II PUC PHYSICS

OCI – Education Resources

Subscribe To Our Channel

(For IMP QPs & Solved QPs)

Passing Package 2025

(Department Of Pre-University)

ELECTRIC CHARGE AND FIELD

1. Write the Properties of electric charges.

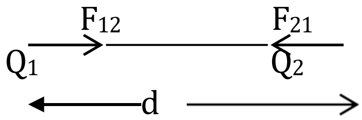
i) Charges possess additive property. [Q = $q_1 + q_2 + q_3$.........................]

ii) Charges are quantized , (Q = $\pm ne$)

iii) Charges are conserved [Charges can never be created nor destroyed.

2. State and explain Coulomb's law of electrostatics or Inverse square law

This law states that "*The force of attraction or repulsion between two point stationary charges is directly proportional to the product of the magnitude of charges and inversely proportional to square of the distance between them*".



i.e. $F \propto \frac{Q_1 Q_2}{d^2}$

$F = K \frac{Q_1 Q_2}{d^2}$

$\therefore$

$$F = \frac{1}{4\pi\mathcal{E}_0} \times \frac{Q_1 Q_2}{d^2}$$

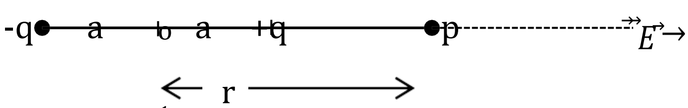
Coulomb's law in Vector form :

In general, $\vec{F} = \frac{1}{4\pi\mathcal{E}_0} \frac{|Q_1 Q_2|}{d^2} \hat{r}$

Where, $\hat{r}$ is the unit vector in the direction of force.

3. Derive an expression for Electric field at a point on the axis of a dipole (E_A).

Let P be a point on the axis of a dipole of Moment $\vec{P}$ and length 2a at a distance 'r' from the midpoint.



Electric – field at 'P' due to +ve charge is $E_1 = \frac{1}{4\pi\mathcal{E}_0} \times \frac{q}{(r-a)^2}$ along OP.

Electric – field at 'P' due to -ve charge is $E_2 = \frac{1}{4\pi\mathcal{E}_0} \times \frac{q}{(r+a)^2}$ along PO.

Electric – field at 'P' due to the dipole = $E_A = E_1 - E_2$.

$$\therefore E_A = \frac{1}{4\pi\mathcal{E}_0} q \left(\frac{1}{(r-a)^2} - \frac{1}{(r+a)^2} \right)$$

$$E_A = \frac{1}{4\pi\mathcal{E}_0} q \left(\frac{(r+a)^2 - (r-a)^2}{(r-a)^2 (r+a)^2} \right)$$

$$E_A = \frac{1}{4\pi\mathcal{E}_0} \times q \left(\frac{(r^2+a^2+2ra)-(r^2+a^2-2ra)}{(r^2-a^2)^2} \right)$$

$$E_A = \frac{1}{4\pi\mathcal{E}_0} \times \frac{q \times 4ra}{(r^2-a^2)^2} = \frac{1}{4\pi\mathcal{E}_0} \times \frac{q \times 2a \times 2r}{(r^2-a^2)^2}$$ (But, q x 2a = P)

$$E_A = \frac{1}{4\pi\mathcal{E}_0} \times \frac{2pr}{(r^2-a^2)^2}$$ along the axis from –ve charge towards +ve charge.

when a < < r, a^2 can be neglected compared with r^2

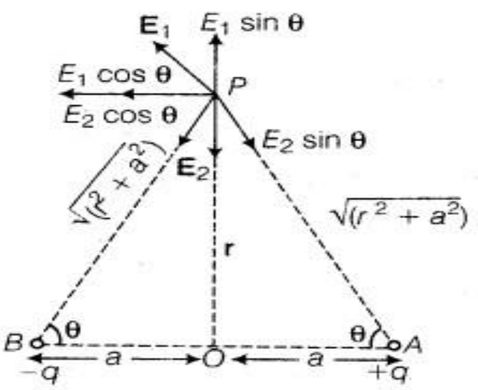
$$E_A = \frac{1}{4\pi\mathcal{E}_0} x \frac{2pr}{r^4} = \frac{1}{4\pi\mathcal{E}_0} x \frac{2p}{r^3}.$$

$$\vec{E_A} = \frac{1}{4\pi\mathcal{E}_0} x \frac{2\vec{p}}{r^3}$$

Direction:

Electric field on the axis ($\vec{E_A}$) of a dipole is along the direction of dipole moment ($\vec{P}$).

4. Obtain an expression for Electric field at a point on the bisector line of dipole



In Δ OPA

$PA^2 = OP^2 + OA^2 = r^2 + a^2$

$PA = (r^2 + a^2)^{1/2}$

$\text{Cos}\ \theta = \frac{OA}{PA} = \frac{a}{(r^2+a^2)^{1/2}}$

Field at P due to +ve charge, $E_1 = \frac{1}{4\pi\mathcal{E}_0} x \frac{q}{(r^2+a^2)}$ along AP

Field at P due to -ve charge, $E_2 = \frac{1}{4\pi\mathcal{E}_0} x \frac{q}{(r^2+a^2)}$ along PB

E_1 along AP is resolved into two components as $E_1\cos\theta$ along a line $\|^{el}$ to AB and $E_1\sin\theta$ along the bisector line in the upward direction.

$\|^{ly}$ E_2 along PB is resolved in to two components as $E_2\cos\theta$ along a line $\|^{el}$ to AB and $E_2\sin\theta$ along the bisector in the down ward direction.

$$|E_1| = |E_2|$$

∴ two equal and opposite components $E_1 \sin\theta$ and $E_2 \sin\theta$ cancel each other.

Field at 'P' due to the dipole is

$$E_B = E\cos\theta + E\cos\theta = 2E\cos\theta$$

$$E_B = 2 x \frac{1}{4\pi\mathcal{E}_0} x \frac{q}{(r^2+a^2)} x \cos\theta$$

$$E_B = \frac{1}{4\pi\mathcal{E}_0} x \frac{2q}{(r^2+a^2)} x \frac{a}{(r^2+a^2)^{1/2}}$$

$\cos\theta = \frac{a}{(r^2+a^2)^{1/2}}$

$q \times 2a = P$

$E_B = \frac{1}{4\pi\mathcal{E}_0} x \frac{P}{(r^2+a^2)^{3/2}}$ along a line $\|^{el}$ to the axis directed from +ve charge towards –ve charge of dipole.

When a << r, a^2 can be neglected compared with r^2

$$\mathbf{E_B = \frac{1}{4\pi\mathcal{E}_0} x \frac{P}{r^3}}$$ or $$\vec{E_B} = \frac{1}{4\pi\mathcal{E}_0} x \frac{\vec{P}}{r^3}$$

Direction : Electric field on the equatorial plane ($\vec{E_B}$) of a dipole is opposite to the direction of dipole moment ($\vec{P}$).

5. Define linear charge density. Mention its SI unit.

The charge distributed uniformly per unit length of the conductor is called as linear charge density.

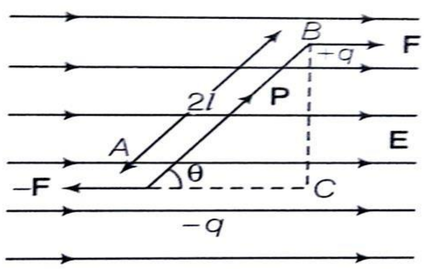
SI Unit : C/m. (coulomb per meter)

6. Define Surface charge density. Mention its SI unit.

Charge distributed uniformly per unit area of the surface of the conductor is called as surface charge density.

SI Unit : C/m^2.

7. Derive an expression for torque acting on a dipole placed in a uniform Electric – field.



Force acting on the + ve charge $F_1 = E q$ in the direction of field.

Force acting on the -ve charge $F_2 = E q$ in opposite to the direction of field.

$$|F_1| = |F_2|$$

These two equal and unlike parallel forces constitute a ***couple*** which tends to rotate the dipole in the direction of the field.

The moment of the couple or torque acting on the dipole is given by

$\tau = F \times \perp^r$ distance between forces.

$\tau = Eq \times BC$.

$\tau = E \times q \times 2l \sin\theta$

$\because$ In the ABN, $\sin\theta = \frac{BC}{AB}$

$BC = AB \sin\theta$

$BC = 2a \sin\theta$

$$\boxed{\tau = E \times p \sin\theta}$$

$(\because q \times 2l = p)$

8. Write any three Properties of electric field lines.

1. Field lines are always starts from +ve charge and ends at –ve charge.
2. Field lines never intersect each other.
3. Field lines will not form a closed path.
4. Field lines do not pass through a conductor.
5. Field lines are equidistant and parallel to one another in uniform EF.

9. What is an electric dipole moment? Mention its direction.

The product of magnitude of either charge of electric dipole and dipole length is called electric dipole moment.

Direction : negative charge to positive charge along the axis of electric dipole.

10. What are polar and non polar molecules? Give examples.

1) **Polar molecules :**

Molecules in which centers of +ve and –ve charge concentration are separated by a small distance are called *polar molecules*.

They have permanent dipole moment.

Ex: NH_3 , H_2O, CO etc.

2) **Non-polar molecules:**

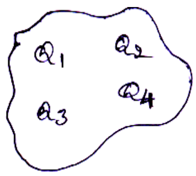
In non-polar molecules the centers of +ve and –ve charge distributions coincide.

They have no no permanent dipole moment.

Ex: O_2, N_2, H_2 CO_2 etc.

11. State and explain Gauss law in electrostatics.

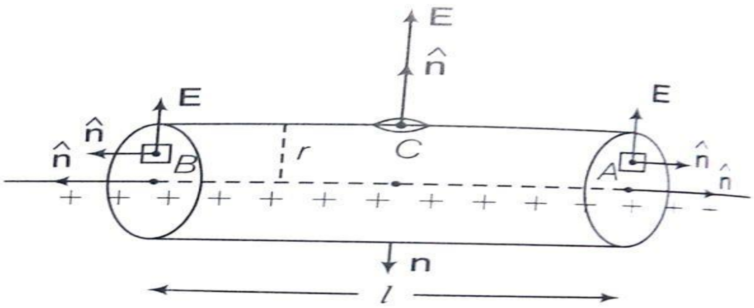
This theorem states that "***the total electric flux over a closed surface enclosing charges is equal to*** $\frac{1}{\varepsilon_0}$ ***times the total charge enclosed by the surface***".



$$\Phi = \frac{1}{\varepsilon_0}[Q]$$

The total charge enclosed by the surface in Q = $q_1 + q_2 + q_3 + \text{- - - - - -}$

12. Obtain an expression for electric fields at a point due to infinitely long straight charged wire.



A cylinder of length *l* with the wire as axis and r as radius is imagined.
The ***electric flux through two end faces will be zero*** because $\vec{ds}$ & E are ⊥er to each other [$\theta = 90^0$, $\cos\theta = 0$].
The ***electric-flux is only through the curved surface*** of the cylinder.

This flux is given by

$\phi = \oint E\, ds \cos\theta$ $\qquad\qquad \theta = 0,\ \cos 0 = 1$

$\phi = E \times \oint ds$ $\qquad\qquad \oint ds = 2\pi r \times \ell$

$\phi = E \times 2\pi r \times \ell$ ------------------------ (1)

By Gauss theorem

$\phi = \frac{1}{\varepsilon_0}(Q)$ $\qquad\qquad$ But, $Q = \lambda\,\ell$

$\phi = \frac{1}{\varepsilon_0} \times \lambda\,\ell$ --------------------------------- (2)

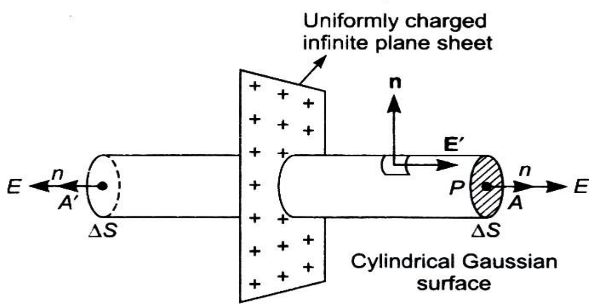
From the equations (1) and (2) we get

$$E \times 2\pi r \ell = \frac{1}{\varepsilon_0} \times \lambda \ell$$

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

13. Obtain an expression for electric field due to an uniformly charged plane sheet.

Electric flux will be through the end faces Δs and Δs^1 only.



Flux through curved surface is zero. Because $\theta = 90^0$, $\cos 90^0 = 0$.

Electric -flux through the cylinder is $\Phi = \oint E \cdot \Delta s + \oint E \cdot \Delta s$

$\Phi = (E \times \Delta s) + (E \times \Delta s)$ $\theta = 0$, $\cos\theta = 1$

$\Phi = 2 E \Delta s$ .... (1)

By gauss theorem,

$\Phi = \frac{1}{\varepsilon_0} \times q$ $\sigma = \frac{q}{\Delta s}$

$\Phi = \frac{1}{\varepsilon_0} \times \sigma \times \Delta s$ .... (2) $(q = \sigma \times \Delta s)$

From equations (1) and (2)

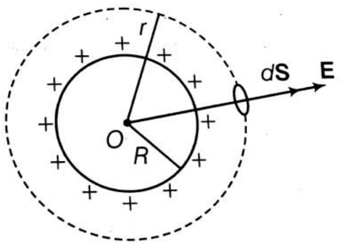
$2 E \times \Delta s = \frac{\sigma \times \Delta s}{\varepsilon_0}$

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

E is independent of the distance of the point from the sheet.

14. Derive an Expression for Electric field due to a uniformly charged thin spherical shell.

a) **At a point outside the shell:**



Electric flux through this sphere is given by

$\Phi = \oint E\cos\theta \times ds$

$\Phi = \oint E \times ds$ $(\because \theta = 0, \cos 0 = 1)$

$\Phi = E \oint ds$

Note:

$\mathbf{\Phi = E \times 4\pi r^2}$ **----- (1)** $(\int ds = 4\pi r^2)$

According to gauss theorem,

$\Phi = \frac{1}{\varepsilon_0} \times q$ ---------------(2)

From equations (1) and (2) we get

$E \times 4\pi r^2 = \frac{1}{\varepsilon_0} \times q$

$$\mathbf{E = \frac{1}{4\pi\varepsilon_0} \times \frac{q}{r^2}}$$

From this equation it is observed that a charged spherical shell behaves as if it's total charge is assumed to be concentrated at the center.

b) **At a point on the surface (r = R) :**

The electric intensity E for the points on the surface of charged spherical shell is given by

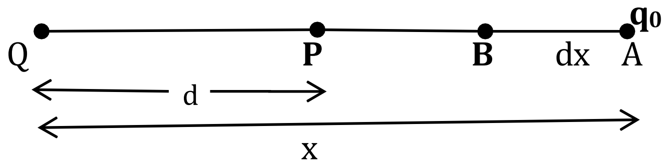
$E = \frac{1}{4\pi\varepsilon_0} \times \frac{q}{R^2}$

$= \frac{1}{4\pi\varepsilon_0} \times \frac{\sigma 4\pi R^2}{R^2}$ $r = R$ (By definition, $\sigma = \frac{q}{4\pi R^2}$, $\therefore q = \sigma 4\pi R^2$)

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

ELECTRIC POTENTIAL AND CAPACITORS

1. Define electric potential at a point. And hence derive an expression for electric potential at a point due to a point charge



Let 'P' be a point at a distance 'd' from a point charge Q at O .
Force acting on unit +ve charge (Q_0) at A due to charge 'Q' is given by

$$F = \frac{1}{4\pi\varepsilon_0} \times \frac{QQ_0}{x^2} \qquad Q_0 = 1\ C$$

$$F = \frac{1}{4\pi\varepsilon_0} \times \frac{Q}{x^2}$$

Work done in moving a unit +ve charge from A to B against the field direction is given by, $dw = -F \times dx$

$$dw = -\frac{1}{4\pi\varepsilon_0} \times \frac{Q}{x^2}\ dx$$

|||ly Work done in bringing a unit +ve charge from ∞ to the point ' P ' against the field direction is given by

$$\int dw = -\int_{\infty}^{d} \frac{1}{4\pi\varepsilon_0} \times \frac{Q}{x^2}\ dx$$

$$w = -\frac{1}{4\pi\varepsilon_0} \times Q \int_{\infty}^{d} \frac{1}{x^2}\ dx$$

$$w = -\frac{1}{4\pi\varepsilon_0} \times Q \left(-\frac{1}{x}\right)_{\infty}^{d}$$

$$W = -\frac{1}{4\pi\varepsilon_0} \times Q \left(-\frac{1}{d} + \frac{1}{\infty}\right)$$

$$W = \frac{1}{4\pi\varepsilon_0} \times \frac{Q}{d}$$

By def W = V,

Potential

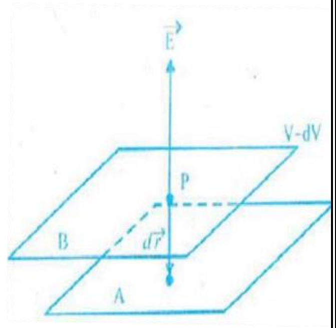
$$\boxed{V = \frac{1}{4\pi\varepsilon_0} \times \frac{Q}{d}}$$

This the expression for potential at point due to a point charge

2. Write any three Properties of equipotential surfaces.

1. No work is done in moving a test charge over an equipotential surface.
2. The electric field is always at right angles to the equipotential surface.
3. The equipotential surfaces gives the direction of the electric field.
4. No two equipotential surfaces can intersect each other.

3. Obtain the Relation between Electric intensity and Electric potential



Let P be a point on the surface B and dr be the perpendicular distance of the surface A from P.

the work done is **:**

$$\mathbf{dW = \vec{E}\cdot d\vec{r} = E\,dr\cos 180° = -E\,.\,dr} \text{ .... (1)}$$

This work done equals the potential difference between the surfaces A and B.

$$\therefore \mathbf{dW = V_A - V_B = V - (V - dV) = dV} \text{ ....(2)}$$

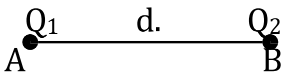
From equations (1) and (2) ,

$$-E\,dr = dV$$

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

The ***negative sign*** shows that the direction of the electric field $\vec{E}$ is in the direction of decreasing potential.

4. Obtain an expression for electric potential energy of a system of two point charges in the absence of external electric field.



Let the charge Q_1 is first brought from infinity to the point A.

No work is done because there is no electric field **. i.e . $W_1 = 0$**

Now the charge Q_2 is brought from ∞ to the point B against the field of Q_1. Work is done in this process.

This work done is given by **$W_2 = V \times Q_2$**

Where 'V' is the potential at B Due to charge Q_1 & is given by $V = \frac{1}{4\pi\mathcal{E}_0} \times \frac{Q_1}{d}$

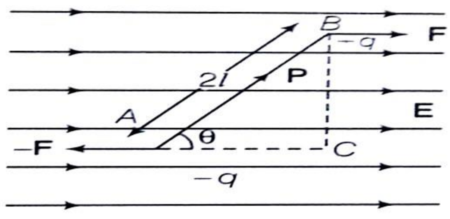
$$\therefore W_2 = \frac{1}{4\pi\mathcal{E}_0} \times \frac{Q1}{d_1} \times Q_2$$

Total work done: $W = W_1 + W_2 = 0 + = \frac{1}{4\pi\mathcal{E}_0} \times \frac{Q1}{d_1} \times Q_2$

By def, W = electric potential energy = U.

$$\therefore \boxed{\mathbf{U = \frac{1}{4\pi\mathcal{E}_0} \times \frac{Q_1Q_2}{d}}}$$

5. Derive an expression for electric potential energy of an electric dipole placed in a uniform electric field.



The torque acting on the dipole is given by

$$\mathbf{\tau = PE\sin\theta}$$

The work done is given by :

$$\mathbf{dw = \tau \times d\theta = \mathit{PE}\sin\theta \times d\,\theta}$$

Total work done in rotating the dipole from the initial position θ_1 to the final position θ_2 is given by

$$\int dw = \int_{\theta_1}^{\theta 2} PE\sin\theta\,.\,d\theta = PE\left[-\cos\theta\right]_{\theta_1}^{\theta_2}$$

$$W = PE\,[-\cos\theta_2 + \cos\theta_1] = PE\,[\cos\theta_1 - \cos\theta_2]$$

By definition, W = U

$U = PE\,[\cos\theta_1 - \cos\theta_2]$, When $\theta_1 = 90$ and $\theta_2 = \theta$ then

$$\boxed{\mathbf{U = -\,PE\cos\theta}}$$

6. Write any three important results of electrostatics of Conductor

1. Inside a conductor, electro static field is zero.
2. At the surface of a charged conductor, electrostatic field must be normal to the surface at every point.
3. Electrostatic Potential is a constant throughout the volume of a conductor and has the same value inside and on its surface.
4. Electric field at the surface of a charged conductor is given by $\vec{E} = \frac{\sigma}{\varepsilon_0}\hat{n}$

7. What are dielectric? What is Electric polarization? Give the relation between electric polarization and susceptibility.

Dielectrics are insulators, they have no free electrons and hence they do not conduct electricity.

The dipole moment acquired per unit volume of the dielectric when placed in uniform electric field is called **Electric polarization**. .

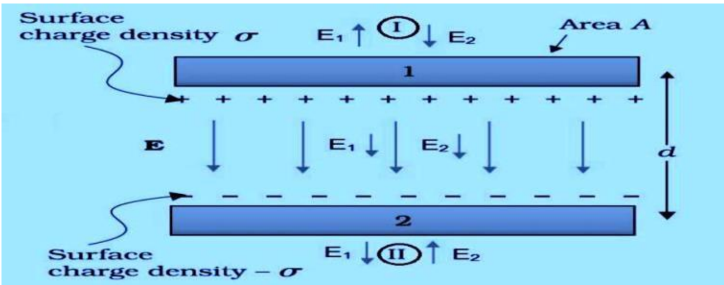
$$P = \epsilon_0 \chi_e . E$$

Where, χ_e is the constant of dielectric called electric susceptibility

8. *On what factors Capacitance of a capacitor* depends?

1) shape and size of the plates of the capacitor
2) distance between the plates
3) dielectric medium between plates.

9. Derive an expression for capacitance of parallel plate capacitor.



The electric intensity between the plates is given by

$E = \frac{\sigma}{\varepsilon_0}$ Where σ is surface charge density $\sigma = \frac{Q}{A}$

$\mathbf{E} = \frac{Q}{A\varepsilon_0}$ ------ (1)

The relation between electric intensity and potential between the plates is given by

$\mathbf{E} = \frac{v}{d}$---- (2) where 'v' is the P.D between plates

From eqn. (1)and (2) we get

$\frac{Q}{A\varepsilon_0} = \frac{V}{d}$.

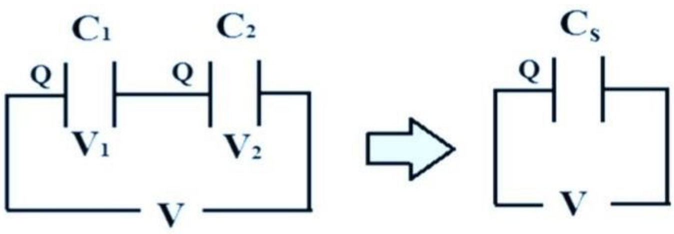
$\frac{Q}{V} = \frac{\varepsilon_0 A}{d}$ By definition, $\frac{Q}{V} = C$ capacitance

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

This is the expression for capacitance of parallel plate capacitor with **air as dielectric.**

When the space between the plates is filled with **dielectric medium.** $C = \frac{\varepsilon_0 \varepsilon_r A}{d}$

10. Expression for equivalent capacitance of two capacitors in series.



As capacitors are in series charge on each of them will be same as Q. The applied potential difference V divides itself into V_1 and V_2 across C_1 and C_2 respectively such that

$$V = V_1 + V_2, ---- \quad (1)$$

Charge on each capacitor is $Q = C_1V_1$ and $Q = C_2V_2$

$$\therefore V_1 = \frac{Q}{C_1} \quad , \quad V_2 = \frac{Q}{C_2}$$

Eqn., (1) becomes

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

$$V = Q\left(\frac{1}{C_1} + \frac{1}{C_2}\right) \quad \dots\dots\dots\dots\dots.. (2)$$

If C_s is the equivalent capacitance of the combination

$$\text{Then } V = \frac{Q}{C_s} \quad ------ (3)$$

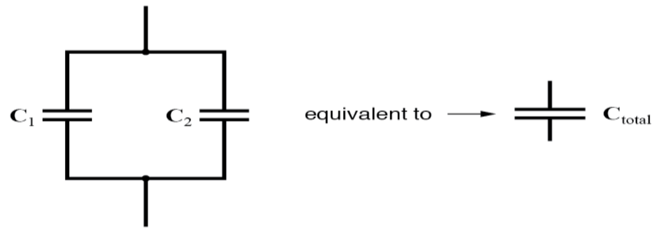
From eqn., (2) and(3)we get

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

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

Thus reciprocal of equivalent capacitance of two capacitors in series is equal to sum of reciprocal of each capacitance.

11. Expression for equivalent capacitance of two capacitors connected in parallel



As capacitors are in parallel potential difference across each of them will be same as the applied potential difference 'V'. The total charge Q is given to the system by the applied voltage divides itself into Q_1 & Q_2 for the capacitors C_1 , C_2 respectively.

Such that, $\mathbf{Q = Q_1 + Q_2}$ ……… (1)

The charge on the first capacitor is given by $Q_1 = C_1V$, $Q_2 = C_2 V$

Equation (1) becomes

$$Q = C_1 V + C_2 V$$

$$Q = V [C_1 + C_2]--------------- (2)$$

If Cp is the effective capacitance of the combination then for the combination, we have

$$Q = C_p V \text{------} (3)$$

From equation (2) and (3) we get,

$$C_p V = V [C_1 + C_2]$$

$$\boxed{C_p = C_1 + C_2}$$

12. Write any three uses of Capacitors.

1) Used to store electric charges
2) Used to store electric potential energy
3) Used In A.C. circuits to control current
4) used to avoid sparking in gaps

13. Write the expression for energy stored in a capacitor and explain the terms.

$$U = \frac{1}{2} C V^2$$

Where, C – capacitance of capacitor

V – Potential

14. Define Dielectric strength. Mention the value of dielectric strength for air.

The maximum value of electric field (or potential gradient) that a dielectric material can tolerate without it's electric breakdown is called it's **dielectric strength**.

For air medium at 1 atmosphere its value is **3×10^6 V/m**

CURRENT ELECTRICITY

1. State and explain Ohm's law.

This law states that, ***the current flowing through a conductor is directly proportional to the potential difference between the ends of the conductor. Provided temperature and other physical conditions of the conductor remaining constant***"

$$I \propto V$$

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

$$\boldsymbol{V = IR}$$

2. Write any three limitations of Ohm's law.

1) The variation between Current and Potential difference is non linear.
2) The relation between Current and Potential difference is non unique.
3) Ohm's law is **not applicable for semiconductors**.
4) Ohm's law is **not applicable for conductors at very low and at very high temperature**.

3. Name the two factors on which the resistance of a metallic wire depends?

Resistance of a metallic wire depends on

a) length of the wire ($R \alpha L$)
b) area of the wire ($R \alpha \frac{1}{A}$)
c) Temperature ($R \alpha T$)

4. Arrive at the expression for current interms of drift velocity.

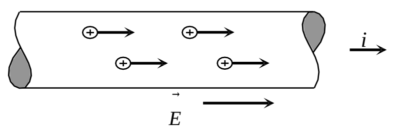
The average thermal velocity of the electrons at a given time t in the conductor will be zero. this velocity is given by :

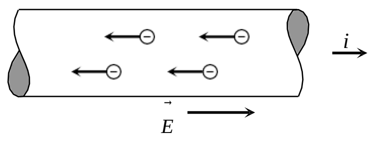
$$V_i = \frac{v_1 \pm v_2 \pm v_3 \pm \ldots\ldots\ldots\ldots \pm v_n}{n} = 0$$

When electric field is applied across a conductor each electron experience a Force

$$\vec{F} = q\vec{E} \text{ in the direction of } \vec{E}. \qquad (q = e)$$

It acquires an acceleration $a = \frac{-e\vec{E}}{m}$ where e is charge on electron and m is its mass.





Drift velocity is average of these velocities of charged particles. Therefore

$$V_d = a\ \tau \qquad , [\because\ \tau = \frac{t1 + t2 + t3 + \cdots tn}{n} = relaxation\ time]$$

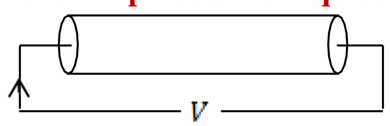
$$\text{or} \quad V_d = \frac{-e\vec{E}\tau}{m} \qquad (a = \frac{-e\vec{E}}{m})$$

$$\boxed{|\mathbf{V_d}| = \frac{e\,E\,\tau}{m}}$$

This is the expression for drift velocity.

5. Derive the vector form of ohm's law $\vec{J} = \sigma\vec{E}$

Or Derive an expression for equivalent form of Ohm's law.



Let I be the current in the conductor due to the potential difference V across the conductor, then according to ohm's law

$$V = IR \ldots\ldots\ldots\ldots\ldots(i)$$

The electric field E produced in the conductor is given by

$$E = \frac{V}{L}$$

$$\therefore V = EL \ldots\ldots\ldots\ldots\ldots\ldots(ii)$$

From (i) and (ii) we get

$$EL = IR$$

$$EL = I \times \rho\frac{L}{A} \qquad (R = \rho\frac{L}{A})$$

$$EL = \rho JL \qquad (\frac{I}{A} = J)$$

$$E = \rho J$$

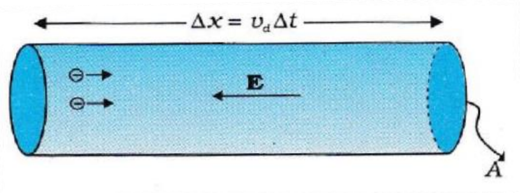
$$J = \frac{E}{\rho} \qquad (\frac{1}{\rho} = \sigma)$$

$\vec{J} = \sigma\vec{E}$ → **This is the vector form of ohm's law.**

6. Give any two differences between current and current density.

CURRENT	CURRENT DENSITY
It is the rate of flow of electric charges flow through it.	It is the amount of electric current per unit area .
It is a scalar quantity	It is a Vector quanity
It's SI unit is ampere (A)	It's SI unit is ampere per meter square (A/m^2)

7. Obtain an Expression for conductivity ($\sigma = \frac{ne^2\tau}{m}$) of a conductor.



The expression for current in the conductor is given by

$I = nAev_d$ but $v_d = \frac{e\tau}{m}E$

$I = nAe\frac{e\tau}{m}E$ by defn., $\frac{I}{A} = J$

$\frac{I}{A} = \frac{ne^2\tau}{m}E$

$|J| = \frac{ne^2\tau}{m}|E|$ As J is parallel to E

$J = \frac{ne^2\tau}{m}E$ but $J = \sigma E$

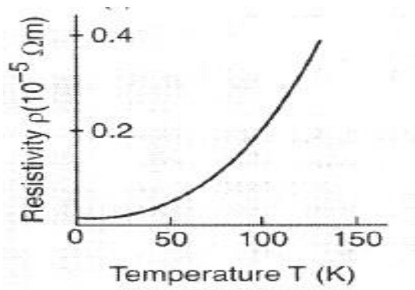
$\sigma E = \frac{ne^2\tau}{m}E$

$\boldsymbol{\sigma = \frac{ne^2\tau}{m}}$ ⟶ This is the **expression for conductivity**

8. Draw the graph for temperature dependence of Resistivity of (a) metals and (b) semiconductors (c) Nichrome

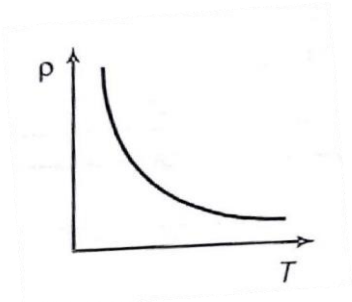
1) **In Metals:** Resistivity is directly proportional to temperature

i.e. $\rho \; \alpha \; T$

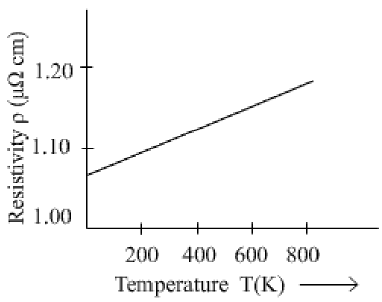


2) **In semiconductors :** Resistivity is inversely proportional to temperature

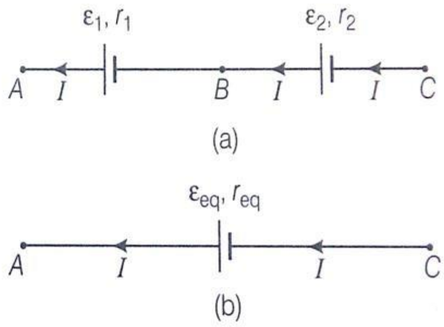
i.e. $\rho \; \alpha \; \frac{1}{T}$



3) **Nichrome :**



9. Obtain an expression for effective emf and internal resistance of Cells connected in series:



The terminal potential of cell E_1 is $V_1 = E_1 - I r_1$

The terminal potential of cell E_2 is $V_2 = E_2 - I r_2$

The terminal potential of the combination

$$V_{eff} = V_1 + V_2 = E_1 - I r_1 + E_2 - I r_2$$
$$= E_1 + E_2 - I(r_1 + r_2)$$

$$V_{eff} = E_1 + E_2 - I[r_1 + r_2] \text{ ------------(1)}$$

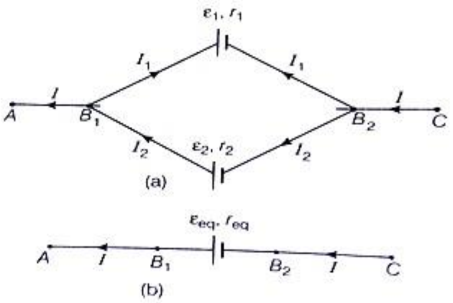
For the combination we have

$$V_{eff} = E_{eff} - I r_{eff} \text{------------------------------------(2)}$$

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

$$E_{eff} = E_1 + E_2 \text{ and } r_{eff} = r_1 + r_2$$

10. Obtain an expression for effective emf and internal resistance Cell in parallel. (5 M)



Potential difference across cell E_1 is $V_1 = E_1 - I_1 r_1$

Potential difference across cell E_2 is $V_2 = E_2 - I_2 r_2$

$$I_1 = \frac{E_1 - V_1}{r_1} = \frac{E_1 - V}{r_1} \qquad (\because V_1 = V_2 = V)$$

|||ly $$I_2 = \frac{E_2 - V}{r_2}$$

Main current in the circuit is given by

$$I = I_1 + I_2$$

$$I = \frac{E_1}{r_1} - \frac{V}{r_1} + \frac{E_2}{r_2} - \frac{V}{r_2}$$

$$I = \frac{E1}{r_1} + \frac{E2}{r_2} - V\left(\frac{1}{r_1} + \frac{1}{r_2}\right)$$

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

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

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

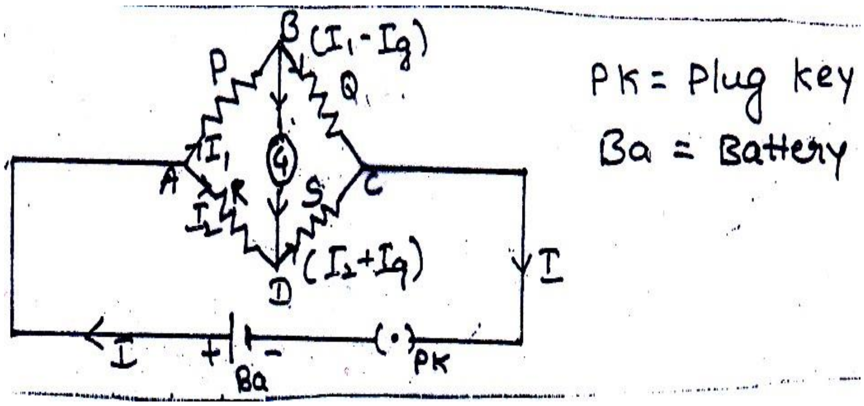
For the combination we have

$$V = E_{eff} - I r_{eff}. \text{-----------(2)}$$

Comparing equations (1) and (2) we get

$$E_{eff} = \frac{E_1 r_2 + E_2 r_1}{r_1 + r_2} \text{ and } r_{eff} = \frac{r_1 r_2}{r_1 + r_2}$$

11. Obtain a condition for Wheat stone's Bridge network using Kirchhoff's rules.(5 M)



Currents flowing through different branches of the bridge will be as shown in the figure.

Applying K.C.L to the junction A, $I = I_1 + I_2$ ------------------------------ (1)

Applying K.V.L to the mesh ABDA , $I_1P + I_gG - I_2R = 0$-------------- (2)

Applying K.V.L to the mesh BCDB , $(I_1 - I_g)Q - (I_2 + I_g)S - I_gG = 0$

$I_1Q - I_gQ - I_2S - I_gS - I_gG = 0$ -------------- (3)

Condition for balance: the current through galvanometer is zero ($I_g = 0$).

equations (2) and (3) becomes, $I_1P - I_2R = 0$

$I_1P = I_2R$ ------------------ (4)

And $I_1Q - I_2S = 0$

$I_1Q = I_2S$------------------- (5)

Divide (4) by (5) , we get

$I_1P / I_1Q = I_2R / I_2S$

$\therefore$ **P / Q = R / S**

This equation represents the balanced condition for wheat stone network.

MOVING CHARGES & MAGNETISM

1. What is Lorentz force? Give an expression for it.

The total force experienced by a charge (q) moving in both electric and magnetic field is called ***Lorentz force***.

$$\vec{F} = q\left(\vec{E} + (\vec{V} \times \vec{B})\right)$$

Where, E – strength of Electric field , B - Strength of magnetic field
V – Velocity of charged particle

2. Mention an expression for Force on a current carrying conductor in a uniform Magnetic field.

$F = B\ I\ L \sin\theta$

when the conductor is $\perp^r$ to field

F = B I L

Where, B – Strength of magnetic field,
L – length of the conductor
I – Current in the conductor

3. Mention an expression for Force due to motion of a charged particle in a uniform magnetic field

$$F = q\,V\,B\sin\theta$$

When $\theta = 90^0$, $\sin\theta = 1$, $F = F_{max.}$

$$F_{max.} = QVB.$$

Where, B - Strength of magnetic field

V – Velocity of charged particle

4. Obtain an expression for radius of circular path of charged particle in a magnetic field.

Magnetic force is given by : $F = Q\,V\,B\sin\theta$

The particle experiences Maximum force $\perp^r$ to both $\vec{V}$ and $\vec{B}$.

This force acts as centripetal force and particle describe circular path.

Centripetal force = force due to magnetic field

$F_c = F_B$

$\therefore \frac{mV^2}{r} = QVB$ where m is the mass of the particle and 'r' is radius of the circular path and V is velocity.

$$r = \frac{mV}{QB}$$

This is the expression for radius of the circular path.

5) What is a solenoid ? Mention an Expression for Magnetic field inside due to a long straight solenoid and explain the terms used.

Solenoid: Solenoid is a long coil of wire consisting of closely packed loops.

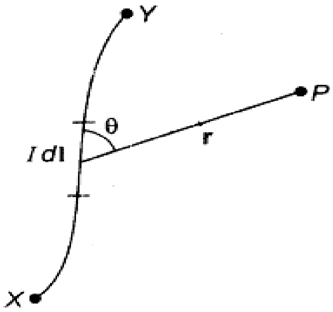
$$B = \mu_0\,n\,I$$

Where $n = \frac{N}{l}$ = number of turns per unit length

I = current passing through the solenoid

μ_0 = Absolute permeability of air

6) State and explain Biot savart's law (or Laplace law).



Magnetic field produced at P due to current I in the element AB is

1) directly proportional to strength of the current ($dB \propto I$)
2) directly proportional to length of the element ($dB \propto dl$)
3) directly proportional to $\sin\theta$ ($dB \propto \sin\theta$) and
4) inversely proportional to square of the distance of point P from the mid point ($dB \propto 1/r^2$)

Mathematically, $dB \propto (I\,dl\sin\theta)/r^2$

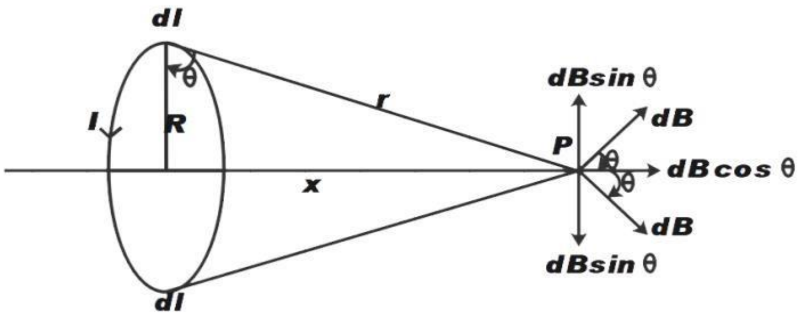
$$dB = k.(I\,dl\sin\theta)/r^2$$

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

It will be along the perpendicular to the plane containing the point and the element.

Biot Savarts law in Vector form : $d\vec{B} = \frac{\mu_0}{4\pi}\frac{i\,d\vec{l}\times\vec{r}}{r^3}$

7. Derive an expression for magnetic field at a point along the axis of circular coil carrying current. (5 M)



Magnetic field produced at P due to current in the element is given by Biot Savart'

$$dB = \frac{\mu_0}{4\pi} \frac{I\,dl\,sin\theta}{r^2} \qquad \theta = 90^0,\ \sin\theta = 1$$

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

dB is resolved into two components as dB cosθ along the axis and dB sinθ ⊥ to the axis.

Magnetic field produced at P due to current in the full loop is given by

$$\sum dB = \sum dB \cos\theta$$

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

$$B = \frac{\mu_0}{4\pi} \frac{I}{r^2} \cos\theta \times 2\pi R$$

In Δ OAP, cos θ = R/r

$r^2 = R^2 + x^2 \Rightarrow r = (R^2 + x^2)^{1/2}$

$\therefore r^3 = (R^2 + x^2)^{3/2}$

$$B = \frac{\mu_0}{4\pi} \frac{I}{r^2} \times \frac{R}{r} \times 2\pi R$$

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

$$\mathbf{B = \frac{\mu_0}{4\pi} \frac{I}{(R^2 + x^2)^{\frac{3}{2}}} 2\pi R^2}$$ along the axis towards the observer

For n turns of the coil,

i.e. $$\boxed{B = \frac{\mu_0}{4\pi} \cdot \frac{2\pi R^2 n I}{(R^2 + x^2)^{\frac{3}{2}}}}$$

At the centre of the coil x = 0 , $B = \frac{\mu_0 n I}{2R}$

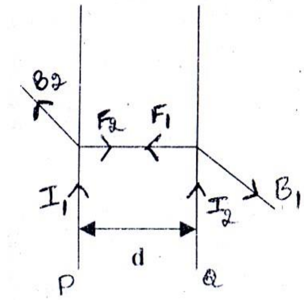
8. State and explain Ampere's circuital law.

This law states that 'The line integral of magnetic field $[\oint \vec{B} \cdot \vec{dl}]$ around any closed path (or circuit) is equal to ' μ_0 ' times the total current (I_t) threading the closed circuit. $\oint \vec{B} \cdot \vec{dl} = \mu_0 I_t$

9. Derive an expression for force between two parallel current carrying conductor. And hence define ampere.

Magnetic field produced by current I_1 on the conductor Q is given by

$$B_1 = \frac{\mu_0}{4\pi}\frac{2I_1}{d} \quad \text{(towards the observer)}$$



The conductor Q carrying current I_2 in the magnetic field B_1 experiences a mechanical force F_1 is given by

$$F_1 = B_1 I_2 L \sin\theta \qquad \text{If } \theta = 90^0 , \sin 90^0 = 1$$

$$F_1 = B_1 I_2 L$$

$$F_1 = \frac{\mu_0}{4\pi}\frac{2I_1I_2L}{d} \quad \text{-------------------(1) (towards the conductor P)}$$

Similarly, conductor P experiences mechanical force F_2 given by

$$F_2 = \frac{\mu_0}{4\pi}\frac{2I_1I_2L}{d} \quad \text{-----------------(2) (towards the conductor Q)}$$

From equations (1) and (2)

$$|F_1| = |F_2| = F$$

$$\therefore F = \frac{\mu_0}{4\pi}\frac{2I_1I_2L}{d}$$

This is the expression for force between two parallel conductors carrying current.

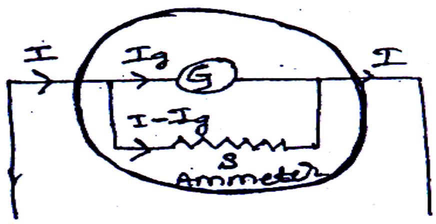
One ampere is defined as that constant current which when maintained in each of the two infinitely long straight and parallel conductors of negligible cross section placed 1m apart in air or vacuum will cause each conductor to experience a force of **2×10^{-7} N/m length**.

10. Explain how a Galvanometer can be converted into an Ammeter

A galvanometer can be converted into ammeter by ***connecting suitable low resistance in parallel*** with the galvanometer.

Let 'S' be the low (shunt) resistance to be connected in parallel with galvanometer to convert it into Ammeter of range I ampere.

Applying Ohm's law to each resistance, we get



$$V = I_g G$$

$$V = (I - I_g) S$$

$$(I - I_g) S = I_g G$$

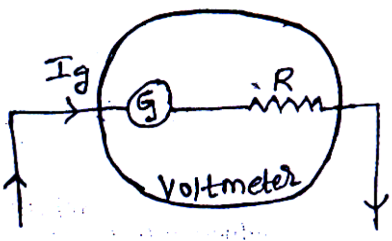
$$\therefore S = \frac{I_g G}{I - I_g}$$

11. Explain how a Galvanometer can be converted into voltmeter

A galvanometer can be converted into voltmeter **by connecting suitable high resistance in series** with the galvanometer.

Let 'R' be the high resistance to be connected in series with galvanometer to convert it into voltmeter of range V volts.

Applying Ohm's law, we get



$$V = I_g (G + R)$$

$$V / I_g = (G + R)$$

$$\therefore R = \frac{V}{I_g} - G$$

12. What is current sensitivity? Mention an expression for it. On what factors it depends?

It is defined as the deflection per unit current.

$$\frac{\theta}{I} = \left(\frac{N\,A\,B}{C}\right)$$

Current sensitivity is

1) Directly proportional to number of turns in the coil.
2) Directly proportional to strength of the magnetic field.
3) Directly proportional to area of coil.
4) Inversely proportional to couple per unit twist of the suspension.

13. What is Voltage sensitivity? Mention an expression for it. On what factors it depends?

It is defined as the deflection per unit voltage.

$$\frac{\theta}{V} = \left(\frac{N\,A\,B}{C\,R}\right)$$

Where R is galvanometer resistance.

Voltage sensitivity is

1) Directly proportional to number of turns in the coil.
2) Directly proportional to strength of the magnetic field.
3) Directly proportional to area of coil.
4) Inversely proportional to couple per unit twist of the suspension.
5) Inversely proportional to resistance of the galvanometer coil.

14. What is moving coil galvanometer? On What principle it works? With the help of a neat-labelled diagram, obtain the expression for the angular deflection produced in moving coil galvanometer.

Moving coil galvanometer is an instrument used to detect and measure current in a circuit.

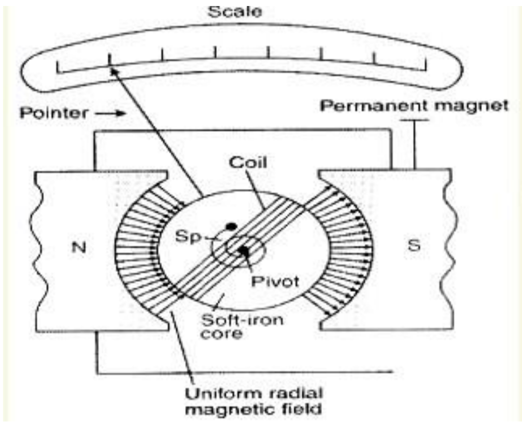
Principle: It works on the principle that a current carrying coil experiences a torque when placed in a magnetic field.

This Torque due to current is given by

$\tau_i = n\,A\,I\,B \sin\theta$,

$\theta = 90^0$, $\sin 90^0 = 1$

$\tau_i = n\,A\,I\,B$ ------------ (1)



Also, $\tau_i \;\alpha\; \theta$

$\tau_i = C\,\theta$ ----------- (2)

From (1) and (2), $n\,A\,I\,B = C\,\theta$,

where C = spring constant called couple per unit twist (Torsional constant of the spring)

$\therefore\; I = \left(\frac{C}{n\,A\,B}\right).\,\theta$

I = K θ where $K = \left(\frac{C}{n\,A\,B}\right)$ called galvanometer constant

I α θ

MAGNETISM AND MATTER

1. Write any three Properties of Magnetic field lines:

1. No two magnetic field lines can intersect each other.
2. The magnetic field lines will be parallel and equidistant in a uniform magnetic field.
3. The magnetic field lines will be more crowded where the strength of the field is more.
4. Outside the body of the Magnet, the Magnetic field lines move from north pole to South pole of the magnet.

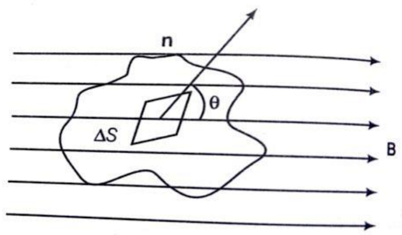
2. State and explain Gauss's law in magnetism.

This law states that, ***the net magnetic flux (Φ_B) through any closed surface is always zero.***

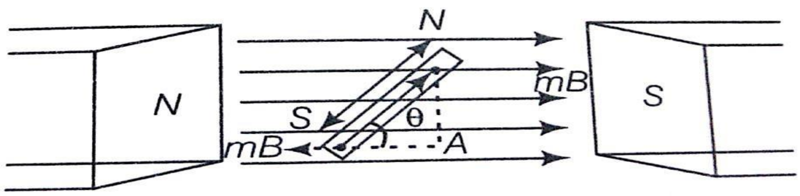
$$\Delta\phi_B = \vec{B} \cdot \vec{ds} = 0$$

Magnetic poles are always exist in pair, outgoing magnetic flux due to the north pole is always equal to incoming magnetic flux due to the south pole. Therefore net magnetic flux through any closed surface is always equal to zero.

$$\Delta\phi_B = \vec{B} \cdot \vec{ds} = 0$$



3. Expression for Magnetic potential energy of an dipole placed in an uniform magnetic field



The torque acting on the dipole is given by

$$\tau = M\ B \sin\theta$$

If the dipole is rotated through a small angle $d\vartheta$ against the Torque. The wonedone is given by

$$dw = \tau \times d\theta = MB \sin\theta \times d\theta$$

Total work done in rotating the dipole from the initial position θ_1 to the final position θ_2 is given by

$$\int dw = \int_{\theta_1}^{\theta_2} MB \sin\theta\, d\theta = MB\left[-\cos\theta\right]_{\theta_1}^{\theta_2}$$

$$W = MB\ [-\cos\theta_2 + \cos\theta_1] = MB\ [\cos\theta_1 - \cos\theta_2]$$

By definition,

$$W = U$$

$$U = MB\ [\cos\theta_1 - \cos\theta_2]$$

When $\theta_1 = 90$ and $\theta_2 = \theta$ then

$$\boxed{U = -MB\cos\theta}$$

4. Write the differences between dia, para and Ferromagnetic materials.

Diamagnetic Materials	Paramagnetic Materials	Ferromagnetic materials
1. These are feebly repelled by a magnet.	1. These are feebly attracted by a magnet.	1. These are strongly attracted by a magnet
2. Magnetic susceptibility has a small – ve value	2. Magnetic susceptibility has a small + ve value.	2. Magnetic susceptibility has a large + ve value.
3. Intensity of Magnetisation (I) has a small – ve value.	3 Intensity of Magnetisation (I) has a small + ve value.	3. Intensity of Magnetisation (I) has a large + ve value.
4. Relative magnetic permeability is less than 1	4. Relative magnetic permeability is > 1	4. Relative magnetic permeability is >>> 1
5. When placed in magnetic field, the lines of force tend to avoid the substance.	5. The lines of force prefer to pass through the substance rather than air.	5. The lines of force tend to crowd into the specimen.

5. Define magnetization of a sample. Mention its SI unit.

It is defined as ***net magnetic dipole moment (m) acquired per unit volume*** of the substance.

Its SI unit is given by **:** A/m.

ELECTROMAGNETIC INDUCTION

1. State and explain Faraday's law of EMI:

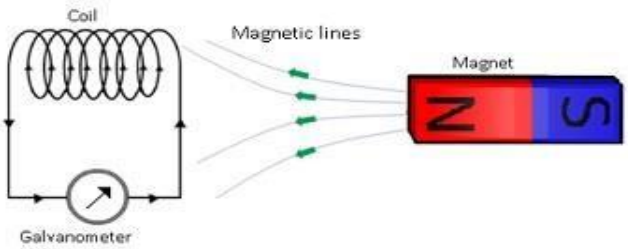
This law states that the magnitude of the induced emf is directly proportional to the rate of change of magnetic flux.

If e is the induced emf when the magnetic flux changed by $d\Phi$ in a time interval dt then from Faraday's law :

i.e. $$e = -\frac{d\Phi}{dt}$$

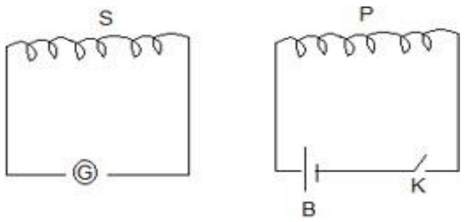
Significance of Lenz's law: Law of conservation of energy

2. Explain Coil and magnet experiment.



When one pole of magnet is Suddenly brought near one face of coil connected to sensitive galvanometer. It shows momentary deflection indicating the flow of momentary current in it, when the magnet is suddenly withdrawn then also there is deflection but in opposite direction. Similar effect is also observed when the coil is moved with respect to stationary magnet. No emf is produced when both coil and magnet are at rest. This illustrates the phenomenon of electromagnetic induction.

3. Explain Coil and Coil experiment.



This experiment consists of two coils, primary and Secondary. Whenever primary circuit is closed or open, galvanometer shows momentary deflection. First in one direction and next in opposite direction. Similar effect is also observed when current in primary is suddenly increased or decreased. Similar effect is also observed when secondary coil is moved with respect to current carrying primary. No deflection is observed when both the coils are at rest, This illustrates the phenomenon of electromagnetic induction.

4. State and explain Lenz's law.

Lenz's law:

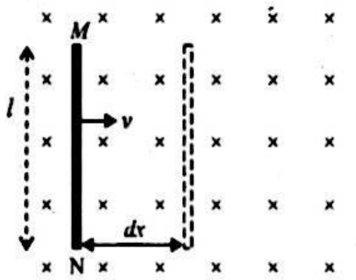
This law states that the direction of induced emf and hence current is such that it tends to oppose the change that produces it.

Lenz's law is just an illustration of the law of conservation of energy.

(i) When north pole of magnet is moved towards the coil, the end face of the coil acts as a N-pole due to the induced current, which flows in the anticlockwise direction. Thus opposes the motion of the magnet, which is the cause of the emf.

(ii) When north pole of the magnet moved away from the coil, the end face acts as S-pole by changing the current in the clockwise direction. This opposes the motion of the magnet

5. Obtain an expression for motional e.m.f induced in a conductor (rod) moving in a magnetic field.



MN – straight metallic conductor,
dx – distance travelled travelled by the conductor
l – Length of the conductor

Flux linked with the conductor is

$$\phi = B\ A \cos\theta$$

As, $\theta = 0^0$, $\cos 0^0 = 1$

$$\phi = B\ A \text{------------} (1)$$

If A is the area covered by the conductor in dt second ,
then $A = l \,.\, dx$

(1) => $\phi = B\ l\,.\,dx$

From Faraday's law, magnitude of emf induced in the rod is given by

$$e = \frac{d\phi}{dt} = \frac{d\ B\ .l.dx}{dt}$$

Then $e = B\ l\ (\frac{dx}{dt})$

$$\mathbf{e = B\ \boldsymbol{l}\ v} \qquad [\because \frac{dx}{dt} = \text{v (velocity)}]$$

6. What is Self inductance? On what factors self inductance of a coil depends?

The Phenomenon of generating an emf and hence current in a coil due to change of current in the coil itself is called 'self inductance'.

Self-inductance of a coil depends on

1) Number of turns in the coil.
2) Area of cross section of the coil.
3) Permeability of material (medium)on which coil is wound.

7. On what factors Mutual induction depends on?

1) Number of turns on either coil
2) Shape and size of coils
3) Separation between the coils.
4) The permeability of the material on which coils are wound.

8. Mention an expression for mutual inductance of two coaxial solenoids.

$$M = \frac{\mu_0 N_1 N_2 A}{L}$$

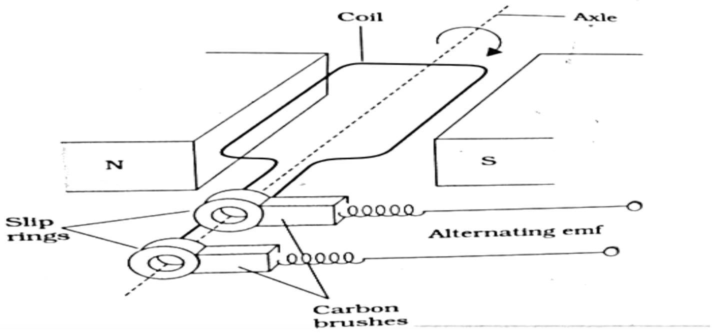
Where $\mu = \mu_0 \mu_r$, is permeability of the core.

9. What is AC generator? Draw a neat labelled diagram of AC generator.

Ans: It is a device used for converting mechanical energy in to electric energy.

Principle : AC generator works on the principle of Electromagnetic Induction **(EMI)**

Diagram:



ALTERNATING CURRENT

1. What is a Transformer? Explain the working of a Transformer.

TRANSFORMER: Transformer is a device used to step up or step down alternating voltages.

Principle: It works on the principle of ***mutual induction***.

Construction: It consists of two coils, primary P and secondary S of fine insulated wire wound on soft iron core of thin laminations insulated from each other. Input is fed to the primary, output is taken across the secondary.

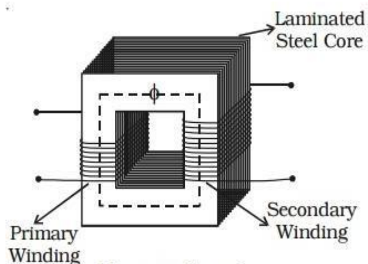


Fig Transformer

Working:

As input is alternating, at every alteration magnetic flux linking round the secondary changes. Therefore an emf of the same nature is induced in the secondary. The magnitude of output voltage depends on number of turns in primary and secondary coils.

Let V_p and V_s are the input and output voltages. n_p and n_s be the number of turns in primary and secondary.

Then it can be shown that

$$\mathbf{V_s / V_p = n_s / n_p = T}$$

Where, T is a constant of the transformer called as turns ratio.

2. Mention any three Sources of Energy losses in Transformer:

Energy losses in transformer are

1) Magnetic flux leakage loss
2) Eddy current loss
3) Resistance of winding loss
4) Hysteresis loss

3. Define : a) Power factor b) wattles current

Power factor: It is defined as ratio of resistance to the impedance of the circuit.

i.e. $\mathbf{Cos\ \phi = \frac{R}{Z}}$

Watt less current: The power factor is zero for inductance or capacitance circuit even though a current flows through the circuit, this current is called 'watt less current'.

4. Distinguish between inductive reactance and capacitive reactance

Inductive reactance	Capacitive reactance
The Resistance offered by inductance coil for the flow of alternating current through it is called inductive reactance	The resistance offered by the capacitor for the flow of alternating current through it is called capacitive reactance
It is directly proportional to frequency of AC	It is inversely proportional to frequency of AC
$X_L = \omega L$	$X_C = 1 / \omega C$
$X_L = 0$ for dc	$X_C = \infty$ for dc

ELECTRO-MAGNETIC WAVES

1. What is displacement current? Write the mathematical form for displacement current?

"The current which comes into play in the region in which the electric field and the electric flux is changing with time".

Mathematical form: $I_D = \epsilon_0 \frac{d\varphi_E}{dt}$

2. Write any two Properties of electromagnetic waves.

1. All these radiations travels in straight line with velocity $3\text{x}10^8$ m/s in air or vacuum.
2. The ratio of magnitudes of electric and magnetic field vectors in free space is constant equal to c

$$\frac{E}{B} = \frac{1}{\sqrt{\mu_0 \varepsilon_0}} = c = 3\times10^8\, m/s$$

3. The velocity of electromagnetic waves in free space, $c = 1 / \sqrt{\mu_0\varepsilon_0}$
4. Electromagnetic waves obey the principle of superposition.
5. Electromagnetic waves can transfer energy as well as momentum to objects placed on their paths.

3. Write any two applications of gamma rays.

i) They are used in the treatment of cancer.
ii) They are used to produce nuclear reaction.
iii) They are used in food preservation like fruits and vegetables.

4. Write any two applications of UV rays.

i) They are used for purification of air and water.
ii) They are used in the synthesis of vitamin D.
iii) They are used in LASIK eye surgery.

5. Write any two applications of IR-rays.

i) They are used for long distance photography.
ii) They are used in the treatment of muscular sprain.
iii) They are used in TV remotes to operate TV.

6. Write any two applications of X-rays.

i) They are used to detect foreign bodies inside human body.
ii) They are used to detect fracture in bones.
iii) They are used in the treatment of skin cancer.

7. Write any two applications of Microwaves

i) They are used in microwave ovens for heating
ii) They are used in RADAR system for aircraft navigation

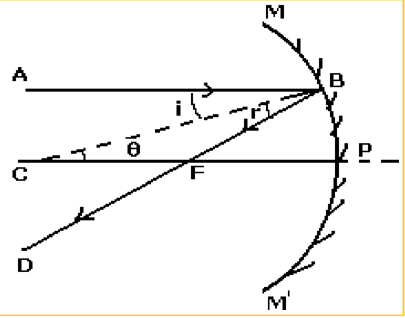
8. Write any two uses of Radio waves.

i) Used in RADAR system
ii) Used in TV and Radio broadcasting

RAY OPTICS

1. Relation between focal length and Radius of curvature for concave mirror (f = R / 2) :

Consider a ray of light, AB || PC,
and CP ≈ CB = R, is the radius of curvature.



The ray AB, after reflection from mirror will pass through F and obeys law of reflection,

i.e., i = r -----------(1) where i is the angle of incidence and r is the angle of reflection.

From the figure,

$\angle BCP = \theta = i$ ----------- (2) (alternate angles)

From (1) and (2)

In ΔCBF, as $\theta = r \quad \therefore BF = FC \, (\because i = r)$

As the aperture of the mirror is small, B lies close to P, BF ≈ PF

∴ FC = FB = PF

PC = PF + FC = PF + PF

R = 2 PF = 2f (∵ PC = R and PF = f , focal length)

f = R / 2

2. Write the Conditions of TIR

1) The ray should go from denser medium to rarer medium.
2) The angle of incidence in the denser medium must be greater than critical angle.

Write Illustrations of TIR

1) Sparkling of diamond is due to total internal reflection.
2) Appearance of mirages is due to TIR.
3) Appearance of rainbow is due to dispersion and TIR.

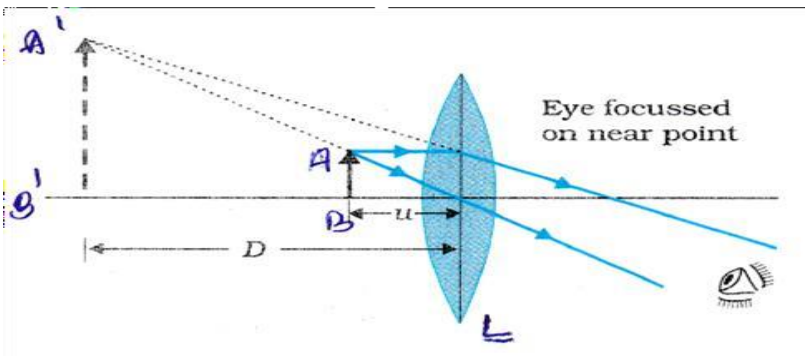
Write any two Applications of TIR;

1) Artificial diamonds are made to sparkle using TIR.
2) Using TIR messages are sent from one place to the other through the optical fibre.

3. Write the Cartesian sign conventions used in analyzing reflection of light by spherical mirrors.

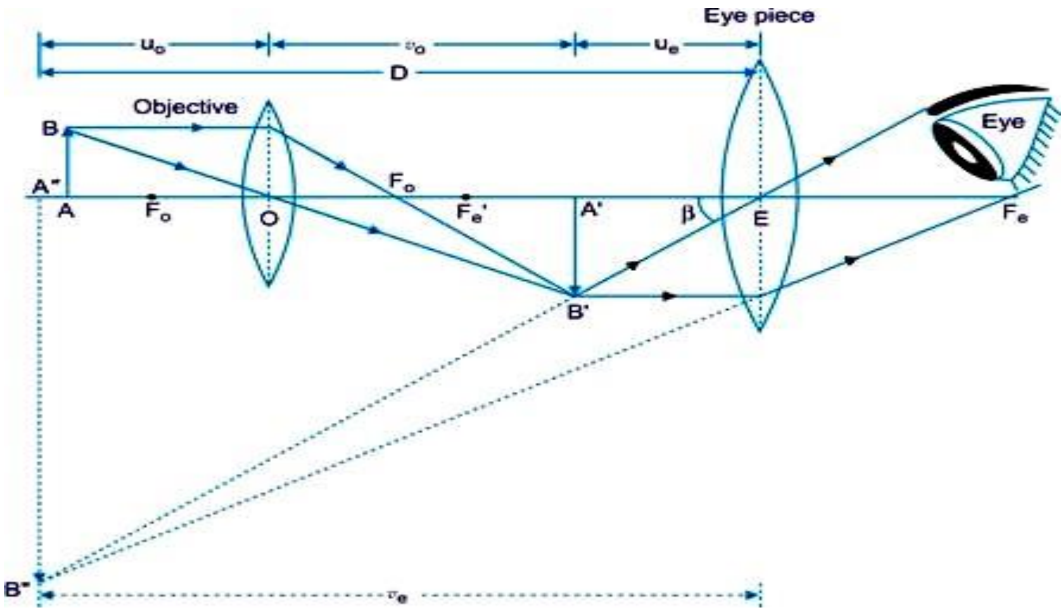
1) All distances are measured from the pole of the spherical mirror along the principal axis.
2) The distances measured along the direction of incident light are taken as positive and those measured in the direction opposite to the direction of incident light are taken as negative.
3) The heights measured upwards perpendicular to the principal axis are taken as positive and the heights measured downwards perpendicular to the principal axis are taken as negative.

4. Write the ray diagram for formation of image in the simple microscope.



(a)

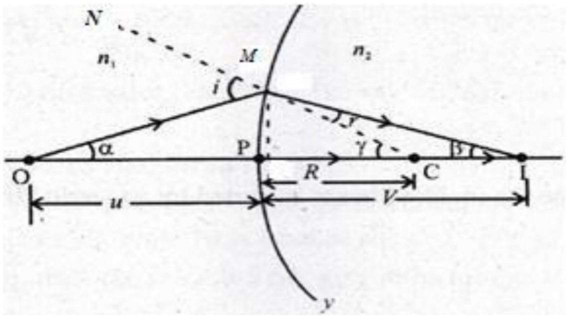
5. Draw the ray diagram of image formation in case of a compound microscope



6. Derive the relation connecting n, u, v and R. (Derive $\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}$)

Let ‘P’ be the pole , ‘C’ be the centre of curvature and ‘R’ be the radius of curvature of a small aperture spherical refracting surface.

CMN is the normal at M. i is the angle of incidence and r is the angle of refraction.



In triangle PMO: $\tan MOP = \tan\alpha = \frac{PM}{PO}$

In triangle PMI: $\tan MIP = \tan\beta = \frac{PM}{PI}$

In triangle MCP: $\tan MCP = \tan\gamma = \frac{PM}{PC}$

In triangle OMC, $i = \alpha + \gamma = \frac{PM}{PO} + \frac{PM}{PC}$,

In triangle MCI, $\gamma = r + \beta$

$$r = \gamma - \beta = \frac{PM}{PC} - \frac{PM}{PI}$$

By snell’s law,

$$n_1 \sin i = n_2 \sin r$$ (as angles are small, sin i ≈ i & sin r ≈ r)

$$n_1 i = n_2 r$$

$$n_1 \left[\frac{PM}{PO} + \frac{PM}{PC}\right] = n_2 \left[\frac{PM}{PC} - \frac{PM}{PI}\right]$$

$$\frac{n_1}{PO} + \frac{n_1}{PC} = \frac{n_2}{PC} - \frac{n_2}{PI}$$

From figure: PO = -u, PC = R & PI = v

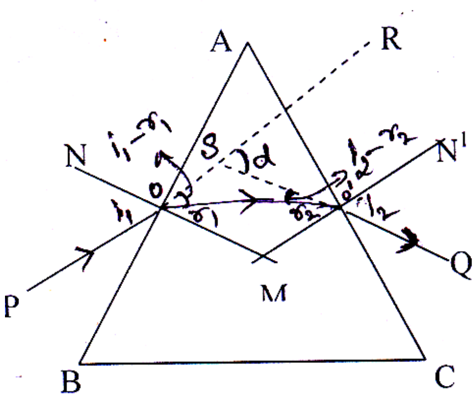
$$-\frac{n_1}{u} + \frac{n_1}{R} = \frac{n_2}{R} - \frac{n_2}{v}$$

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

7. Derive the expression : $n = \frac{\sin\left(\frac{A+D}{2}\right)}{\left(\frac{A}{2}\right)}$ for refraction through a prism. (With usual notations)

A ray of light PO incident ray, OO^1 is the refracted ray O^1Q is the emergent at the face AC.

MN and MN^1 are the normal.



In quadrilateral $AOMO^1$

$\angle A + \angle M = 180^0$ ---------------------(1)

In Δ^{le} OMO^1

$\angle r_1 + \angle r_2 + \angle M = 180^0$----------------- (2)

From (1) and (2)

$\angle A + \angle M = \angle r_1 + \angle r_2 + \angle M$

$$\angle A = \angle r_1 + \angle r_2 \text{-----------------------} (3)$$

In Δ SOO[1] ,

$$\angle d = (i_1 - r_1) + (i_2 - r_2)$$

$$= (i_1 + i_2) - (r_1 + r_2)$$

$$= (i_1 + i_2) - (A)$$

$$\mathbf{A + d = i_1 + i_2} \text{------------------------}(4)$$

At minimum, deviation position, $d = D$ and $i_1 = i_2 = i$ and $r_1 = r_2 = r$

Equations (3) and (4) becomes

$$A = \angle r_1 + \angle r_2 = r + r = 2r$$

$$\mathbf{r = A / 2}$$

$$A + D = i_1 + i_2 = i + i = 2i$$

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

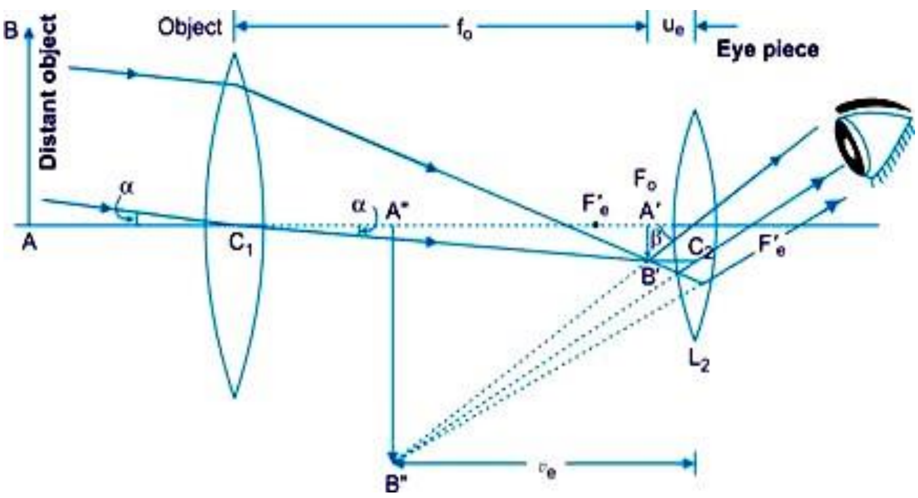
Substituting the values of i and r in the Snell's law equation. We get

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

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

$$\boxed{\mathbf{n = \frac{\sin (A + D) / 2}{\sin A / 2}}}$$

8. Draw the ray diagram for image formation in refracting telescope.



WAVE OPTICS

1. Define Wavefront. Mention the different types of wavefronts and their source.

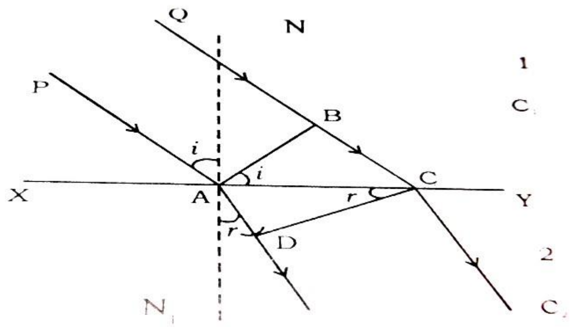
A wavefront is defined as the continuous locus of all the particles which are vibrating in the same phase.

Wavefronts due to point source => Spherical wavefront
Wavefronts due to line source => Cylindrical wavefront
Wavefronts from large distances => Plane wavefronts

2. Huygens' Principle of (Secondary waves) Wave Propagation

(i) Every point on a given wave-front may be regarded as a source of new disturbance.
(ii) The new disturbances from each point spread out in all directions with the velocity of light and are called the secondary wavelets.
(iii) The surface of tangency to the secondary wavelets in forward direction at any instant gives the new position of the wave-front at that time.

3. Prove Snell's law of refraction at a plane surface using Huygens's principle.



Let XY be a plane refracting surface separating two media 1 and 2 of refractive indices n_1 and n_2

If the secondary wavelets from B strike the surface X Y at C in time t then

BC = v_1t and similarly **AD = v_2t**

From fig in Δ , $\sin i = \frac{BC}{AC}$

Again, from fig in Δ ADC : $\sin r = \frac{AD}{AC}$

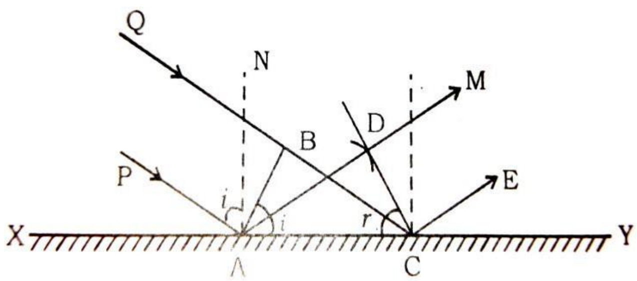
$$\frac{Sin\, i}{Sin\, r} = \frac{BC}{AD}$$

$$\frac{Sin\, i}{Sin\, r} = \frac{v_1}{v_2} \text{ x } \frac{c}{c} = \frac{c}{v_2} \text{ x } \frac{1}{\frac{c}{v_1}} = \frac{n_2}{n_1}$$

$$n_1 \sin i = n_2 \sin r$$

This is Snell's law of refraction.

4. Using Huygens principle show that angle of incidence is equal to the angle of reflection during a plane wave front reflected by a plane surface.



Let XY be a plane reflecting surface and AB be a plane wavefront incident on the surface at A. PA and QBC are perpendiculars drawn to AB at A and B respectively.

Here, CD is the reflected plane wavefront and AD is the reflected ray.

w.k.t , $v = \frac{\Delta x}{\Delta t} = \frac{BC}{t}$

⇨ BC = v t

Similarly, AD = v t

From the figure, In Δ ABC , $\sin i = \frac{BC}{AC} = \frac{v\,t}{AC}$ ……………. (1)

In ADC , $\sin r = \frac{AD}{AC} = \frac{v\,t}{AC}$ ……………………………(2)

Fom (1) and (2) , Sin i = Sin r

- **i = r** **Hence law of reflection**

5. *What is an Interference ?* Write any two conditions for sustained interference.

Modification (redistribution) in the intensity of light (energy) when two or more similar light waves travelling in the same direction super impose on each other is called 'Interference'.

The two sources must be coherent

1) Two sources must be very narrow

6. Write Conditions for constructive interference:

(i) Phase difference **δ = 2nπ** where n = 0,1, 2,3,………..

(ii) Path difference between the waves is

x = n λ n = 0, 1 , 2 , ………..

Write the Conditions for destructive Interference:

(i) Phase difference **δ = (2n + 1) π**

where n = 0,1,2,3,………..

δ = π, 3π, 5π, 7π,… ……………odd multiples of π

(ii) Path difference between the waves is

x = (2n + 1) . (λ/2) where n = 0,1,2,3,…………………..

7. Distinguish between Interference and diffraction

INTERFERENCE	DIFFRACTION
1. The modification in the intensity when two similar light waves traveling in same direction super impose on each other is called interference. 2. It is produced due to superposition of two waves from two coherent sources. 3. Interference pattern consists of alternate bright and dark band. 4. Interference bright bands are of equal thickness and intensity.	1. The phenomenon of light waves bending round the corners or obstacles, is called diffraction. 2. It is produced due to the superposition of no. of secondary waves of same sources. 3. Diffraction pattern consists of central bright band bordered by alternate dark and bright band of decreasing intensity. 4. Diffraction bright bands are of unequal thickness and intensity.

4. State and explain Malus Law.

According to Malus : ***When a completely plane polarised light beam is incident on a polarising sheet the intensity of the emergent light varies as the square of the cosine of the angle between the direction of electric field vector of the incident light and the polarising direction of the sheet.***

$$I = I_0 \cos^2\theta$$

5. What are Polaroids? Write any two uses of Polaroids.

Polaroid is an optical device which can be used as Polariser and analyser.

USES

1) They are used as sun glasses.
2) They are used as polarizers.
3) They are used as analyser.
4) They are used to view 3d pictures.
5) They are used to avoid head light glare of incoming vehicles.

Dual Nature of matter & Radiation

1. Mention any two types of electron emission.

1. Photoelectric emission 2. Thermionic emission
3. Field emission

2. Explain experimental observations of photoelectric effect.

1) Photoelectric effect is an instantaneous effect. (as time lag is 10^{-9} second)
2) For a photometal there is a minimum frequency of incident radiation below which there is no photoelectric effect, this minimum frequency is called '***threshold frequency*** **(υ_0)'.**
3) Above threshold frequency, kinetic energy of photoelectrons is directly proportional to the frequency of incident radiation. (**K.E α υ**)
4) Above threshold frequency, number of photoelectrons (and hence photoelectric current) is directly proportional to the intensity of incident radiation.
5) Above threshold frequency, there is a ***minimum negative potential of the anode*** for which photoelectric current becomes zero. This minimum negative potential of anode is called as "***stopping potential***" or "***retarding potential***".

3. Define: a) Work function b) Photoelectric effect c) Threshold wavelength

Work function: The minimum energy required to take out electron from the surface of metals is called as work-function.

Photoelectric effect : Certain metals emit electrons when suitable frequency of radiation is incident on them. This phenomenon is called '*Photoelectric effect.*

Threshold wavelength : For a photometal there is a maximum wavelength of the incident radiation above which there is no photoelectric effect, that wavelength is called ***threshold wavelength.***

4. Describe Einstein's explanation of photoelectric effect by considering his mathematical equations.

Einstein explained photoelectric effect on the basis of '***Quantum theory of radiation'***.
When radiation incident on the metal surface, ***elastic collision*** takes place between photon and electron.

$$K.E_{max} = E - \phi_0$$

$$K.E_{max} = h(\upsilon - \upsilon_0) \quad (\text{since. } E = h\upsilon \ \& \ \phi_0 = h\upsilon_0)$$

$$\tfrac{1}{2} mv^2 = h(\upsilon - \upsilon_0)$$

Where , m = mass of an electron, v = velocity of an electron
h = Planck's constant, υ = Frequency of incident radiation
υ_0 = Threshold frequency

Conclusions:

1) Photoelectric effect is instantaneous effect and takes place due to elastic collision between photon and electron inside the metal.
2) If $\nu < \nu_0$, then $\frac{1}{2} mv^2_{max}$ is negative, which is not possible. Therefore, for photoelectric emission to take place $\nu > \nu_0$.
3) It is clear that $\frac{1}{2}$ **mv²$_{max}$** α **ν** as h and ν_0 are constant.
   This shows that **K.E. of the photoelectrons is directly proportional to the frequency** of the incident light.

5. Write any three Characteristic Properties of photon

1. Photons travel at the speed of light in vacuum. i.e. 3×10^8 m/s.
2. Photons travel in straight lines. (Only in a homogeneous).
3. A photon has zero rest mass. i.e. $m_0 = 0$. It means photon can not exist at rest.
4. Photons do not have any charge. They are electrically neutral.

6. a) Mention an expression for de-Broglie's wavelength interms of accelerating potential.

Ans: $\lambda = \frac{h}{\sqrt{2\,m\,q\,V}}$

Where m = mass of particle , q = charge of the particle
h = Planck's constant, V = accelerating potential

b) Mention an expression for de-Broglie's wavelength interms of Temperature.

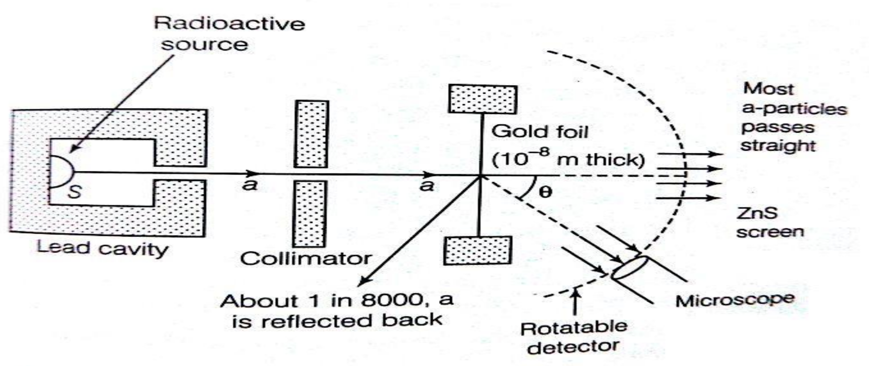
$$\boldsymbol{\lambda = \frac{h}{\sqrt{3\,m\,k\,T}}}$$ where k = Boltzmann constant

c) Mention an expression for de-Broglie's wavelength interms of Kinetic energy.

$$\boldsymbol{\lambda = \frac{h}{\sqrt{2\,m\,E}}}$$ where, E = kinetic energy

ATOMS & NUCLEI

1. With a neat labelled diagram Explain Geiger-Marsden scattering experiment.



Observations :

(i) Most of α-particles pass through the gold foil unreflected.
(ii) A very small number of α-particles (1 in 8000) suffered large angle deflection.
(iii) Some of them retraced their original path or suffered 180° deflection.

2. What is impact parameter? When will it is maximum and minimum?

The *impact parameter* is the perpendicular distance of the initial velocity vector of the α-particle from the centre of the nucleus.

For $\theta = 0^0$. Impact parameter is maximum
$\theta = 180^0$, Impact parameter is minmum

3. Write any two limitations (Drawbacks) of Rutherford Model of atom.

i) It could not explain the stability of atoms.
ii) It could not explain the line spectrum

4. Explain the postulates of Bohr's Atom Model.

(i) **Stationary Circular Orbits:** A*n electron in an atom could revolve in certain stable orbits without the emission of radiant energy called Stationary orbits.*

ii) **Quantum Condition:** E*electron* revolves around the nucleus *only in those orbits for which the angular momentum is some integral multiple of* $\frac{h}{2\pi}$

(That is $L = \frac{nh}{2\pi}$ (L = mvr)

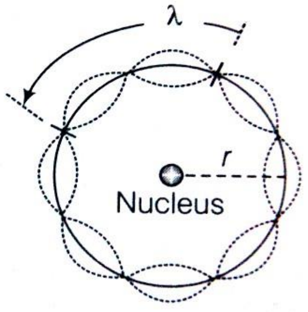
iii) **Frequency condition:** Electron emits energy only when they jumps from stationary orbit of higher energy level to lower energy level.

i.e. $\mathbf{h\nu = E_2 - E_1}$.

5. Write any two limitations of Bohr's atom model.

1) Bohr' theory is not applicable to atoms having more than one electron.
2) Bohr's theory fails to explain fine structure of spectral line.
3) This theory does not account for the wave nature of electrons.

6. Explain de-Broglie's comment on Bohr's Second Postulate.



Total distance covered = circumference of the orbit = $2\pi r_n$

∴ for the permissible orbit, $2\pi r_n = n\lambda$

According to de-Broglie, $\lambda = \frac{h}{mv_n}$

$\therefore\ 2\pi r_n = \frac{nh}{mv_n}$

$$\mathbf{m v_n r_n = \frac{nh}{2\pi} = n\left(\frac{h}{2\pi}\right)}$$

Hence, angular momentum of electron revolving in the n^{th} orbit must be an integral multiple of $\frac{h}{2\pi}$, which is the quantum condition proposed by Bohr in second postulate.

7. Write any two Properties (Characteristics) of nuclear force.

1. The nuclear force is much stronger than the Coulomb force
2. Nuclear force is a short range force.
3. Nuclear force is charge independent force and spin dependent force.
4. Nuclear force is non-central and non-gravitational force.

8. Distinguish between nuclear fission and fusion.

Nuclear fission	Nuclear fusion
1) It is a process in which heavier nucleus breaks up into two or more lighter nuclei of comparable masses. 2) Reaction is controllable. 3) Energy released can be controlled.	1) Nuclear fusion is a process in which two lighter nuclei are fussed together to form a heavier nucleus. 2) Reaction is uncontrollable. **3)** Energy released cannot be controlled.

9. What are Isotopes, Isobars and Isotones? Give example.

1. Isotopes:

The atoms of an element having same atomic number (Z) but different mass-numbers are called isotopes.

Ex: $_6C^{12}$, $_6C^{13}$, $_6C^{14}$

2. Isobars:

The nuclei having same mass number but different atomic number are called isobars.

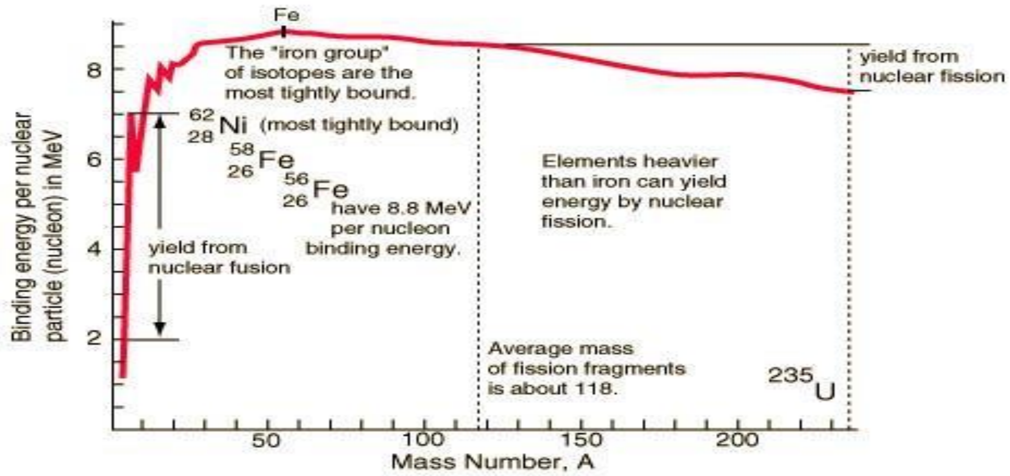
Ex: $_1H^3$, $_2He^3$

3. Isotones:

The nuclei containing the same number of neutrons are called isotones.

Ex: $_1H^3$, $_2He^4$

10. Draw Observations of Binding Energy curve



SEMICONDUCTOR ELECTRONICS

1. **Explain the Classification of Solids on the basis of energy bands into conductors, semiconductors and insulators :**

Sl. No	Conductors	Semiconductors	Insulators
1	Conductivity is very high	Conductivity is between less than that of conductors	Conductivity is negligible
2	Resistivity is very low	Resistivity is more than conductors	Resistivity is very large
3	Temperature co-efficient of resistance is positive for conductor.	Temperature co-efficient of resistance of a Sc is negative and large.	Temperature coefficient of resistance is slightly negative.
4	Type of bonding present is metallic bonding	Type of bonding present is Covalent	Type of bonding present is ionic. (or covalent)
5	Ex: Cu, Ag, Au etc	Ex: Ge, Si etc	Ex: Wood, Plastic, mica etc.

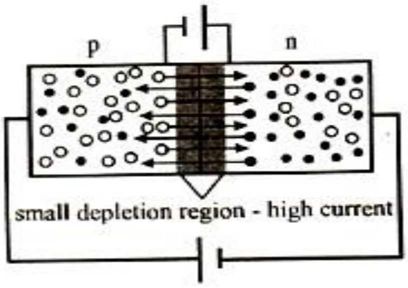
2. **Write the differences between Intrinsic and extrinsic semiconductors**:

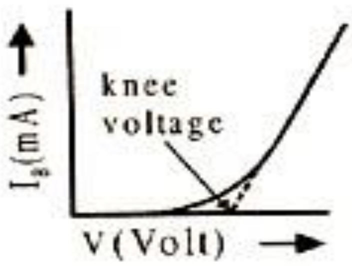
Intrinsic semiconductors	Extrinsic semiconductors
1. It is a pure semiconductor 2. Number of holes and electrons are equal 3. Conductivity depends only on temperature 4. Conductivity is due to both electrons and holes 5. Here, $n_e = n_h = n_i$ Ex: Ge in its purest state	**1.** It is a semiconductor doped with impurities. **2.** Number of holes and electrons are unequal **3.** Conductivity depends on impurities added. **4.** Conductivity is mainly due to majority charge carriers. **5.** Here, $n_e . n_h = n_i^2$ Ex: Ge doped with As

3. Write the differences between n-type and p-type semiconductors.

n-type	p-type
1) Majority charge carriers are electrons. 2) Minority charge carriers are holes. 3) Produced by adding pentavalent impurities 4) Electrical conductivity is mainly due to free electrons. Ex: Ge doped with Arsenic	1) Majority charge carriers are holes. 2) Minority charge carriers are electrons. 3) They are produced by adding trivalent impurities 4) Electrical conductivity is mainly due to holes. . Ex: Ge doped with Indium

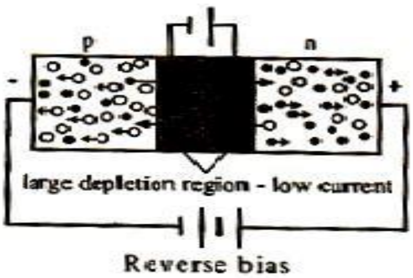
4. Explain the Action of diode when forward biased. Draw IV curve for it.

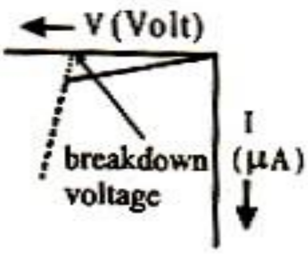




Diode is said to be forward biased when p-side of the diode is connected to positive of the battery and n-side of diode is connected to negative of the battery.
Positive of the battery attracts electron from n-side to p-side through the junction, negative of the battery attracts holes from p-side to n-side through the junction therefore thickness of depletion layer decreases, its resistance decreases and conductivity increases, it conducts current. A diode conducts current when it is forward biased.

5. Explain the Action of diode when reverse biased. Draw IV curve for it.



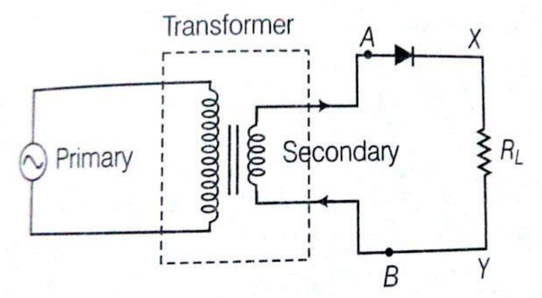


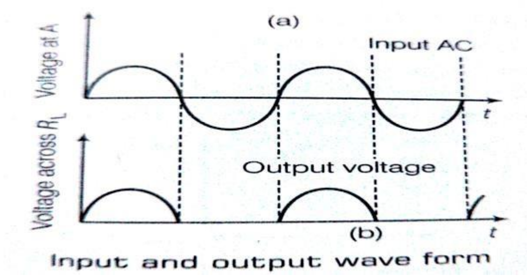
Diode is said to be reverse biased when p-side is connected to negative of the battery and n-side is connected to positive of the battery. The positive of the battery attracts electrons directly from n-side. Negative of the battery attracts holes directly from p-side, thickness of depletion layer increases. Its resistance increases and conductivity decreases therefore it does not conduct current.

Rectifier : It is a device used to convert AC into DC.

Rectification : The process of converting AC into DC.

6. Explain the working of half-wave Rectifier with its waveform.





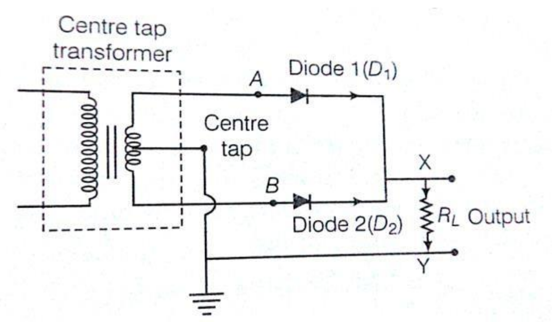
A half wave rectifier is one in which rectification is done for only one half cycle of input AC.

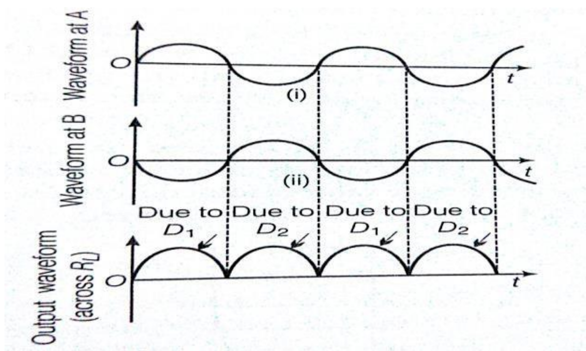
Working :

(i) During the positive half cycle of input AC, A is +ve and B is –ve hence ***diode is forward biased, it conducts current*** therefore a current flows through the load resistance, there will be voltage across the load resistance.

(ii) During negative half cycle, A is –ve and B is +ve hence ***diode becomes reverse biased, it will not conduct current***, no current flows through the load resistance and there is no voltage across the load resistance. Thus half cycle of input AC is blocked by the diode. This process is called as half wave rectification. *Output is DC but not steady*.

7. Explain the construction and working of Full-wave Rectifier with waveform.





A full wave rectifier is one in which rectification is done for the complete (both) cycle of input Ac.

Working:

(i) During positive half cycle of input AC , A is +ve and B is –ve hence diode ***D_1 is forward biased*** and ***D_2 is reverse biased***, ***D_1 only conducts current***. Current flows through the load resistance in the direction D_1 R_L T there will be output voltage across the load résistance.

(ii) During negative half cycle of input AC, A is –ve and B is +ve hence diode ***D_2 is forward biased*** and ***D_1 is reverse biased***. Diode ***D_2 only conducts current***. A current flows through the load resistance in the direction D_2 R_L T. There will be voltage across the load resistance.

In both the cases current flows in the same direction through the load resistance. Therefore output is DC and steady. This process is called as “full wave rectification”.