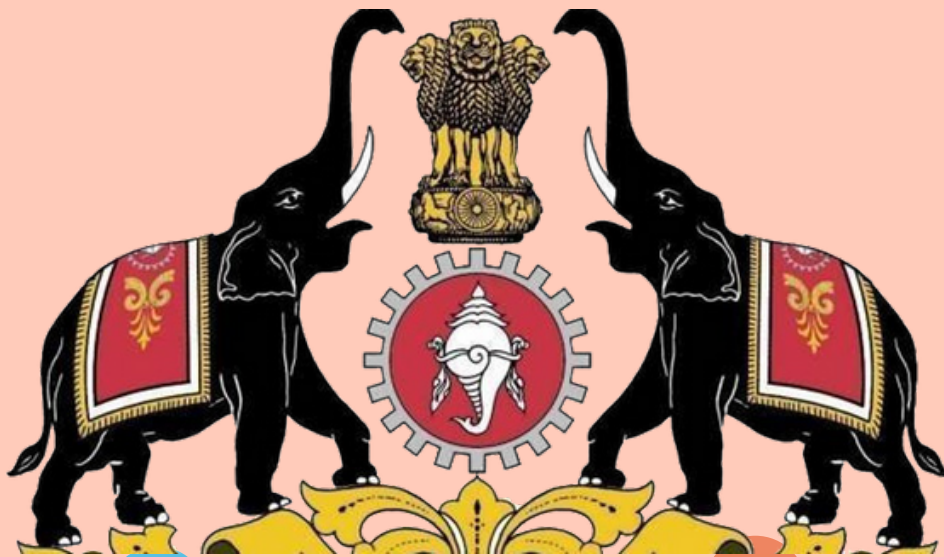


PLUS

2

NOTES

Chapter Wise



ELECTROSTATICS-CHAPTER 1

ELECTRIC CHARGES AND FIELDS

Topics Included

- Electric Charge
- Properties of Electric Charge
- Methods of Charging
- Coulomb's Law
- Electric Field
- Electric Field Lines
- Electric Dipole
- Electric Flux
- Gauss's Theorem

Electric charge 'Q'

Electric charge is a fundamental property of a particle (just like its mass) due to which electric and magnetic effects are produced in the matter.

- SI unit of charge is coulomb (C)

Properties of electric charges

i) Additive property

Electric charge is additive like real numbers .That is total charge on a body is equal to the algebraic sum of charges present at different parts of the body.

ii) Quantization of charges

Quantization of charge means that the total charge of a body is always an integral multiple of certain smallest charge (charge of an electron)

ie $Q = \pm n e$

Where Q = Total charge on the body

$n = 1, 2, 3, 4, \dots$

$e =$ charge of an electron ($1.6 \times 10^{-19} \text{C}$)

+ sign stands for loss of electron and – sign stands for gain of electron.

- ▶ Number of electrons constituting 1C of charges is 6.25×10^{18}

$$\{ n = Q/e = 1\text{C}/1.6 \times 10^{-19} \text{C} = 6.25 \times 10^{18} \}$$

iii) Conservation of charges

Total charge on an isolated system remains constant. This means that there is only a transfer of charges from one body to other, but no creation or destruction of charges

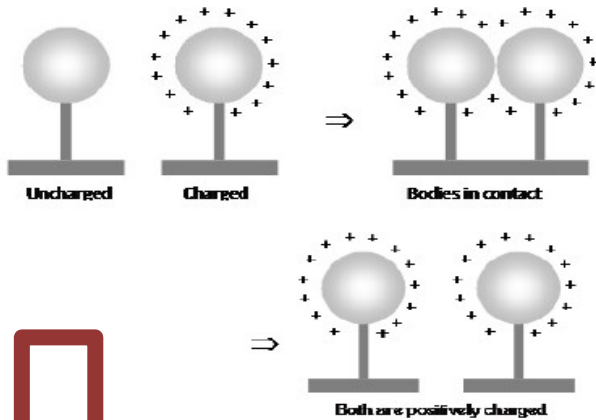
Methods of charging a body

1 . Charging by friction

2 . Charging by conduction

3 . Charging by induction

1. **Charging by friction** : When two insulating surfaces are rubbed against each other, due to friction, electrons are transferred from one body to other. Hence both get charged. The electric charges so acquired are called frictional electricity or charging by friction.
 - ▶ The substance which loses electrons become positively charged and which gain electrons become negatively charged.
 - ▶ When a body is charged negatively, electrons are added hence its mass increases
 - ▶ When a body is charged positively, electrons are removed hence its mass decreases.
2. **Charging by conduction**: When an un charged conductor is brought in to contact with a charged body, charge flows from the charged body to the uncharged body.
 - During charging by conduction, both objects acquire the same type of charge.



2. Charging by conduction

Problem 1

How many electrons are present in -1 coulomb of charge ?

Solution: $q = ne$ (or) $n = \frac{q}{e} = \frac{1}{1.6 \times 10^{-19}} = 6.25 \times 10^{18}$

ie, -1 C means 6.25×10^{18} electrons are excess.

Similarly +1 C means 6.25×10^{18} electrons are deficient.

Problem 2

A polythene piece rubbed with wool is found to have a negative charge of 3×10^{-7} C.

a). Estimate the number of electrons transferred (from which to which?)

b). Is there a transfer of mass from wool to polythene?

Solution: a) $Q = 3 \times 10^{-7}$ C

$$Q = ne$$

$$n = \frac{Q}{e} = \frac{3 \times 10^{-7}}{1.6 \times 10^{-19}} = 1.875 \times 10^{12}, \text{ electrons transferred from wool to polythene}$$

b) yes. There is a mass transfer from wool to polythene

$$\text{Mass of electrons transferred} = nm_e$$

$$= 1.875 \times 10^{12} \times 9.1 \times 10^{-31} = 1.706 \times 10^{-18} \text{ kg}$$

Point charges

When the size of charged bodies are much smaller than the distance separating them, their sizes can be neglected and the charged bodies can be treated as point charges.

Coulomb's law OR Inverse square law in electrostatics

According to this law "The magnitude of force of attraction or repulsion between any two point charges at rest is directly proportional to product of magnitudes of their charges and inversely proportional to the square of the distance between them".

Consider two point charges Q_1 and Q_2 separated by a distance r . The force between them

$$F \propto Q_1 Q_2, \quad F \propto \frac{1}{r^2}$$

$$F \propto \frac{Q_1 Q_2}{r^2}$$

$$F = \text{Constant} \frac{Q_1 Q_2}{r^2}$$

In SI system

$$F = \frac{1}{4\pi\epsilon_0\epsilon_r} \frac{Q_1 Q_2}{r^2}$$

where $\epsilon_0 \rightarrow$ Permittivity of air or free space

$\epsilon_r \rightarrow$ Relative permittivity of the medium

where the charges are placed

$$\epsilon_0 = 8.854 \times 10^{-12} \text{ C}^2 \text{N}^{-1} \text{m}^{-2}$$

wherefore $\frac{1}{4\pi\epsilon_0} = 9 \times 10^9$

$$F = \frac{9 \times 10^9}{\epsilon_r} \frac{Q_1 Q_2}{r^2}$$

- ▶ For air or free space $\epsilon_r = 1$
- ▶ Since $\epsilon_r > 1$, $F_{\text{air}} > F_{\text{medium}}$
- ▶ ϵ_r is also called dielectric constant (K) of the medium
 - For vacuum $K = 1$, for air $k = 1.008$, for water $K = 80$
- ▶ ϵ_r has no unit or dimensional formula.

Electric field 'E'

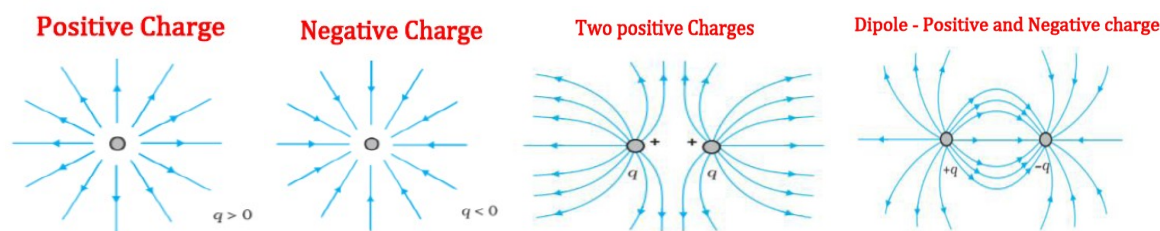
The space around a charge within which its electro static force is experienced is called electric field.

$$E = \frac{F}{q}$$

- ▶ SI unit of Electric field intensity is Newton / coulomb (N C^{-1}) or volt/meter (V m^{-1})
- ▶ E is a vector quantity
- ▶ Force experienced by a charge q placed in an electric field of strength E is given by $F = qE$

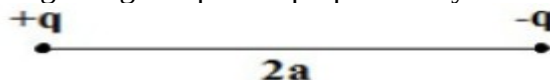
Electric Field Lines or Electric Lines of Forces

Diagrammatic visualization of electric field around a charged configuration is called Electric field lines.



Electric dipole

A pair of equal and opposite charges separated by a small distance is called an electric dipole. Figure shows an electric dipole having charges $+q$ and $-q$ separated by a distance $2a$.



Electric dipole moment :

The strength a dipole is measured in terms of its dipole moment which is defined as the product of magnitude of one of the charges and length of the dipole .

Ie Dipole moment $P = Q 2a$

- ▶ P is a vector quantity directed from negative to positive charge along the axis of the dipole
- ▶ SI unit of dipole moment is coulomb meter (C m)

Dipole field

The electric field produced by a dipole is called dipole field. The total charge of a dipole is zero, but the dipole field is not zero

i) Field at any point on the axial line of the dipole

$$E = \frac{1}{4\pi\epsilon_0} \frac{2P}{r^3}$$

ii) Field at any point on the equatorial line of the dipole

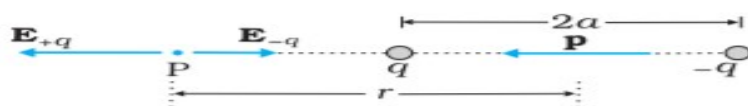
$$E = \frac{1}{4\pi\epsilon_0} \frac{P}{r^3}$$

iii) Field at any point (general case)

$$E = \frac{1}{4\pi\epsilon_0} \frac{P}{r^3} \sqrt{3\cos^2\theta + 1}$$

$$E_{\text{axial}} : E_{\text{equit}} = 2 : 1$$

Case 1: Field at any point on the axial line of the dipole



The electric field at P due to +q

$$E_{+q} = \frac{1}{4\pi\epsilon_0} \frac{q}{(r-a)^2} \quad (\text{in the direction of dipole moment } \vec{p})$$

The electric field at P due to -q

$$E_{-q} = \frac{1}{4\pi\epsilon_0} \frac{q}{(r+a)^2} \quad (\text{opposite to the direction of dipole moment } \vec{p})$$

Total field, $E = E_{+q} - E_{-q}$

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

Thus the total electric field at P

$$E = \frac{q}{4\pi\epsilon_0} \left[\frac{1}{(r-a)^2} - \frac{1}{(r+a)^2} \right]$$

On simplifying we get

$$E = \frac{q}{4\pi\epsilon_0} \left[\frac{4ar}{(r^2 - a^2)^2} \right]$$

For $r \gg a$, there for

$$E = \frac{1}{4\pi\epsilon_0} \left[\frac{4qa}{r^3} \right] \quad 2qa = \vec{p} \text{ (dipole moment)}$$

$$\vec{E} = \frac{1}{4\pi\epsilon_0} \left[\frac{2\vec{p}}{r^3} \right]$$

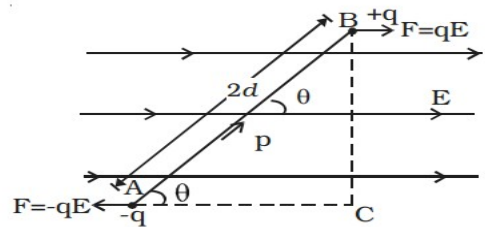
Torque on an electric dipole placed in an uniform electric field

Consider an electric dipole of length $2a$ placed in a uniform electric field of strength E making an angle θ with field.

Torque = Force x Perpendicular distance between forces

$$\begin{aligned} \tau &= F (BC) \\ &= QE (AB \sin\theta) \\ &= QE (2a \sin\theta) \\ &= Q 2a E \sin\theta \\ \tau &= P E \sin\theta, \end{aligned}$$

$$\tau = \vec{P} \times \vec{E}$$



Dipole in a uniform field

Electric flux

Total number of electric lines of force passing through a given surface is called flux through it. Then flux of electric field through the area element dS

$$d\Phi = E dS \cos \theta$$

The electric flux through the whole surface is given by

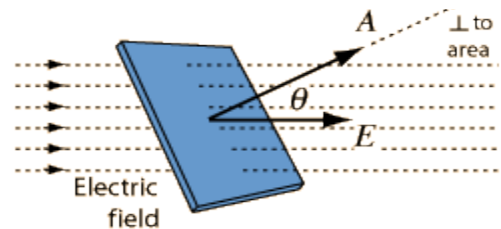
$$\Phi = \int_S d\Phi$$

$$\Phi = \int_S E dS \cos \theta$$

$$\Phi = \int_S \vec{E} \cdot d\vec{S}$$

If the field is uniform over the surface the total flux $\Phi = E S \cos \theta$

- Maximum flux passes through the surface when it is held perpendicular to the electric field (Here $\theta = 0$) $\Phi_{\max} = E S$
- No flux passes through the surface when it is held parallel to the electric field (Here $\theta = 90^\circ$) $\Phi = 0$
- Electric flux is a scalar quantity



➤ SI unit of flux is $\text{NC}^{-1} \text{m}^2$ or V m

Gauss's Theorem

According to this Law "Total electric flux through any closed surface in free space is equal to $1/\epsilon_0$ times the net charge enclosed within the surface".

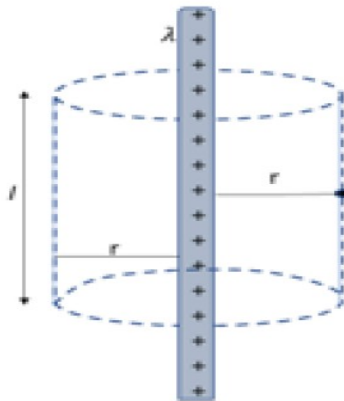
ie
$$\Phi = \frac{1}{\epsilon_0} Q$$

$$\oint_S \mathbf{E} \cdot d\mathbf{S} = \frac{1}{\epsilon_0} Q$$

Where Q is the net charge enclosed and ϵ_0 is the permittivity of free space

Applications of Gauss's Theorem

1. Electric field due to an infinitely long straight charged wire.



To find the electric field at point P at distance r consider cylindrical Gaussian surface of radius r

$$\phi = E S$$

$$\phi = E \times 2\pi r l \quad \text{--- (1)}$$

By Gauss's law $\phi = \frac{q}{\epsilon_0}$

$$\lambda = \frac{q}{l}$$

$$q = \lambda l$$

$$\phi = \frac{\lambda l}{\epsilon_0} \quad \text{--- (2)}$$

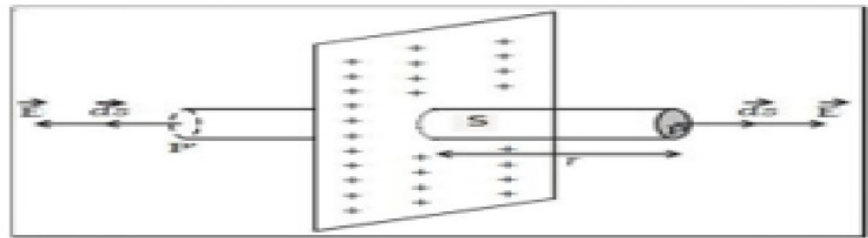
From equations (1) and (2)

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

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

$$E \propto \frac{1}{r}$$

2. Electric Field due to uniformly charged infinite plane sheet.



The field lines cross only the 2 end faces of the Gaussian surface. So the flux through the Gaussian surface

$$\phi = 2 E S \quad \text{--- (1)}$$

By Gauss law

$$\phi = \frac{q}{\epsilon_0} \quad (\sigma = q/S)$$

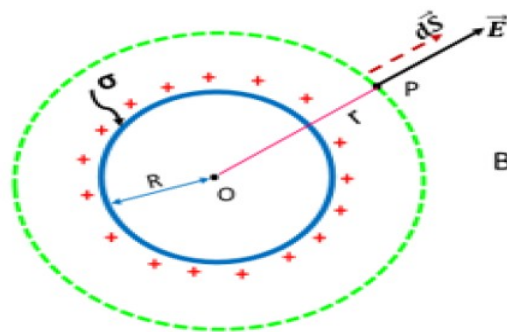
$$\phi = \frac{\sigma S}{\epsilon_0} \quad \text{--- (2)}$$

From equations (1) and (2)

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

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

Electric Field due to a uniformly charged thin spherical shell



a) Field outside the shell

$$\phi = ES$$

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

By Gauss's law $\phi = \frac{q}{\epsilon_0}$

$$\phi = \frac{\sigma A}{\epsilon_0}$$

$$\sigma = \frac{q}{A}$$

$$q = \sigma A$$

$$\phi = \frac{\sigma \times 4\pi R^2}{\epsilon_0} \longrightarrow (2)$$

From equations (1) and (2) $E \times 4\pi r^2 = \frac{\sigma \times 4\pi R^2}{\epsilon_0}$

$$\boxed{E = \frac{\sigma R^2}{\epsilon_0 r^2}}$$

$$E \propto \frac{1}{r^2}$$

b) field on the surface of the shell

On the surface of shell $r = R$

$$E = \frac{\sigma R^2}{\epsilon_0 r^2}$$

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

E is maximum at the surface of the shell

c) field inside the shell

$$\phi = ES \longrightarrow (1)$$

Inside the shell $q=0$

By Gauss's law $\phi = \frac{q}{\epsilon_0} = 0 \longrightarrow (2)$

From equations (1) and (2)

$$E S = 0 \quad (S \neq 0)$$

$$\boxed{E = 0}$$

Important Previous Questions

1. State Gauss's Theorem. Find electric field due to an infinitely long straight charged wire.
2. Derive an expression for Electric field due to an electric dipole at a point on the axial line.
3. Two point charges $q_1 = 3\mu\text{C}$ and $q_2 = 6\mu\text{C}$ separated by a distance 3m apart in air. Find the electrostatic force between them.
4. Draw electric field lines around
 - a) An isolated negative charge
 - b) An electric dipole

ELECTROSTATICS-CHAPTER 2

ELECTRIC POTENTIAL AND CAPACITANCE

Topics Included

- Electric potential
- Equipotential Surface
- Electric Capacitance
- Capacitance of PPC
- Combinations of Capacitors
- Energy stored in a capacitor

Electric Potential 'V'

The work done in bringing a unit positive test charge (without acceleration) from infinite to a point in an electric field gives the potential at the point.

Electric Potential

$$V = W/q$$

- SI unit of potential is J/C or volt (V)
- Potential is a scalar quantity
- Potential due to an isolated positive charge is positive and negative charge is negative

Potential due to a point charge

$$V = \frac{1}{4\pi\epsilon_0} \frac{Q}{r} \quad V \propto \frac{1}{r}$$
$$E = \frac{1}{4\pi\epsilon_0} \frac{Q}{r^2} \quad V \propto \frac{1}{r^2}$$

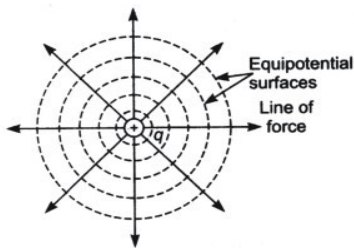
Equipotential surface

A surface with a constant value of potential at all points on it is called equipotential surface

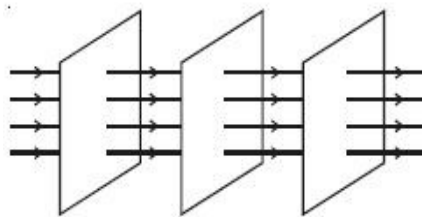
Eg surface of a charged conductor

Properties of Equipotential surface

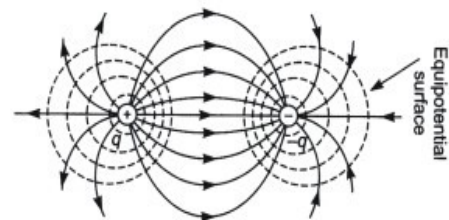
- 1) Potential is same at every point on the ep surface
- 2) Pd between any two points on the ep surface is zero
- 3) No work is done for moving a test charge from one point to other on an ep surface
- 4) Electric field lines are always perpendicular to the ep surface
- 5) For an isolated point charge ep surfaces are concentric spheres with charge at the centre
- 6) For uniform electric field ep surfaces are parallel planes right angles to the lines of force



Point Charge (+q)



Uniform Field



An Electric Dipole

Electric Capacitance 'C'

It is the measure of ability of a conductor to store electric charge. When some charge is given to a conductor its potential rises. The increase in potential is directly proportional to the charge given

$$Q \propto V$$

$$Q = CV \quad \text{or} \quad C = Q/V$$

Where C is a constant called electrical capacitance or capacity of the conductor

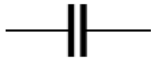
- SI unit of capacitance is 'farad' (F)

Capacitor

Capacitor is a device used to store large amount of electric charge in a very small space. It consists of two conducting plates separated by a dielectric medium or Air.

Symbol of capacitor

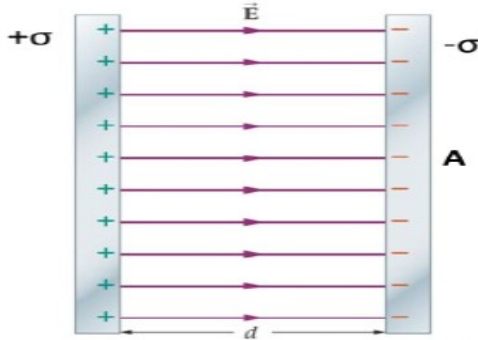
Fixed capacitance



Variable capacitance



Capacitance of a parallel plate capacitor (PPC)



Capacitance, $C = \frac{Q}{V}$

$$Q = \sigma A$$

$$V = Ed$$

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

$$V = \frac{\sigma d}{\epsilon_0}$$

$$C = \frac{\sigma A}{\frac{\sigma d}{\epsilon_0}}$$

$$C = \frac{\epsilon_0 A}{d}$$

Capacitance can be increased,

- By increasing the area of the plates.
- By decreasing the distance between the plates.
- By introducing a dielectric medium between the plates.

Effect of dielectric on capacitance

The capacitance of a parallel plate capacitor when the medium between the plates is air,

$$C_{\text{air}} = \frac{\epsilon_0 A}{d}$$

When dielectric medium of dielectric constant K is placed between the plates, the capacitance,

$$C_{\text{med}} = \frac{K\epsilon_0 A}{d}$$

The capacitance increases K times, where K is the dielectric constant.

$$C_{\text{med}} = K C_{\text{air}}$$

Combination of capacitors

Capacitors can be combined in two ways

1) Series Combination

In series combination charge on each capacitor is same but potential across each capacitor is different.

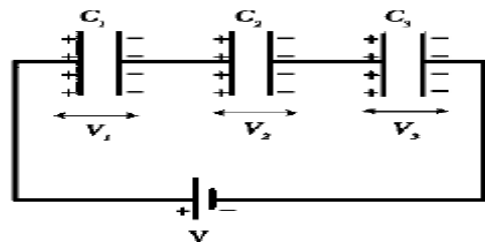
So Net applied voltage $V = V_1 + V_2 + V_3 + \dots$ (1)

We have $V = Q/C$

there for (1) $\Rightarrow Q/C_s = Q/C_1 + Q/C_2 + Q/C_3 + \dots$ (2)

$$Q/C_s = Q[1/C_1 + 1/C_2 + 1/C_3]$$

$$1/C_s = [1/C_1 + 1/C_2 + 1/C_3]$$



2) Parallel Combinations

In parallel combinations Potential on each capacitor is same Charge is different.

Total Charge from Source $Q = Q_1 + Q_2 + Q_3$

$$Q_1 = VC_1 = C_1V$$

$$Q_2 = VC_2 = C_2V$$

$$Q_3 = VC_3 = C_3V$$

$$Q_{\text{para}} = VC_1 + VC_2 + VC_3$$

$$Q_{\text{para}} = V(C_1 + C_2 + C_3)$$

$$\frac{Q}{V} = C_1 + C_2 + C_3$$

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

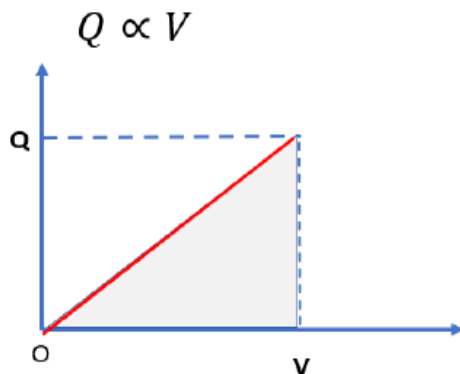
$$C_P = C_1 + C_2 + C_3$$

C_P = Effective (equivalent) capacitance in parallel

For n identical capacitors in parallel $C_P = nC$

Energy Stored in a Capacitor

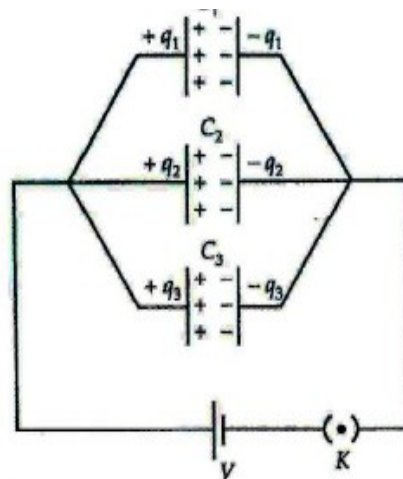
Graphical method



Area under the graph $= \frac{1}{2} QV = \text{Energy}$

Area under Q - V graph

Energy stored in a capacitor



Important Previous questions:

- 1) Explain the Series/Parallel combination of 3 capacitors of capacitances C_1, C_2 and C_3
- 2) Derive an equation for energy stored in a capacitor.
- 3) Give any 2 properties of equipotential surfaces.
- 4) Derive an expression for capacitance of a parallel plate air capacitor.

5) Draw equipotential surface around

- a) An isolated positive charge
- b) An electric dipole
- c) An uniform electric field

CHAPTER 3

CURRENT ELECTRICITY

Ohm's Law

At constant temperature, the current flowing through a conductor is directly proportional to the potential difference between the ends of the conductor

$$V \propto I$$

$$V = RI \quad R \text{ is called the resistance of the conductor}$$

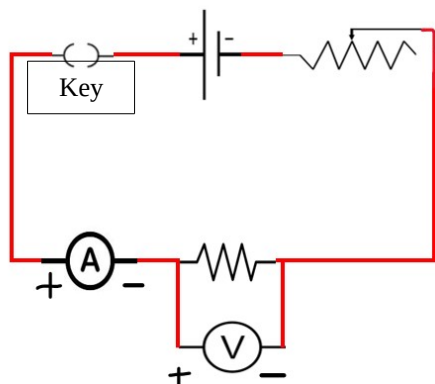
The SI units of R is ohm (Ω .)

Conductance (K)

The reciprocal of resistance is called Conductance

unit :mho (Ω^{-1})siemens

Connection Diagram to study Ohm's Law



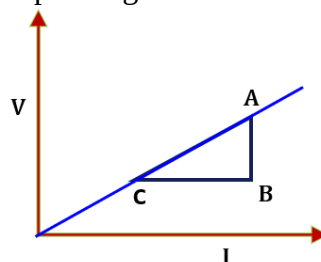
Voltage –Current Graph (V-I Graph)

$$\text{Slope} = AB/BC$$

$$\text{Slope} = V/I = R$$

Slope of V-I graph gives Resistance.

Its reciprocal gives conductance



Factors on which the Resistance of a Conductor Depends

i)Length of the conductor $R \propto l$

ii) Area of cross section of the conductor $R \propto A$

iii) Material of the conductor

iv) Temperature

Resistance of a particular conductor at constant temperature depends only up on length and area

$$R \propto l/A \quad R = \rho l/A \quad \rho \text{ is called Resistivity} \quad \text{Unit } \Omega \text{ m}$$

Conductivity (σ)

Reciprocal of resistivity is called conductivity $\sigma = 1 / \rho$ unit $\Omega^{-1}\text{m}^{-1}$ or mho m^{-1}

Electric Power

Power is the energy dissipated per unit time

$$P = \frac{E}{t}$$

Unit of power is watt(W)

$$E = VI t$$

$$E = \frac{V^2 t}{R}$$

$$E = I^2 R t$$

$$P = \frac{VI t}{t}$$

$$P = \frac{V^2 t}{R} / t$$

$$P = \frac{I^2 R t}{t}$$

$$P = VI$$

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

$$P = I^2 R$$

Electro motive force (emf) and Terminal potential difference of a cell

Electro motive force (emf) is the potential difference between two terminals of a cell in open circuit. Terminal potential difference is the potential difference between two terminals of a cell (or any two points in an electrical circuit) in a closed circuit.

Consider a resistance R connected across a cell of emf E whose internal resistance is r. If a current I is flowing through the circuit, then according to Ohm’s law,

Current through R,
$$I = \frac{\text{emf of the cell}}{\text{total resistance}} = \frac{E}{R+r} \text{ ----- (1)}$$

Potential difference across R,
$$V = I R = \frac{E R}{R+r} \text{ ----- (2)}$$

Rearranging eq (2) we get
$$r = \left[\frac{E-V}{V} \right] R = \left[\frac{E}{V} - 1 \right] R \text{ ----- (3)}$$

Difference between emf and Potential difference

No	emf	P.D
1	Maximum potential difference between the two poles of a cell when the cell is in open circuit.	Difference in potential between two poles of a cell when the cell is in closed circuit.
2	Independent of the resistance of the circuit and depends on the nature of the electrodes and nature of the electrolyte.	Depends on the resistance of the circuit and current flowing through the circuit.
3	Term emf is used for the source of electric current.	The P.d is measured between any two points of the electric circuit.
4	It is a cause.	It is an effect.

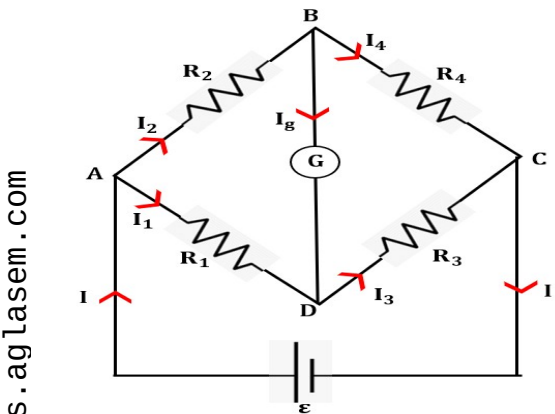
Kirchhoff’s Rules

(a) Kirchhoff’s First Rule - Junction Rule: $\Sigma I=0$

Kirchhoff’s junction rule is in accordance with law of conservation of charge.

(b) Kirchhoff’s Second Rule –Loop Rule: $\Sigma IR= \Sigma E$

Wheatstone Bridge



For a balanced Wheatstone's bridge , the resistors are such that the current through the galvanometer $I_g = 0$.

Apply Kirchhoff's junction rule to junction B & junction D

$$I_2 = I_4 \text{-----}(1)$$

$$I_1 = I_3 \text{-----}(2)$$

Apply Kirchhoff's loop rule to closed loop ABDA

$$I_1 R_1 = I_2 R_2 \text{-----}(3)$$

Apply Kirchhoff's loop rule to closed loop CBDC

$$I_3 R_3 = I_4 R_4 \text{-----}(4)$$

$$\frac{\text{eq (3)}}{\text{eq (4)}} \text{-----} \frac{I_1 R_1}{I_3 R_3} = \frac{I_2 R_2}{I_4 R_4}$$

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

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

This is the balance condition for the galvanometer to give zero or null deflection

CHAPTER 4

MOVING CHARGES AND MAGNETISM

Topics Included

- Magnetic Field
- Magnetic Lorentz force
- Lorentz force
- Biot–Savart law
- Magnetic field on the axis of a circular current loop
- Ampere’s circuital law
- Moving Coil Galvanometer (MCG)
- Conversion of galvanometer in to ammeter
- Conversion of galvanometer in to voltmeter

Magnetic Field ‘B’

It is the space around a magnet or a current carrying conductor or a moving charge with in which its magnetic effect can be experienced.

Magnetic Lorentz force

Force experienced by a charged particle moving through a magnetic field is called Magnetic Lorentz force ,which is given by

$$\mathbf{F} = q (\mathbf{v} \times \mathbf{B})$$

The magnitude of the force is given by

$$\mathbf{F} = q v B \sin \theta$$

where $q \rightarrow$ magnitude of the charge

$v \rightarrow$ velocity of the particle

$B \rightarrow$ strength of magnetic field

$\theta \rightarrow$ angle between direction of motion (v) and direction of magnetic field (B)

- The direction of the force is perpendicular to both velocity and magnetic field

Case I : If $\theta = 0$ or 180 , then $F = 0 \implies$ **path of the particle is straight line**

Case II : If $\theta = 90$,then $F = q v B \sin 90$, $F = q v B$ (maximum force) . $\implies$ **the path of the charged particle is circular.**

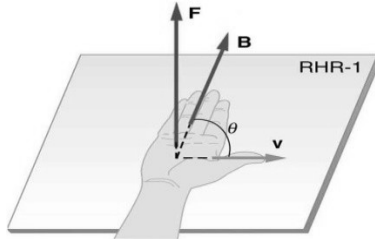
Case III : When the charged particle is moving inclined to the magnetic field ($\theta \neq 0, 90, 180$)
the path of the particle is helical.

Case IV : If the charged particle is at rest ($v = 0$) then $F = 0$

Direction of Magnetic Lorentz force

Fleming’s right hand palm rule

If the thumb of the **right hand** point in the direction of v , the fingers in the direction of B , and the force F is directed perpendicular to the **right hand** palm.



Lorentz Force

Force experienced by a charged particle moving through an electromagnetic field is called Lorentz

$$\mathbf{F} = q\mathbf{E} + q (\mathbf{v} \times \mathbf{B})$$

Magnetic field due to a current element-Biot –Savart Law

Consider a conductor XY of finite length carrying current I. To find the strength of magnetic field at a point p at a distance r, consider an infinitesimal element dl of the conductor.

According to Biot –savart's law "The strength of Magnetic field at p due to this current element is

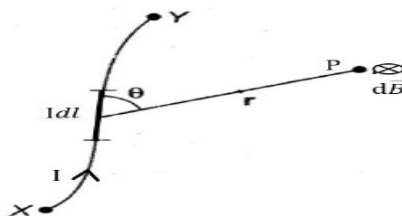
$$dB \propto I$$

$$dB \propto dl$$

$$dB \propto \sin \theta$$

$$dB \propto 1/r^2$$

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



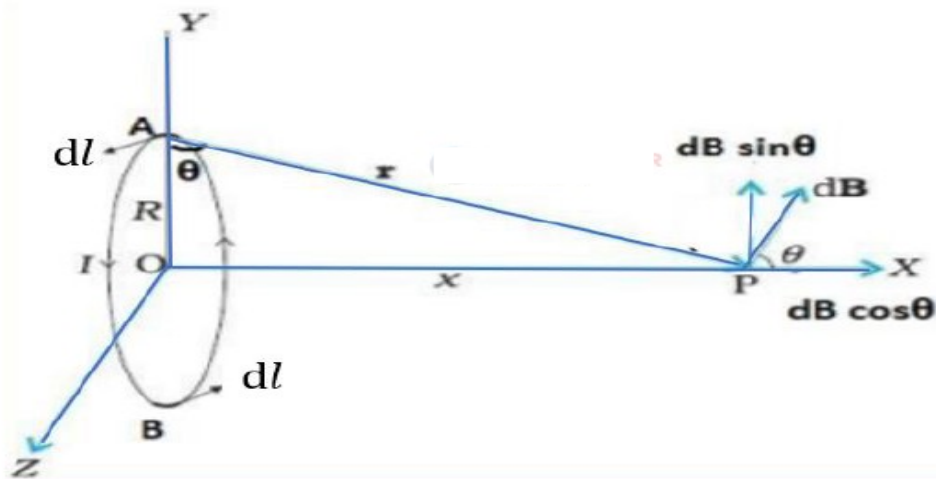
$$dB = \frac{\mu_0}{4\pi} \frac{I dl \sin \theta}{r^2}$$

$\mu_0 = 4\pi \times 10^{-7}$ is a constant called permeability of air or free space.

In vector form

$$dB = \frac{\mu_0}{4\pi} \frac{I (dl \times r)}{r^3}$$

Magnetic Field on the Axis of a Circular Current Loop



$$dB = \frac{\mu_0}{4\pi} \frac{Idl \sin 90}{r^2}$$

$$dB = \frac{\mu_0}{4\pi} \frac{Idl}{r^2}$$

$$r^2 = x^2 + R^2$$

$$dB = \frac{\mu_0}{4\pi} \frac{Idl}{x^2 + R^2} \text{ -----(1)}$$

$$\text{Total field } B = \int dB \cos \theta \text{ -----(2)}$$

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

Substituting for dB and cos theta

$$B = \int \frac{\mu_0}{4\pi} \frac{Idl}{x^2 + R^2} \frac{R}{(x^2 + R^2)^{1/2}} \text{ -----(3)}$$

$$B = \frac{\mu_0}{4\pi} \frac{IR}{(x^2 + R^2)^{3/2}} \int dl$$

$$B = \frac{\mu_0}{4\pi} \frac{IR}{(x^2 + R^2)^{3/2}} \times 2\pi R$$

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

Magnetic field at the centre of the loop

At the centre $x=0$

$$B = \frac{\mu_0 IR^2}{2R^3}$$

$$B = \frac{\mu_0 I}{2R}$$

Ampere's circuital law

“The line integral of magnetic field around any closed loop (path) is equal to μ_0 times net current enclosed by the path”.

$$\oint B \cdot dl = \mu_0 I$$

Where I refers to current enclosed by the path

Moving coil galvanometer

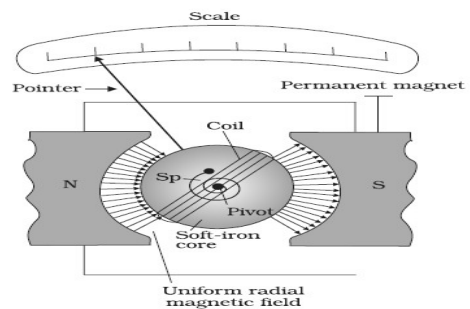
It is a device used to measure or detect small current in an electric circuit

Principle : It is based on the fact that a current carrying coil behaves like a magnetic dipole and experiences torque when placed in an external magnetic field.

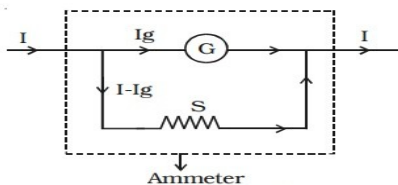
$$N I A B = k \Phi$$

$$I = \frac{k \Phi}{N A B}$$

Now k / NAB is a constant called Galvanometer constant G
therefore $I = G \Phi$ $I \propto \Phi$

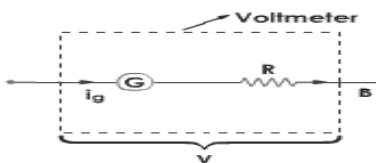


Conversion of galvanometer in to ammeter



$$I_g = IS / G + S$$

Conversion of galvanometer in to voltmeter



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

Important Previous Questions.

1. State Biot-Savart law. Derive an expression for magnetic field due to a circular current carrying coil at a point on the axis of coil.
2. State Ampere's circuital law.
3. How can we convert a moving coil galvanometer in to ammeter and voltmeter.
4. What is the path of charged particle when it moves perpendicular with magnetic field?

CHAPTER-5 MAGNETISM AND MATTER

Topics

- Magnetic dipole
- Magnetic dipole moment.
- Gauss's Law in magnetism.
- Magnetisation.
- Magnetic intensity.

Important points.

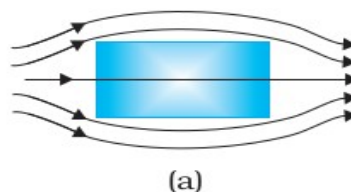
1. **Magnetic dipole** : Two unlike poles of equal strength separated by a small distance.
2. S.I. unit of pole strength (p) is Am .It is a scalar quantity.
3. **Magnetic dipole moment (m)** = pole strength(p) x distance between poles (2L)
$$m = p \cdot 2L$$
4. S.I. unit of magnetic dipole moment is Am². It is a vector quantity.
5. **Gauss's theorem** : The total magnetic flux through any closed surface is zero.

$$\Sigma B \cdot \Delta S = 0$$

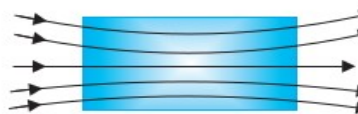
6. Behaviour of magnetic field lines near a

(a) diamagnetic,

(b) Ferromagnetic or paramagnetic substance.



(a)



(b)

6. **Magnetisation M** of a sample to be equal to the net magnetic moment per unit volume . $M = \frac{m}{V}$
7. **Magnetic intensity** $H = \frac{B}{\mu_0}$
8. **Magnetic susceptibility (χ_m)** : It is the ratio of intensity of magnetisation and the magnetic intensity of the magnetic field

Important Questions:

1. State gauss's law for magnetism.
2. Which physical quantity has the unit Wb m⁻² ? Is it a scalar or a vector quantity ?
3. S.I. unit of magnetic induction is

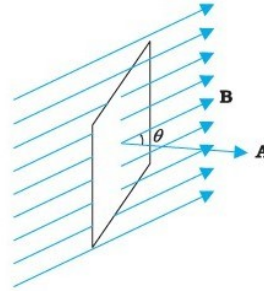
CHAPTER 6

ELECTROMAGNETIC INDUCTION

Magnetic flux ϕ

$$\phi = NBA \cos \theta$$

N-no of turns of coil,
B – magnetic field,
A – Area of coil
 θ -Angle between **B** and **A**



Faraday's Law of electromagnetic Induction

I Law: The definition of electromagnetic induction- Whenever the magnetic flux linked with a coil changes an emf is induced at the two ends of the coil. This phenomenon is called electromagnetic induction, emf so generated is called induced emf.

II law: the magnitude of the induced emf is equal to the rate of change of magnetic flux linked with the coil.

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

Lenz's Law

The direction of induced current is such that which is always opposing the cause producing it.

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

Lenz's Law is in accordance with law
of Conservation of Energy

Motional emf

When a conductor of length l moving with velocity v perpendicular to magnetic field B , an emf is induced at two ends of the conductor. It is called motional emf

$$\epsilon = Blv$$

Self-Induction

The phenomenon of production of induced emf in a coil itself when current through the coil changes is called self induction

The magnetic flux linked with the coil is proportional to the current through the coil.

$$\phi \propto I$$

$$\phi = LI$$

L is called **self-inductance** of the coil. Its unit is Henry (H)

When the current is varied, the flux linked with the coil also changes and an emf is induced in the coil. This **induced emf** is also called **back emf**

$$\epsilon = -\frac{d\phi}{dt} \quad \phi = LI \quad \epsilon = -L \frac{dI}{dt}$$

Self Inductance of a Solenoid

Consider a solenoid of cross sectional area A and length l , having n turns per unit length and N no of turns, $N=n l$ or $n=N/l$

If I be the current flows through the solenoid

The magnetic flux linked with solenoid

$$\phi = LI \text{ -----(1)}$$

Also we have $\phi = NBA \cos \theta$ here $\theta=0$ and $\cos \theta=1$ and inside solenoid $B = \mu_0 n I$

$$\phi = N (\mu_0 n I) A \text{ -----(2)}$$

From equations (1) & (2) $LI = N (\mu_0 n I) A$

$$L = \mu_0 N n A \text{ -----(3)}$$

Put $N=n \ell$ in equation (3) $L = \mu_0 n^2 A \ell \text{ -----(4)}$

Put $n=N/\ell$ in equation (3) $L = \mu_0 N^2 A / \ell \text{ -----(5)}$

Equations (3),(4) & (5) are different forms of self inductance of solenoid

Mutual induction

The phenomenon of production of induced emf in a coil by varying the current through a neighbouring coil is called mutual-induction

The magnetic flux linked with the coil is proportional to the current through the neighbouring coil.

$$\phi \propto I$$

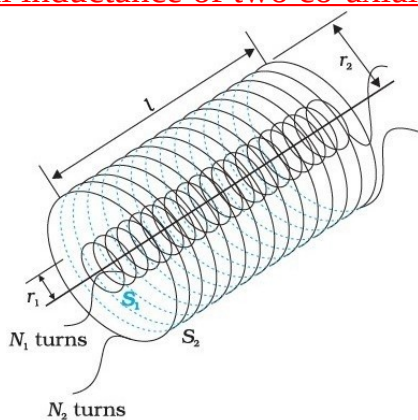
$$\phi = M I$$

M is called mutual-inductance of the coil

When the current in the neighbouring coil is varied, the flux linked with the first coil changes and an emf is induced in the coil.

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

Mutual inductance of two co-axial solenoids



$$M_{12} = \mu_0 n_1 n_2 \pi r_1^2 l$$

Energy stored in an inductor

Small work done $dw = P dt \text{ -----(1)}$

(electric Power $P = \varepsilon I$ & Induced emf $\varepsilon = -L \frac{dI}{dt}$)

$$dw = \left(L \frac{dI}{dt} I \right) dt$$

$$dw = L I dI \text{ -----(2)}$$

Total work done $W = \int dw$

$$W = L \int I dI \text{ -----(3)}$$

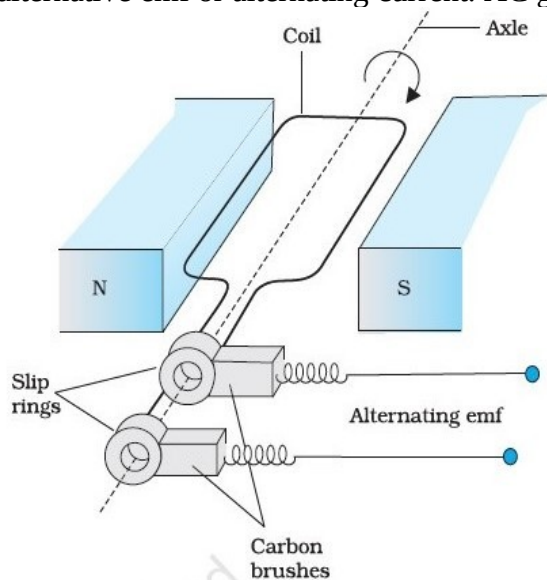
$$W = \frac{LI^2}{2} \text{-----(4)}$$

This work done is stored in the magnetic field of inductor as potential energy

$$\text{Energy stored in an inductor } U = \frac{LI^2}{2}$$

Ac Generator

An AC generator is a device that converts mechanical energy into electrical energy in form of alternative emf or alternating current. AC generator works on the principle of Electromagnetic Induction



When coil rotates with constant angular frequency ω magnetic flux linked with coil changes and induced emf is produced.

$$\phi = NBA \cos \theta$$

$$\theta = \omega t \quad \varepsilon = \frac{-d\phi}{dt}$$

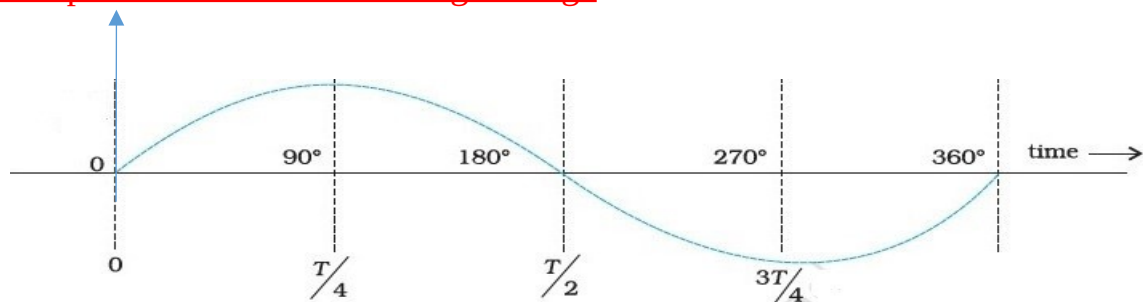
$$\varepsilon = -NBA \frac{d(\cos \omega t)}{dt}$$

$$\varepsilon = NBA \omega \sin \omega t$$

$$\varepsilon = v \wedge NBA \omega = V_0 \text{---Peak value of alternating voltage}$$

$$V = V_0 \sin \omega t$$

Graphical representation of Alternating Voltage



CHAPTER-7

ALTERNATING CURRENT

Topics

- AC Voltage applied to a Resistor.
- Representation of AC Current and Voltage by rotating vectors – PHASORS.
- AC Voltage applied to an Inductor.
- AC Voltage applied to a Capacitor.
- AC Voltage applied to a series LCR Circuit.
- Power in an AC circuit and the power factor.
- Transformers

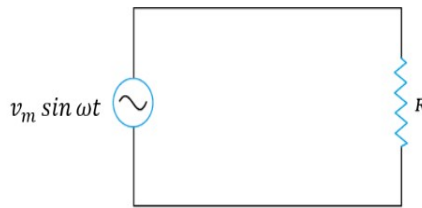
Important points.

1. The rms current (Root Mean Square Current) or Effective Current:

$$I_{\text{rms}} \text{ or } I = \frac{i_m}{\sqrt{2}}$$

$$\text{The rms voltage, } V_{\text{rms}} \text{ or } V = \frac{V_m}{\sqrt{2}}$$

2. AC Voltage Applied to a Resistor :



$$V_m \sin \omega t - i R = 0$$

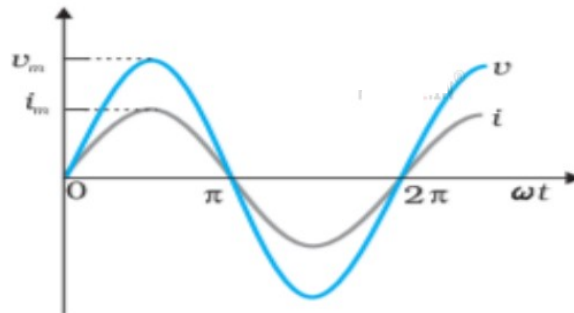
$$V_m \sin \omega t = i R$$

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

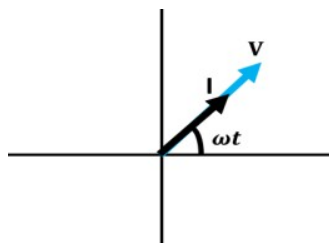
$$\mathbf{i = i_m \sin \omega t}$$

where $i_m = \frac{V_m}{R}$ is called maximum value of current or peak value of current.

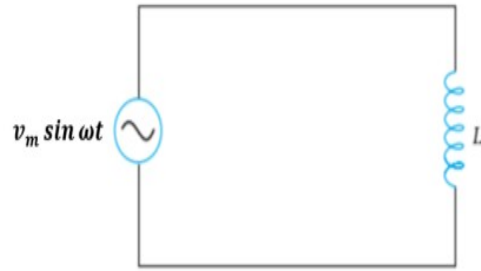
Graphical representation of v and i versus ωt



Phasor diagram



3. AC Circuit containing an Inductor:



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

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

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

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

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

$$i = -\frac{V_m}{\omega L} \cos \omega t$$

$$\mathbf{i = i_m \sin (\omega t - \pi/2)}$$

where $i_m = \frac{V_m}{\omega L}$ is the peak value of current.

In a pure inductor, the current lags the voltage by $\pi/2$.

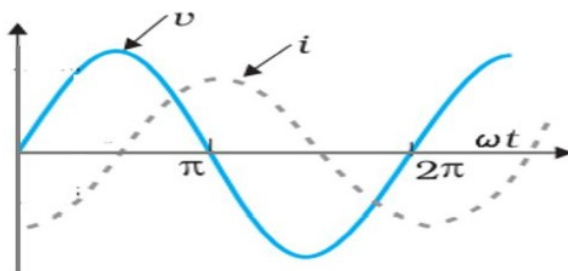
Inductive Reactance (X_L):

The current amplitude, $i_m = \frac{V_m}{\omega L}$

The quantity ωL is analogous to the resistance and is called inductive reactance, denoted by X_L

$$X_L = \omega L = 2\pi fL$$

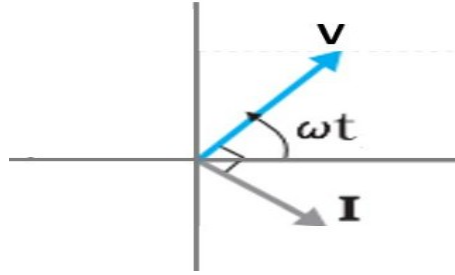
Graphical representation of v and i versus ωt



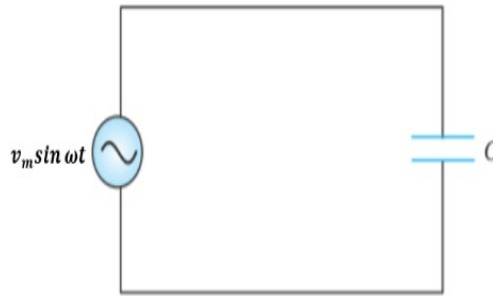
$$v = v_m \sin \omega t$$

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

Phasor diagram



4. AC Circuit containing Capacitor :



$$V_m \sin \omega t - \frac{q}{C} = 0$$

$$V_m \sin \omega t = \frac{q}{C}$$

$$q = CV_m \sin \omega t$$

$$i = \frac{d}{dt} (CV_m \sin \omega t)$$

$$i = C V_m \omega \cos \omega t$$

$$i = C \omega V_m \cos \omega t$$

$$i = i_m \cos \omega t$$

$$\mathbf{i = i_m \sin (\omega t + \pi/2)}$$

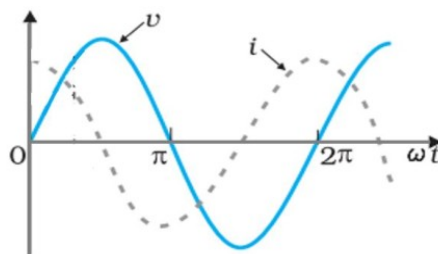
$$i_m = \frac{V_m}{(1/\omega C)} \text{ is the peak value of current.}$$

In a purely capacitive circuit, the current leads the voltage by $\pi/2$.

The quantity $(1/\omega C) = X_c$ is analogous to the resistance and is called capacitive reactance.

$$X_c = (1/\omega C) = \frac{1}{2\pi f C}$$

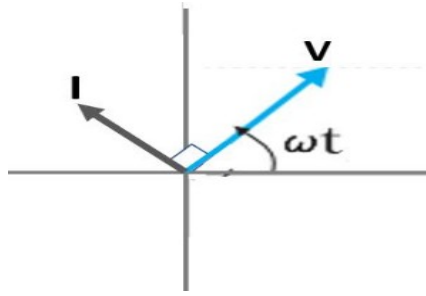
Graphical representation of v and i versus ωt :



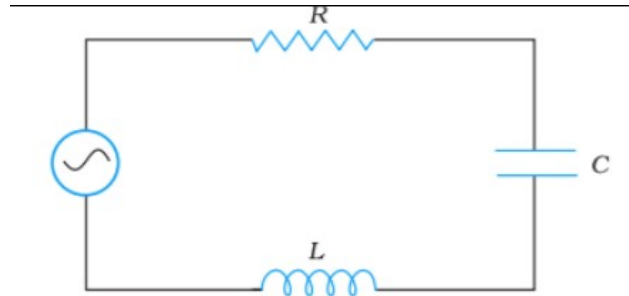
$$v = v_m \sin \omega t$$

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

Phasor diagram :



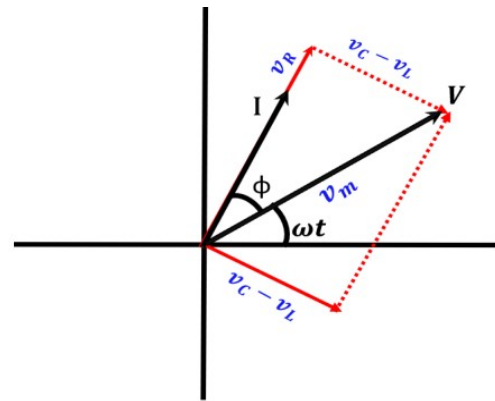
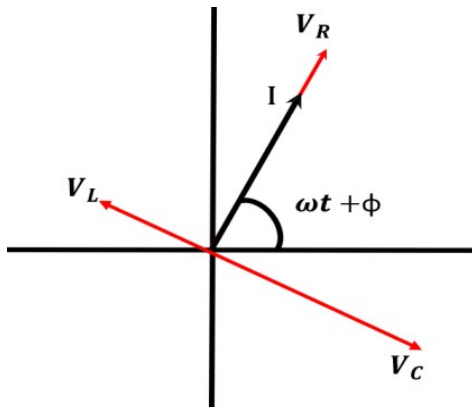
5. AC Voltage Applied to a Series LCR Circuit:



V_R be the potential difference across R , and in phase with I.

V_C be the potential difference across C , which lags the current I by $\pi/2$ or 90°

V_L be the potential difference across L , which leads the current I by $\pi/2$ or 90°



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

$$V_m^2 = (i_m R)^2 + (i_m X_C - i_m X_L)^2$$

$$V_m^2 = i_m^2 [(R)^2 + (X_C - X_L)^2]$$

$$i_m^2 = \frac{V_m^2}{(R)^2 + (X_C - X_L)^2}$$

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

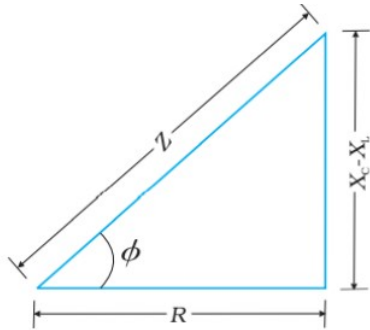
$$i_m = \frac{V_m}{Z}$$

The quantity $\sqrt{(R)^2 + (X_C - X_L)^2}$ is analogous to resistance and is called impedance Z in an

ac circuit.

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

Impedance Triangle



The phase difference ϕ between voltage and current is ,

$$\phi = \tan^{-1} \frac{X_C - X_L}{R}$$

6. Resonance

When $X_C = X_L$, $Z = R$ and $\phi = 0$. This is condition for resonance.

Resonance frequency $f = \frac{1}{2\pi\sqrt{LC}}$

7. Power in an AC circuit

Power In AC Circuit , $P = V I$

$$P = V_m \sin \omega t \times i_m \sin (\omega t + \phi)$$

$$P = V_{rms} I_{rms} \cos \phi$$

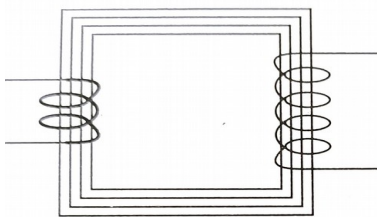
The quantity $\cos \phi$ is called the **power factor**.

8. Transformers

Principle – It works on the principle of electromagnetic Induction When current in one circuit changes, an induced current is set up in the neighbouring circuit.

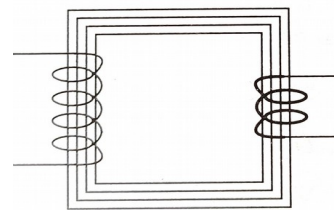
Step-up Transformer

Primary secondary



Step-down transformer

Primary secondary



Working : Alternating emf is supplied to the primary coil PP'. The resulting current produces an induced current in secondary. Magnetic flux linked with primary is also linked with the secondary. The induced emf in each turn of the secondary is equal to that induced in each turn of the primary.

Alternating emf applied to primary , $E_p = -n_p \frac{d\phi}{dt}$... (1)

where n_p be the number of turns in the primary

Induced emf in the secondary, $E_s = -n_s \frac{d\phi}{dt}$... (2)

where n_s be the number of turns in the primary

Dividing eq (2) in (1) we get $\frac{E_s}{E_p} = \frac{n_s}{n_p} = k$

Transformation ratio.

For step-up transformer, $K > 1$ $\therefore E_s > E_p$

For step-down transformer, $K < 1$ $\therefore E_s < E_p$

According to law of conservation of energy, Input power = output power

$$E_p I_p = E_s I_s$$

$$\therefore \frac{E_s}{E_p} = \frac{I_p}{I_s}$$

Important questions:

1. A series LCR circuit connected to an AC source .
 - i) Write an expression for impedance offered by the circuit .
 - ii) Draw an impedance diagram and write the expression for the power factor from the diagram.
2. i) What are the condition for resonance in a series LCR circuit. Write the expression for resonance frequency.
 - ii) At resonance in an LCR circuit the emf and current are
3. The S.I. unit of inductive reactance is.....
4. A transformer steps down 220V to 11V. What is the transformer ratio ?

CHAPTER-8

ELECTROMAGNETIC WAVES

Topics

- Displacement current.
- Electromagnetic waves.

Important points.

1. Displacement current:

Displacement current is that current which comes into play in vacuum or dielectric when electric field is changing with time.

$$I_d = \epsilon_0 \frac{d\phi}{dt}$$

Maxwell introduced the idea of displacement current for the consistency of Amperes equation.

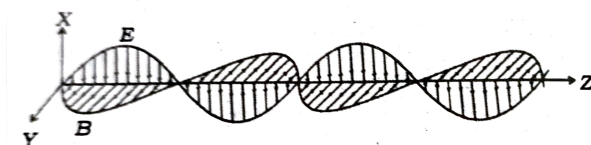
$$\oint_1 \vec{B} \cdot d\vec{l} = \mu_0 (I_c + I_d) .$$
$$= \mu_0 (I_c + \epsilon_0 \frac{d\phi_E}{dt})$$

Characteristics of displacement current :

- $I_d = 0$ in a conductor
- I_d not equal to zero in vacuum and dielectric
- In series circuit $I_d = I_c$ where I_c is the conduction current.
- I_d is produced by the rate of change of electric field.

2. Electromagnetic waves:

Oscillating charges can produce electromagnetic waves.



For a plane electromagnetic wave propagating along x- direction is represented by

$$E_x = E_0 \sin (kz - wt)$$

Magnetic field along y-direction is given by

$$B_y = B_0 \sin (kz - wt)$$

Properties

Velocity of electromagnetic waves in vacuum is given by

$$c = \frac{1}{\sqrt{\mu_0 \epsilon_0}} = \frac{E_0}{B_0} = 3 \times 10^8 \text{ ms}^{-1}$$

In a material medium,

$$\text{velocity } v = \frac{1}{\sqrt{\mu \epsilon}} = \frac{c}{\sqrt{\mu_r \epsilon_r}}$$

The ratio of magnitudes of electric and magnetic field vectors in free space is constant

$$\text{i.e., } c = \frac{E}{B} \quad E \text{ and } B \text{ are in same phase.}$$

No medium is required for propagation, transverse in nature

Electromagnetic waves show properties of reflection, refraction, interference, diffraction and polarisation.

Electromagnetic waves have capability to carry energy from one place to another.

ELECTROMAGNETIC SPECTRUM

a) Radio waves

Radio waves are produced by the accelerated motion of charges in conducting wires. They are used in radio and television communication systems. Used in mobile communication.

b) Micro waves

Due to their short wavelengths, they are suitable for the radar systems used in aircraft navigation, Microwave ovens, communication satellite, cell phone network, etc.

c) Infrared waves

Infrared waves are produced by hot bodies and molecules. Infrared lamps are used in physical therapy. Infrared rays are widely used in the remote switches of household electronic systems such as TV, video recorders etc. Used to take photographs in darkness. Used in solar water heaters

d) Visible light

It is the part of the spectrum that is detected by the human eye. Visible light emitted or reflected from objects around us provides us information about the world.

e) UV rays

Sun is an important source of ultraviolet light. UV lamps are used to kill germs. Used for eye surgery, preserve food etc.

f) X-rays

X-rays are used as a diagnostic tool in medicine and as a treatment for certain forms of cancer. Used for study of atomic structure. Used to detect fractures.

g) Gamma rays

They lie in the upper frequency range of the electromagnetic spectrum. They are used in medicine to destroy cancer cells, radiation therapy. Used for inspection of material.

Important Questions

- Which of the following is not an electromagnetic wave.
i) X-rays ii) γ -rays iii) β -rays iv) Microwaves.
- An electromagnetic wave propagates through a medium of permittivity ϵ and permeability μ .
What is the speed of this wave through the medium?
- Arrange the following radiations in an ascending order in respect of their frequencies
X-rays, microwaves, UV rays and microwaves.
- Name the following constituent radiations of electromagnetic spectrum which
i) produce intense heating effect ii) is absorbed by the ozone layer in the atmosphere
iii) is used for studying crystal structure. iv) is used in satellite communication
- What is displacement current?

CHAPTER-9

RAY OPTICS AND OPTICAL INSTRUMENTS

Topics

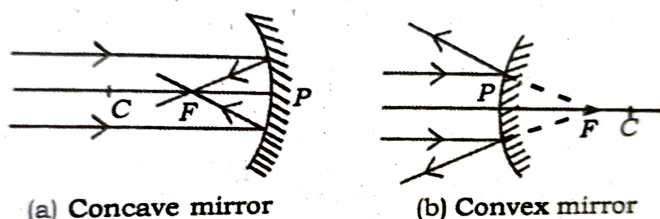
- Laws of Reflection.
- Refraction of light by spherical mirrors.
- Relation between focal length and Radius of curvature.
- The mirror equation.
- The linear magnification.
- Laws of refraction.
- Refraction at a spherical surface.
- Lens makers formula.
- Power of a lens.
- Refraction through a prism.
- Simple microscope.
- Compound microscope.

Important points.

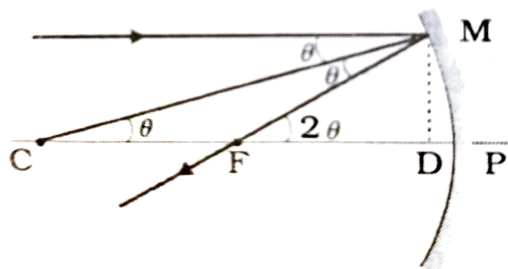
1. **Laws of reflection:**

- i) The incident ray, reflected ray and the normal at the point of incidence all lie in a same plane.
- ii) The angle of incidence is equal to angle of reflection. $i = r$.

2. **Reflection of light by spherical mirrors :**



3. **Relation between focal length and Radius of curvature.**



$$\text{From } \triangle MDC, \tan \theta = \frac{MD}{DC} \text{----- (1)}$$

$$\triangle MDF, \tan 2\theta = \frac{MD}{DF} \text{----- (2)}$$

$$\begin{aligned} (1) \quad & \frac{1}{2} = \frac{DF}{DC} = \frac{f}{R} \quad ; \\ (2) \quad & \end{aligned}$$

$$\mathbf{R = 2f \quad \text{or} \quad f = \frac{R}{2}}$$

4. **The mirror equation :**

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

5. **Linear magnification :** $m = -\frac{v}{u}$

6. **Laws of Refraction:**

- The incident ray , refracted ray and the normal to the surface at the point of incidence lie in the same plane.
- Snell's law : The ratio of sin of angle of incidence to the sin of angle of refraction is a constant for a given pair of media and for a given colour of light.

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

If c is the velocity of light in vacuum and v is that in a medium, the absolute refractive index of the medium is

$$n = \frac{c}{v}$$

7. **Refraction at a spherical surface :**

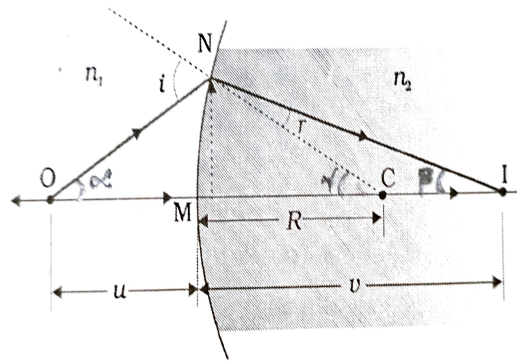


Fig shows formation of image I of an object O on the principle axis of a spherical surface with centre of curvature C and radius of curvature R.

By snell's law , $n_1 \sin i = n_2 \sin r$

For small angles , $n_1 i = n_2 r$

For ΔONC , $i = \alpha + \gamma$

For ΔNCI , $\gamma = r + \beta$ or $r = \gamma - \beta$

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

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

From ΔOMN , $\tan \alpha = \frac{NM}{OM} = \frac{NM}{u}$

From ΔMNC , $\tan \gamma = \gamma = \frac{NM}{MC} = \frac{NM}{R}$

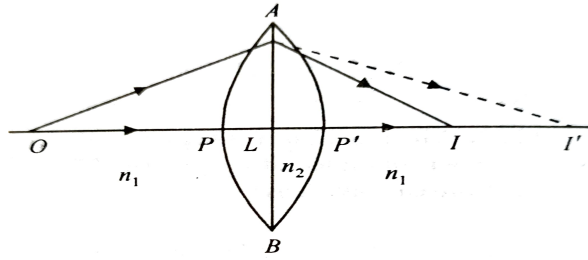
From ΔMNI , $\tan \beta = \beta = \frac{NM}{MI} = \frac{NM}{v}$

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

Applying sign convention $u = -ve$, $v = +ve$ and $R = +ve$ we get ,

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

8. Lens makers formula :



For refraction at first surface APB, we get
$$\frac{n_2}{v'} - \frac{n_1}{u} = \frac{(n_2 - n_1)}{R_1} \quad \text{----- (1)}$$

$v' = PI'$ and $R_1 =$ Radius of curvature of 1st surface.

For refraction at second surface AP'B, we get
$$\frac{n_1}{v} - \frac{n_2}{v'} = \frac{(n_1 - n_2)}{R_2} \quad \text{----- (2)}$$

$v = PI$ and $R_2 =$ Radius of curvature of 2nd surface.

Adding (1) + (2), we get
$$n_1 \left[\frac{1}{v} - \frac{1}{u} \right] = (n_2 - n_1) \left[\frac{1}{R_1} - \frac{1}{R_2} \right]$$

Dividing both sides by n_1 , we get,

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

Let the lens be placed in air, $n_1 = 1$ and $n_2 = n$.

$$\frac{1}{v} - \frac{1}{u} = (n - 1) \left[\frac{1}{R_1} - \frac{1}{R_2} \right] \quad \text{----- (3)}$$

When $u = \infty$, then $v = f$

$$\frac{1}{f} = (n - 1) \left[\frac{1}{R_1} - \frac{1}{R_2} \right] \quad \text{----- (4)}$$

This is the Lens makers formula.

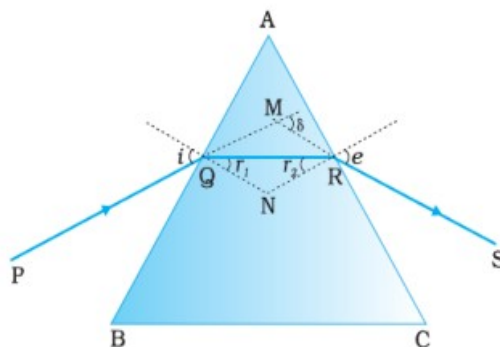
Comparing (3) and (4), we get
$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f} \quad \text{.This is the lens formula.}$$

9. Power of a lens

Power of a lens is defined the reciprocal of its focal length expressed in metre..

$$P = \frac{1}{f} \quad \text{S.I. unit of power is dioptre (D).}$$

10. Refraction through a prism.



$$\angle A + \angle QNR = 180^\circ$$

In the quadrilateral AQNR,

From ΔQNR ,
$$r_1 + r_2 + \angle QNR = 180^\circ$$

From the above equations,
$$r_1 + r_2 = A \text{ ----- (1)}$$

We know, exterior angle = sum of interior angles, thus $d = (i - r_1) + (e - r_2)$

$$d = (i + e - (r_1 + r_2)) \text{ or } d = (i + e - A)$$

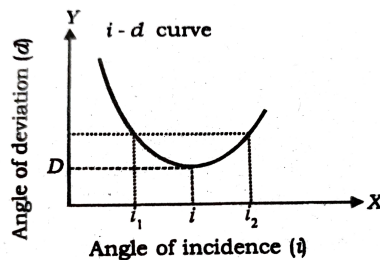
At the minimum deviation, $d = D$, $i = e$, $r_1 = r_2 = r$ therefore

Equation (1) becomes,
$$2r = A \text{ or } r = \frac{A}{2}$$

Equation (2) becomes,
$$A + D = 2i \text{ or } i = \frac{A + D}{2}$$

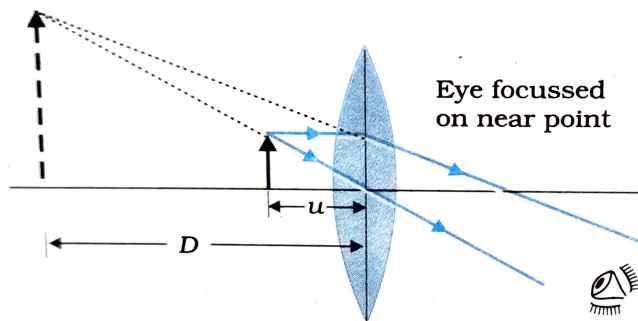
Refractive index ,
$$n = \frac{\sin \frac{A + D}{2}}{\sin \frac{A}{2}}$$

i - d curve



12. Microscopes

I. Simple microscope:



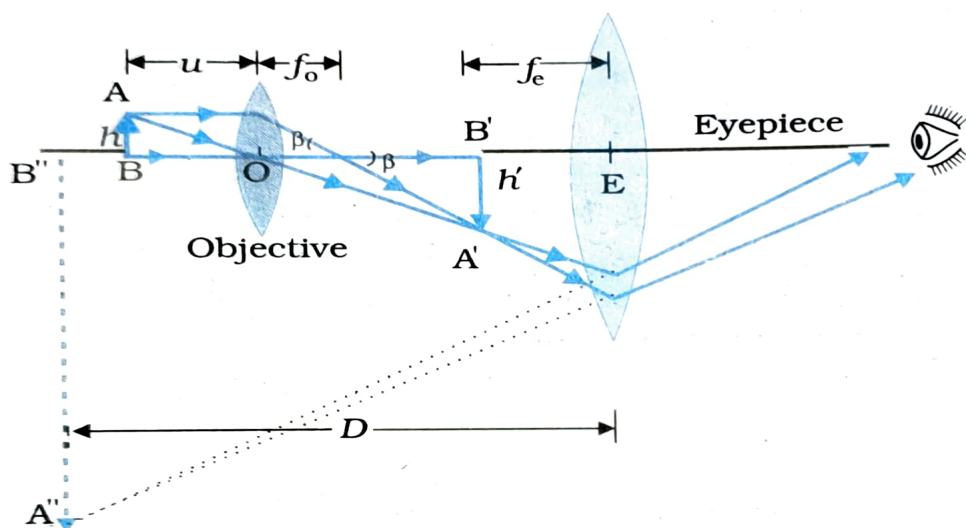
The object to be magnified is placed in between the principle focus and the optic centre of the lens. A magnified , virtual erect image is formed at the least distance of distinct vision(D).

Magnifications,
$$m = 1 - \frac{V}{f}$$

At the least distance of distinct vision , $V = - D$

Magnification ,
$$m = 1 + \frac{D}{f}$$

II. Compound microscope :



Magnification due to objective , $m_0 = \frac{L}{f_0}$ where L – distance between objective and eyepiece.
 f_0 - focal length of objective.

As the first image is near the focal point of eyepiece , the magnification due to eyepiece is

$$m_e = 1 + \frac{D}{f_e}$$

When the image is formed at infinity ,

$$m_e = \frac{D}{f_e}$$

Total magnification, $m = m_0 \times m_e$

$$m = \frac{L}{f_0} \times \frac{D}{f_e}$$

Important Questions :

1. Consider refraction of light at a spherical surface separating two media of refractive indices n_1 and n_2 ($n_2 > n_1$). With the help of ray diagram show the formation of image of point object placed in the medium of refractive index n_1 .
2. i) Define power of a lens. What is its unit ?
 ii) Derive the lens makers formula.
3. i) Draw the diagram showing the path of a monochromatic light through a triangular prism.
 ii) What do you mean by angle of minimum deviation ?
 Iii) Arrive at the expression

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

4. Draw the ray diagram showing the formation of image by a compound microscope. Derive expression for its magnification.
5. Draw ray diagram of simple microscope that uses a single convex lens. Derive an expression for its linear magnification.

CHAPTER 10

WAVE OPTICS

Topics Included

- Wavefront
- Huygen's Principle
- Superposition Principle
- Coherent Sources of light
- Interference Of Light
- Polarization
- Law of Malus

Wavefront

When a wave propagates through a medium, the particles of the medium vibrate about their mean position. The locus of all particles of the medium vibrating in the same phase at a given instant constitute a wave front.

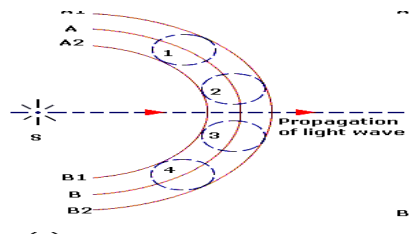
Wave fronts are of three types



Huygen's Principle

According to this principle

- 1) "Each point of the given wave front is a source of secondary wavelets. The secondary wavelets from these points spread out in all direction with speed of the wave".
- 2) "The position of a wave front after a time t is given by the forward envelop of these secondary wave lets".



Superposition Principle

When two or more wave propagates through a medium simultaneously; the resultant displacement of a particular point in the medium at any instant will be the vector sum of displacement due to individual waves

ie $\mathbf{Y} = \mathbf{Y}_1 + \mathbf{Y}_2 + \mathbf{Y}_3 + \mathbf{Y}_4$

a) Constructive Superposition

Crest of one wave falls on crest of other (or trough on trough)
the amplitude and intensity of resultant wave increases.

b) Destructive superposition

Here crests of one wave falls on trough of other,
the amplitude and intensity of resultant wave decreases.

Coherent sources of light

Two light sources are said to be coherent if they emit light waves of same frequency, (wave length), and nearly same amplitude also the waves must be in the same phase or must have constant phase difference.

Interference

The phenomenon of re distribution of energy due to the super position of light waves from two coherent sources is called interference.

Condition for constructive interference

Phase difference $\Phi = 2 n \pi$

Path difference $\delta = n \lambda$

Where $n = 0, 1, 2, 3, \dots$

Amplitude of resultant wave

Expression for fringe width

$$\beta = \lambda D / d$$

$$R_{\max} = (a + b)$$

Intensity of Resultant wave

$$I_{\max} = (a + b)^2$$

Condition for destructive interference

$$\text{Phase difference } \Phi = (2n + 1)\pi$$

$$\text{Path difference } \delta = (2n + 1)\frac{\lambda}{2}$$

Where $n = 1, 2, 3, \dots$

2

Amplitude of resultant wave

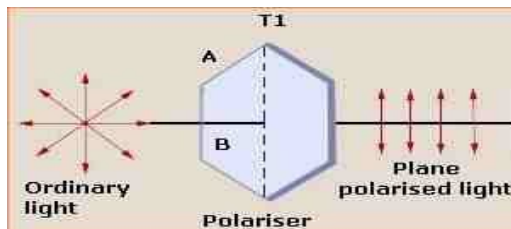
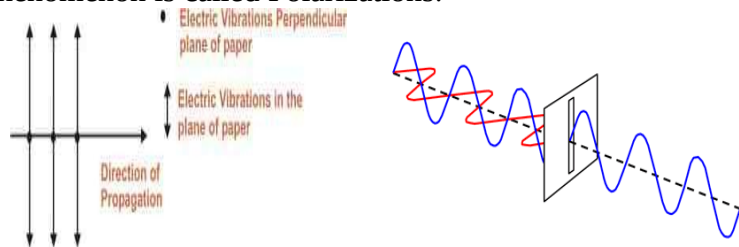
$$R_{\min} = (a - b)$$

Intensity of Resultant wave

$$I_{\min} = (a - b)^2$$

Polarization

When unpolarised light is allowed to pass through certain crystals like Tourmaline, calcite etc., the light emerging from the crystal contains electric field vectors vibrating in a single plane (Polarised light) this phenomenon is called Polarizations.



Law of Malus

“The intensity of polarized light transmitted through the analyzer varies as the square of cosine of angle between the pass axis of polarizer and analyzer”. Let

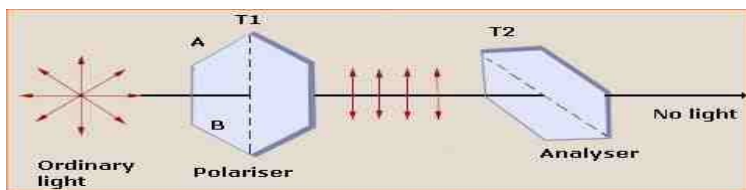
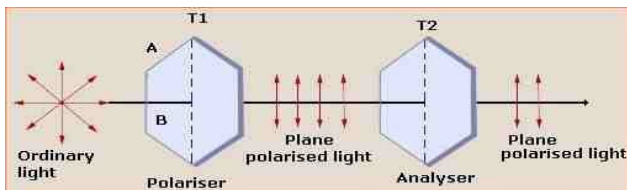
$I \rightarrow$ intensity of light transmitted through the analyzer

$I_0 \rightarrow$ the intensity of light falling on analyzer

$\theta \rightarrow$ angle between the pass axis of polarizer and analyzer

$$I \propto \cos^2 \theta$$

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



Important Previous Questions

1. State Huygen's Principle
2. Define Interference of light. Give the expression of fringe width.
3. Define polarization.
4. State Malu's Law
5. State Brewster's Law
6. Explain Polarization by scattering.

Chapter 11

DUAL NATURE OF RADIATION AND MATTER

Different methods to emit electrons from metal surface

1. Thermionic emission 2. Field emission 3. Secondary emission 4. Photo-electric emission

Photo electric effect

The phenomenon of ejection of electrons from metal surface when light of suitable frequency falls on it is called photoelectric effect

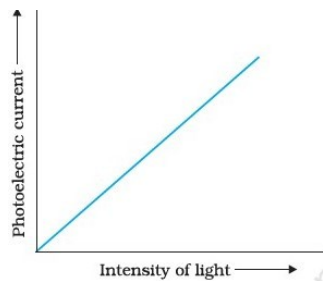
Threshold frequency (ν_0)

The minimum frequency of incident radiation to emit electron from metal surface.

Work Function (ϕ_0)

The minimum energy required to eject an electron from the metal surface is called work function. $\phi_0 = h\nu_0$

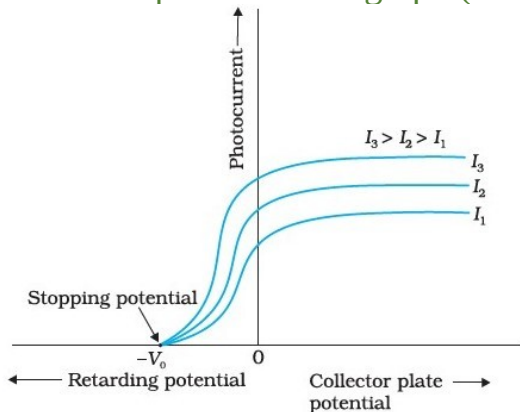
Effect of intensity of light on photoelectric current



The photoelectric current increases with intensity of

Effect of potential on photoelectric current

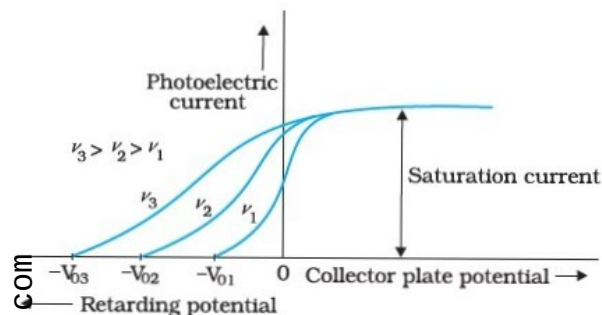
Potential –photo current graph (for different intensities I_1, I_2 & I_3 with fixed frequency)



The photoelectric current increases with increase in the potential applied to the collector.

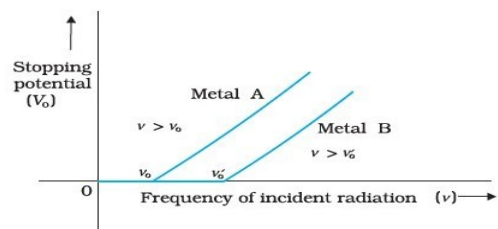
Stopping potential doesn't change with intensity of incident radiation

Potential-photo electric current graph (for fixed intensity with different frequencies ν_1, ν_2 & ν_3)



Stopping potential changes with change in frequency of incident radiation

Stopping potential is directly proportional to frequency



EINSTEIN'S PHOTOELECTRIC EQUATION

$$h\nu = \phi_0 + K_{\max} \quad K_{\max} = h\nu - \phi_0$$

$K_{\max}$ = Maximum Kinetic Energy of ejected electron

$\phi_0 = h\nu_0$ = work function

CHAPTER 3

ATOMS

BOHR MODEL OF THE HYDROGEN ATOM

Postulates:

1. An electron in an atom could revolve in certain stable orbits without the emission of radiant energy.
2. The electrons can orbit only those orbits for which the angular momentum is an integral multiple $h/2\pi$.
I.e, angular momentum, $L = mvr = nh / 2\pi$
Here n is called the principal quantum number and it has the integral values 1,2,3....
3. When an electron jumps from higher energy orbit to lower energy orbit, a photon is emitted having energy equal to the energy difference between the initial and final states.

If E_i and E_f are the energies associated with the orbits of principal quantum number n_i and n_f respectively ($n_i > n_f$), then the amount of energy radiated in the form of photon is

$$h\nu = E_i - E_f$$

Here ν is the frequency of photon

Expression for radius

$$\text{We have } v = \frac{nh}{2\pi mr}$$

$$mv^2 = \frac{1}{4\pi\epsilon_0} \frac{e^2}{r}$$

$$\text{therefore } m \left(\frac{nh}{2\pi mr} \right)^2 = \frac{1}{4\pi\epsilon_0} \frac{e^2}{r}$$

$$\frac{mn^2h^2}{4\pi^2m^2r^2} = \frac{1}{4\pi\epsilon_0} \frac{e^2}{r}$$

$$\frac{n^2h^2}{4\pi^2mr} = \frac{e^2}{4\pi\epsilon_0}$$

$$\text{thus } r = \frac{n^2h^2}{4\pi^2m} \frac{4\pi\epsilon_0}{e^2}$$

$$r_n \propto n^2$$

The radii of the stationary orbits are in the ratio, $1^2 : 2^2 : 3^2 : \dots$ or $1 : 4 : 9 : \dots$

$$r_1 = \frac{h^2 \epsilon_0}{\pi m e^2} = a_0 \text{ is Bohr radius. (radius of the lowest orbit)}$$

$$a_0 = 5.29 \times 10^{-11} \text{ m}$$

Thus, the radius of n^{th} orbit becomes $r_n = a_0 n^2$

CHAPTER 13

NUCLEI

Atomic mass unit (u)

Atomic mass unit is defined as the $1/12^{\text{th}}$ mass of the carbon-12 atom.

$$\text{ie } 1u = \frac{\text{mass of C 12 atom}}{12} = \frac{1.9926 \times 10^{-26} \text{ kg}}{12}$$
$$1u = 1.66 \times 10^{-27} \text{ kg}$$

Energy equivalent of 1u

According to Einstein's mass - energy relation,

$$E = mc^2$$

$$\text{Here } m = 1u = 1.66 \times 10^{-27} \text{ kg and } c = 3 \times 10^8 \text{ m/s}$$

$$\therefore E = 1.66 \times 10^{-27} \times (3 \times 10^8)^2 = 1.484 \times 10^{-10} \text{ J}$$

In electron volt or eV , $1u = 931 \text{ MeV}$

Mass Defect

The difference in the actual mass of a nucleus and its constituents is called the mass defect (ΔM)

$$\text{Mass defect , } \Delta M = [Zm_p + (A - Z) m_n - M]$$

m_p – Mass of proton, m_n - mass of neutron and M – actual mass of nucleus.

Binding energy (E_b)

Binding energy is the energy required to hold the nucleons together.

$$\text{Binding Energy, } E_b = \Delta M c^2$$

If the mass defect is in atomic mass unit, then binding energy in MeV is

$$\text{Binding Energy, } E_b = \Delta M \times 931 \text{ MeV.}$$

Nuclear fusion

The process of combining two lighter nuclei into a stable and heavier nuclei.

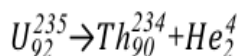
The energy liberated by the sun and other stars is due to the nuclear fusion reactions occurring at very high stellar temperatures .

Hydrogen bomb is a fusion bomb.

Nuclear fission

Nuclear fission is the process in which a heavy nucleus splits up into two stable nuclei of comparable mass with release of large amount of energy.

An example of fission is



The energy released in the fission reaction of nuclei like uranium is of the order of 200 MeV per fissioning nucleus.

Atom bomb is a fission bomb.

Isotopes

Isotopes are variants of a particular element with different number of neutrons. For example, the two isotopes of uranium are ${}^{235}_{92}\text{U}$ and ${}^{239}_{92}\text{U}$.

Isobars

Isobars are elements that have the same number of nucleons (sum of protons and neutrons).

For example ${}^{40}_{16}\text{S}$ and ${}^{40}_{17}\text{Cl}$

Isotones

Isotones are atoms that have the same neutron number but different proton number.

For example ${}^{38}_{18}\text{Ar}$ and ${}^{39}_{19}\text{K}$

Important Questions

1. What is the source of solar energy ?
2. Define binding energy of a nucleus.
3. What do you mean by mass defect of a nucleus?

Chapter 14

Semiconductor Electronics: Materials, Devices and Simple Circuits Introduction

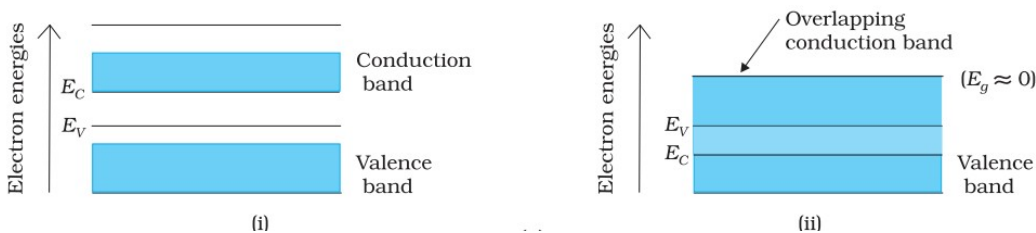
Classification of Metals, Conductors and Semiconductors

On the basis of conductivity: On the basis of the relative values of electrical conductivity (σ) or resistivity ($\rho = 1/\sigma$), the solids are broadly classified as:

- (i) **Metals:** They possess very low resistivity (or high conductivity).
 $\rho \sim 10^{-2} - 10^{-8} \Omega \text{ m}$
 $\sigma \sim 10^2 - 10^8 \text{ S m}^{-1}$
- (ii) **Semiconductors:** They have resistivity or conductivity intermediate to metals and insulators.
 $\rho \sim 10^{-5} - 10^6 \Omega \text{ m}$
 $\sigma \sim 10^5 - 10^{-6} \text{ S m}^{-1}$
- (iii) **Insulators:** They have high resistivity (or low conductivity).
 $\rho \sim 10^{11} - 10^{19} \Omega \text{ m}$
 $\sigma \sim 10^{-11} - 10^{-19} \text{ S m}^{-1}$

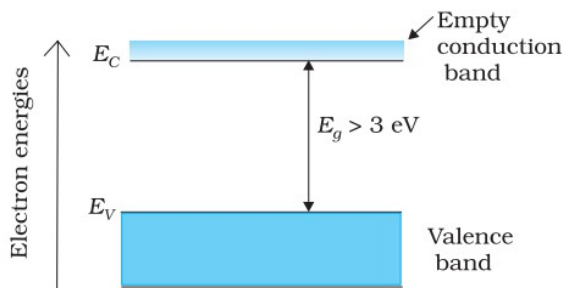
Classification of Metals, Conductors and Semiconductors On the basis of energy bands

i. metals



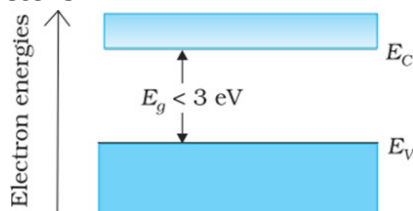
In some metals, the conduction band is partially filled and the valence band is partially empty with small energy gap and in some others the conduction and valence bands overlap. When there is overlap electrons from valence band can easily move into the conduction band. Therefore, the resistance of such materials is low or the conductivity is high.

ii. Insulators



In insulators a large band gap, $E_g > 3 \text{ eV}$. There are no electrons in the conduction band, and therefore no electrical conduction is possible. The energy gap is so large that electrons cannot be excited from the valence band to the conduction band by thermal excitation.

iii. Semiconductors



In semiconductors a finite but small band gap ($E_g < 3 \text{ eV}$) exists. Because of the small band gap, at room temperature some electrons from valence band can acquire enough energy to cross the energy gap and enter the conduction band. These electrons (though small in numbers) can move in the conduction band. Hence, the resistance of semiconductors is lower than that of insulators.

When the electrons from valence band move to the conduction band vacant energy levels will be created in the valence band. This vacancy of electrons is called hole. Other valence electrons can move to this hole thereby producing hole current.

Intrinsic Semiconductor

Pure semiconductors are called 'intrinsic semiconductors'.

Si and Ge have four valence electrons. In a pure Si or Ge crystal, each atom makes covalent bond with four neighbouring atoms and share the four valence electrons.

In intrinsic semiconductors, the number of free electrons, n_e is equal to the number of holes, n_h .

$$n_e = n_h = n_i$$

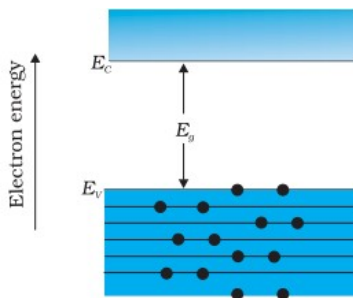
where n_i is called intrinsic carrier concentration

The total current, I is thus the sum of the electron current I_e and the hole current I_h :

$$I = I_e + I_h$$

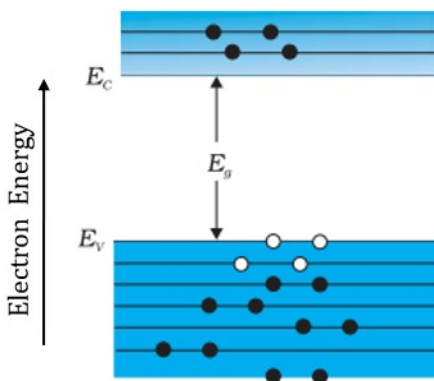
Energy-Band Diagram of an Intrinsic Semiconductor at $T=0\text{K}$

An intrinsic semiconductor will behave like an insulator at $T = 0 \text{ K}$.



Energy-Band Diagram of an Intrinsic Semiconductor at $T > 0\text{K}$

At temperatures ($T > 0\text{K}$), some electrons are excited from the valence band to the conduction band, leaving equal number of holes there.



Extrinsic Semiconductor

When a small amount of a suitable impurity is added to the pure semiconductor, the conductivity of the semiconductor is increased . Such materials are known as extrinsic semiconductors or impurity semiconductors.

n-type semiconductor

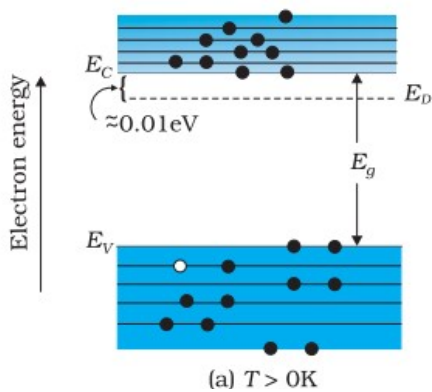
n-type semiconductor is obtained by doping Si or Ge with pentavalent atoms (donors) like As, Sb, P, etc.

For n-type semiconductors, $n_e \gg n_h$

Here electrons become the majority carriers and holes the minority carriers. The electron and hole concentration in a semiconductor in thermal equilibrium is given by

$$n_e n_h = n_i^2$$

Energy bands of n-type semiconductor at $T > 0K$



p-type semiconductor

p-type semiconductor is obtained when Si or Ge is doped with a trivalent impurity like Al, B, In, etc.

For p-type semiconductors $n_h \gg n_e$

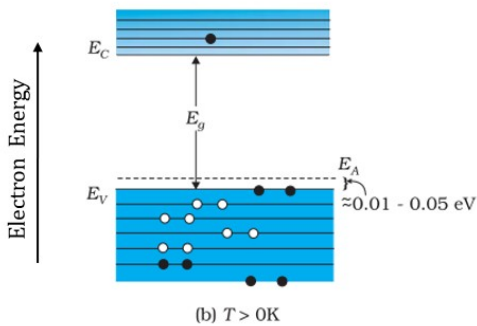
Here holes become the majority carriers and electrons the minority carriers. The electron and hole concentration in a semiconductor in thermal equilibrium is given by

$$n_e n_h = n_i^2$$

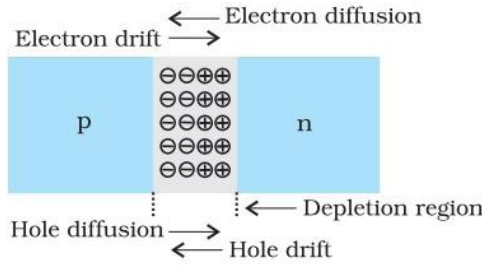
Energy bands of p-type semiconductor at $T > 0K$

For p-type semiconductor, the acceptor energy level E_A is slightly above the top E_V of the valence band. With very small supply of energy an electron from the valence band can jump to the level E_A and ionize the acceptor.

Negatively.



p-n junction



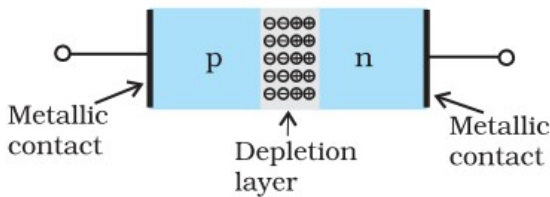
A p-n junction can be formed by adding a small quantity of pentavalent impurity to a p-type semiconductor or by adding a small quantity of trivalent impurity to an n-type semiconductor. Two important processes occur during the formation of a p-n junction: diffusion and drift

Barrier Potential

The loss of electrons from the n-region and the gain of electron by the p- region causes a difference of potential across the junction of the two regions. Since this potential tends to prevent the movement of electron from the n region into the p region, it is often called a barrier potential.

The barrier potential of a Ge diode is 0.2V and that of a Si diode is 0.7V.

Semiconductor Diode

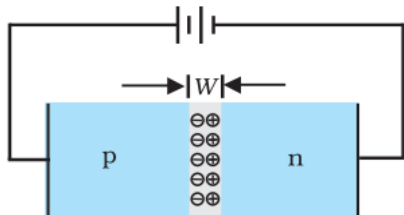


A semiconductor diode is basically a p-n junction with metallic contacts provided at the ends for the application of an external voltage. It is a two terminal device.

Symbol of a p-n junction Diode



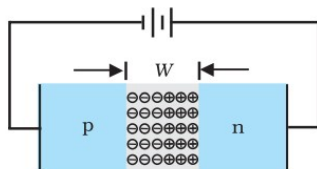
p-n junction diode under forward bias



If p-side of the diode is connected to the positive terminal and n-side to the negative terminal of the battery, it is said to be forward biased.

- Conducts current and it is due to majority charge carriers
- Width of depletion region decreases
- Potential barrier decreases.

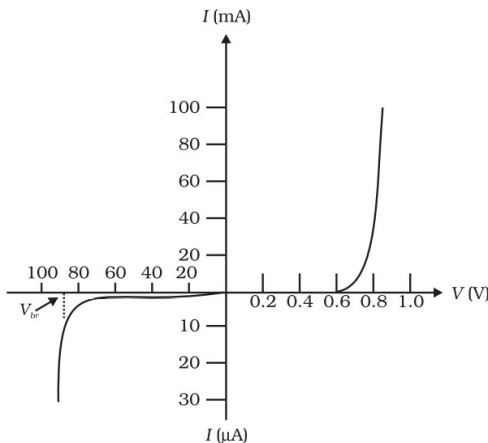
p-n junction diode under reverse bias



If n-side of the diode is connected to the positive terminal and p-side to the negative terminal of the battery, it is said to be reverse biased.

- Doesn't Conduct current
- Width of depletion region increases
- There will be a very small current due to minority charge carriers.

V-I characteristics of a silicon diode.



In forward bias, the current first increases very slowly, till the voltage across the diode crosses a certain value. This voltage is called the threshold voltage or cut-in voltage (0.2V for germanium diode and 0.7 V for silicon diode).

- After threshold voltage, the diode current increases significantly, even for a very small increase in the diode bias voltage.
- For the diode in reverse bias, the current is very small ($\sim \mu\text{A}$) and almost remains constant with change in bias. It is called reverse saturation current. However, at very high reverse bias called break down voltage V_{br} , the current suddenly increases. The general purpose diode are not used beyond the reverse saturation current region.

Threshold Voltage

The forward voltage beyond which the diode current increases significantly is called threshold voltage or cut-in voltage.

Break down Voltage

The reverse voltage at which the reverse current increases suddenly is called break down voltage.

Dynamic Resistance(r_d)

Dynamic resistance is defined as the ratio of small change in voltage ΔV to a small change in current ΔI

$$r_d = \frac{\Delta V}{\Delta I}$$

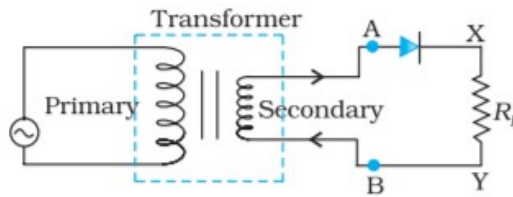
Application of Junction Diode as a Rectifier

The diode allows current to pass only when it is forward biased.

Rectifier

The process of conversion of ac voltage to dc voltage is called rectification and the circuit used for rectification is called rectifier.

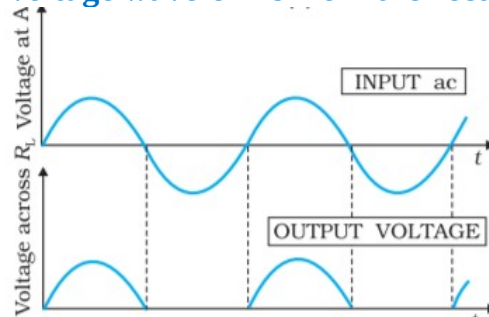
Half wave Rectifier



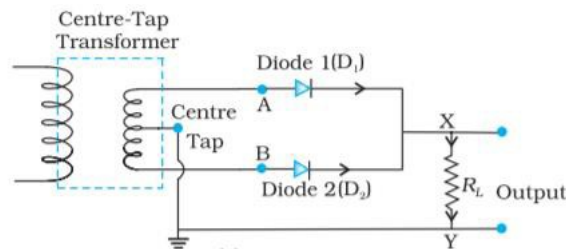
In the positive half-cycle of ac there is a current through the load resistor RL and we get an output voltage, whereas there is no current in the negative half cycle. Since the rectified output of this circuit is only for half of the input ac wave it is called as half-wave rectifier.

In the positive half-cycle of ac there is a current through the load resistor RL and we get an output voltage, whereas there is no current in the negative half cycle. Since the rectified output of this circuit is only for half of the input ac wave it is called as half-wave rectifier.

Input ac voltage and output voltage waveforms from the rectifier circuit



Full wave rectifier



For a full-wave rectifier the secondary of the transformer is provided with a centre tapping and so it is called centre-tap transformer.

- During this positive half cycle, diode $D1$ gets forward biased and conducts, while $D2$ being reverse biased is not conducting. Hence we get an output current and a output voltage across the load resistor RL .
- During negative half cycle, diode $D1$ would not conduct but diode $D2$ conducts, giving an output current and output voltage across RL in the same direction as in positive half.
- Thus, we get output voltage during both the positive as well as the negative half of the cycle. This is a more efficient circuit for getting rectified voltage or current than the halfwave rectifier.

Input ac voltage and output voltage waveforms from the rectifier circuit.

