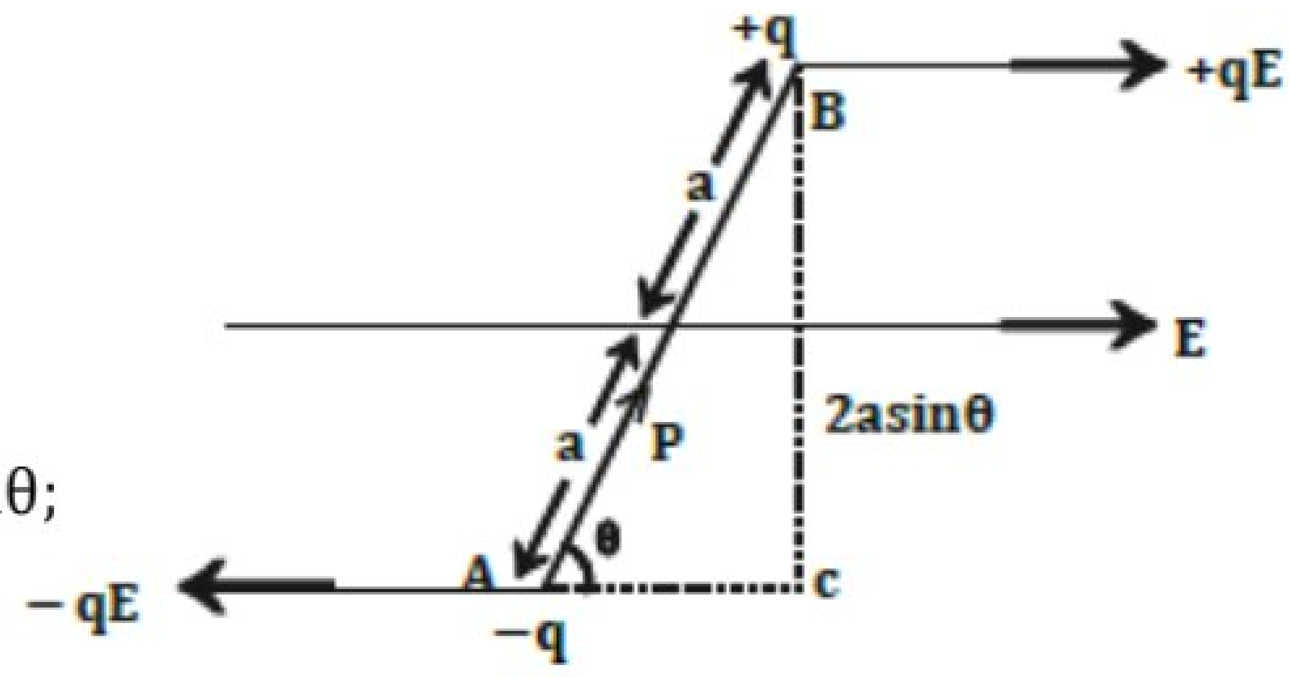
Total work done in rotating the dipole;

$W = \int dW = \int pE\sin\theta\, d\theta$

$W = -pE\cos\theta$

This work done will be stored as potential energy of a dipole

$U = -pE\cos\theta$



FIG

11. What is an equipotential surface? Mention any four properties of it

Ans: Equipotential surface is the surface having the same potential at every point.

Properties of equipotential surface

- Two equipotential surfaces cannot intersect.
- Equipotential surfaces are closer in the region of strong electric field.
- Equipotential surfaces are farther in the region of weak electric field.
- Work done in moving a test charge over an equipotential surface is zero.
- The direction electric field is always normal to the equipotential surfaces.

12. What is effective / equivalent capacitance? Obtain the expression for effective capacitance of two capacitors connected in series

Ans: Effective capacitance is the capacitance of a group of capacitors.

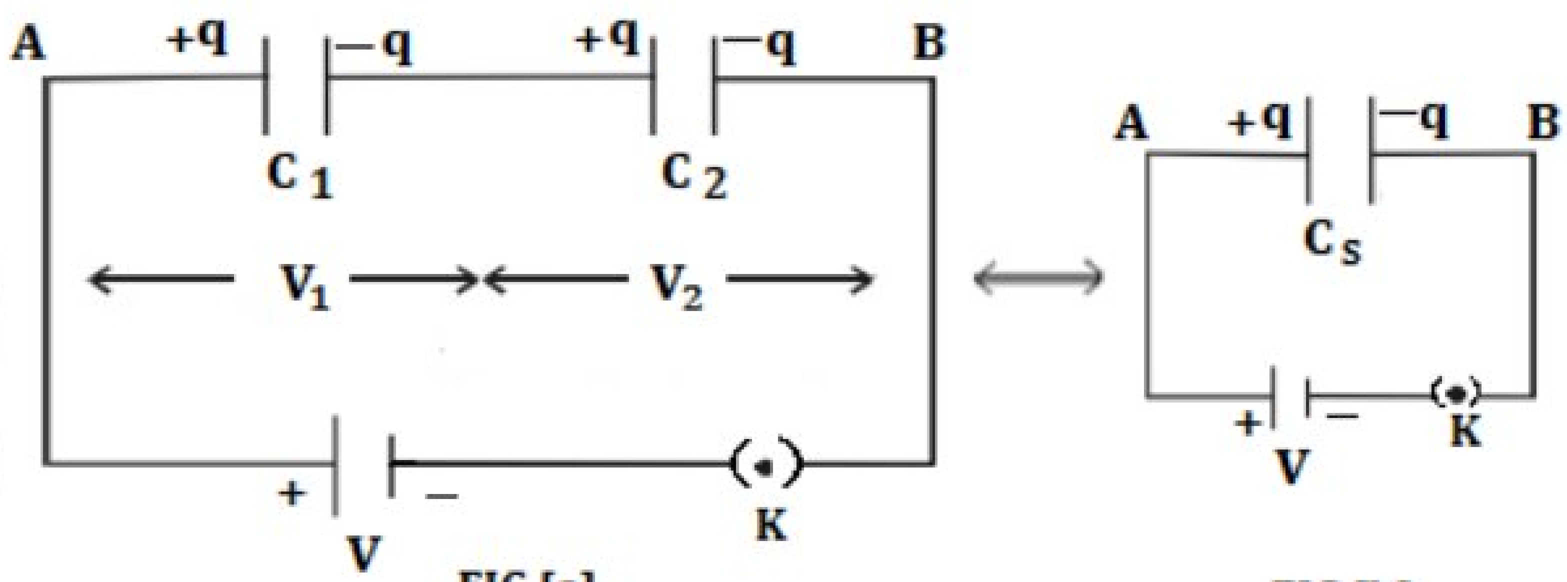


FIG [a] FIG [b]

Let C_1 and C_2 be the two capacitors connected in series.

V_1 and V_2 be the potential difference across C_1 and C_2 respectively

We have $V = \frac{q}{C}$ where q is charge on each capacitor

$\therefore\ V_1 = \frac{q}{C_1}$ and $V_2 = \frac{q}{C_2}$

For equivalent capacitor; $V = \frac{q}{C_s}$ [Fig (b)]

Total potential difference between A and B is given by

$$V = V_1 + V_2$$

$$\frac{q}{C_s} = \frac{q}{C_1} + \frac{q}{C_2}$$

$$\frac{q}{C_s} = q\left[\frac{1}{C_1} + \frac{1}{C_2}\right]$$

$$\frac{1}{C_s} = \frac{1}{C_1} + \frac{1}{C_2}$$

13. What is effective capacitor? Obtain the expression for effective capacitance of two capacitors connected in parallel.

Ans: Effective capacitor is a single capacitor that has same capacitance as that of group of capacitors.

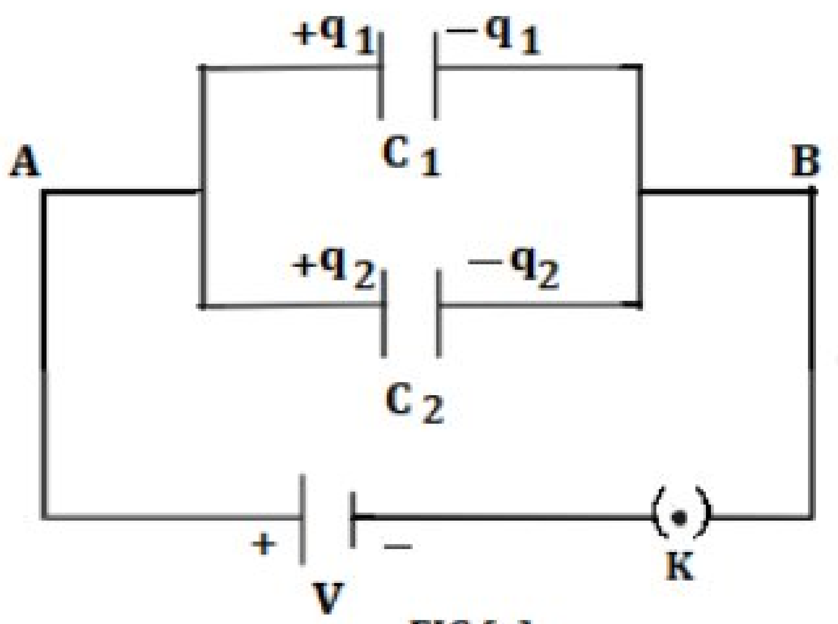


FIG [a]

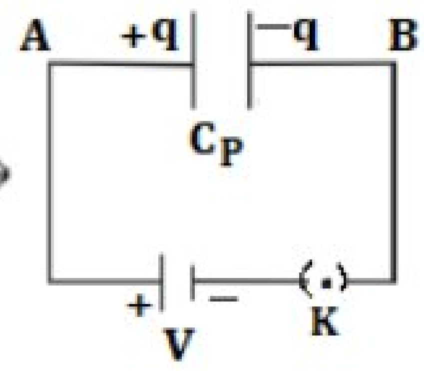


FIG [b]

Let C_1 and C_2 be the two capacitors connected in parallel.

q_1 and q_2 be the charges on C_1 and C_2 respectively

V is potential difference applied across the combination.

We have q = CV

$\therefore \quad q_1 = C_1V$ and $q_2 = C_2V$

For equivalent capacitor; $q = C_p V$ [Fig (b)]

Total charge between A & B is given by

$$q = q_1 + q_2$$
$$C_pV = C_1V + C_2V$$
$$C_pV = V(C_1 + C_2)$$
$$C_p = C_1 + C_2$$

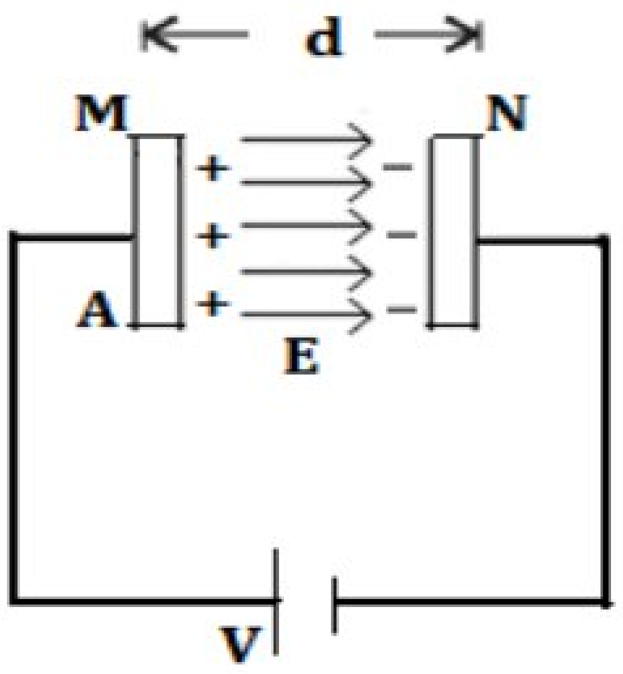
14. Derive the expression for capacitance of parallel plate capacitor with dielectric medium.

Ans: Let A be the area of each plate of charge 'q'.

d be the distance between the plates of parallel plate capacitor.

E be the uniform electric field between the plates.

V be the potential difference between the plates.



FIG

The electric field E between the plates;

$E = \frac{\sigma}{\varepsilon_0}$

Surface density of charge, $\sigma = q / A$

$E = \frac{q}{A\varepsilon_0}$

But $E = \frac{V}{d}$

$\frac{V}{d} = \frac{q}{A\varepsilon_0}$

$\frac{q}{V} = \frac{A\varepsilon_0}{d}$

$C = \frac{A\varepsilon_0}{d}$ Where ε_0 - Permittivity of free space

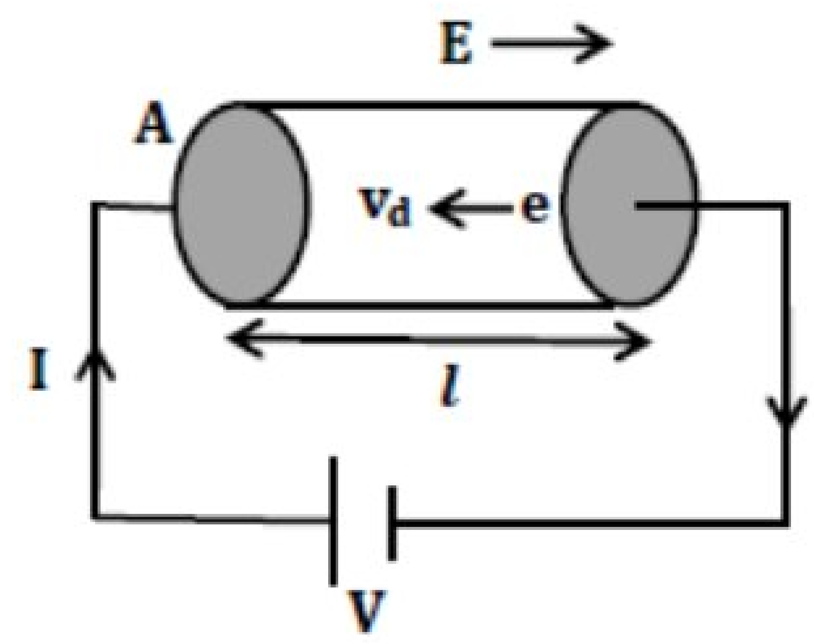
If space between the plates contains a dielectric medium of dielectric constant ε_r , then

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

Note: Condenser / Capacitor is a device used to store electric charge and electrical energy.

1. 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. Define the term mobility.

Ans: In the figure,



I – Current in the conductor

V – Potential difference applied across the conductor

E – Electric field set up in the conductor.

l – Length of the conductor

V_d – Drift velocity

A – The area of cross section of conductor

Current density, $J = \sigma E$

$$\sigma = \frac{J}{E}$$

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

$$\therefore \sigma = \frac{I}{AE}$$

But $I = neAV_d$

$$\therefore \sigma = \frac{neAV_d}{AE}$$

$$\sigma = \frac{neV_d}{E}$$

But $V_d = \frac{Ee\tau}{m}$

$$\therefore \sigma = \frac{ne^2\tau}{m}$$

❖ **Mobility** is defined as the magnitude of drift velocity per unit electric field.

2. Two cells of emf E_1 and E_2 and internal resistances r_1 and r_2 are connected in parallel such that they send current in same direction. Derive an expression for equivalent resistance and equivalent emf of the combination

Ans: Let E_1 and E_2 be the emfs of the two cells connected in parallel

r_1 and r_2 be internal resistance of E_1 and E_2 respectively.

I_1 and I_2 be the current through E_1 and E_2 respectively.

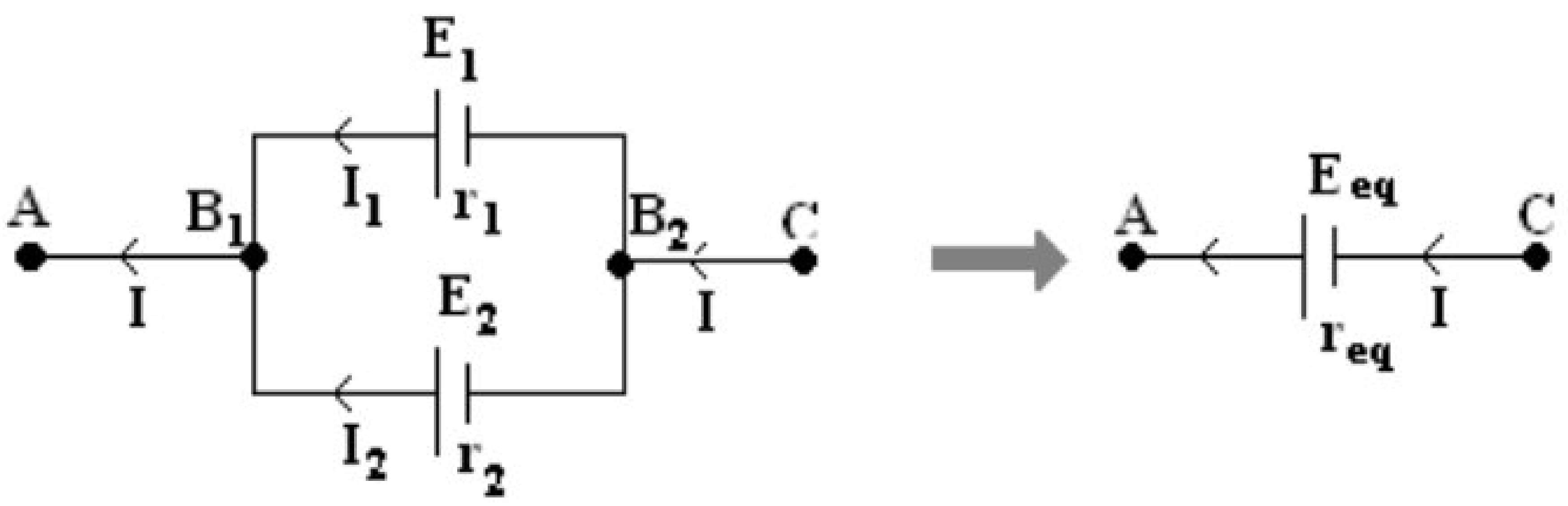


Fig (a) Fig (b)

The potential difference across the first cell; $V = E_1 - I_1r_1$

$\therefore I_1 = \frac{E_1 - V}{r_1}$

The potential difference across the second cell; $V = E_2 - I_2r_2$

$\therefore I_2 = \frac{E_2 - V}{r_2}$

Total current, $I = I_1 + I_2$

$$= \left(\frac{E_1 - V}{r_1}\right) + \left(\frac{E_2 - V}{r_2}\right)$$

$$I = \left(\frac{E_1}{r_1} + \frac{E_2}{r_2}\right) - V\left(\frac{1}{r_1} + \frac{1}{r_2}\right)$$

$$I = \left(\frac{E_1 r_2 + E_2 r_1}{r_1 r_2}\right) - V\left(\frac{r_1 + r_2}{r_1 r_2}\right)$$

$$V\left(\frac{r_1 + r_2}{r_1 r_2}\right) = \left(\frac{E_1 r_2 + E_2 r_1}{r_1 r_2}\right) - I$$

$$V = \left(\frac{E_1 r_2 + E_2 r_1}{r_1 + r_2}\right) - I\left(\frac{r_1 r_2}{r_1 + r_2}\right) \quad \ldots\ldots\ldots(1)$$

For equivalent circuit; $V = E_{eq} - I\, r_{eq}$ ....(2)

Comparing equations (1) and (2), we get

Equivalent emf, $E_{eq} = \left(\frac{E_1 r_2 + E_2 r_1}{r_1 + r_2}\right)$

Equivalent internal resistance, $r_{eq} = \left(\frac{r_1 r_2}{r_1 + r_2}\right)$

3. Obtain the expression for effective emf and effective internal resistance when two different cells are connected in series.

Ans: Consider two cells in series with negative terminal of one cell connected to the positive terminal of the other.

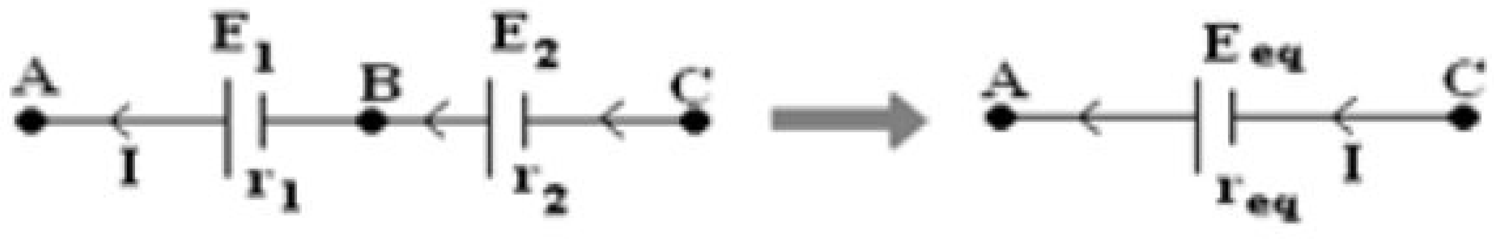


Fig (a) Fig (b)

In the figure

E_1 and E2 —emf of cell -1 and cell -2 respectively

r_1 and r_2 — Internal resistance of cell -1 and cell -2 respectively

I — Current send by the two cells

The potential difference across the first cell; $V_1 = V_A - V_B = E_1 - Ir_1$

The potential difference across the second cell; $V_2 = V_B - V_C = E_2 - Ir_2$

The potential difference between the terminals A and C is given by

$V = V_1 + V_2$

$= E_1 - Ir_1 + E_2 - Ir_2$

$V = E_1 + E_2 - I(r_1 + r_2)$ ....(1)

For equivalent circuit; $V = E_{eq} - I\, r_{eq}$ ......(2)

Comparing equations (1) and (2), we get

$E_{eq} = E_1 + E_2$ and $r_{eq} = r_1 + r_2$

4. Derive the condition for balance of Wheatstone's bridge using Kirchhoff's laws.

Ans: A Wheat stone's bridge consists of four resistors P, Q, R and S connected to forma quadrilateral ABCD. A galvanometer of resistance G is connected between one pair of diagonally opposite corners B & D. A cell of emf E is connected between the other pair of diagonally opposite corners A & C.

Applying KCL to the junctions B and D, we get

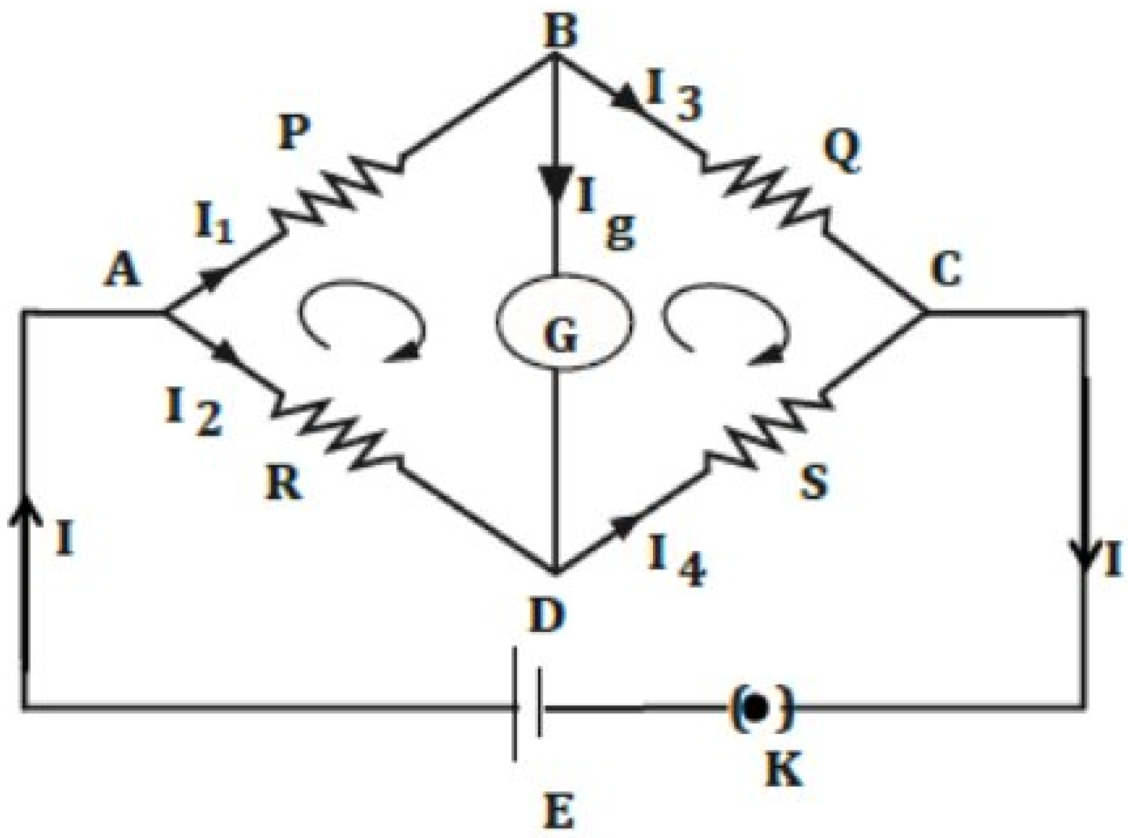
$I_1 = I_3 + I_g$ -------------- (1)

$I_4 = I_2 + I_g$ -------------- (2)

Applying KVL to the loop ABDA

$-I_1 P - I_g G + I_2 R = 0$

$\Rightarrow I_1 P + I_g G = I_2 R$ -------------- (3)



Applying KVL to the loop BCDB,

$-I_3Q + I_4S + I_gG = 0$

$\Rightarrow I_4S + I_gG = I_3Q$ ------------- (4)

At balancing condition, $I_g = 0$.

Substitute $I_g = 0$ in equations (1), (2), (3) and (4), we get

$I_1 = I_3$; $I_2 = I_4$

$I_1P = I_2R$ -------------- (5)

$I_3Q = I_4 S$ -------------- (6)

Dividing (5) and (6) we get

$\frac{I_1P}{I_3Q} = \frac{I_2R}{I_4S}$

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

This is the condition for balancing of Wheat stone's network.

5. Derive an expression for magnetic field at a point on the axis of a circular coil carrying current

Ans:

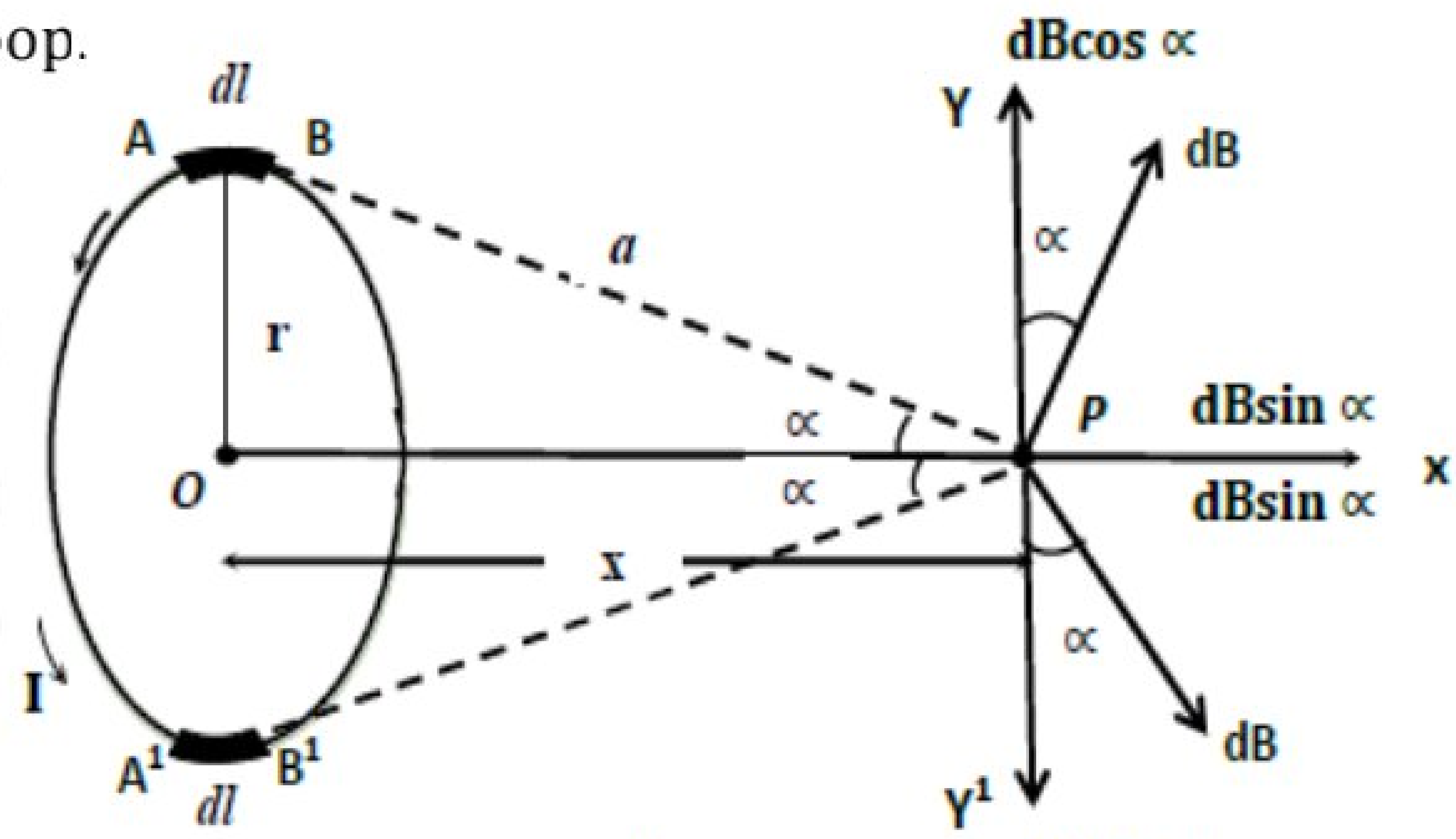
Let P be a point on the axis at a distance 'x' from O.

I be the current in the circular loop.

r be radius of circular coil

dl be length of current element.

a is distance between P and *d*



Fig

Magnetic field at P due to AB,

$dB = \frac{\mu o}{4\pi}\frac{I\,dl\sin\theta}{a^2}$

$dB = \frac{\mu o}{4\pi}\frac{I\,dl}{a^2}$ ……(1) $[\because \theta = 90°]$

Total magnetic field at 'P'

$B = \Sigma dB \sin\propto$…….(2)

Substitute equ (1) in equ (2), we get

$B = \Sigma \frac{\mu_0}{4\pi}\frac{I\,dl}{a^2}\sin\propto$

$= \frac{\mu_0}{4\pi}\frac{I}{a^2}\sin\propto \;\; \Sigma dl$

But $\Sigma dl = 2\pi r$ and $\sin\propto = \frac{r}{a}$

$\therefore B = \frac{\mu_0}{4\pi}\frac{I\,(2\pi r)}{a^2} \cdot \frac{r}{a}$

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

In fig, $a = (r^2 + x^2)^{1/2}$

$\therefore B = \frac{\mu_0}{4\pi}\frac{2\pi I r^2}{(r^2 + x^2)^{3/2}}$

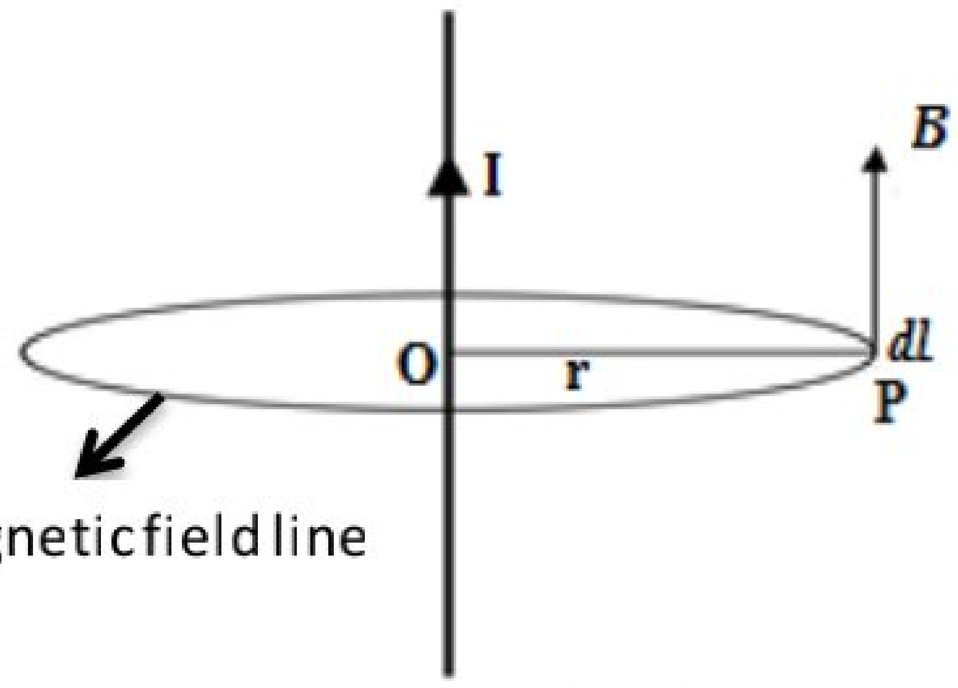
For n –turns, $B = \frac{\mu_0}{4\pi}\frac{2\pi n I r^2}{(r^2 + x^2)^{3/2}}$

6. State Ampere's circuital law. Using it derive the expression for magnetic field near a point due to a long straight current carrying conductor.

Ans: It states that "The line integral of magnetic field over a closed surface is equal to μ_o times the total current enclosed by the loop".

In the figure

I is current flowing through infinitely long straight wire.
P is point on the magnetic field line
O is centre of magnetic field line
r is radius of magnetic field line
dl is length of magnetic element
B is magnetic field at P



From Ampere's circuital law,

$\oint \vec{B}.\vec{dl} = \mu_o I$

$B \oint dl = \mu_o I$

$B (2\pi r) = \mu_o I$

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

7. Derive the expression for the force between two straight parallel conductors carrying current in same direction and hence define ampere.

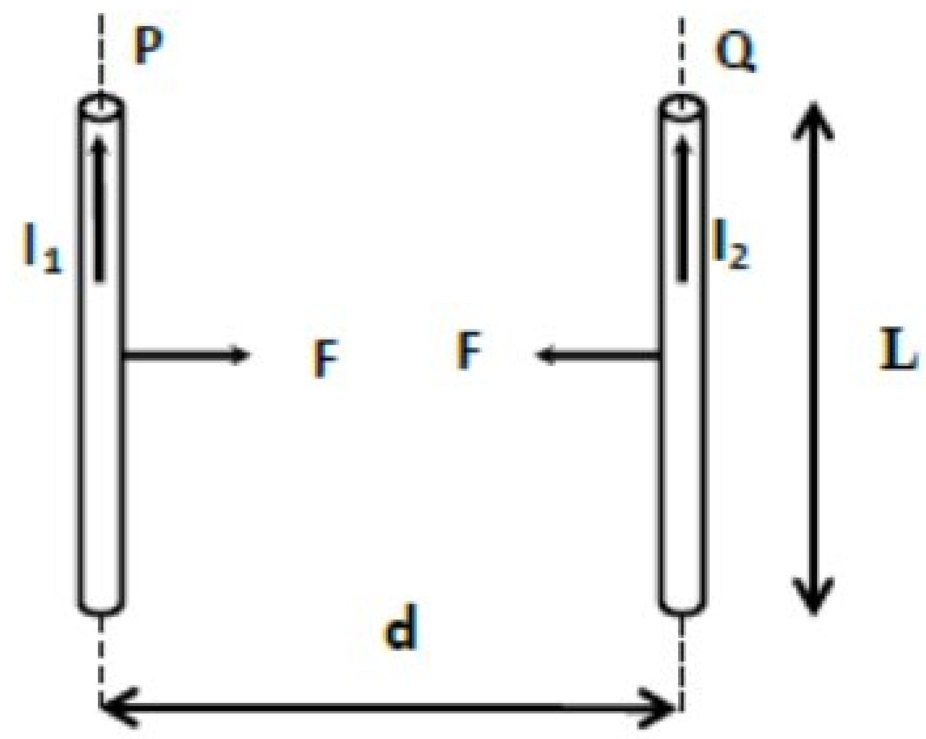
Ans: Consider two conductors P and Q carrying the currents I_1 and I_2 in the same direction. Let'd' be the separation between the two conductors and L be the length of segment of conductor.

Magnetic field due to current 'I_1' is

$B = \frac{\mu o}{2\pi} \frac{I_1}{d}$ ......(1) into the plane

Force on the conductor - Q is

$F = BI_2L$ .....(2) towards conductor – P



Fig

Equation (1) in (2), we get

$F = \left(\frac{\mu o}{2\pi} \frac{I_1}{d}\right) I_2 L$

Similarly Force on the conductor - P is

$F = \left(\frac{\mu o}{2\pi} \frac{I_2}{d}\right) I_1 L$ towards conductor – Q

$\frac{F}{L} = \frac{\mu o}{2\pi} \frac{I_1 I_2}{d}$

Definition of one ampere:

Current in each straight parallel conductor is said to be one ampere when they are separated by a distance of 1m and experience a force per unit length of 2×10^{-7} Nm^{-1}

8. With the help of a diagram, derive an expression for torque on a rectangular loop placed in a uniform magnetic field.

Ans: Consider a rectangular loop PQRS of length 'l' carrying current 'I' placed in a uniform magnetic field 'B'.

The magnetic force on side QR, $F_1 = B I l \sin\theta$

The magnetic force on side SP, $F_2 = B I l \sin\theta$

These two forces acting on the loop constitute torque.

The torque acting on the loop is given by

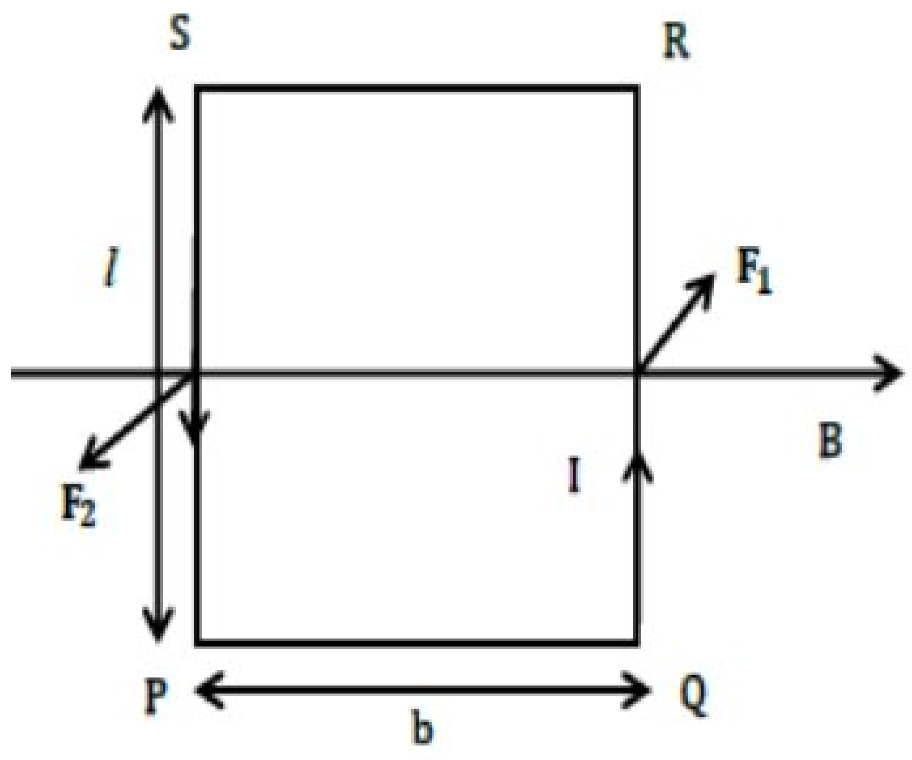
τ = Either force $\times$ Perpendicular distance (b)

$\tau = BI\sin\theta\ (l \times b)$

$\tau = BIA\sin\theta$ [$\because$ Area; $A = l \times b$]

But M = IA; Magnetic dipole moment.

$\therefore \tau = BM\sin\theta$ Where θ is angle between M and B



Fig

QUESTION NO. : 41 **[EMI (OR) AC]**

1. **What is self-induction? Write the expression for self-induction in terms of geometry of the coil. Obtain the expression for energy stored in an inductor.**

Ans: The phenomenon in which emf is induced in the coil due to change of current in the same coil is known as self-induction.

Self-induction, $L = \mu_0 n^2 A l$

Let dW be the work done in developing the current I in an inductor in time dt. Let 'e' be the emf induced in an inductor. The rate of work done is given by

$$\frac{dW}{dt} = |e|I$$

But $|e| = L\frac{dI}{dt}$

$\therefore \frac{dW}{dt} = LI\frac{dI}{dt}$

$dW = LI\,dI$

Total amount of work done in establishing the current I is

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

$W = \frac{1}{2}LI^2$

This work done is equal to the energy stored in the inductance.

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

2. **Derive an expression for instantaneous induced emf in an AC generator.**

Ans

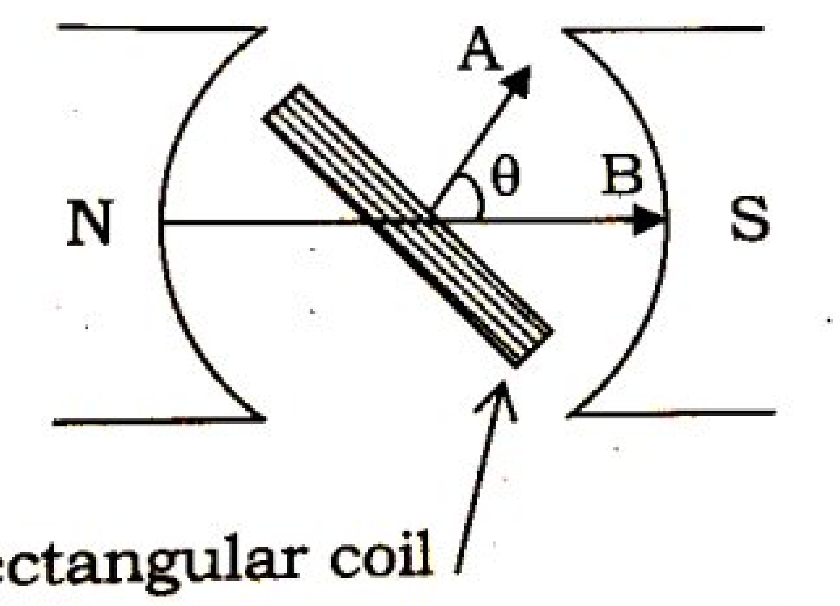
Let 'n' be the number of turns and A be the area of the coil. B is the strength of the magnetic field. θ is the angle between the area vector and magnetic field.

As the coil rotates, the flux linked with the coil changes and hence emf is induced. The magnetic field linked with the coil at any instant of time t is given by

$\varphi = nAB\cos\omega t$ .....(1)

Where ω is the angular speed of the coil at time 't'

From faraday's laws



$e = -\frac{d\phi}{dt}$

$= -\frac{d(nAB\cos\omega t)}{dt}$ [From equ(1)]

$= -nAB(-\omega\sin\omega t)$

$e = (nAB\omega)\sin\omega t$

$e = e_0\sin\omega t$

Where $e_0 = nAB\omega$, peak value of induced emf

9. Show that voltage leads the current when ac circuit containing a pure inductor.

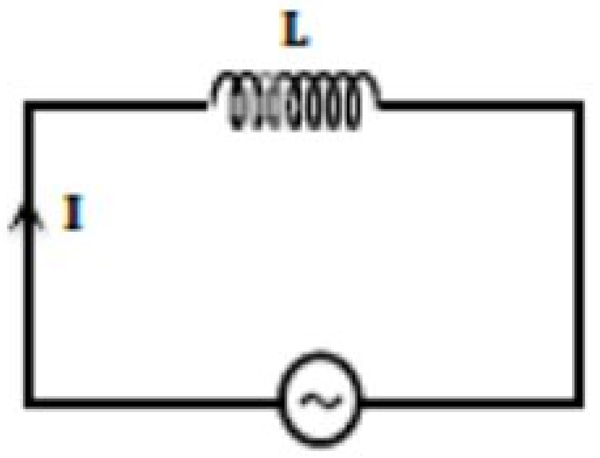
Consider an inductor of self-inductance L connected across an AC source as shown in fig (a). The potential difference across the inductor is given by

$V = V_0 \sin \omega t$ ....(1)

Where, V_0 is the peak value of potential difference and ω = Angular frequency of AC.

From Faradays laws the induced emf in the coil, $e = -L\frac{dI}{dt}$

According to Kirchhoff's voltage law



$V = V_0 \sin\omega t$

Fig [a]

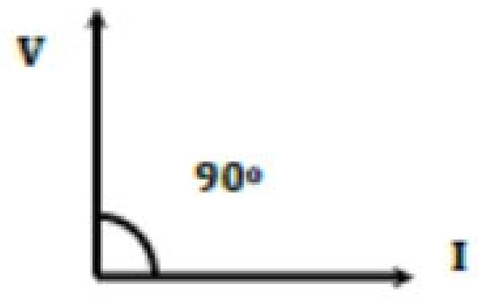


Fig [b]

$V + e = 0$

$\therefore V - L\frac{dI}{dt} = 0$

$V = L\frac{dI}{dt}$

Using equ(1), $L\frac{dI}{dt} = V_0 \sin \omega t$

$dI = \frac{V_0}{L} \sin\omega t \; dt$

Integrating the above equation, we get

$I = \int \frac{V_0}{L} \sin\omega t \; dt = \frac{V_0}{L}\left[-\frac{\cos\omega t}{\omega}\right]$

$= \frac{V_0}{\omega L}(-\cos\omega t)$

$= \frac{V_0}{\omega L}\sin(\omega t - \frac{\pi}{2})$ $\quad [\because -\cos \omega t = \sin(\omega t - \frac{\pi}{2})]$

$I = I_0 \sin(\omega t - \frac{\pi}{2})$ ....(2)

Where $I_0 = \frac{V_0}{\omega L}$, Peak value current

From the equations (1) and (2), it is observed that the voltage leads the current by 90°(fig c).

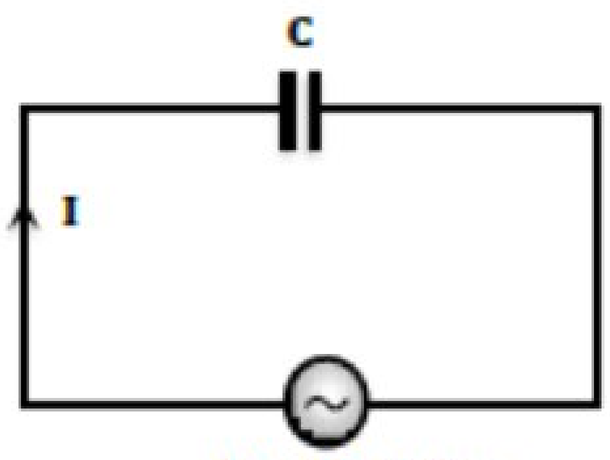
The variations of current and voltage with time are as shown in fig (b).

10. Show that current leads the voltage when ac circuit containing a pure capacitor.

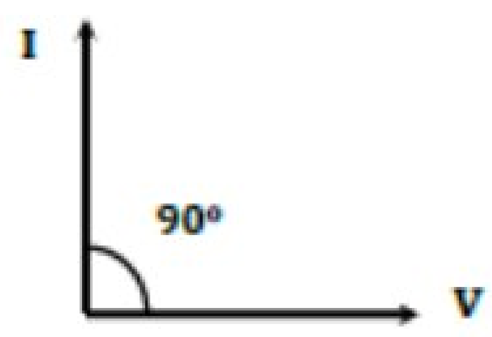
Consider a capacitor of capacitance C connected across an AC source as shown in fig (a). The applied alternating voltage is given by $V = V_0 \sin \omega t$ ....(1)

Where V_0 is the peak value of voltage and ω is angular frequency

Instantaneous charge on the capacitor,



$V = V_0 \sin\omega t$



Fig

$q = CV = CV_0 \sin \omega t$

The instantaneous value of current in the circuit;

$I = \frac{dq}{dt} = \frac{d}{dt}(CV_0 \sin \omega t)$

$I = CV_0 (\omega \cos \omega t)$

$I = \omega C V_0 \cos \omega t$

$I = \omega C V_0 \sin(\omega t + \pi/2)$

$I = I_0 \sin(\omega t + \pi/2)$ ....(2)

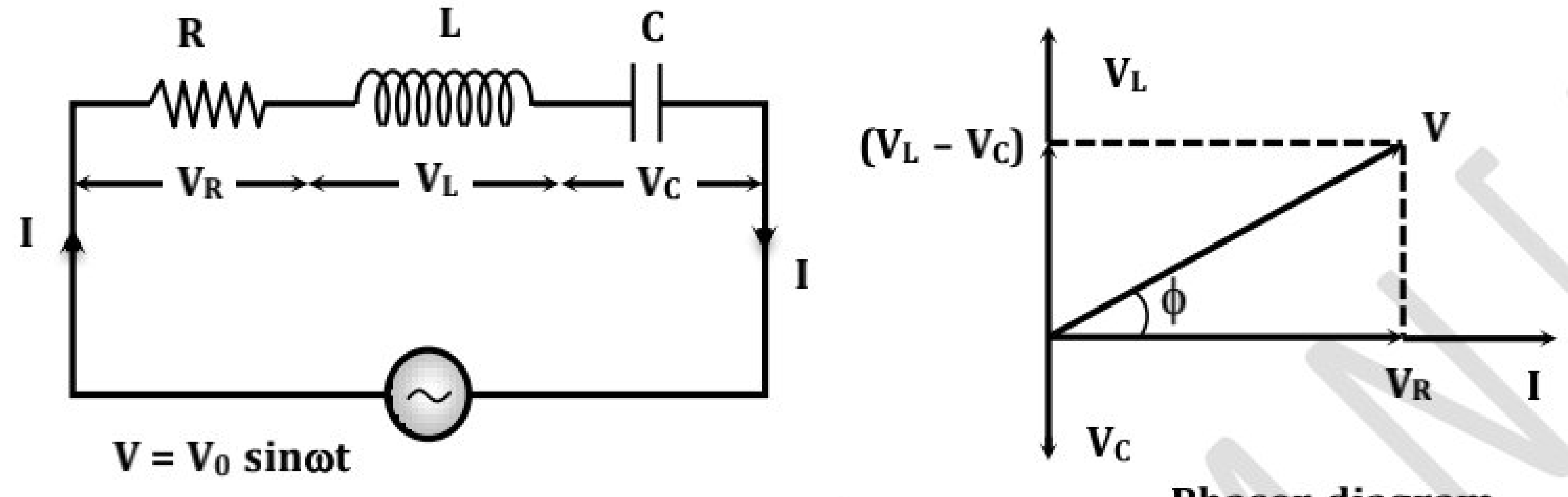
Where $\omega C V_0 = I_0$, Peak current.

Comparing equations (1) and (2) it can be observed that current leads the voltage across the capacitor by 90°. The variations of current and voltage with time are as shown in fig

11. Derive an expression for resultant voltage, impedance, current and phase angle of a series LCR circuit using phasor diagram method

Ans: In phasor diagram,

V_L is the voltage across the inductor.
V_C is the voltage across the capacitor.
V_R is the voltage across the resistor.
$(V_L - V_C)$ is the resultant of V_L and V_C
V is the resultant voltage of $(V_L - V_C)$ and V_R
I is the current in the series LCR circuit.
ϕ is the phase angle between V and I.



Fig

In the right angled triangle OCB;

$$OB^2 = OC^2 + CB^2$$

$$V^2 = V_R^2 + (V_L - V_C)^2$$

$$= (IR)^2 + (IX_L - IX_C)^2$$

$$V^2 = I^2 [R^2 + (X_L - X_C)^2]$$

$\therefore$ Resultant voltage, $V = I\sqrt{R^2 + (X_L - X_C)^2}$

$$\frac{V}{I} = \sqrt{R^2 + (X_L - X_C)^2}$$

But, Impedance, $Z = \frac{V}{I}$

$\therefore$ Impedance, $Z = \sqrt{R^2 + (X_L - X_C)^2}$

Current through the circuit, $I = \frac{V}{Z} = \frac{V}{\sqrt{R^2 + (X_L - X_C)^2}}$

To find the phase angle

In the right angled triangle OCB,

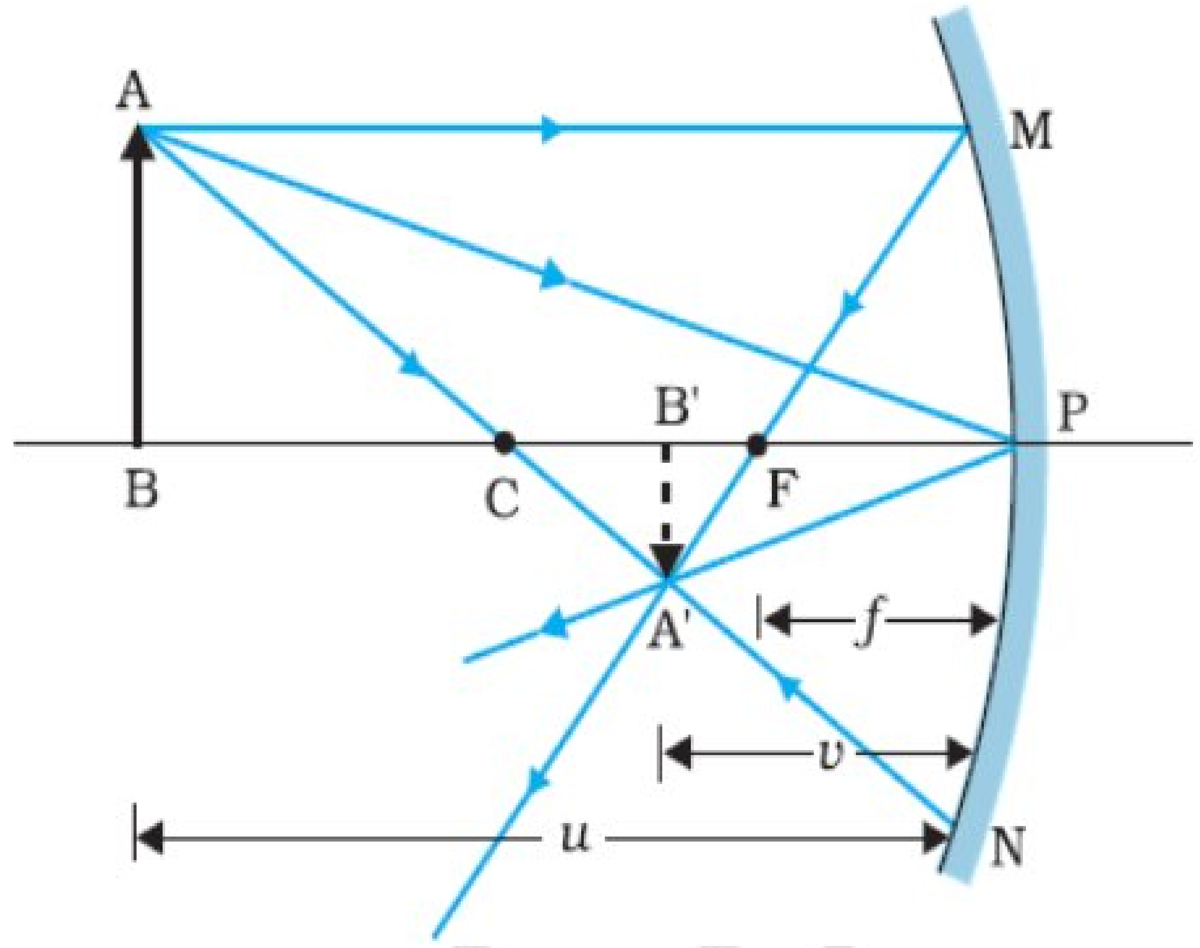
$$\tan\phi = \frac{CB}{OC}$$

$$= \frac{V_L - V_C}{V_R} = \frac{I(X_L - X_C)}{IR} = \frac{X_L - X_C}{R}$$

$$\phi = \tan^{-1}\left(\frac{X_L - X_C}{R}\right)$$

1. Derive mirror equation

Ans: Consider a concave mirror of radius curvature R and Centre of curvature C



In ray diagram,

AB – Object placed on the principal axis

A^1B^1 – Real and inverted image

AM, AP and AN - Incident rays

MA^1, PA^1 and NA^1 – Reflected rays

In the fig,

consider similar triangles ABP and A^1B^1P

$\therefore \frac{A^1B^1}{AB} = \frac{PB^1}{PB}$ …………..(1)

For paraxial rays, M is close to P and MP is considered as a straight line perpendicular to CP.

Consider similar triangles FPM and FA^1B^1

$\therefore \frac{A^1B^1}{PM} = \frac{FB^1}{PF} \Rightarrow \frac{A^1B^1}{AB} = \frac{FB^1}{PF}$ …….(2) $\because$ PM = AB

Compare equation (1) and equation (2), we get

$\frac{PB^1}{PB} = \frac{FB^1}{PF}$

From fig, $PB^1 = -v$, $PB = -u$, $FB^1 = PB^1 - PF = -v - (-f) = -v + f$ and $PF = -f$

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

$-vf = -uv + uf$

On dividing by uvf on both sides, we get

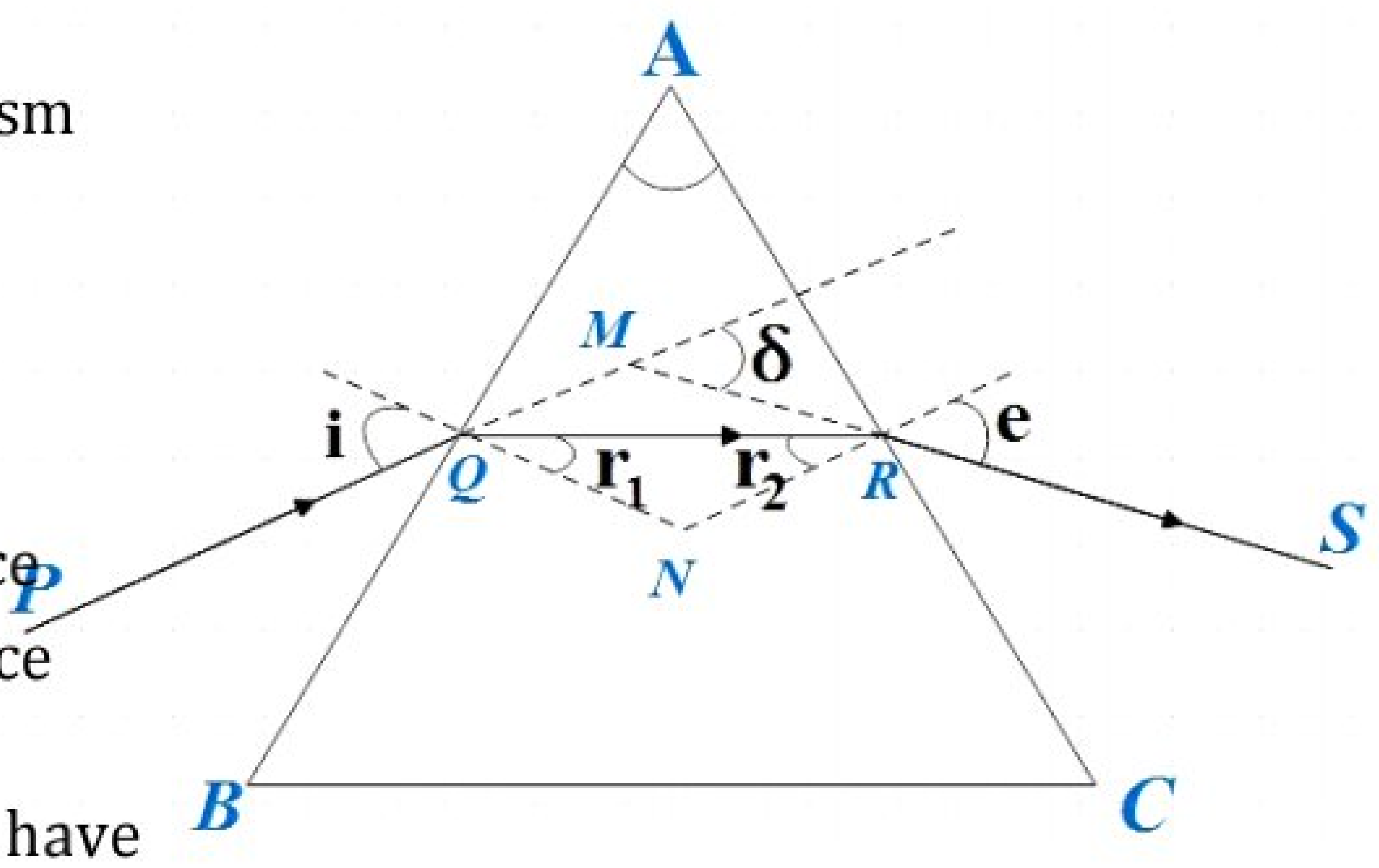
$\frac{-1}{u} = \frac{-1}{f} + \frac{1}{v}$

On rearranging, we get $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$

2. Derive the expression for refractive index of the material of the prism in terms of angle of the prism and angle of minimum deviation.

Ans:

In the figure,



ABC is Principal section of prism

PQ is Incident ray

RS is Emergent ray

i is angle of incidence

e is angle of emergence

r_1 is angle of refraction at I face

r_2 is angle of incidence at II face

δ is angle of deviation

From quadrilateral AQNR, we have

$Q\hat{N}R + \hat{A} = 180^0$ ………… (1)

From triangle QNR, we have

$Q\hat{N}R + r_1 + r_2 = 180^0$ …………… (2)

From equations (1) and (2) we can write

$A = r_1 + r_2$ ………. (3)

We know that, Exterior angle = sum of opposite interior angles

$\delta = [i - r_1] + [e - r_2]$

$= i + e - (r_1 + r_2)$

$= i + e - A$ ...... (4)

From the above graph we have

At minimum deviation, $e = i$ and $r_1 = r_2 = r$, $\delta = D$

Equation (3) becomes; $A = 2r$

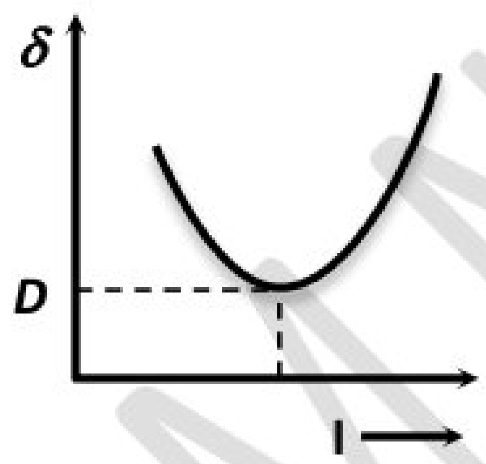
$\Rightarrow \mathbf{r} = \frac{A}{2}$

Equation (4) becomes

$D = i + i - A$

$A + D = 2i$

$i = \frac{A+D}{2}$



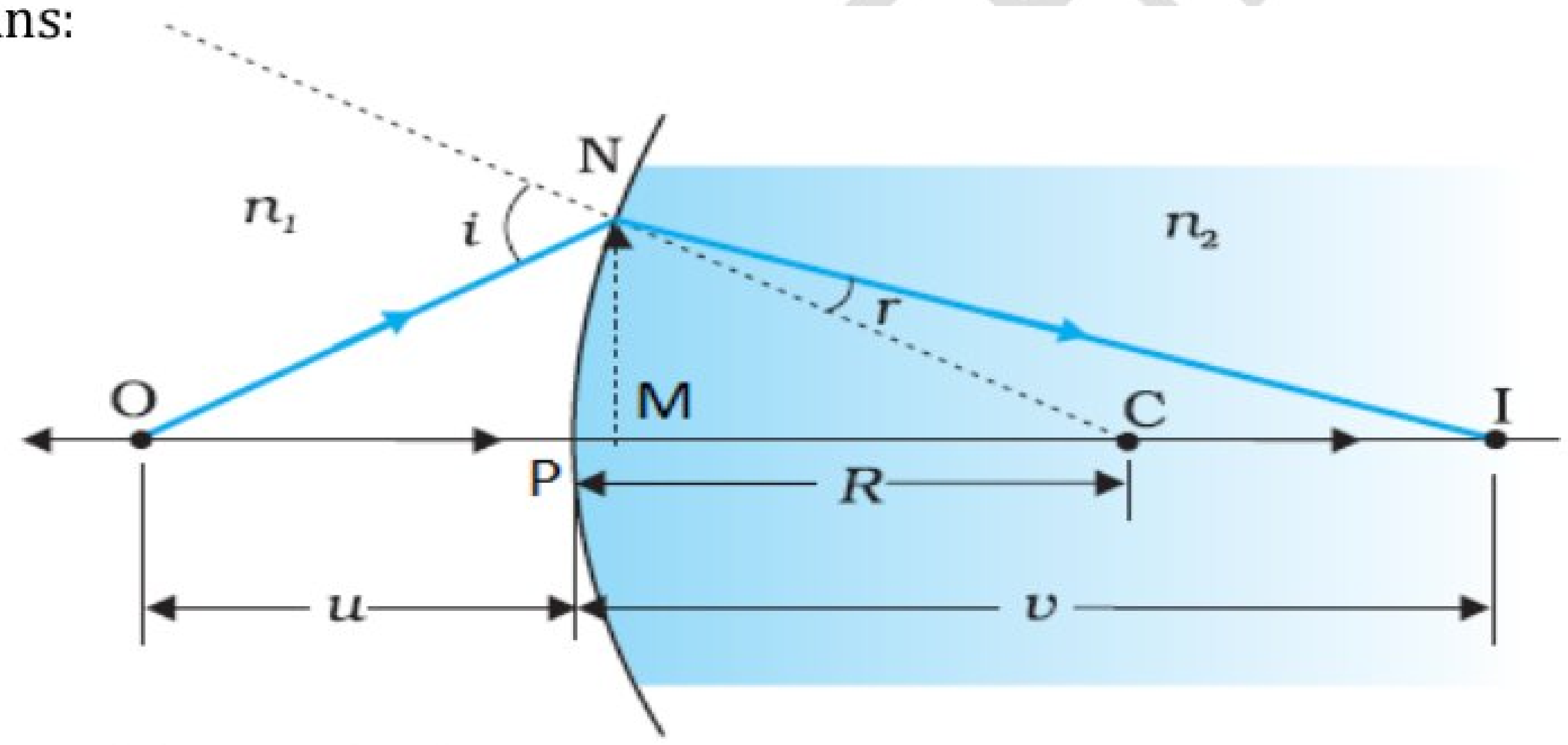
From Snell's law of refraction,

$n = \frac{\sin i}{\sin r}$

$n = \frac{\sin\left(\frac{A+D}{2}\right)}{\sin\left(\frac{A}{2}\right)}$

3. Deduce the relation between n, u, v and R for refraction at a spherical surface, where the symbols have their usual meanings.

Ans:



In ray diagram,

O is luminous point object placed on the principal axis in a rarer medium of refractive index n_1

I is image formed in a denser medium of refractive index n_2

P is pole of spherical surface

R is radius of curvature

C is centre of Curvature

'i' is the angle of incidence and

'r' is the angle of refraction.

Draw NM perpendicular to principal axis.

Let $N\hat{O}M = \alpha$; $N\hat{C}M = \beta$; $N\hat{I}M = \gamma$

$\therefore \tan\alpha = \frac{NM}{MO}$; $\tan\beta = \frac{NM}{MC}$; $\tan\gamma = \frac{NM}{MI}$

Since α, β, γ are small angles (from assumptions),

$\tan\alpha \cong \alpha$; $\tan\beta \cong \beta$; $\tan\gamma \cong \gamma$

$\therefore\ \alpha = \frac{NM}{MO};\ \beta = \frac{NM}{MC};\ \gamma = \frac{NM}{MI}$

From Δ NOC, Exterior angle = sum of interior opposite angles

$$\text{i.e., } i = \alpha + \beta \Rightarrow i = \frac{NM}{MO} + \frac{NM}{MC}$$

Also from Δ NCI, Exterior angle = sum of interior opposite angles

$$\text{i.e., } \beta = r + \gamma \Rightarrow r = \beta - \gamma \Rightarrow r = \frac{NM}{MC} - \frac{NM}{MI}$$

From Snell's law,

$\frac{\sin i}{\sin r} = \frac{n_2}{n_1} \Rightarrow n_1 \sin i = n_2 \sin r$

Since i, r are small angles (from assumptions), $\sin i \cong i$; $\sin r \cong r$

$\therefore\ n_1 i = n_2 r$

$\therefore\ n_1 \left(\frac{NM}{MO} + \frac{NM}{MC}\right) = n_2 \left(\frac{NM}{MC} - \frac{NM}{MI}\right)$

Since aperture is small, M is close to P.

$\therefore\ n_1 \left(\frac{1}{PO} + \frac{1}{PC}\right) = n_2 \left(\frac{1}{PC} - \frac{1}{PI}\right)$

So from sign conventions,

MO = PO = $-u$ (object distance); MC = PC = +R (radius of curvature);

MI = PI = +v (image distance)

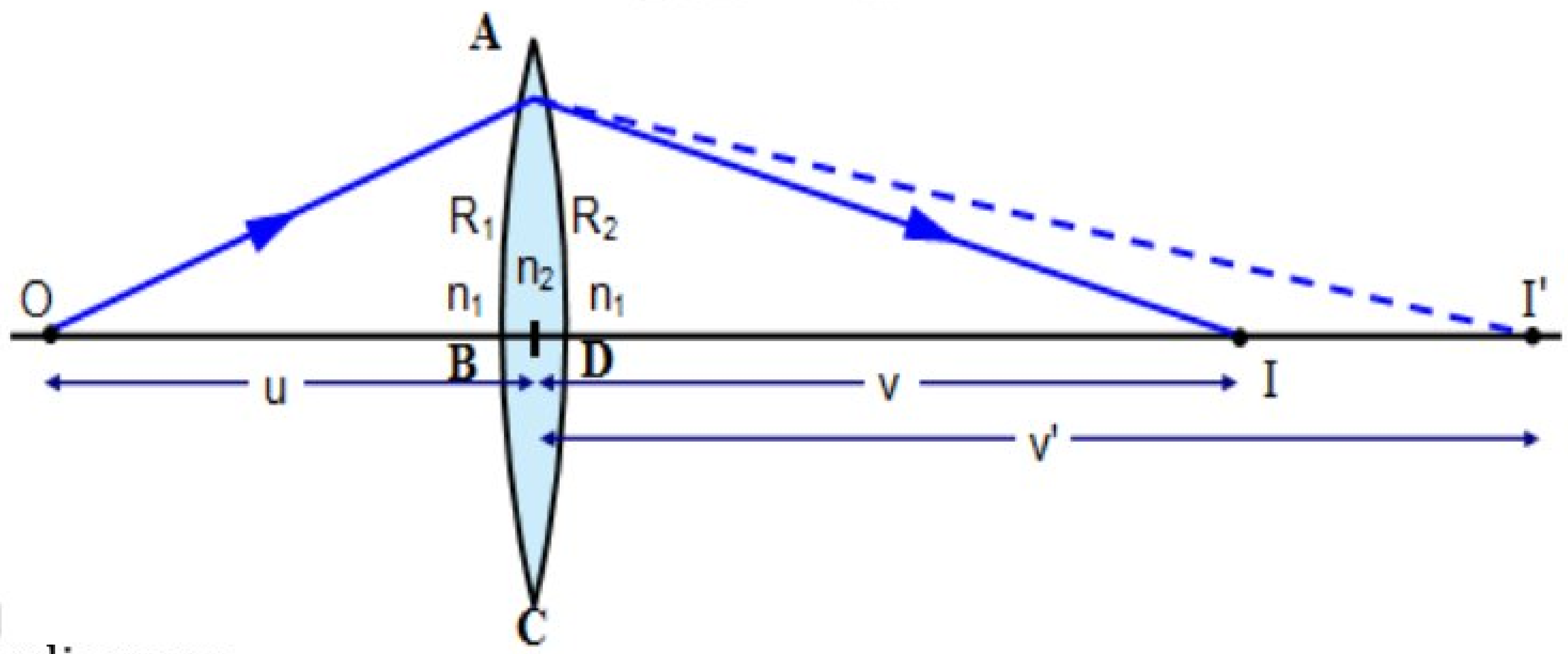
$\therefore\ \left(\frac{n_1}{PO} + \frac{n_1}{PC}\right) = \left(\frac{n_2}{PC} - \frac{n_2}{PI}\right)$

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

On rearranging the equation, we get $\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}$

4. Derive Lens maker's formula for a convex lens.

Ans: Lens maker's formula gives the relation connecting the focal length of a lens, the refractive index of the material of the lens and the radii of curvature of its surfaces.



In ray diagram,

'O' is the point object placed on the principal axis of the lens.

'n_2' is refractive index of thin lens.

'n_1' is refractive index of air medium.

ABC and ADC are two refracting surfaces of lens.

R_1 and R_2 are radii of curvatures of ABC and ADC surfaces respectively.

For spherical surface, we have

$\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}$......(1)

Refraction at the first surface ABC (ray moves from air to glass medium)

O is the object and its image is formed at I^1.

$\therefore$ Equ (1) $\Longrightarrow \frac{n_2}{v^1} - \frac{n_1}{u} = \frac{n_2 - n_1}{R_1}$ ......(2)

Refraction at the second surface ADC (Ray moves from glass to air medium)

I^1 acts as a virtual object and its image is formed at I.

$\therefore$ Equ (1) $\Rightarrow \frac{n_1}{v} - \frac{n_2}{v^1} = \frac{n_1 - n_2}{R_2}$

$\Rightarrow \frac{n_1}{v} - \frac{n_2}{v^1} = -\left(\frac{n_2 - n_1}{R_2}\right) \dots\dots (3)$

Adding equations (2) and (3), we get

$\frac{n_2}{v^1} - \frac{n_1}{u} + \frac{n_1}{v} - \frac{n_2}{v^1} = \frac{n_2 - n_1}{R_1} - \left(\frac{n_2 - n_1}{R_2}\right)$

$\Rightarrow n_1 \left[\frac{1}{v} - \frac{1}{u}\right] = (n_2 - n_1)\left\{\frac{1}{R_1} - \frac{1}{R_2}\right\}$

$\frac{1}{v} - \frac{1}{u} = \frac{(n_2 - n_1)}{n_1}\left\{\frac{1}{R_1} - \frac{1}{R_2}\right\}$

$\frac{1}{v} - \frac{1}{u} = \left(\frac{n_2}{n_1} - 1\right)\left\{\frac{1}{R_1} - \frac{1}{R_2}\right\}$

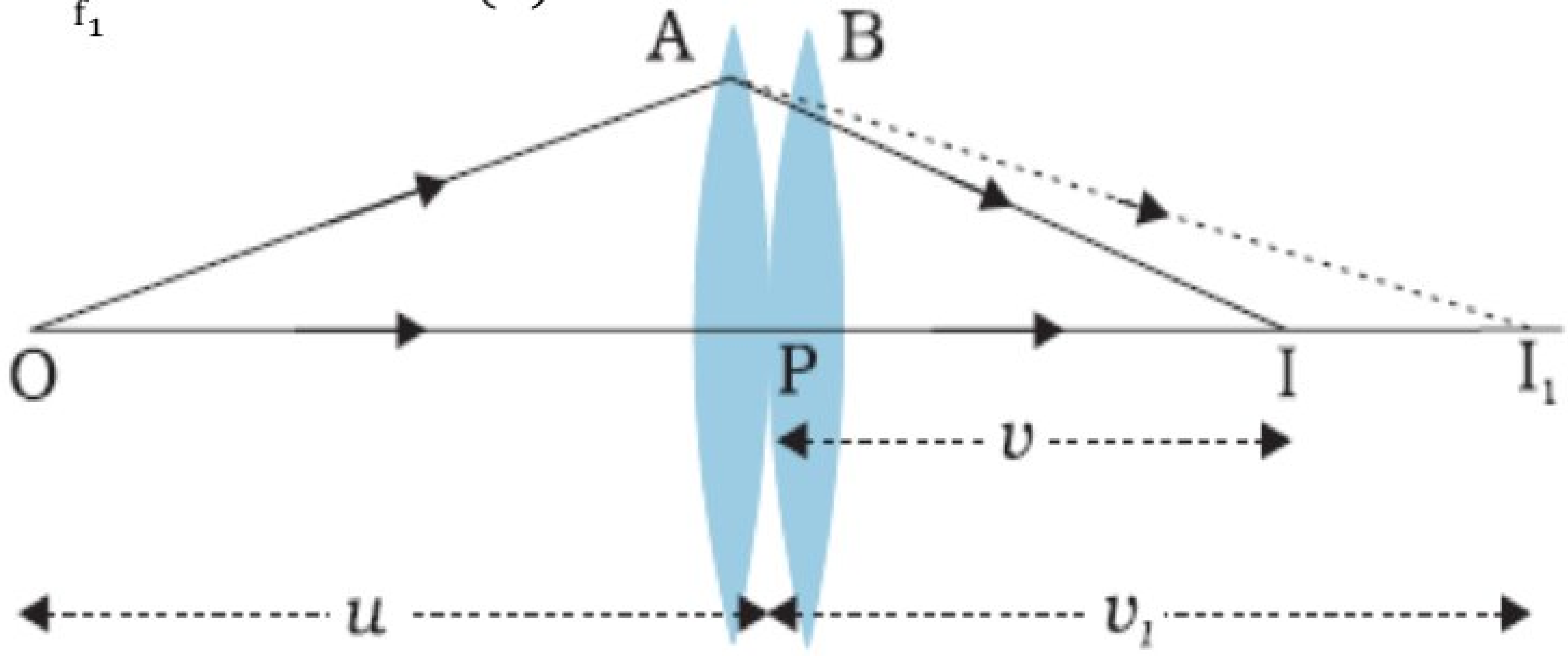
But $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$ [Thin lens formula]

$\therefore \frac{1}{f} = (\frac{n_2}{n_1} - 1)\left\{\frac{1}{R_1} - \frac{1}{R_2}\right\}$

5. **Derive an expression for the equivalent focal length of two thin lenses kept in contact.**

Ans: Consider two thin lenses A & B of focal lengths f_1 and f_2 placed in contact with each other. Let the object be placed at point 'O' beyond the focus of first lens A.

1. In the absence of the second lens B, the first lens produces a real image I_1.
   Using lens equation for first lens, we get
   $\frac{1}{v_1} - \frac{1}{u} = \frac{1}{f_1} \dots\dots\dots\dots\dots\dots (1)$



2. For refraction through second lens B, I_1 serves as a virtual object for the second lens B, producing the final image at I.
   Using lens equation for second lens, we get

$$\frac{1}{v} - \frac{1}{v_1} = \frac{1}{f_2} \dots\dots\dots\dots\dots\dots (2)$$

Adding equations (1) and (2), we get

$\frac{1}{v_1} - \frac{1}{u} + \frac{1}{v} - \frac{1}{v_1} = \frac{1}{f_1} + \frac{1}{f_2}$

$\Rightarrow \frac{1}{v} - \frac{1}{u} = \frac{1}{f_1} + \frac{1}{f_2}$

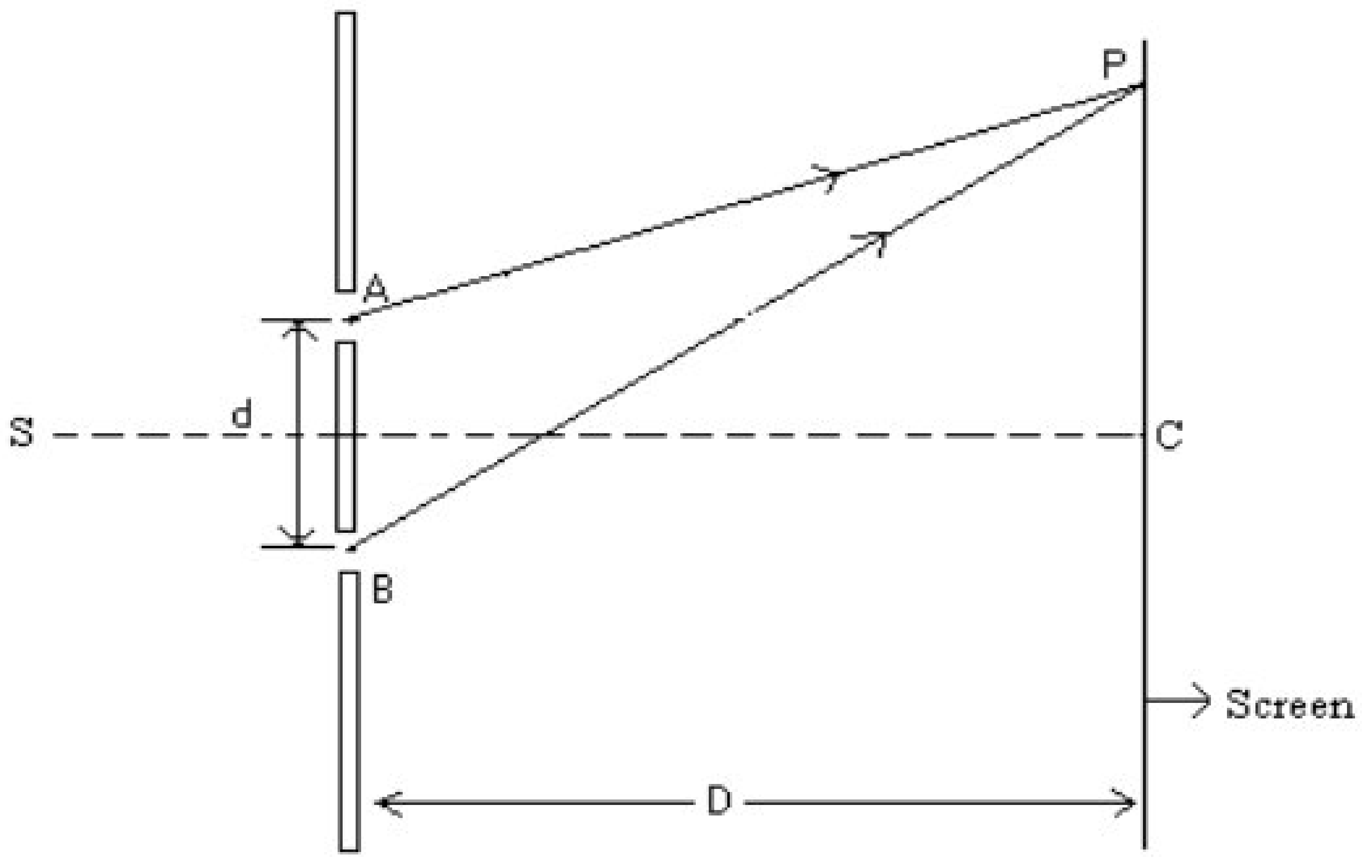
But, $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$

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

6. **What is interference of light? Give the theory of interference**

Ans: The modification in the distribution of light energy or intensity due to superposition of two or more light waves travelling in the same direction is called interference of light.

Consider two waves of same amplitude travelling in same direction. They are represented as



$y_1 = a \cos \omega t$ and $y_2 = a \cos (\omega t + \phi)$

Where a – Amplitude

ω – Angular frequency

ϕ – Phase difference between two waves

According to the principle of superposition,

The net displacement is

$$y = y_1 + y_2$$

$$= a \cos \omega t + a \cos (\omega t + \phi)$$

$$= a [\cos \omega t + \cos (\omega t + \phi)]$$

$$= 2a \cos\left(\frac{\phi}{2}\right) \cos\left(\omega t + \frac{\phi}{2}\right) \quad \left[\because \cos A + \cos B = 2\cos\left(\frac{A+B}{2}\right)\cos\left(\frac{A-B}{2}\right)\right]$$

$$y = R \cos\left(\omega t + \frac{\phi}{2}\right) \;......(1)$$

Where, $R = 2a \cos\left(\frac{\phi}{2}\right)$ is amplitude of the resultant wave

Eqn. (1) shows that the resultant wave is also a simple harmonic wave.

Resultant intensity at P

Intensity is proportional to the square of the amplitude. i.e. $I \propto [\text{amplitude}]^2$

$$I \propto \left[2a \cos\left(\frac{\phi}{2}\right)\right]^2$$

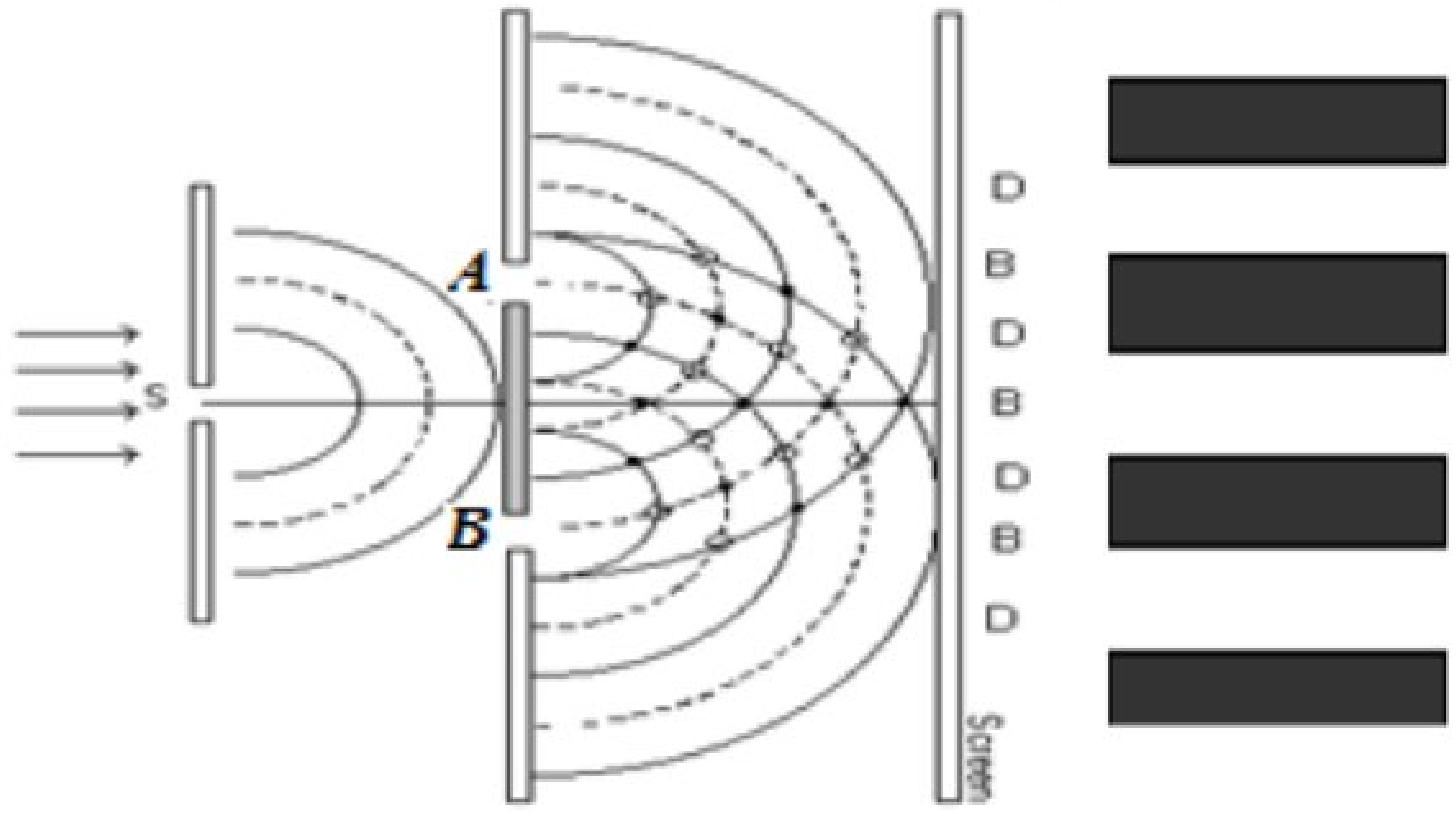
$$I = 4a^2 \cos^2\left(\frac{\phi}{2}\right)$$

$$I = 4I_0 \cos^2\left(\frac{\phi}{2}\right)$$

Where I_0 is the individual wave intensity

7. Explain young's double slit experiment.

Ans:



Thomas Young in 1801 first demonstrated the phenomenon of interference. The experimental arrangement is as shown in fig. Monochromatic light from the source is made to fall on the slit 'S'.

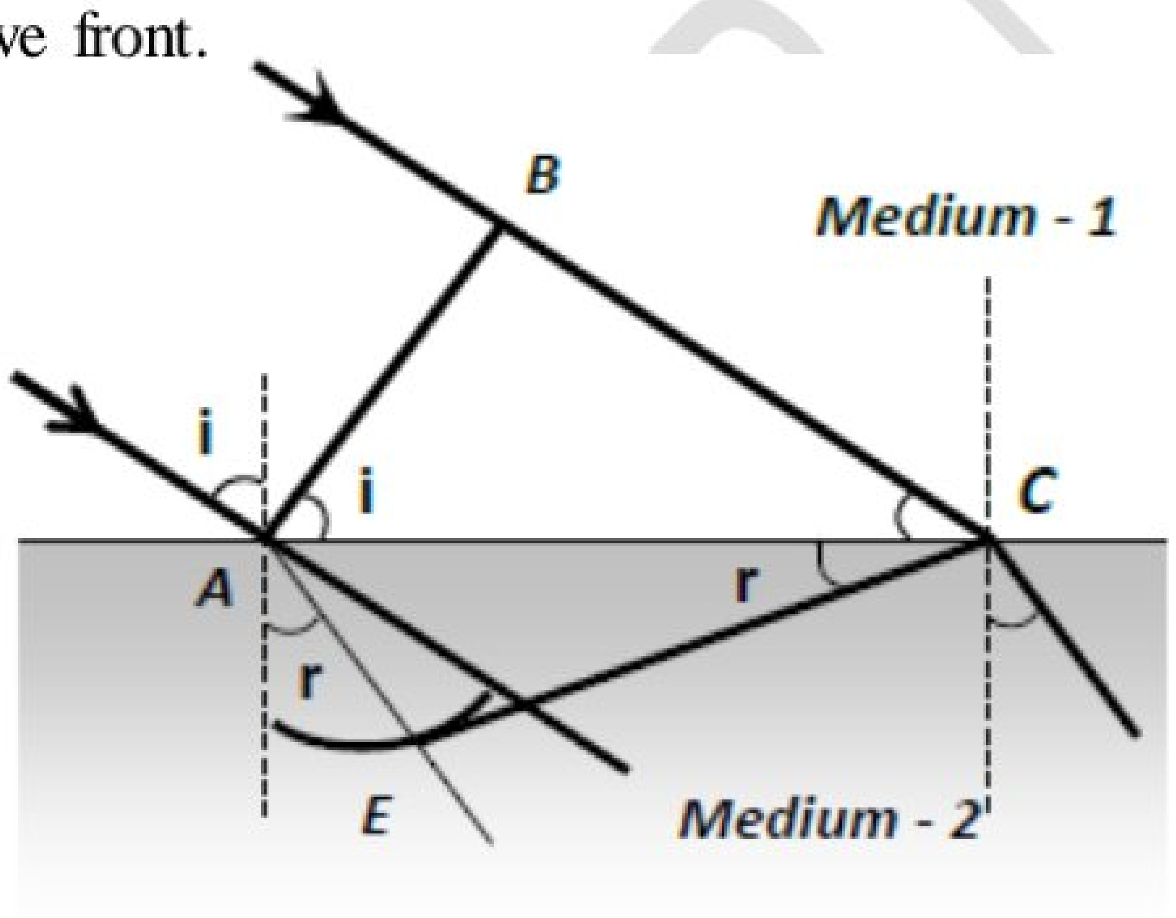
The light from S is incident on two narrow slits A and B which are close to each other and equidistant from S. The two slits A and B act as coherent sources. Light waves coming from A and B superpose and form interference pattern on the screen placed at some distance from the slits A and B.

Characteristics of interference pattern

- It consists of alternate bright and dark fringes.
- All bright fringes are equally bright.
- All dark fringes are equally dark.
- All bright and dark fringes are equally spaced.
- The fringe width is same for both bright and dark fringes.

8. What is meant by wave front? Arrive at Snell's law of refraction using Huygens principle for plane wave

Ans: The locus of points of constant phase is called wave front.



In ray diagram,

i = Angle of incidence
r = Angle of refraction
EC - Refracted wave front.
AB – Incident wave front
PP[1]- Surface separating medium-1 and medium-2
V_1 and V_2 - velocity of light in medium -1 and medium -2 respectively
n_1 and n_2 - Refractive index of medium- 1 and medium -2 respectively

In a time 't', incident wave front will travel the distance BC. Then BC = $V_1 t$
In a time 't', refracted wave front will travel the distance AE. Then AE = $V_2 t$

From the Δ ABC, $\sin i = \frac{BC}{AC}$

From the Δ AEC, $\sin r = \frac{AE}{AC}$

$\therefore \frac{\sin i}{\sin r} = \frac{BC}{AE} = \frac{V_1 t}{V_2 t} = \frac{V_1}{V_2}$

But $\frac{V_1}{V_2} = \frac{n_2}{n_1}$

$\therefore \frac{\sin i}{\sin r} = \frac{n_2}{n_1}$

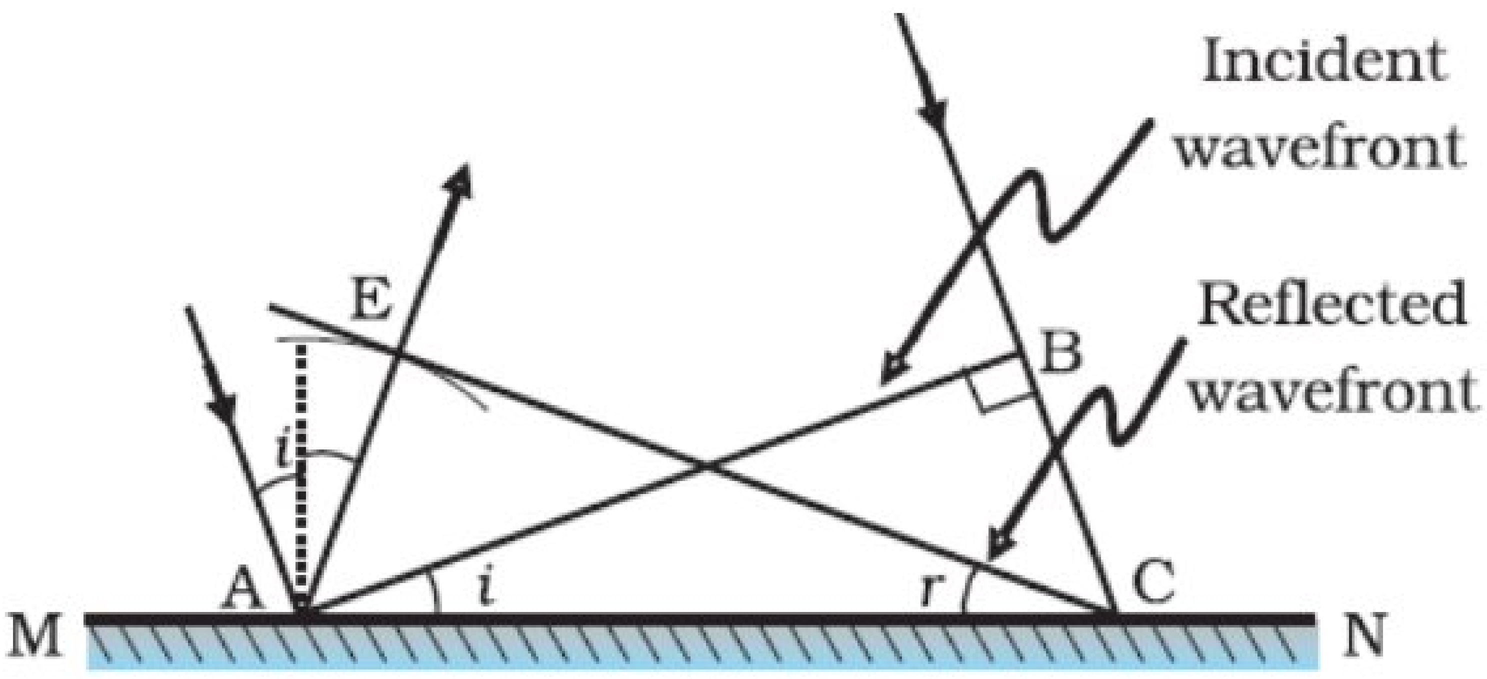
This is Snell's law of refraction.

9. State Huygens principle. Arrive at Snell's law of reflection using Huygens principle for plane wave

Ans: **According to Huygens principle**

- Each point on a wave front is a source of new disturbance called secondary wavelet which travels in all directions with the speed of the wave.
- The tangent drawn to all secondary wavelets represents the position of new wave front.

In figure,
MN- Reflecting surface
AB- Incident wave front
CE- Reflected wave front
i- Angle of incidence
r- Angle of reflection.



Let 'V' be the velocity of light in the medium. In a time 't', incident wave front will travel the distance BC. Then BC =Vt

In a time 't', reflected wave front will travel the distance AE. Then AE = Vt

From similar triangles AEC and CBA, AE = BC and AB = CE.

Hence $B\hat{A}C = E\hat{C}A$

$\therefore \quad i = r$

This is law of reflection.

10. Distinguish between between interference and diffraction.

Interference	Diffraction
1. Width of all fringes is same	1. Width of all fringes is not same
2. Intensity of all bright fringes is same	2. Intensity of all bright fringes is not same
3. Intensity of dark fringes is zero	3. Intensity of dark fringes is not zero
4. Number of fringes observed is more	4. Number of fringes observed is less
5. It is independent of diffraction	5. It depends on interference

QUESTION NO. : 43 [DUAL NATURE OF RADIATION AND MATTER]

1. What is meant by photoelectric effect? Write the four observations of experimental study

Ans: The phenomenon of emission of electrons from the metal surface when a radiation of suitable frequency is incident on it is known as photoelectric effect

Laws or experimental observations of photoelectron effect

a) The photoelectron emission is an instantaneous process.
b) For a given photosensitive surface, there is a minimum frequency for incident radiation below which there is no emission of photoelectron. This minimum frequency is known as threshold frequency.
c) For a given metal, the strength of the photoelectric current is directly proportional to the intensity of the incident radiation.
d) Above threshold frequency, the maximum kinetic energy of photoelectrons varies linearly with the frequency of incident radiation.
e) The minimum negative potential given to the anode at which photocurrent becomes zero is called stopping potential.

2. Write Einstein's equation of photoelectric effect. Give Einstein's explanation of photoelectric effect.

Ans: Einstein's equation of photoelectric equation,

$$h\nu = h\nu_o + \frac{1}{2}mv^2_{max}$$

Above equation clears that

a) It is an instantaneous process.
b) If frequency of incident light (ν) equal to threshold frequency (ν_o), the velocity of the photoelectron becomes zero.
c) If frequency of incident light (ν) less than threshold frequency (ν_o), photoelectric effect does not takes place.
d) If frequency of incident light (ν) greater than threshold frequency (ν_o), photoelectric effect takes place.

3. a) Explain Hallwach's and Lenard's observations on photoelectric effect.
b) Define: 1) Work function 2) Threshold frequency and 3) Stopping potential

Ans: a) **According to Lenard**, when u-v radiation is incident on cathode, it emits negatively charged particles. Lenard observed that when UV rays are allowed to fall on cathode, electrons are ejected from it.

According to Hallwach's when u-v radiation is incident on zinc plate, it becomes positively charged. Hallwch's concluded that negatively charged particles were ejected from zinc plate under the action of u-v radiations.

b)
1) The minimum amount of energy required to remove an electron from a metal surface is known as work function
2) It is the minimum frequency of incident radiation below which there is no electron emission.
3) The minimum negative potential given to the anode at which photocurrent becomes zero is known as stopping potential

4. What is photon? Give characteristics of photon.

Ans: A packet of energy of radiation is called photon.

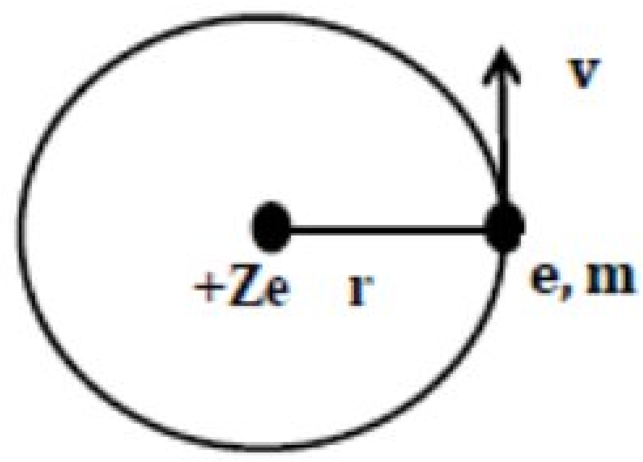
Properties of photon

a) It travels with the speed of light in vacuum.
b) It is electrically neutral.
c) Its rest mass is zero.
d) It carries energy
e) Energy of photon is directly proportional to frequency of photon

5. Derive an expression for the total energy of an electron in stationary state of the hydrogen atom.

Ans: Consider an electron of mass 'm' revolving around the nucleus of charge 'Ze'.

Where, Z – Atomic number
r – Radius of orbit.
v – Velocity of electron
e – Charge of electron.



For stable orbit, centripetal force = Electrostatic force

$$\frac{mv^2}{r} = \frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{r^2} \ldots\ldots(1)$$

Eq (1) ÷ 2 , we get

$$\frac{mv^2}{2} = \frac{1}{8\pi\varepsilon_0}\frac{Ze^2}{r}$$

$$K.E = \frac{1}{8\pi\varepsilon_0}\frac{Ze^2}{r}$$

PE = (Electric potential at a distance 'r' from the nucleus) (Charge on electron)

$$P.E = \left[\frac{1}{4\pi\varepsilon_0}\frac{Ze}{r}\right](-e)$$

$$PE = -\frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{r}$$

PE = − 2KE

Therefore, Total energy E = P.E + KE

E = −2KE + KE

E = −KE

$$E = -\frac{1}{8\pi\varepsilon_0}\frac{Ze^2}{r} \text{.........(2)}$$

But, the radius of the orbit, $r = \frac{n^2h^2\varepsilon_0}{\pi m Z e^2}$.......(3)

Substituting Equation (3) in equation (2), we get $E = -\frac{mZ^2e^4}{8n^2h^2{\varepsilon_0}^2}$

Thus, Energy of electron in the n^{th} orbit, $E_n = -\frac{mZ^2e^4}{8n^2h^2{\varepsilon_0}^2}$

For hydrogen, Z = 1 $\therefore E_n = -\frac{me^4}{8n^2h^2{\varepsilon_0}^2}$

Negative sign indicates that electron is bound the nucleus

Where

n—Principal quantum number, h— Planck's constant and ε_0 —Permittivity of free space.

6. What is nuclear force? Write the characteristics of nuclear forces.

Ans: A force which holds the nucleons together inside the nucleus is called nuclear force

Characteristics of nuclear force

a) It is strongest force in nature
b) It is shot range force
c) It is charge independent force
d) It is exchange force
e) It does not obey inverse square law

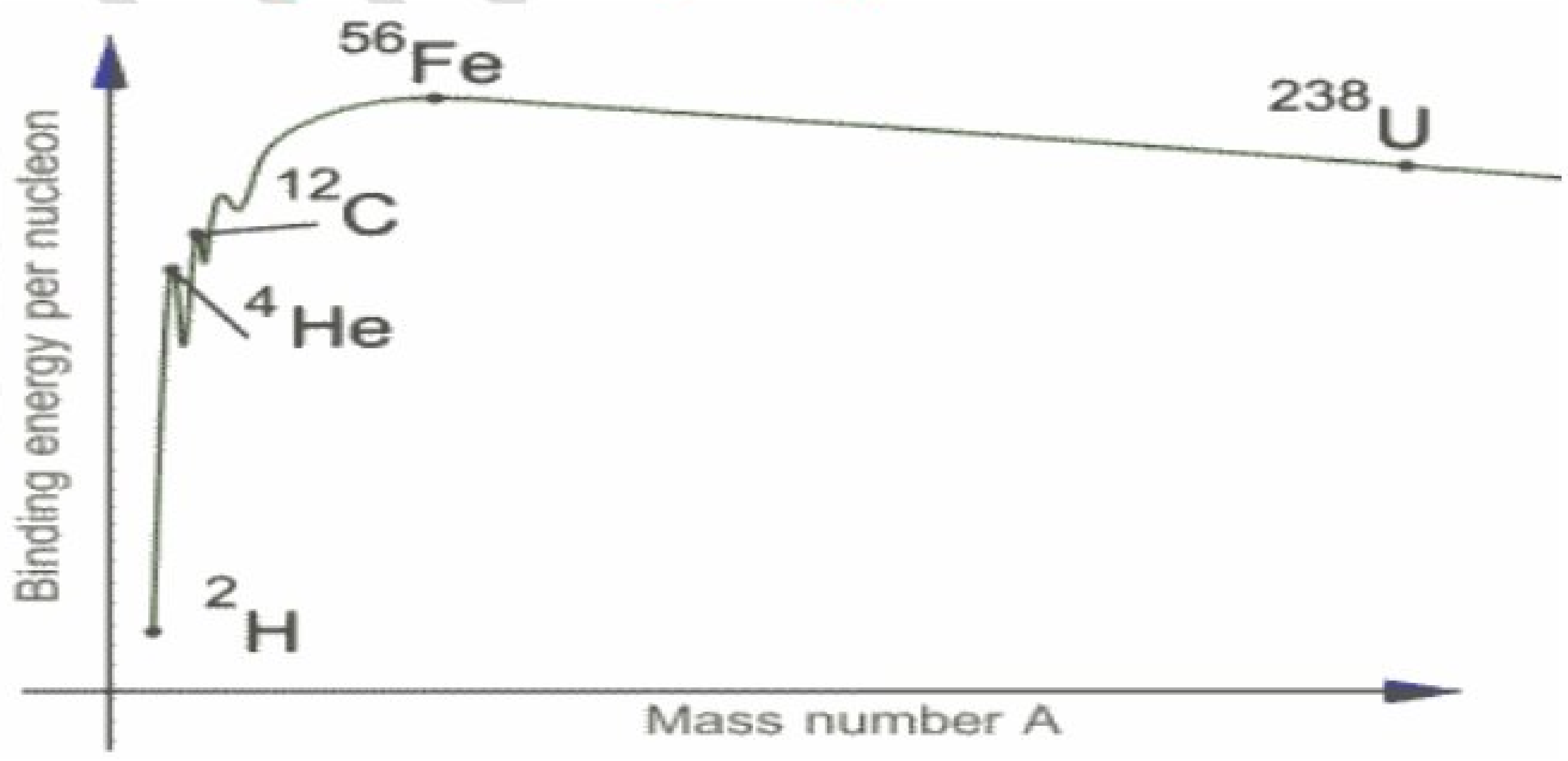
7. Distinguish between nuclear fission and nuclear fusion

Ans:

Nuclear fission	Nuclear fusion
The energy liberated per fission is high	The energy liberated per fusion is low
The energy liberated per nucleon is low	The energy liberated per nucleon is high
It requires low temperature	It requires high temperature
Products are harmful	Products are harmless
The linked particle is neutron	The linked particle is proton

8. Write a note on specific binding energy curve.

Ans:



a) The specific binding energy is less for light nuclei.
b) The specific binding energy increases rapidly upto A = 20 and curve contains peaks. Peaks indicate that these elements are more stable than their neighbors.
c) For Fe -56, specific binding energy is maximum
d) Between A = 40 to 120 specific binding energy is very high.
e) The specific binding energy is less for heavy nuclei.

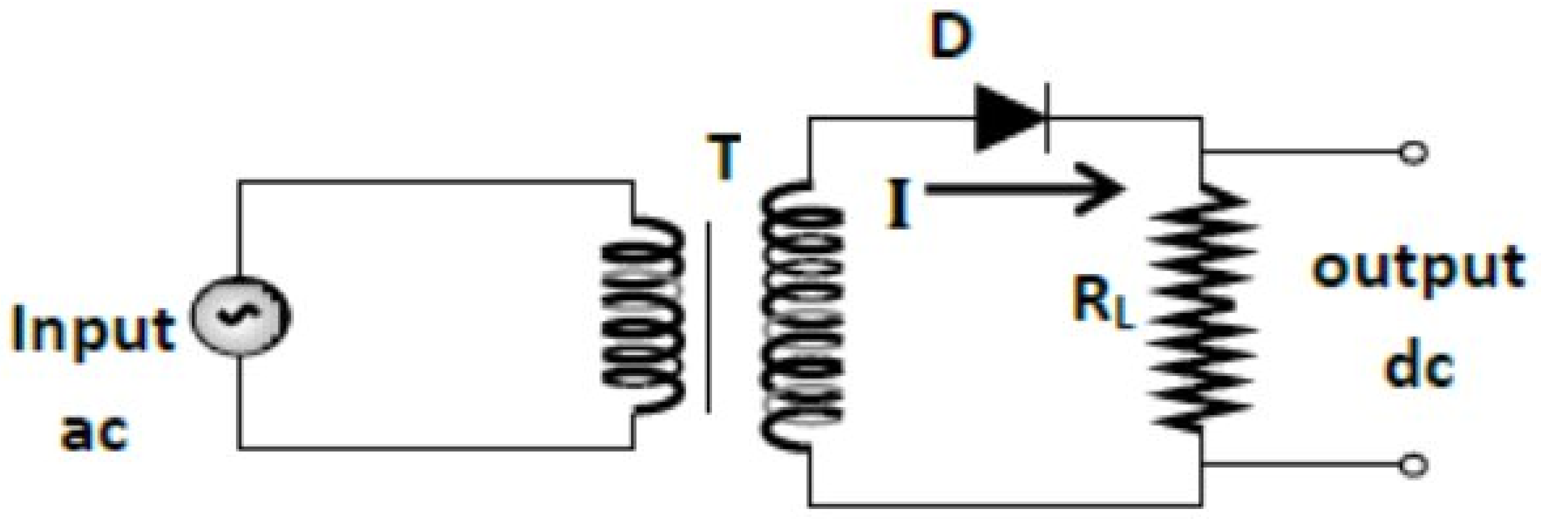
1. a] What is rectifier?

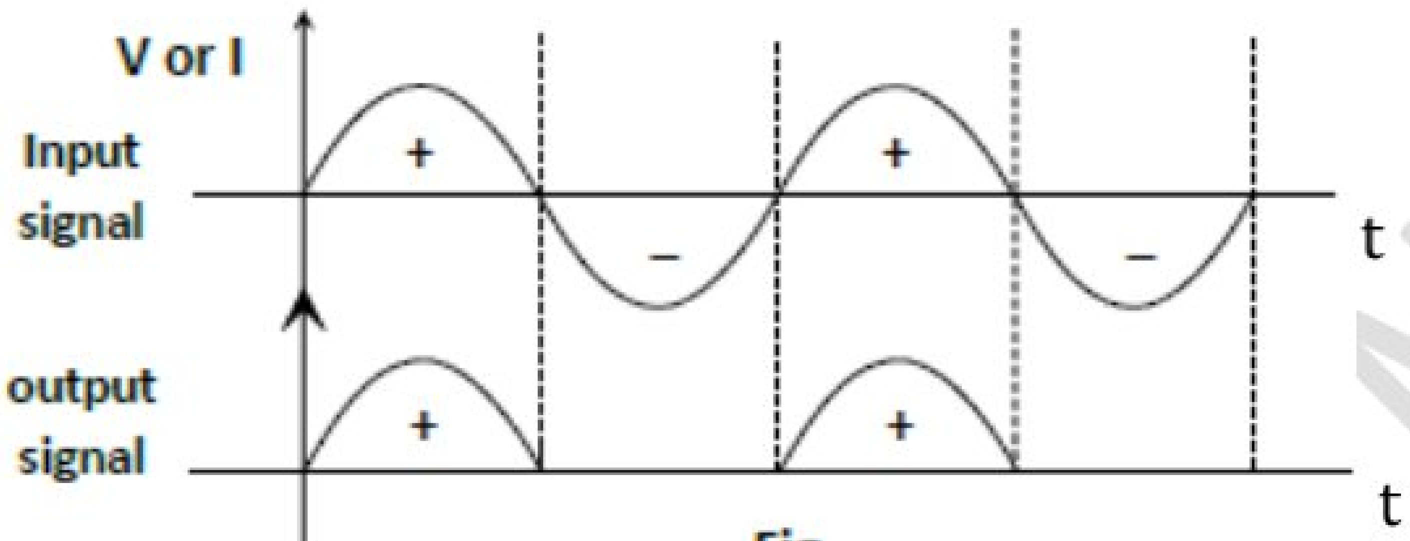
b] Draw relevant circuit diagram and wave form of a half wave rectifier

c] Explain the working of P-N junction diode as a half wave rectifier

Ans: a] It is a device which converts alternating current into direct current.

b]





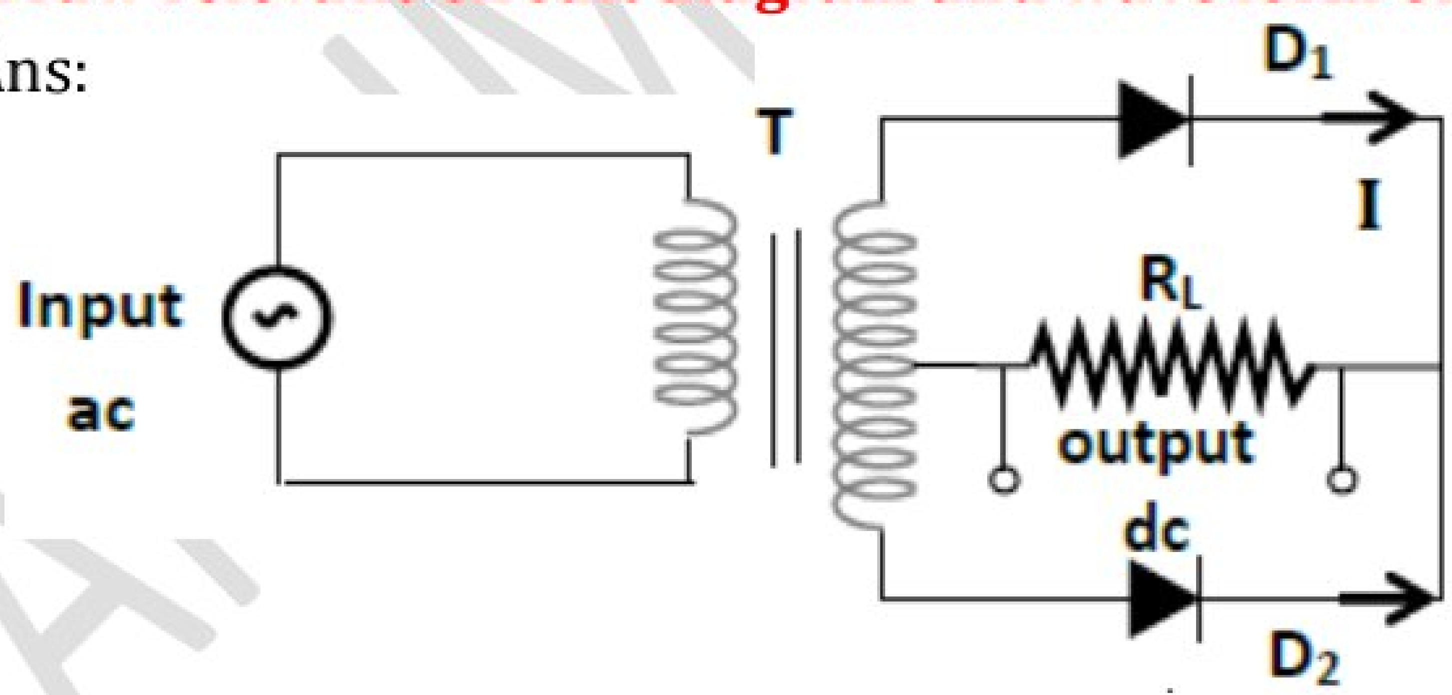
Fig

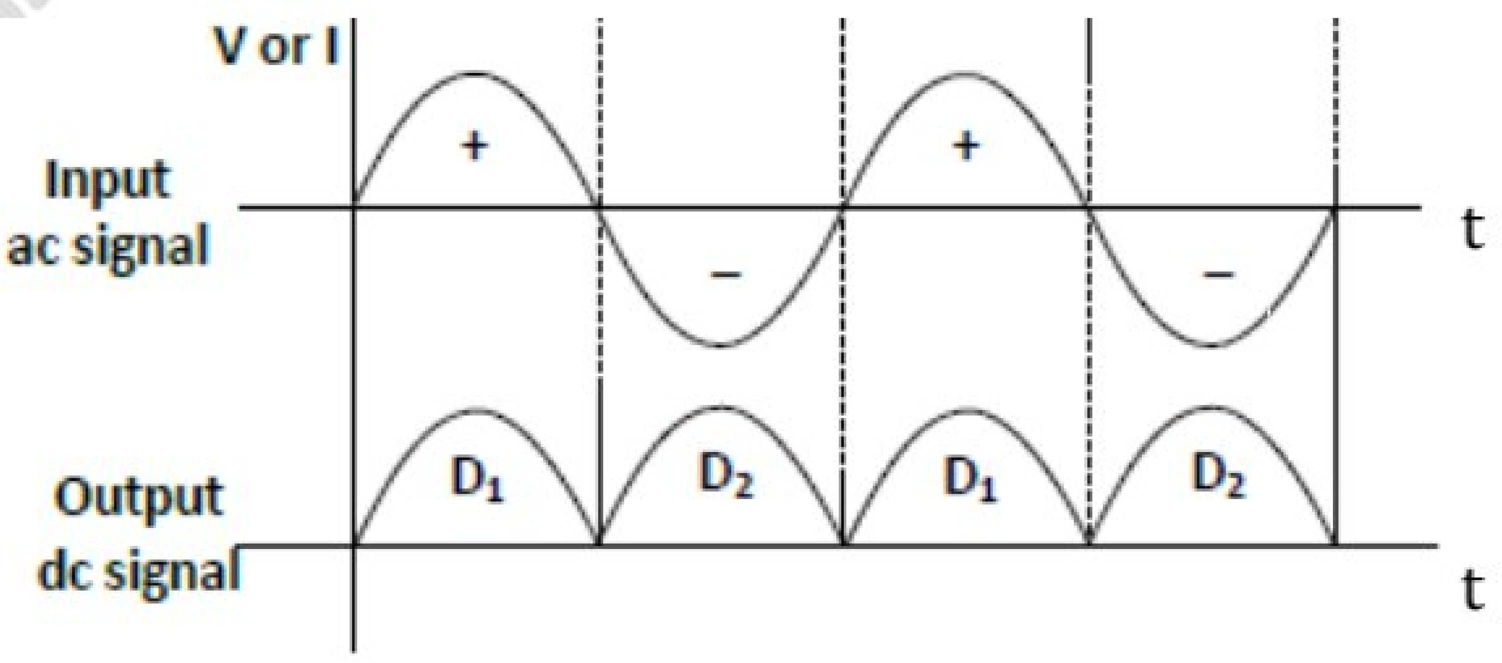
c] Working:

- During the positive half cycle of the AC input, the diode becomes forward biased. Hence it conducts.
- During the negative half cycle of AC input, the diode becomes reverse biased. Hence it does not conduct.
- A diode conducts only positive half cycles of AC through load resistance. Hence it acts as a half wave rectifier.

2. What is rectification? Explain the working of P-N junction diode as a full wave rectifier Draw relevant circuit diagram and wave form of a full wave rectifier

Ans:





Fig

- A process of conversion of AC into DC is known as rectification.

Working

- During the positive half cycle of the AC input, the diode D_1 becomes forward biased and D_2 becomes reverse biased. Hence D_1 conducts.
- During the negative half cycle of the AC input, the diode D_1 becomes reverse biased and D_2 becomes forward biased. Hence D_2 conducts.
- A diode conducts both the half cycles of AC through load resistance. Hence it acts as a full wave rectifier.

3. a] When does p-n junction is said to be reverse biased.
b] Explain the working of p-n junction in reverse bias. Draw the typical characteristic curve.

Ans: When p-type of the semiconductor is connected to the negative terminal of the battery and n-type of the semiconductor is connected to the positive terminal of the battery, then diode is said to be reverse biased **(Fig -1).**

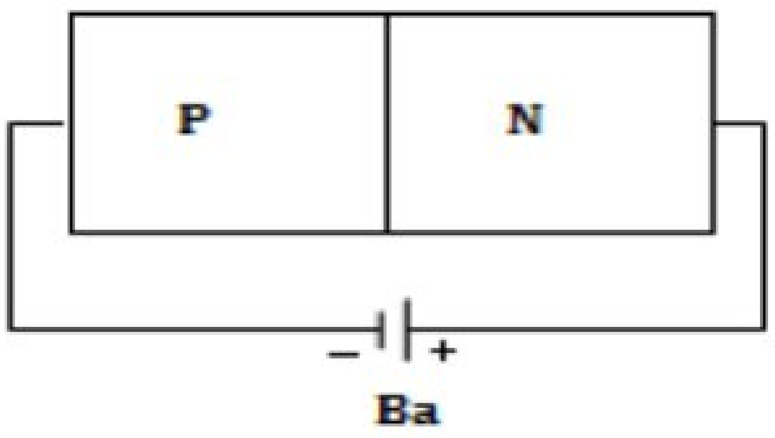
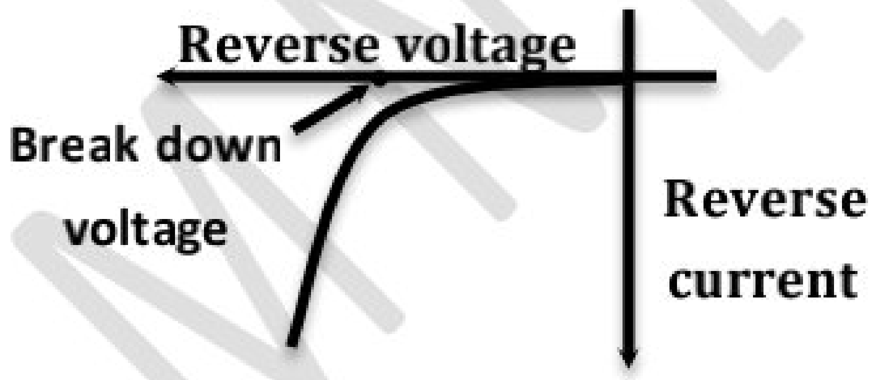


FIG -1



In reverse bias

a) Width of depletion region increases
b) Conductivity decreases
c) Resistivity increases
d) Current is due to minority charge carriers

4. a] When does p-n junction is said to be forwards biased.
b] Explain the working of p-n junction in forward bias. Draw the typical characteristic curve.

Ans: When p-type of the semiconductor is connected to the positive terminal of the battery and n-type of the semiconductor is connected to the negative terminal of the battery, then diode is said to be forward biased

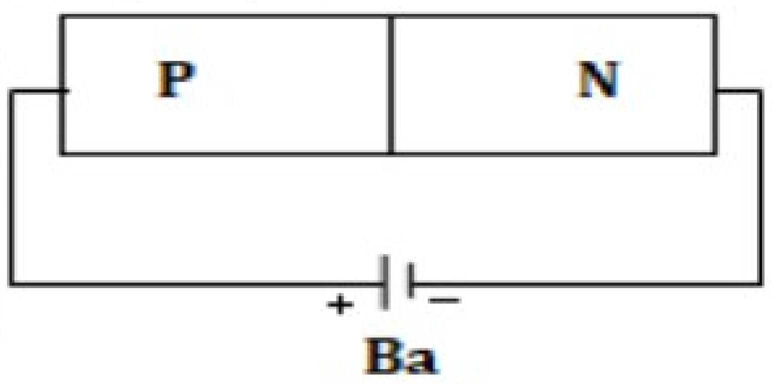
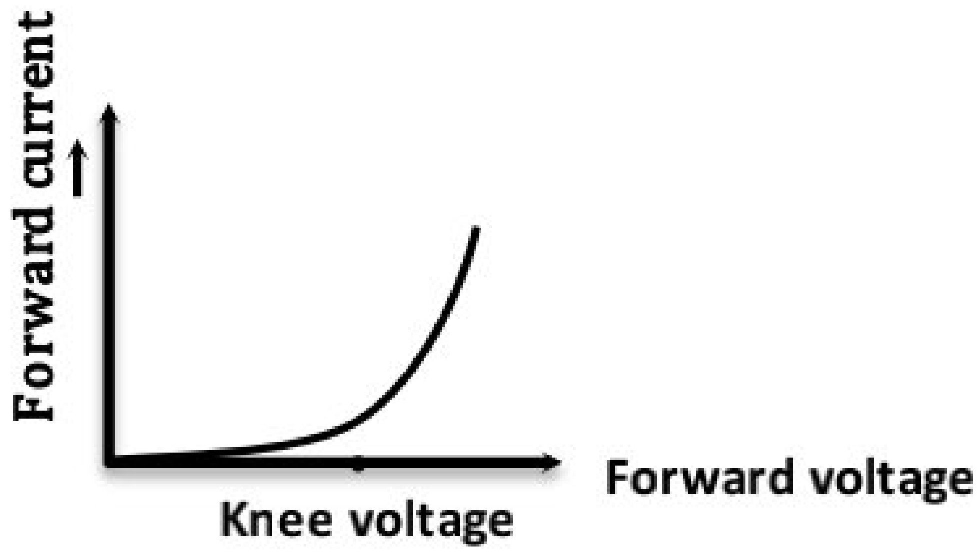


FIG -1



In forward bias

a) Width of depletion region decreases
b) Conductivity increases
c) Resistivity decreases
d) Current is due to majority charge carriers.

5. a] Explain the formation of energy bands in solids.

b] On the basis of energy bands distinguish between a conductor, semiconductor and an insulator.

Ans: **a]** In an isolated atom, the energy levels of electrons are well defined. In solids, nucleus of each atom interacts with the electrons of the neighboring atoms. Also valence electrons of different neighboring atoms interact with each other. This splits each energy level into number of closely spaced energy levels with continuous variation are called energy bands

b]

Conductors	Semiconductors	Insulators
Energy gap is zero	Energy gap is less than 3eV	Energy gap is more than 3eV
Electrons are available in conduction band.	Few electrons are available in conduction band at room temperature.	All electrons are present in valence band.
Conductivity is very high.	Conductivity is moderate	Conductivity is low.

6. a] What is i] conduction band and ii] valance band?

b] Write three differences between intrinsic and extrinsic semiconductor.

Ans: a] The energy band which may be partially filled at room temperature but completely empty at zero Kelvin is called the conduction band

The highest energy band which is completely filled at absolute zero Kelvin is called Valence band.

b]

Intrinsic semiconductor	Extrinsic semiconductor
Number of electrons and holes are equal	Number of electrons and holes are unequal
Conductivity depends on temperature.	Conductivity depends on temperature and impurities.
Conductivity is due to both electrons and holes.	Conductivity is due to majority charge carriers.

7. a] Give any three differences between n-type and p-type semiconductors.

b] What is a) Knee voltage and Breakdown voltage?

Ans: a]

p- type semiconductor	n-type semiconductor
It is pure semiconductor doped with trivalent impurities.	It is a pure semiconductor doped with pentavalent impurities.
Number of holes is greater than electrons.	Number of electrons is greater than holes.
Conductivity is mainly because of holes.	Conductivity is mainly because of electrons

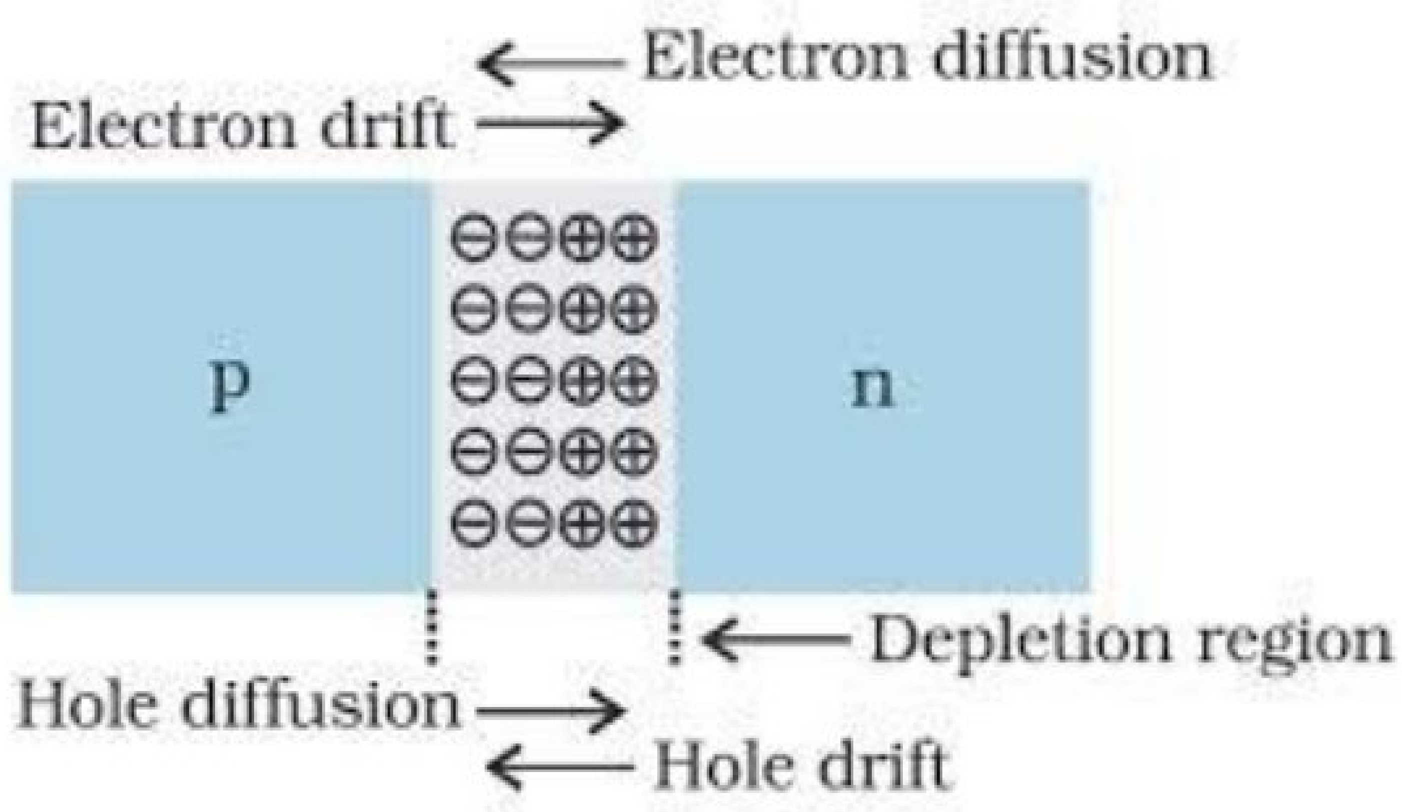
b] Knee voltage: It is the forward bias voltage at which the current through the diode increases rapidly

Breakdown voltage: It is the reverse bias voltage at which current through the diode increases sharply.

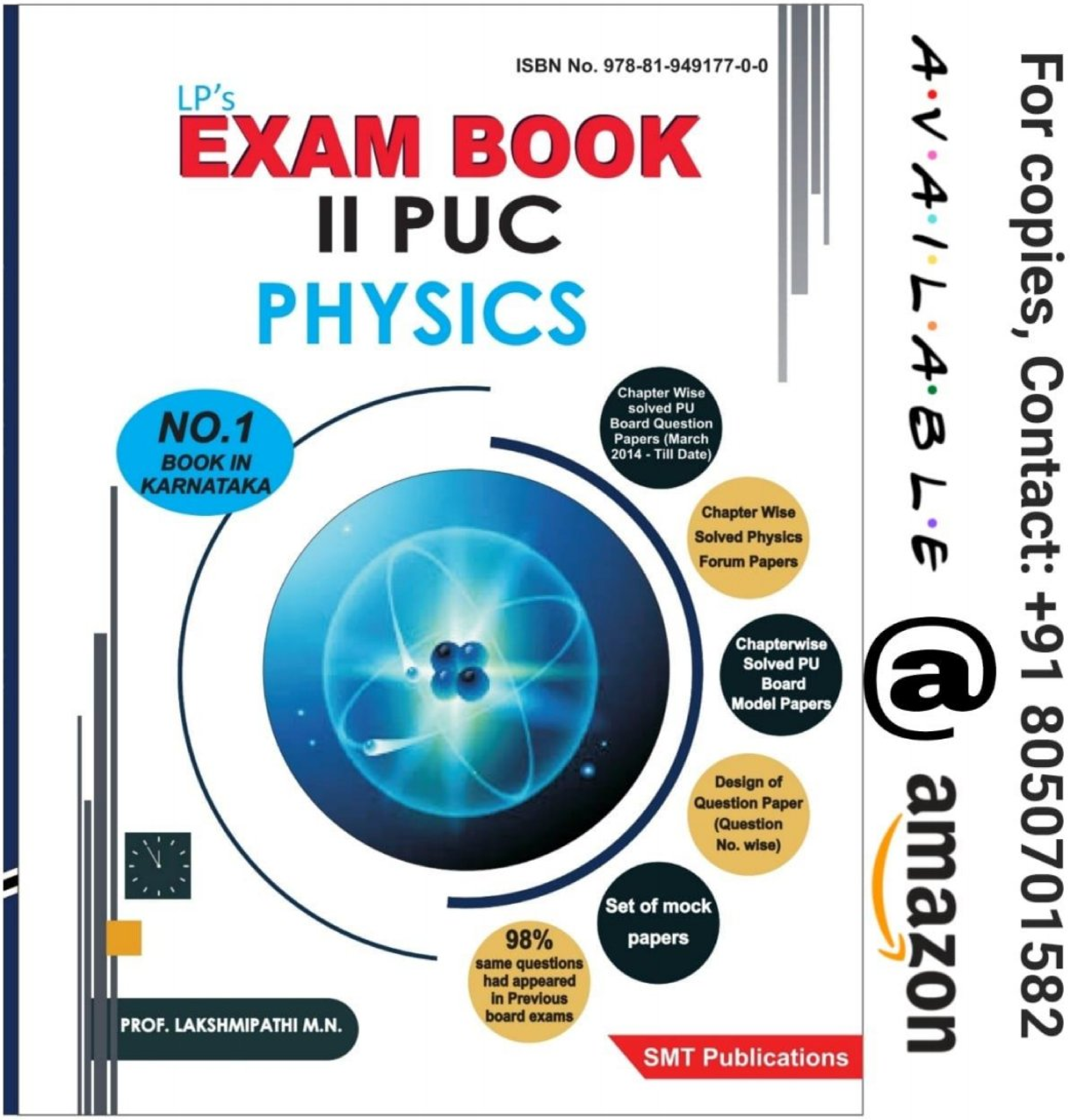
8. a] What is p-n junction?

b] Explain the formation of p-n junction

Ans: P-N junction: It is the junction between p-type and n-type semiconductor.



- Because of difference in concentration of holes and electrons, electrons diffuse from n to p-region and holes diffuse from p-region to n- region.
- When electron diffuses from n to p-side, then immobile positive ion is left on n-side. Similarly when a hole diffuses from p to n- side, then immobile negative ion is left on p-side as shown in fig.
- Therefore a potential difference is developed across the junction which stops the further flow of majority charge carriers. This potential difference is called potential barrier.
- A small region around the p-n junction that has immobile charge carriers is called the depletion region.
- The thickness of the depletion region is of the order 10^{-6}m.



GOOD LUCK MY DEAR STUDENTS