तत् त्वं पूषन् अपावृणु

केन्द्रीय विद्यालय संगठन

KENDRIYA VIDYALAYA SANGATHAN

CHENNAI REGION

MINIMUM LEARNING MATERIAL

CLASS XII

PHYSICS (042)

Session 2022-23

CHIEF PATRON

Ms. T.Rukmani

Offg.Deputy Commissioner

KVS Chennai Region

PATRON

Mr.P I Thanga Raja

Assistant Commissioner

KVS Chennai Region

COURSE DIRECTOR

Mr. R.N.Senthil Kumar

Principal

Kendriya Vidyalaya, Nagercoil.

CONTENT DEVELOPMENT TEAM

S.No	Name of the Unit	Name of the Teacher	Name of the KV
1	Unit - 1 -Electrostatics	Shri R. CHANDRAKALADHARAN	SULUR
2	Unit - II Current Electricity	Shri.K RAMASUNDARAM	HVF AVADI
3	Unit - III Magnetic Effects of Current and Magnetism	Shri .P.SRIRAMAN	KARAIKKAL
4	Unit - IV Electromagnetic Induction and Alternating	Smt UMA KARPOORAM	NO.2, MADURAI
5	Unit - V Electromagnetic Waves	MS.I. SELVAMATHY	VIRUDHUNAGAR
6	Unit - VI Optics (Ray Optics & optical instruments	MS.I. SELVAMATHY	VIRUDHUNAGAR
7	Unit - VI Optics (wave Optics)	Smt .SHOBANA JULIUS	NO.2, TRICHY
8	Unit - VII Dual Nature of Radiation and Matter	Shri . KAPIL KUMAR	PORT BLAIR NO.2
9	Unit - VIII Atoms and Nuclei	Shri D.R.GOVINDARAJAN	ASHOK NAGAR, CHENNAI
10	Unit - IX Electronic Devices	Shri .RATHINAKUMAR	CHENNAI ISLAND GROUNDS

EDITING AND COMPILATION BY RESOURCE PERSONS

Shri.S KUMAR, KV CRPF AVADI

Shri .K V SRINIVASAN, K.V No.1, TAMBARAM, CHENNAI

Shri .S DHAMODHARAN, KV GILL NAGAR, CHENNAI

Shri.P.SEENIVASAN, K.V No.1, NARIMEDU, MADURAI

Shri.S CHANDRA KUMAR, KV NAGERCOIL

Smt.A. BEULAH JASMINE, KV NAGERCOIL

INDEX

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Total		**160**	**70**

Unit I: Electrostatics

Chapter–1: Electric Charges and Fields

Electric charges, Conservation of charge, Coulomb's law-force between two- point charges, forces between multiple charges; superposition principle and continuous charge distribution.

Electric field, electric field due to a point charge, electric field lines, electric dipole, electric field due to a dipole, torque on a dipole in uniform electric field.

Electric flux, statement of Gauss's theorem and its applications to find field due to infinitely long straight wire, uniformly charged infinite plane sheet and uniformly charged thin spherical shell (field inside and outside).

Chapter–2: Electrostatic Potential and Capacitance

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

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

Unit II: Current Electricity(Chapter–3: Current Electricity)

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

Unit III:Magnetic Effects of Current and Magnetism :Concept of magnetic field, Oersted's experiment.Biot - Savart law and its application to current carrying circular loop.

Ampere's law and its applications to infinitely long straight wire. Straight solenoid (only qualitative treatment), force on a moving charge in uniform magnetic and electric fields.Force on a current-carrying conductor in a uniform magnetic field, force between two parallel current-carrying conductors-definition of ampere, torque experienced by a current loop in uniform magnetic field; Current loop as a magnetic dipole and its magnetic dipole moment, moving coil galvanometer- its current sensitivity and conversion to ammeter and voltmeter.

Chapter–5: Magnetism and Matter : Bar magnet, bar magnet as an equivalent solenoid (qualitative treatment only), magnetic field intensity due to a magnetic dipole (bar magnet) along its axis and perpendicular to its axis (qualitative treatment only), torque on a magnetic dipole (bar magnet) in a uniform magnetic field (qualitative treatment only), magnetic field lines.Magnetic properties of materials- Para-, dia- and ferro - magnetic Substances with examples, Magnetization of materials, effect of temperature on magnetic properties.

Unit IV:Electromagnetic Induction and Alternating Currents (Chapter–6: Electromagnetic Induction):Electromagnetic induction; Faraday's laws, induced EMF and current; Lenz's Law, Self and mutual induction.

Chapter–7: Alternating Current:Alternating currents, peak and RMS value of alternating current/voltage; reactance and impedance; LCR series circuit (phasors only), resonance, power in AC circuits, power factor, wattless current.AC generator, Transformer.

Unit V:Electromagnetic waves (Chapter–8: Electromagnetic Waves):Basic idea of displacement current, Electromagnetic waves,their characteristics, their transverse nature (qualitative idea only).Electromagnetic spectrum (radio waves, microwaves, infrared, visible, ultraviolet, X-rays, gamma rays) including elementary facts about their uses.

Unit VI: Optics **Chapter–9: Ray Optics and Optical Instruments**

Ray Optics: Reflection of light, spherical mirrors, mirror formula, refraction of light, total internal reflection and optical fibers, refraction at spherical surfaces, lenses, thin lens formula, lens maker's formula, magnification, power of a lens, combination of thin lenses in contact, refraction of light through a prism.

Optical instruments: Microscopes and astronomical telescopes (reflecting and refracting) and their magnifying powers.

Chapter–10: Wave Optics

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

Unit VII: Dual Nature of Radiation and Matter

Chapter–11: Dual Nature of Radiation and Matter

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

Unit VIII: Atoms and Nuclei(Chapter–12: Atoms)

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

Chapter–13: Nuclei :Composition and size of nucleus, nuclear force,Mass-energy relation, mass defect; binding energy per nucleon and its variation with mass number; nuclear fission, nuclear fusion.

Unit IX: Electronic Devices

Chapter–14: Semiconductor Electronics: Materials, Devices and Simple Circuits

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

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UNIT – I- ELECTROSTATICS-FORMULAE

S. No	FORMULAE	SYMBOLS	APPLICATION
1	Q = $\pm$ N e	Q = Charge N = Number of electrons	Quantization of charges
2	$F = k\frac{Q_1 Q_2}{r^2}$	Q_1, Q_2 are point charges F= Force	To find force between two point charges
3	F = Q E	E = Electric field	Relation between F and E
4	$E = k\frac{Q}{r^2}$	$k = \frac{1}{4\pi\epsilon_0}$, r= distance ϵ_0= electric permittivity	Electric field due to a point charge.
5	$\emptyset_E = \oint \vec{E} \cdot \vec{ds} = E \oint ds\ cos\theta$	ds = small area	To find electric flux
6	$\emptyset_E = \frac{q}{\epsilon_0}$	$\emptyset_E$ = Electric Flux	Gauss Theorem
7	$\Delta V = V_A - V_B = \frac{W_{AB}}{q}$	ΔV=potential difference V_A=Electric potential at A V_B=Electric Potential at B q=charge	To find the potential difference using Work done from a point A to a point B
8	$V = k\ \frac{q}{r}$	$k = \frac{1}{4\pi\ \epsilon_0}$ r= distance	Electrostatic potential due to a point charge
9	$V = k\frac{pcos\theta}{r^2}$	p = dipole moment	Electric potential due to a dipole
10	$E = \frac{-dV}{dr}$	dV / dr=potential gradient	Relation between electric field and potential
11	$U = W = k\frac{q_1 q_2}{r_{12}}$	U = Potential Energy W = Work done	Potential energy of a system of two point charges
12.	$E = \frac{\lambda}{2\pi\epsilon_0 r}$	λ=linear charge density	Field intensity due to infinitely long straight uniformly charged wire

13.	a) outside the shell: $E = k\,\frac{q}{r2}$ b) on the shell: $E = k\,\frac{q}{R^2}$ As q=4πR^2.σ E= σ/ϵ$_0$ a) inside the shell: E=0	r=radius of Gaussian surface(outside the shell) R=radius of shell σ =surface charge density	Field intensity due to uniformly charged spherical shell
14.	$E = \frac{\sigma}{2\,\epsilon_0}$	E = Electric field ϵ$_0$= electric permittivity	Field intensity due to thin infinite plane sheet of charge
15.	C=4πϵ$_0$r	C=capacitance r=radius of conductor	Capacity of isolated spherical conductor
16.	$C = \frac{\epsilon_0\,A}{d}$	A = area of plates d = distance between the plates	Capacitance of a parallel plate capacitor
17.	Grouped capacitors: a) In series: $\frac{1}{C_s} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$ b) In parallel: $C_p=C_1+C_2+C_3$	C_s= equivalent capacitance in series C_p=equivalent capacitance in parallel	To calculate equivalent capacitance of a circuit
18.	$U = \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2}CV^2 = \frac{1}{2}QV$	U = Electrostatic energy stored in capacitor	Energy stored in a capacitor
19.	$u = \frac{1}{2}\epsilon_0\,E^2$	E= electric field strength	Energy density of a parallel plate capacitor
20.	$V = \frac{C_1V_1 + C_2V_2}{C_1 + C_2}$	V = Common potential	To find Common potential due to sharing of charge
21.	$E_1 - E_2 = \frac{C_1C_2(V_1 - V_2)^2}{2(C_1 + C_2)}$	$E_1 - E_2$ = Loss of energy	Loss of energy due sharing charges
22.	K=1+χ	K=dielectric constant χ =electric susceptibility	Relation between dielectric constant & electric susceptibility
23.	$C = \frac{C_0}{(1 - \frac{t}{d})}$	t=thickness of slab d=distance between the	Capacitance of parallel plate capacitor with conducting slab in

		plates C_0=capacitance with vacuum in between	between
24.	$C = \dfrac{\epsilon_0 A}{d - t(1 - \frac{1}{K})}$	K=dielectric constant	Capacitance of parallel plate capacitor with dielectric slab in between
25	• Values of Different quantities after Introducing dielectric slab between the plates of the charged capacitor:		

Description	When Battery connected	When Battery disconnected
Charge	K Q_0	Q_0
Potential difference	V_0	V_0/K
Electric Field	E_0	E_0/K
Capacitance	KC_0	KC_0
Energy	K times $\frac{1}{2}\varepsilon_0 E^2$ [Energy is supplied By battery	1/K times $\frac{1}{2}\varepsilon_0 E^2$ [Energy used for Polarization

MINIMUM LEARNING MATERIAL

The intrinsic property of fundamental particle of matter which give rise to electric force between objects is called charge.

- Conservation of Charge- The total charge of an isolated system is always conserved, i.e. initial and final charge of the system will be same.
- Coulomb's Law :- It states that the electrostatic force of attraction or repulsion between two stationary point charges kept apart in air or vacuum is given by

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

$$\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9 \text{ N-m}^2/\text{C}^2 \qquad \varepsilon_0 = 8.85419 \times 10^{-12} \text{ C}^2/\text{N-m}^2$$

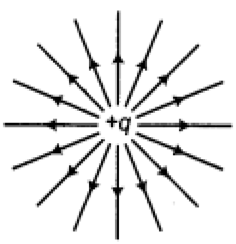
. Electric Field- Force experienced per unit positive test charge

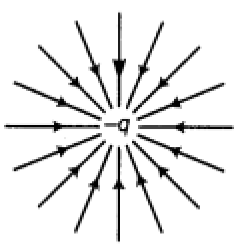
$$E = \frac{Force(F)}{Charge(q)}$$

- Electric Field Intensity due to a Point Charge:-

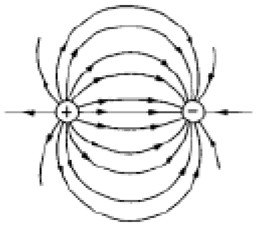
$E = kq / r^2$, Where $k = 1/4\pi\varepsilon_0 = 9\times10^9$

- Field lines due to positive and negative charges

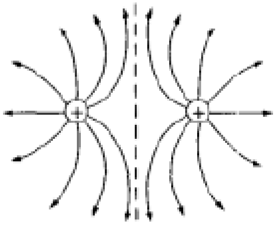




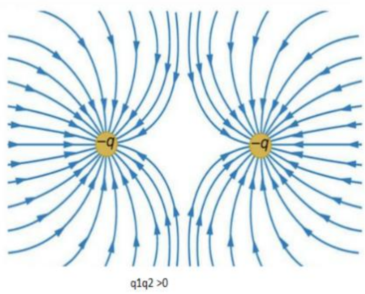
- Field lines due to charges (i)q1q2>0 and (ii) q1q2 < 0



q1q2 <0

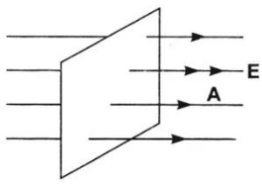


q1q2 > 0



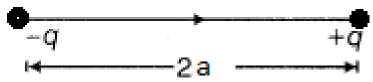
q1q2>0

- Properties of electric field lines
  1. Electric field lines start from a positive charge and end at a negative charge, in case of a single charge, electric field lines end at infinity
  2. In a charge-free region, electric field lines are continuous and smooth
  3. Two electric field lines never intersect or cross each other, as if they do, there will be two vectors depicting two directions of the same electric field, which is not possible
  4. Electric field lines never form a closed loop.
- Electrostatic Force due to Continuous Charge Distribution: -
- Electric Flux:- Number of field line passing normally through a closed surface



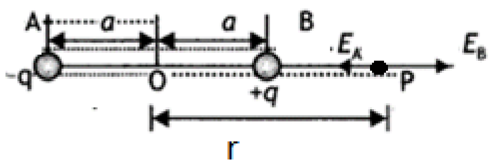
$\varphi = E\,A\cos\theta$ where E is an electric field, A is the area of the surface and θ is the angle between the electric field lines and normal to A.

- Electric Dipole :-Two point charges of same magnitude and opposite nature separated by a small distance form an electric dipole.



Dipole moment is $p = q\,(2a)$

- The field of an electric dipole for points on the axis



$$E_A = \frac{1}{4\pi\varepsilon_0}\frac{q}{(r+a)^2} \text{ and } E_B = \frac{1}{4\pi\varepsilon_0}\frac{q}{(r-a)^2}$$

$E = E_B - E_A$

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

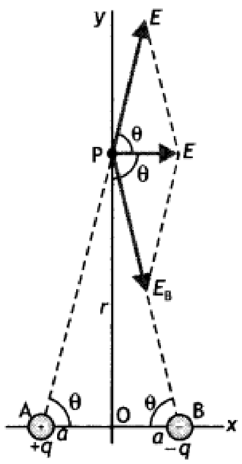
Solving we get

$$E = \frac{1}{4\pi\varepsilon_0} \frac{2pr}{\left(r^2 - a^2\right)^2}$$

If the dipole is short then r >> a, therefore, ‘a’ is neglected as compared to r, hence

$$E = \frac{1}{4\pi\varepsilon_0} \frac{2pr}{r^4} = \frac{1}{4\pi\varepsilon_0} \frac{2p}{r^3}.$$

- The field of an electric dipole for points on the equatorial plane



The two electric fields have magnitudes

$$E_A = \frac{1}{4\pi\varepsilon_0} \frac{q}{\left(r^2 + a^2\right)}$$ in the direction of AP

$$E_B = \frac{1}{4\pi\varepsilon_0} \frac{q}{\left(r^2 + a^2\right)}$$ in the direction of PB.

the resultant electric field at point P is

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

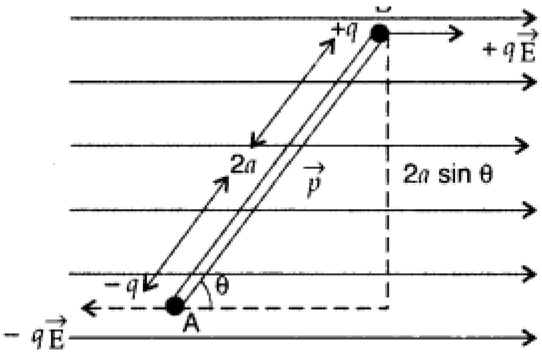
$$= 2E_A\cos\theta = \frac{1}{4\pi\varepsilon_0} \frac{2q}{\left(r^2 + a^2\right)}\cos\theta \qquad ...(5)$$

$$E = \frac{1}{4\pi\varepsilon_0} \frac{2qa}{\left(r^2 + a^2\right)^{3/2}} = \frac{1}{4\pi\varepsilon_0} \frac{p}{\left(r^2 + a^2\right)^{3/2}}$$

For a short dipole r >>a,

$$E = \frac{1}{4\pi\varepsilon_0}\frac{p}{r^3}.$$

- Torque on a dipole in uniform external field



Force exerted on charge $+q$ by field

$\vec{F} = q\vec{E}$ (along $\vec{E}$)

Force exerted on charge $-q$ by field,

$\vec{F} = q\vec{E}$ (opposite to $\vec{E}$)

$\vec{F}_{total} = +q\vec{E} - q\vec{E} = 0$

Torque = Either force × Perpendicular distance between the two forces

= qE × 2a sin θ

= pE sin θ [∵ p = q × 2a; p is dipole moment]

$\tau = pE \text{ Sin } \theta$

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

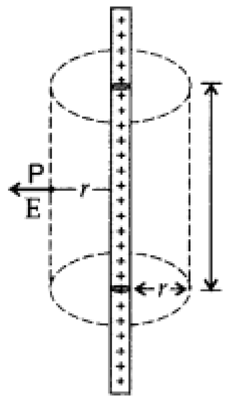
- Gauss's Law

Total electric flux out of a closed surface is equal to the charge enclosed by the closed surface divided by the permittivity.

$$i.e., \ \phi = \int_S \vec{E}.d\vec{S} = \frac{q}{\varepsilon_0}$$

- Applications of Gauss's law

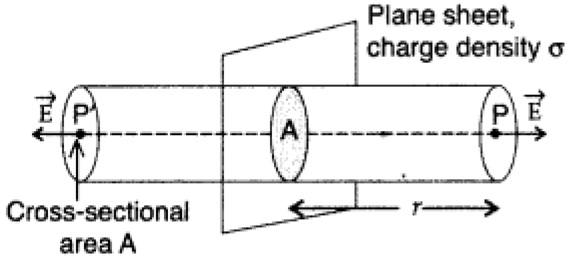
(i) field due to an infinitely long straight uniformly charged wire



$$E \times 2\pi r l = \lambda l/\varepsilon_0$$

$$\int_S \vec{E}.d\vec{S} = \frac{q}{\varepsilon_0} \quad , \quad \boxed{E = \frac{\lambda}{2\pi\varepsilon_0 r}}$$ where $\lambda = q/l$

(ii) Field due to a uniformly charged infinite plane sheet

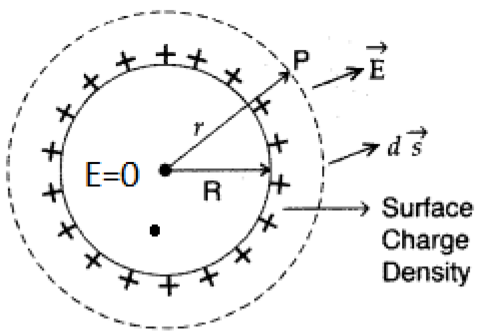


$$\int_S \vec{E}.d\vec{S} = \frac{q}{\varepsilon_0}$$

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

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

(iii) Field due to a uniformly charged thin spherical shell

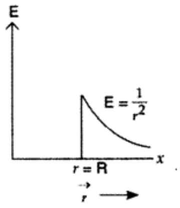


(i) field outside the shell

$$\text{Gauss's theorem,} \quad \phi = \oint_S \vec{E}.d\vec{S} = \frac{q}{\varepsilon_0}$$

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

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

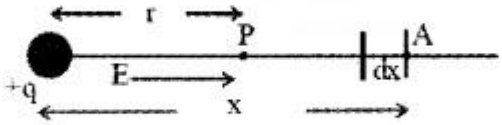


(ii) Field inside the shell

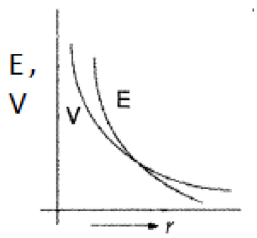
At a point inside the shell, q=0 so E = 0

Chapter-2 Electrostatic potential and Capacitance.

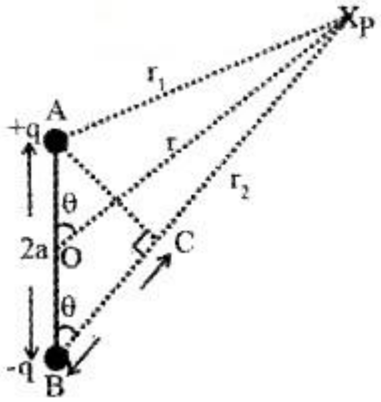
- Electric potential = work done/ charge = W/ q
- Potential due to a point charge



V = kq / r



- Variation of V and E with r
- Potential due to an electric dipole



The potential due to +q , $V_+ = \frac{1}{4\pi\varepsilon_0}\frac{+q}{r_1}$

The potential due to -q , $V_- = \frac{1}{4\pi\varepsilon_0}\frac{-q}{r_2}$

Total potential at P is

$$V = \frac{1}{4\pi\varepsilon_0}\frac{+q}{r_1} + \frac{1}{4\pi\varepsilon_0}\frac{-q}{r_2}$$

$$= \frac{q}{4\pi\varepsilon_0}\left(\frac{1}{r_1} - \frac{1}{r_2}\right) = \frac{q}{4\pi\varepsilon_0}\left(\frac{r_2 - r_1}{r_1 r_2}\right) \quad \text{——(1)}$$

From ΔABC , we get $(r_2 - r_1) = 2a\cos\theta$

we can also take $r_2 = r_1 = r$ (since '2a' is very small)

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

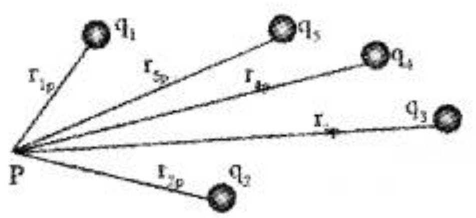
$$V = \frac{1}{4\pi\varepsilon_0}\frac{P\cos\theta}{r^2} \qquad (\text{since } P = q2a)$$

But $\vec{P}.\hat{r} = P\cos\theta$, where $\hat{r} = \frac{\vec{r}}{|r|}$

$$V = \frac{1}{4\pi\varepsilon_0}\frac{\vec{P}.\hat{r}}{r^3}$$

At a point on the axial line, $V = kP/r^2$
At a point on the equatorial line $V = 0$

Potential due to a system of charges



$$V_1 = \frac{1}{4\pi\varepsilon_0}\frac{q_1}{r_{1P}}$$

$$V_2 = \frac{1}{4\pi\varepsilon_0}\frac{q_2}{r_{2P}}$$

$V = V_1 + V_2 + \ldots\ldots + V_n$

$$V = \frac{1}{4\pi\varepsilon_0}\frac{q_1}{r_{1P}} + \frac{1}{4\pi\varepsilon_0}\frac{q_2}{r_{2P}} + \ldots\ldots\ldots\ldots + \frac{1}{4\pi\varepsilon_0}\frac{q_n}{r_{nP}}$$

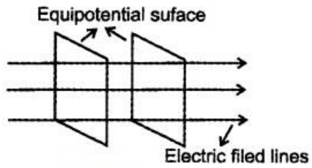
$$V = \frac{1}{4\pi\varepsilon_0}\left(\frac{q_1}{r_{1P}} + \frac{q_2}{r_{2P}} + \ldots\ldots\ldots\ldots + \frac{q_n}{r_{nP}}\right)$$

- Equipotential Surface:- The surface over which the electric potential is same is called an equipotential surface.

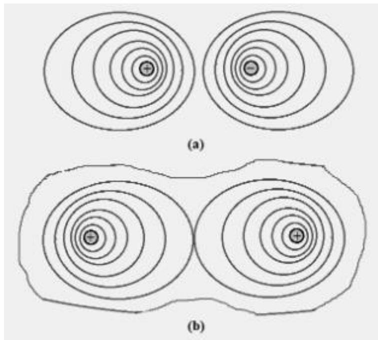
Properties:- 1. Direction of electric field is perpendicular to the equipotential surface.

2.No work is done to move a charge from one point to another along the equipotential surface.

3. Equipotential surfaces for a uniform electric filed:



Equipotential surfaces for a(a) dipole and (b) two identical positive charges



- Relation Between Electric Field And Potential-

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

- Potential Energy U = Potential x charge = Vxq
- Potential Energy of System of Two Charges

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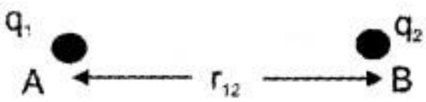
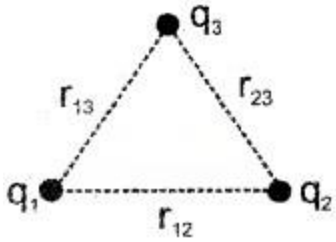


i.e. $\boxed{U_{12} = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r_{12}}}$

- Potential Energy of System of Three Charges



$U = U_{12} + U_{23} + U_{13}$

$$U = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r_{12}} + \frac{1}{4\pi\varepsilon_0}\frac{q_2q_3}{r_{23}} + \frac{1}{4\pi\varepsilon_0}\frac{q_1q_3}{r_{13}}$$

$$\boxed{U = \frac{1}{4\pi\varepsilon_0}\left(\frac{q_1q_2}{r_{12}} + \frac{q_2q_3}{r_{23}} + \frac{q_1q_3}{r_{13}}\right)}$$

- Potential energy of a dipole in an external field

work done $dw = \tau d\theta = PE \sin\theta\, d\theta$

Total work done in rotating the dipole from $\theta 1$ to $\theta 2$

$$W = \int_{\theta_1}^{\theta_2} PE\sin\theta \, d\theta$$

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

This work done is stored as potential energy

- Electrostatics Of Conductors

  (i) Inside a conductor, the electrostatic field is zero

  (ii) At the surface of a charged conductor, the electrostatic field must be normal to the surface at every point

  (iii) The interior of a conductor can have no excess charge in the static situation

  (iv) Electrostatic potential is constant throughout the volume of the conductor and has the same value (as inside) on its surface.

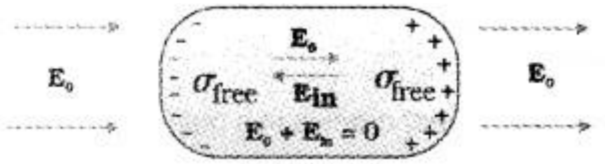
  (v) Electric field at the surface of a charged conductor $E = \sigma/\varepsilon_0 \, n$

  (vi) Electric field inside a metal cavity is zero

- Polarisation = Dipole moment / volume

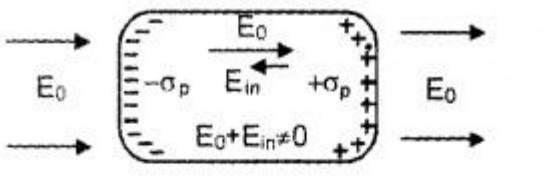
  For linear isotropic dielectrics. $P = \chi_0 E$

- Behaviour of conductors and dielectric in an uniform external field



Conductor

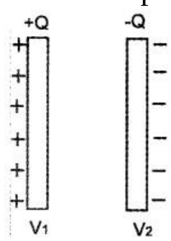
$E_0 + E_{in} = 0$ net electric field inside the metal becomes zero.



Dielectric

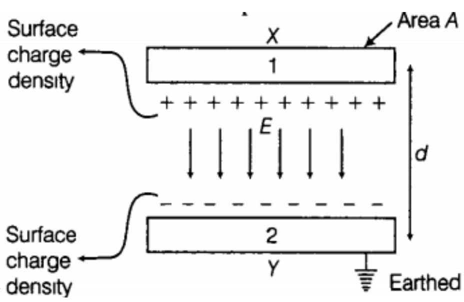
$E_0 + E_{in} \neq 0$ Total electric field is reduced inside the dielectric

- Capacitors And Capacitance



$Q \propto V$, $Q = CV$ where Q is charge, V is p.d, C is capacitance

- Capacitance of parallel plate capacitor

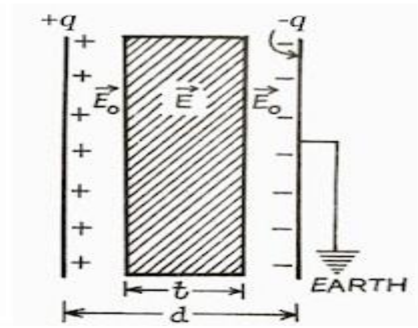


$\sigma = q/A$ and $E = q/\varepsilon_0 A$…………(i)

$E = V/d$ or $V = Ed$…..(ii)

From (i) and (ii), $V = qd/\varepsilon_0 A$ $C = q/V = \varepsilon_0 A / d$

-
- Effect Of Dielectric On Capacitance



$V = Et + E_0(d-t)$

$\Rightarrow V = E_0t/k + E_0(d-t)$

$\Rightarrow V = E_0(d - t + t/k)$

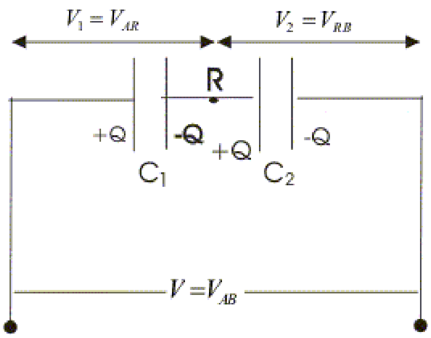
we know that, $E_0 = q/\varepsilon_0 A$

$\Rightarrow V = q(d - t + t/k)/\varepsilon_0 A$

$\Rightarrow C = q/V$

$\Rightarrow C = \varepsilon_0 A/(d - t + t/k)$, $C_m > c_0$

- Capacitors in series:

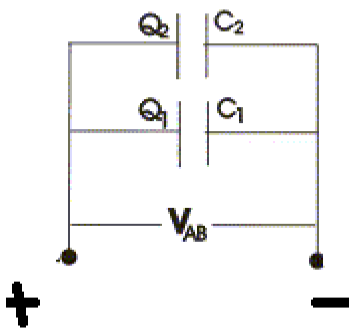


$$V = V_1 + V_2 + V_3.$$

$$\frac{Q}{C_S} = \frac{Q}{C_1} + \frac{Q}{C_2} + \frac{Q}{C_3}.$$

$$\frac{1}{C_S} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}.$$

- Capacitors in parallel



Total charge on both the capacitors is,
Q=Q1+Q2
=V(C1+C2)

and

C= Q/V=C1+C2

- Energy Stored In A Capacitor

$$\boxed{U = \frac{1}{2}CV^2}$$

MULTIPLE CHOICE QUESTIONS

01. Which one of the following is the unit of electric field?

(a) Coulomb (b) Newton (c) Volt (d) N/C

02. If an electric dipole is kept in a uniform electric field then resultant electric force on it is

(a) always zero (b) never zero (c) increases gradually (d) None

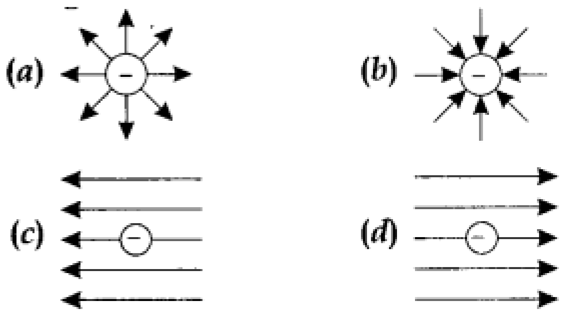
03. When placed in a uniform field, a dipole experience

(a) a net force (b) a torque (c) both a net force and torque (d) neither a net force nor a torque

04. In non-uniform electric field, electric dipole experiences:

(a) torque only (b) torque as well as net force (c) force only (d) None of these

05. Which of the following figures represent the electric field lines due to a single negative charge?



06 . Two charges q1 and q2 are placed in vacuum at a distance d and the force acting between them is F. If a medium of dielectric constant 4 is introduced between them, the force now will be

(a) F (b) F/2 (c) F/4 (d) 4F

07. Two similar spheres having +Q and -Q charges are kept at a certain distance. F force acts between the two. If at the middle of two spheres, another similar sphere having +Q charge is kept, then it experiences a force

(a) zero having no direction. (b) 8F towards +Q charge.

(c) 8F towards -Q charge. (d) 4F towards +Q charge.

08. Two charges of equal magnitudes kept at a distance r exert a force F on each other. If the charges are halved and distance between them is doubled, then the new force acting on each charge is

(a) $\frac{F}{8}$ (b) $\frac{F}{4}$

(c) $4F$ (d) $\frac{F}{16}$

09. A cylinder of radius R and length L is placed in a uniform electric field E parallel to the cylinder axis. The total flux for the surface of the cylinder is given by

(a) $2\pi R^2 E$ (b) πr^2

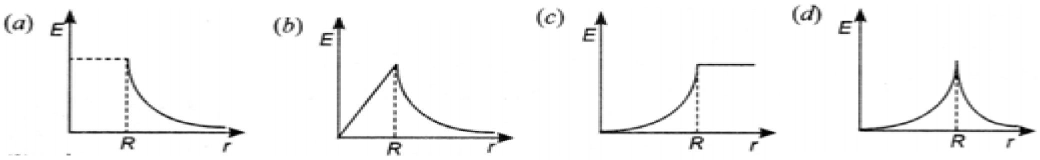
(c) $\frac{\pi R^2 - \pi R}{E}$ (d) Zero

10. An electric charge q is placed at the centre of a cube of side a. The electric flux on one of its faces will be

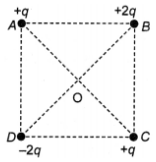
(a) $\frac{q}{6\varepsilon_0}$ (b) $\frac{q}{\varepsilon_0 a^2}$

(c) $\frac{q}{4\pi\varepsilon_0 a^2}$ (d) $\frac{q}{\varepsilon_0}$

11. Which of the following graphs shows the variation of electric field E due to a hollow spherical conductor of radius R as a function of distance from the centre of the sphere?



12. Four charges are arranged at the comers of a square ABCD, as shown. The force on a positive charge kept at the centre O is



(a) zero

(b) along the diagonal AC

(c) along the diagonal BD

(d) perpendicular to side AB

13. An electric dipole is placed at an angle of 30° with an electric field of intensity 2 × 105 NC–1, It experiences a torque of 4 Nm. Calculate the charge on the dipole if the dipole length is 2 cm.

(a) 10 mC (b) 2μC (c) 6 μC (d) 2 mC

14. If a unit positive charge is taken from one point to another over an equipotential surface, then

(a) work is done on the charge

(b) work is done by the charge.

(c) work done is constant

(d) no work is done.

15. A hollow metal sphere of radius 5 cm is charged so that the potential on its surface is 10 V. The potential at the centre of the sphere is

(a) 0 V (b) 10 V (c) Same as at point 8 cm away from the surface

(d) Same as at point 10cm away from the surface

16. The capacitance of a parallel plate capacitor C having a charge Q and area A, is

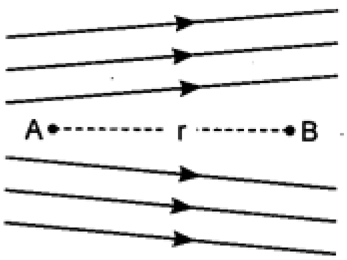
(a) proportional to the square root of the distance between the plates.

(b) linearly proportional to the distance between the plates.

(c) independent of the distance between the plates.

(d) inversely proportional to the distance between the plates.

17. Figure shows the electric lines of force emerging from a charged body. If the electric field at A and B are EA and EB respectively and if the displacement between A and B is r then



(a) EA > EB (b) EA < EB (c) EA = EB/r (d) EA = EB /r^2

18. Which of the following options is correct? In a region of constant potential

(a) the electric field is uniform

(b) the electric field is zero.

(c) there can be charge inside the region.

(d) the electric field shall necessarily change if a charge is placed outside the region.

19. A parallel plate capacitor is connected with the terminals of a battery. The distance between the plates is 6mm. If a glass plate (dielectric constant K = 9) of 4.5 mm is introduced between them, then the capacitance will become

(a) 2 times (b) the same (c) 3 times (d) 4 times.

20. A capacitor is charged by using a battery which is then disconnected. A dielectric slab is then introduced between the plates, which results in

(a) reduction of charge on the plates and increase of potential difference across the plates.
(b) increase in the potential difference across the plate, reduction in stored energy, but no change in the charge on the plates.
(c) decrease in the potential difference across the plates, reduction in the stored energy, but no change in the charge on the plates.
(d) none of these

21. Which of the following statement is true?

(a) Electrostatic force is a conservative force.

(b) Potential at a point is the work done per unit charge in bringing a charge from any point to infinity.

(c) Electrostatic force is non-conservative (d) Potential is the product of charge and work.

22. Which of the following statements is false for a perfect conductor?

(a) The surface of the conductor is an equipotential surface.

(b) The electric field just outside the surface of a conductor is perpendicular to the surface.

(c) The charge carried by a conductor is always uniformly distributed over the surface of the conductor.

(d) None of these.

23. In a parallel plate capacitor, the capacitance increases if

(a) area of the plate is decreased. (b) distance between the plates increases.

(c) area of the plate is increased. (d) dielectric constant decreases.

24. Two capacitors of capacitance 6 μF and 4 μF are put in series across a 120 V battery. What is the potential difference across the 4 μF capacitor?

(a) 72 V (b) 68 V (c) 28 V (d) zero

1	2	3	4	5	6	7	8	9	10	11	12
D	a	b	B	b	c	C	d	D	a	A	A
13	14	15	16	17	18	19	20	21	22	23	24
D	d	b	D	a	b	C	c	A	d	C	A

ELECTROSTATICS- Assertion and Reason

Directions: These questions consist of two statements, each printed as Assertion and Reason. While answering these questions, you are required to choose any one of the following four responses.
(a) Both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.
(b) Both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.
(c) Assertion is correct, Reason is incorrect
(d) Assertion incorrect and Reason is correct.
(e) Both assertion and Reason is incorrect

01. **Assertion:** No two electric lines of force can intersect each other.
Reason: Tangent at any point of electric line of force gives the direction of electric field.

02. **Assertion :** In a cavity within a conductor, the electric field is zero.
Reason : Charges in a conductor reside only at its surface.

03. Assertion: The Coulomb force between two points charges depend upon the dielectric constant of the intervening medium.
Reason: Coulomb's force varies inversely with the dielectric constant of medium.

04. Assertion : Electric field at the surface of a charged conductor is always normal to the surface at every point.
Reason : Electric field gives the magnitude & direction of electric force $(\vec{F})$ experienced by any charge placed at any point

05. Assertion : The net force on a dipole in a uniform electric dipole is zero.
Reason : Electric dipole moment is a vector directed from –q to +q.

06. Assertion : Two equipotential surfaces cannot cut each other.
Reason : Two equipotential surfaces are parallel to each other.

07. Assertion : A dielectric is inserted between the plates of a battery connected capacitor. The energy of the capacitor increases.
Reason : Energy of the capacitor, $U=CV^2/2$

08. Assertion : Sensitive instruments can protect from outside electrical influence by enclosing them in a hollow conductor.
Reason: Potential inside the cavity is zero.

09. Assertion : Polar molecules have permanent dipole moment.
Reason : In polar molecules, the centres of positive and negative charges coincide even when there is no external field.

10. Assertion: Work done by the electrostatic force in bringing the unit positive Charge form infinity to the point P is positive.
Reason : The force on a unit positive test charge is attractive, so that the electrostatic force and the displacement (from infinity to P) are in the same direction.

1	2	3	4	5	6	7	8	9	10
A	a	a	b	b	c	a	c	c	A

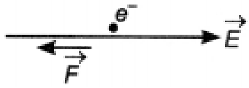
2 mark questions

01. Show that at a point where the electric field intensity is zero, electric potential need not be zero.
Ans: E=-dV/dr when E=0, then V= constant

02. How does the electric flux, electric field enclosing a given charge vary when the area enclosed by the charge is doubled?
Ans: (a) $\emptyset = q/\varepsilon_0$ = constant (b) $E \alpha 1/A$, E is halved

03. Is the force acting between two point electric charges q1 and q2 kept at some distance apart in air, attractive or repulsive when
(i) q1q2 > 0 (ii) q1q2 < 0 ?
Ans: (i) When q1q2 > 0, force is repulsive.
(ii) When q1q2 < 0, force is attractive.

04. The force on an electron kept in an electric field in a particular direction is F. What will be the magnitude and direction of the force experienced by a proton kept at the same point in the field? Mass of the proton is about 1836 times the mass of the electron.



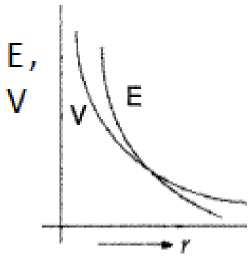
Ans: Magnitude remain same but direction is opposite(along field direction)
Since F = qE

05. A cubical Gaussian surfaces encloses 30 C per unit permittivity of charge. What is the electric flux through each face of the cube ?
Ans:- According to gauss's law $\oint E\cdot ds = qo / \epsilon o = 30C/6\epsilon o = 5\ Nm^2/C$

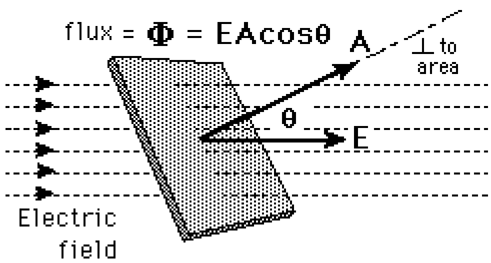
06. In which orientation, a dipole placed in a uniform electric field is in (i) stable and (ii) unstable equilibrium ?
Ans:- (i)For stable equilibrium, a dipole is placed parallel to the electric field.
(ii) For unstable equilibrium, a dipole is placed antiparallel to the electric field.

07. Why do the electric field lines never cross each other?
Ans:-The electric lines of force give the direction of the electric field. In case, two lines of force intersect, there will be two directions of the electric field at the point of intersection, which is not possible.

08. Show on a plot the nature of variation of the (i)Electric field (E) and (ii) potential (V), of a point charge with the distance (r) of the field point from the centre of the charge .



09. Define electric flux. Write its S.I. unit.
Ans:- Electric flux over an area in an electric field is the total number of lines of force passing through the area. It is represented by ϕ . It is a scalar quantity. Its S.I unit is $Nm^2\ C^{-1}$ or Vm.



$\Phi = E . A = EA \cos\theta$

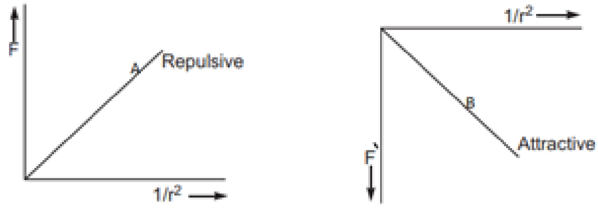
10. A charge q is enclosed by a spherical surface of radius R. If the radius is reduced to half, how would the electric flux through the surface change?

Ans:- $\phi = \int_S \vec{E}.d\vec{S} = \frac{q}{\varepsilon_0}$ Since flux is independent on radius, electric flux remain same.

11. Plot a graph showing the variation of coulomb force (F) versus 1/ r2 where r is the distance between the two charges of each pair of charge (i) (1 μC,2 μC) and (ii) (1 μC,−3 μC). Interpret to the graphs obtained.

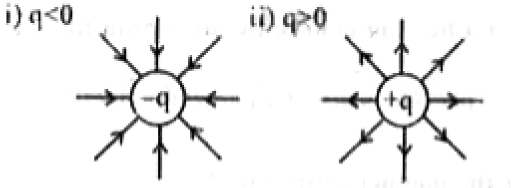
Ans:- $F = Kq1q2/ r^2$

(i) Both charges will repel each other, as they are of same sign, hence slope is positive (ii) Both charges are of opposite sign, therefore they will attract each other, hence the slope is negative.



(i) (ii)

12. Draw the electric field lines of a point charge q when (i) q < 0 and (ii) q > 0



13. Find the electric field between two metal plates 3mm apart, connected to 12V battery.

Ans:- $E = V/d = 12 / 0.003 = 4 \times 10^3$ V/m

14. When is the potential energy of a dipole kept in uniform electric field is minimum and maximum?

Ans:- PE (U) = -PE cosθ

(i) When θ=0º, U = -PE= minimum

(ii) When θ = 180º, U = PE = maximum

15. Two capacitors of capacitance 6μf and 12μf are connected in series with a battery. The voltage across the 6μf capacitor is 2V. Compute the total battery voltage.

Ans:- In series combination , Q is same in both capacitors

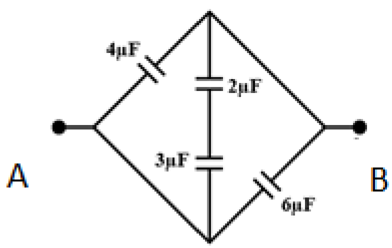
Q1= Q2, C1V1 = C2V2, 6μf x 2V = 12μf x V2

V2 = 6x2 / 12 = 1 volt

V=V1 + V2 = 2V+1V = 3V

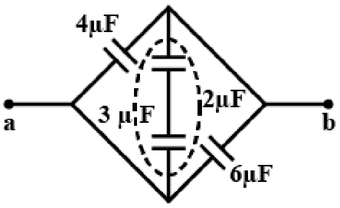
3 –Mark Questions

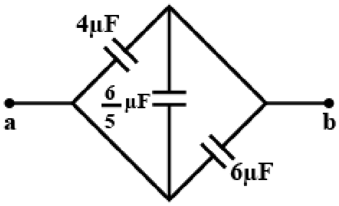
16. From the given figure, find the equivalent capacitance between the points A and B.



Ans:- In series combination C = (C1C2) / (C1+C2) = 3μfx 2μf / 5μf = 6/5 μf

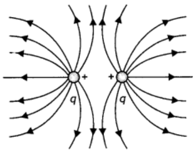
In parallel combination C_{AB}=C1+C2+C3 = 4µf + 6/5µf + 6µf = 56/5µf = 11.2µf



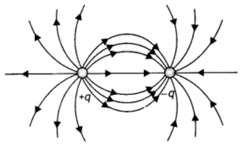


17. Draw electric field lines due to (i) two similar charges, (ii) two opposite charges, separated by a small distance.

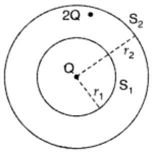
(i) The diagram is as shown.



(ii) The diagram is as shown



18. A sphere S_1 of radius r_1 encloses a net charge Q. If there is another concentric sphere S_2 of radius r_2 (r_2 > r,) enclosing charge 2Q, find the ratio of the electric flux through S_1 and S_2. How will the electric flux through sphere S_1 change if a medium of dielectric constant K is introduced in the space inside S_2 in place of air?



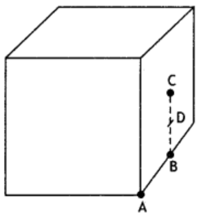
$$\text{Flux through } S_1(\phi_1) = \frac{Q}{\epsilon_0} \quad \ldots(i)$$

$$\text{Flux through } S_2(\phi_2) = \frac{Q+2Q}{\epsilon_0} = \frac{3Q}{\epsilon_0} \quad \ldots(ii)$$

$$\therefore \quad \text{Ratio of flux} = \frac{\phi_1}{\phi_2} = \frac{Q/\epsilon_0}{3Q/\epsilon_0} = \frac{1}{3}$$

Therefore, there will be no change in the flux through S_1 on introducing dielectric medium inside the sphere S_2.

19. What will be the total flux through the faces of the cube (figure) with the side of length 'a' if a charge q is placed at



(a) A: a corner of the cube.
(b) B: mid-point of an edge of the cube.
(c) C: centre of the face of the cube.
(d) D: mid-point of B and C.

(a) The charge wilt is shared by eight cubes if it has to be enclosed. Therefore the flux through the cube will be one-eighth of the total flux. $\Phi = q/8\varepsilon_0$

(b) The charge will be shared by four cubes if it has to be enclosed. Therefore the flux through the cube will be one-fourth of the total flux. $\Phi = q/4\varepsilon_0$

(c) The charge will be shared by two cubes if it has to be enclosed. Therefore the flux through the cube will be one-half of the total flux. $\Phi = q/2\varepsilon_0$

(d) The charge will be shared by two cubes if it has to be enclosed. Therefore the flux through the cube will be one-half of the total flux. $\Phi = q/2\varepsilon_0$

20. A charge of 17.7×10^{-4} C is distributed uniformly over a large sheet of area 200 m^2. Calculate the electric field intensity at a distance of 20 cm from it in the air.

Answer:

Given $q = 17.7 \times 10^{-4}$C, A = 200 m^2, r = 20cm = 0.2 m

Using the relation

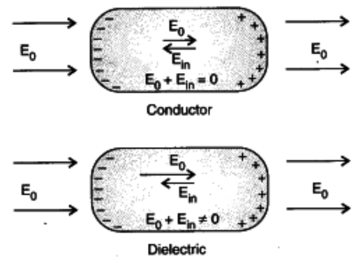
$$E = \frac{\sigma}{\varepsilon_0} = \frac{q}{A\varepsilon_0} = \frac{17.7\times10^{-4}}{200\times8.854\times10^{-12}} = 9.9\times10^5\ NC^{-1}$$

21. Explain using suitable diagrams, the difference in the behaviour of a conductor and dielectric in the presence of external electric field. Define the terms polarisation of a dielectric and write its relation with susceptibility.

Answer-

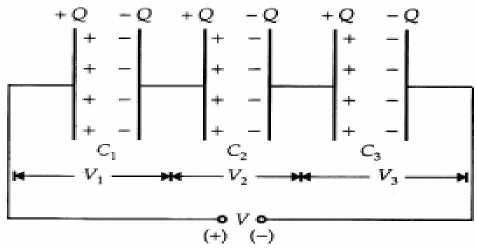
When a conductor is placed in an external electric field, the free charges present inside the conductor redistribute themselves in such a manner that the electric field due to induced charges opposes the external field within the conductor. This happens until a static situation is achieved, i.e. when the two fields cancels each other, then the net electrostatic field in the conductor becomes zero.

Dielectrics are non-conducting substances. i.e. they have no charge carriers. Thus, in a dielectric, free movement of charges is not possible. When a dielectric is placed in an external electric field, the molecules are re-oriented and thus induces a net dipole moment in the dielectric. This produces an electric field. The diagram clearly shows that the net electric field in case of a conductor becomes zero, whereas in case of a dielectric net electric field intensity becomes non zero.



The dipole moment per unit volume of the substance is called polarisation and is denoted by P for linear isotropic dielectrics. $P=\chi E$, χ is the susceptibility.

22. Find the equivalent capacitance of three capacitors connected in series with a battery.



V = V1 + V2 = V3

Q/C = Q/C1 + Q/C2 + Q/C3

1./C = 1/C1 + 1/C2 + 1/C3

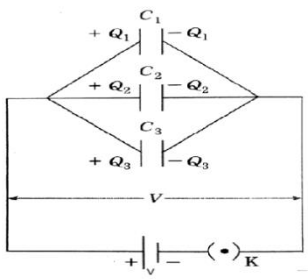
23. Find the equivalent capacitance of three capacitors connected in parallel with a battery.

Potential difference across the capacitors is same as battery potential

Total charge Q = Q1 + Q2 + Q3

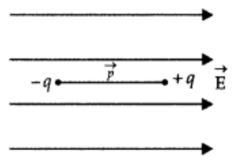
CV = C1V + C2V + C3V

C = C1 + C2 + C3

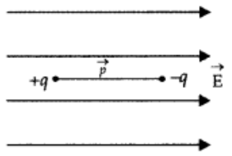


24. Depict the orientation of the dipole in (a) stable, (b) unstable equilibrium in a uniform electric field.

(a) For stable equilibrium, the angle between p and E is 0°,



(b) For unstable equilibrium, the angle between p and E is 180°,



26. Two identical point charges, q each, are kept 2 m apart in the air. A third point charge Q of unknown magnitude and sign is placed on the line joining the charges such that the system remains in equilibrium. Find the position and nature of Q

The third charge Q. wilt is in equilibrium if it experiences zero net force. Let it be placed at a distance x meter from the charge q.

$$k\frac{qQ}{x^2} = k\frac{qQ}{(2-x)^2}$$

$$\text{or } x^2 = (2-x)^2$$

Solving for x, we have x= 1 m

For the equilibrium of charges "q", the nature of charge Q must be opposite to the nature of charge q and should be placed at the centre of two charges.

5- Marks Questions

27. Derive an expression for the torque experienced by an electric dipole kept in a uniform electric field. Consider an electric dipole consisting of charges + q and – q and of length 2a placed in a uniform electric field E making an angle θ with it. It has a dipole moment of magnitude,

Refer Minimum Learning Material

28. A thin conducting spherical shell of radius R has charge Q spread uniformly over its surface. Using Gauss's law,(i) derive an expression for an electric field at a point outside the shell (ii) And at a point inside the shell.

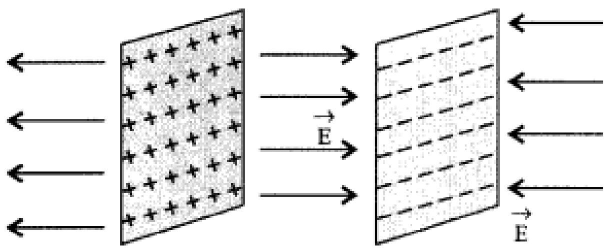
Refer Minimum Learning Material

29. Using Gauss's law, prove that the electric field at a point due to a uniformly charged infinite plane sheet is independent of the distance from it. How is the field directed if

(i) the sheet is positively charged,

(ii) negatively charged?

Refer Minimum Learning Material



(i) (ii)

30. Derive an expression for the electric field at a point on the axis of an electric dipole of dipole moment p.

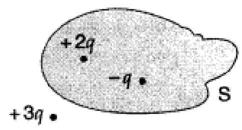
Refer Minimum Learning Material

31. Derive the expression for the electric field at a point on the equatorial line of an electric dipole.

Refer Minimum Learning Material

32. (i) A thin straight infinitely long conducting wire having charge density λ is enclosed by a cylindrical surface of radius r and length l, its axis coinciding with the length of the wire. Find the expression for the electric field through the surface of the cylinder

(ii) Figure shows three point charges, +2q, -q and + 3q. Two charges +2q and -q are enclosed within a surface 'S'. What is the electric flux due to this configuration through the surface 'S' ?



(a) Electric field due to an infinitely long thin straight wire is radial.

Refer Minimum Learning

(ii)

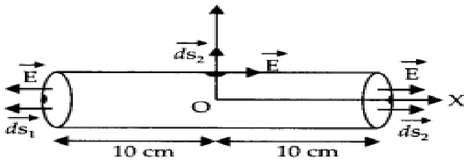
According to *Gauss's law*, $\phi = \oint_S \vec{E}.\vec{dS} = \frac{q_1}{\varepsilon_0}$

where q_1 is the total charge enclosed by the surface S

$$\phi = \frac{2q-q}{\varepsilon_0} = \frac{q}{\varepsilon_0} \quad \therefore \quad \textbf{Electric flux, } \phi = \frac{q}{\varepsilon_0}$$

33. An electric field along the x-axis is given by $\vec{E} = 100\,\hat{i}$ N/C for x > 0 and $\vec{E} = -100\,\hat{i}$ N/C for x < 0. A right circular cylinder of length 20 cm and radius 5 cm lies parallel to the x-axis with its centre at the origin and one face at x = +10 cm, the other face at x = -10 cm. Calculate the net outward flux through the cylinder.

Here $E_x = 100\,\hat{i}\,NC^{-1}$ for $x > 0$
$E_x = -100\,\hat{i}\,NC^{-1}$ for $x < 0$
$l = 20$ cm $= 0.2$ m



r = 5 cm = 0.05 m , Φ = ?

Net outward flux through the cylinder

$\Phi = \Phi_1 + \Phi_2 + \Phi_3$

$= \vec{E}\cdot\vec{dS_1} + \vec{E}\cdot\vec{dS_2} + \vec{E}\cdot\vec{dS_3}$

$= Eds_1 \cos 180° + Eds_2 \cos 90° + Eds3 \cos 0°$

$= -Eds_1 + Eds_2\,(0) + Eds \cos 0°$

$= -(-100)\,ds + 100\,ds$

$= (100 + 100)\,ds$

$= 200 \times \pi r^2 = 200 \times 3.14 \times (0.05)^2$

$= 1.57\ Nm^2\,C^{-1}$

34. Derive the expression for the capacitance of a parallel plate capacitor having plate area A and plate separation d. **Refer Minimum Learning**

35. (i) Derive the expression for the electric potential at any point along the axial line of an electric dipole(ii) What is its potential at a point on the equatorial line?

(i) **Refer Minimum Learning**

(ii) At a point on the equatorial line V=0

36. (i) Find the Capacitance of parallel plate capacitor with a dielectric medium between the plates (ii) Net capacitance of three identical capacitors in series is 1 pF. What will be their net capacitance if connected in parallel? Find the ratio of energy stored in the two configurations if they are both connected to the same source. Ans ; (i) **Refer Minimum Learning**

(ii) Let C be the capacitance of a capacitor

Given : C1 = C2 = C3 = C When connected in series:

When connected in series:

$C_S = \frac{C}{3} = 1\ \mu F \qquad \therefore C = 3\ \mu F$

When connected in parallel:

$C_p = C + C + C = 3 + 3 + 3 = 9\ \mu F$

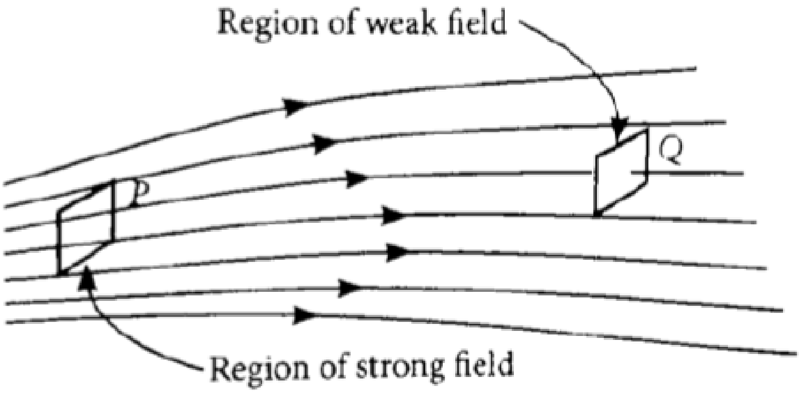
Energy stored in capacitor

$E = \frac{1}{2}CV^2$

$\therefore \frac{E_s}{E_p} = \frac{\frac{1}{2}C_sV^2}{\frac{1}{2}C_pV^2} = \frac{C_s}{C_p} = \frac{1}{9} = \mathbf{1:9}$

CASE STUDY QUESTIONS

01. Electric field strength is proportional to the density of lines of force i.e., electric field strength at a point is proportional to the number of lines of force cutting a unit area element placed normal to the field at that point. As illustrated in given figure, the electric field at P is stronger than at Q.



(i) Why no two field lines intersect each other?

Ans: - At the point of intersection, there should be two directions of force. Physically a body can not move in two directions at the same time. Hence no two field lines intersect each other

(ii) Why do the electric field lines not form any closed loops?
Ans- They originate from positive charge and end at negative charge.

(iii) How will you find electric field strength at point in the field? Where is it strong? At P or Q?

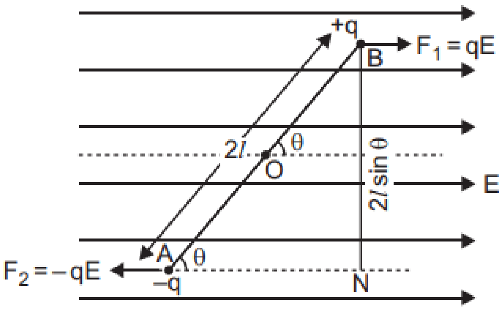
Ans- The number of field lines crossing a unit area, when it is held normal to field line, gives field strength at that point. Field is strong at P than at Q

OR

How will you represent uniform field area? An electron and proton are kept in such field, then find the ratio of force experienced by them.

Ans -Field lines should be parallel and equally spaced. Ratio of forces is 1:1

02. When electric dipole is placed in uniform electric field, its two charges experience equal and opposite forces, which cancel each other and hence net force on electric dipole in uniform electric field is zero. However, these forces are not collinear, so they give rise to some torque on the dipole. Since net force on electric dipole in uniform electric field is zero, so no work is done in moving the electric dipole in uniform electric field. However, some work is done in rotating the dipole against the torque acting on it.



(i) The dipole moment of a dipole in a uniform external field $\bar{E}$ is B. What is the expression for the torque τ acting on the dipole ?

Ans- $\tau = p \times E$

(ii) When an electric dipole is held at an angle in a uniform electric field, What is the net force on the dipole ?

Ans- zero

(iii) An electric dipole consists of two opposite charges, each of magnitude 1.0 μC separated by a distance of 2.0 cm. The dipole is placed in an external field of 10^5 NC^{-1}. Find the maximum torque on the dipole .

Ans- $\tau = p\,E = 2 \times 10^{-3}$ Nm

OR

When is a dipole said to be in (a)stable and (b)unstable equilibrium? Show diagrammatically.

Ans-(a) P and E are in same direction. (b) P and E are opposite direction.

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UNIT- II CURRENT ELECTRICITY

S. No	FORMULAE	SYMBOL	APPLICATION
1	$I = \frac{Q}{t} = \frac{n e}{t}$	I=current, Q=charge , t=time, e= charge of electron	To find the current in a current carrying wire.
2	$V = IR$ (Ohms law)	V= Potential difference, R= resistance	Relation between V and I
3	$I = n e A V_d$ (n = number density of free electron)	V_d= Drift velocity A=area of cross section	Relation between current and drift velocity
4	$R = \frac{\rho l}{A} = \frac{m l}{n e^2 \tau A}$	R = Resistance , ρ = Resistivity τ = relaxation time, m= mass of electron	Relation between (i) R and ρ (ii) R and relaxation time
5	$\rho = \frac{R A}{l} = \frac{m}{n e^2 \tau}$	e = charge of electron ρ = Resistivity	Relation for resistivity and relaxation time τ
6	$C = \frac{1}{R}$ and $\sigma = \frac{1}{\rho} = \frac{l}{R A}$	C= conductance, σ = conductivity	To find C and σ
7	$j = \frac{I}{A} = n e V_d$ $j = \sigma E$	j = current density , σ = conductivity	Relation between j with v_d and j with E
8	$\mu = \frac{V_d}{E} = \frac{e \tau}{m}$	μ = mobility of electron	To find μ from V_d
9	$\rho = \rho_0 [1 + \alpha(T - T_0)]$	α = temperature coefficient of resistance	Variation of ρ with temperature
10	$\alpha = \frac{R_2 - R_1}{R_1 (T_1 - T_2)}$	$T_1 - T_2$ = temperature difference	Formula for α
11	$R_S = R_1 + R_2 + R_3 + \ldots$	R_s = equivalent resistance in series combination	Series combination
12	$1/R_P = 1/R_1 + 1/R_2 + \ldots$	R_P = equivalent resistance in series combination	Parallel combination

13	P = VI = I^2 R = V^2/R	P= Electrical power	Relation for P with V,I and R
14	$E = V + IR = I(R + r)$	E = emf of cell ,	Relation for E and V
15	$(i) V = E - Ir$ $(ii) V = E + Ir$	r = internal resistance V = Potential difference	(i) Current is drawn (ii) cell is being charged
16	$r = (\frac{E}{V} - 1)R$	r = internal resistance R = External resistance	To find internal resistance of cell
17	I = $\frac{nE}{(R+nr)}$	n = number of cells in series R = External resistance	Current drawn when n cells are connected in series
18	I = $\frac{mE}{(mR+r)}$	m = number of cells in parallel	Current drawn when m cells are connected in parallel
19	ΣI = 0 (loop rule) ΣΔV = 0 (junction rule)	ΣI = algebraic sum of charge ΣV = algebraic sum of potential difference	Kirchhoff' s law
20	Drift velocity of electron	**V_d = e E τ/m** V_d = e τ V/m l	E – Electric field

MINIMUM LEARNING MATERIAL

- Electric current is defined as the amount of charge flowing through any cross section of the conductor in unit time. The rate of flow of chrge through the conductor is called electric current. $I = Q/t$. SI Unit Ampere (A).
- The electric current flowing through the conductor is said to be one ampere when one coulomb charge flows through it in one second.
- Current density |J| = I/A.
- Ohm's law: The electric current passing through a conductor is directly proportional to the potential difference applied across it provided the physical conditions such as temperature, pressure etc., remain constant. $V \alpha I$ i.e. $V = IR$, Where R is the resistance of the conductor. Resistance R is the ratio of V & I
- The device which opposes the flow of electric current through it is called resistor. Resistance is the characteristic property of the conductor which offers opposition for the flow of electric current.
- Resistance $R = \rho l/A = ml/ne^2\tau A$ where ρ is the resistivity of the material of the conductor- length and A area of cross section of the conductor. If l is increased n times, new resistance becomes n^2R. If A is increased n times, new resistance becomes $\frac{1}{n^2}R$.
- Resistivity is the characteristic property of the material which is the resistance of the conductor of unit length and unit area of cross section.
- Resistivity $\rho = m/ne^2\tau$, Where m, n, e are mass, number density and charge of electron respectively, τ-relaxation time of electrons. ρ is independent of geometric dimensions.
- Relaxation time is the average time interval between two successive collisions

- Conductance of the material G =1/R and conductivity σ=1/ρ
- Drift velocity is the average velocity of all electrons in the conductor which drift in opposite direction to the applied electric field. Drift velocity $V_d = (eE/m)\tau$ also $I = neAv_d$
- Mobility (μ) of a charge carrier is the ratio of its drift velocity to the applied electric field $\mu = \frac{V_d}{E}$
- Effect of temperature on resistance: Resistance of a conductor increase with the increase of temperature of conductor $R_T = R_o(1+\alpha T)$, where α is the temperature coefficient of resistance of the conductor. α is slightly positive for metal and conductor, negative for semiconductors and insulators and highly positive for alloys.

Kirchhoff's Laws

(i) Junction Rule

The algebraic sum of all currents meeting at a junction in a closed circuit is zero, i.e., Σ I = O.

This law follows law of conservation of charge.

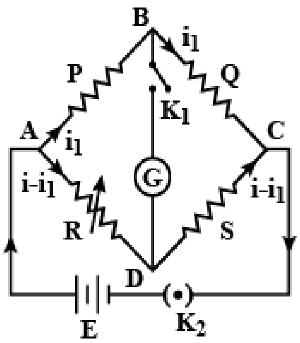
(ii) Loop Rule

The algebraic sum of all the potential differences in any closed circuit is zero, i.e.,

$\Sigma V = 0 \Rightarrow \Sigma E = \Sigma IR$

This law follows law of conservation of energy

. **Wheatstone bridge (balanced)** – Let i be the current from battery E .At point A , current i1 flows through resistance P and current $i-i_1$ flows through R. In balanced state , no current flows through BD , hence point B and D are at same potential .Therefore current i_1 flows through resistance Q also and current $i-i_1$ flows through S.



Applying Kirchhoff's loop rule in closed mesh ABDA , $I_1 P-(i-i_1)R=0$

or $i_1P=(i-i_1)R$.................eq1

In closed mesh BCDB , $i_1Q-(i-i_1)S=0$

Or $i_1Q=(i-i_1)S$ eq2

Dividing eq1 from eq2 , we get

P/Q=R/S This is the condition for balance in a Wheatstone's bridge .

MULTIPLE CHOICE QUESTIONS

1. Among the following dependences of drift velocity v on electric field E, Ohm's law is obeyed when

a) v α E b) v α 1/E c) v α E2 d) v= constant

2. When electric field is applied on the ends of a conductor, the free electrons acquire a small velocity in a direction

a) Along the electric field b) Opposite to the electric field

c) Perpendicular to electric field d) At an angle to the electric field

3.If the electron in Hydrogen atom makes 6.25 x 10^{15} revolutions in one second, the current is

a) 1.12mA b) 1mA c)1.25mA d)1.5mA

4. From the following quantities, the term analogous to temperature is

a) Potential b) Resistance c) Current d) Charge

5. The flow of electric current through a metallic conductor is

a) only due to electrons b) only due to positive charges

c) due to both positive charges and electrons d) neither electrons or positive

6. For making standard resistor, which of following material is used

a) Carbon b)Copper c)Silver d)Manganin

7. A piece of silver and another of silicon are heated from room temperature.The resistance of

a) both increases b) both decreases c)Silver increases and silicon decreases

d)Silver decreases and silicon increases

8. A certain piece of copper is to be shaped into a conductor of minimum resistance.

Its length and cross-sectional area should be

a) L and A b)2L and A/2 c)L/2 and 2A d)3L and A/3

9. With the increase in temperature, the ratio of conductivity to resistivity of a metallic conductor

a)Decreases b)Remains same c)Increases d)Depends on the metal

10. When a piece of aluminium wire of finite length is drawn to reduce its diameter to

half its original value, its resistance become

a)Two times b)Four times c) Eight times d)Sixteen times

11. Consider a rectangular slab of length L, area of cross section A. A current I is passed through it.If the length is doubled, then the potential drop across the end faces for the same current

a) Becomes half of the initial value b) Becomes one-fourth of the initial value

c) Becomes double the initial value d) Remains same

12. A metallic block has no potential difference applied across it, then the mean velocity of free electrons is

a) Proportional to absolute temperature b) Proportional to square root of absolute temperature

c) Zero d) Finite but independent of absolute temperature

13. The resistance of a metal increases with increasing temperature because

a) The collisions of the conducting electrons with the electrons increase

b) The collisions of the conducting electrons with the lattice consisting of the ions of the metal increases

c) The number of conduction electrons decreases d) The number of conduction electrons increases

14. In the absence of applied potential, order of random velocity of the free electron is

a) mm/s b) cm/s c) m/s d) km/s

15. A wire has resistance 12Ω. It is bent in the form of a circle. The effective resistance between two points across its diameter is

a) 3Ω b)6Ω c)12Ω d)24Ω

16. The resistance of a wire of 100cm length is 10Ω. Now, it is cut into 10 equal parts and all of them are twisted to form a single bundle. Its resistance is

a) 1 ohm b)0.5 ohm c) 5 ohm d) 0.1 ohm

17. A piece of wire of resistance 4 ohm is bent through 180^0 at its midpoint and the two halves are twisted together. Then the resistance is

a) 8 ohm b)1 ohm c) 2 ohm d) 5 ohm

18. Two lamps have resistance r and R, R > r. If they are connected in parallel in an electric circuit, then

a) The lamp with resistance R will shine more brightly
b) The lamp with resistance r will shine more brightly
c) The two lamps will shine equal brightly d) The lamp with resistance R will not shine at all

19. The direction of current inside a cell is
a) Negative pole to positive pole during discharging (b) Positive pole to negative pole during discharging
c) Always negative pole to positive pole (d) Always flows from positive pole to negative pole

20. The terminal voltage of a cell is greater than its emf when it is
a) Being charged b) An open circuit
c) Being discharged d) It never happens

21. What is constant in a battery (also called a source of emf?
a) Current supplied by it b) Terminal potential difference
c) Internal resistance d) Emf

22. In a circuit two or more cells of the same emf are connected in parallel in order
a) Increase the potential difference across a resistance in the circuit
b) Decreases potential difference across a resistance in the circuit
c) Facilitate drawing more current from the battery system
d) Change the emf across the system of batteries

25. The resistance of an open circuit is
a) Infinity b) Zero c) Negative d) Positive

26. Internal resistance of a cell depends on
a) Concentration of electrolyte b) Distance between electrodes
c) Area of electrode d) All the above

27. The terminal potential difference of a cell is equal to its emf if
a) External resistance is infinity b) Internal resistance is zero
c) Both a) and b) d) Neither a) nor b)

28. Kirchhoff's law of junctions is also called the law of conservation of
a) Energy b) Charge c) Momentum d) Angular momentum

29. If galvanometer and battery are interchanged in balanced Wheatstone's bridge, then
a) The battery discharges b) The bridge still balances
c) The balance point is changed d) The galvanometer is damaged due to flow of high current

30. A p.d. V is applied across a conductor of length L and diameter D. How are electric field E and resistance R affected if the p.d. V is halved
a) E and R become double b) E doubles and R is halved
c) E and R become half d) E is halved and R remains same

ANSWERS :

1	2	3	4	5	6	7	8	9	10
A	B	b	A	A	d	c	C	a	d

11	12	13	14	15	16	17	18	19	20
C	C	b	C	A	d	b	B	a	a
21	22	23	24	25	26	27	28		
D	C	a	D	C	b	b	D		

II Assertion and Reason questions

Directions: These questions consist of two statements, each printed as Assertion and Reason. While answering these questions, you are required to choose any one of the following four responses.
(a) If both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.
(b) If both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.
(c) If the Assertion is correct but Reason is incorrect.
(d) If both the Assertion and Reason are incorrect.

Q.1. Assertion : In a simple battery circuit, the point of the lowest potential is positive terminal of the battery.
Reason : The current flows towards the point of the higher potential, as it does in such a circuit from the negative to the positive terminal.

Q.2. Assertion : A larger dry cell has higher emf.
Reason : The emf of a dry cell is proportional to its size.

Q.3. Assertion : The resistivity of a substance is a characteristic property of the material.
Reason : The resistivity of a substance does not depend on the nature of the substance and temperature.

Q.4. Assertion : Voltmeter is connected in parallel with the circuit.
Reason : Resistance of a voltmeter is very large.

Q.5. Assertion : Ohm's law is applicable for all conducting elements.
Reason: Ohm's law is a fundamental law.

Q.6. Assertion : An electric bulb becomes dim, when the electric heater in parallel circuit is switched on.
Reason Dimness decreases after sometime.

Q.7. **Assertion :** Voltmeter always gives e.m.f of a cell if it is connected across the terminals of a cell.
Reason Terminal potential of a cell is given by $V = E\text{-}Ir$

Q.8. Assertion : Bending a wire does not effect electrical resistance.

Reason : Resistance of wire is proportional to resistivity of material.

Q.9. Assertion : Kirchoff's junction rule can be applied to a junction of several lines or a point in a line.

Reason : when steady current is flowing, there is no accumulation of charges at any junction or at any point in a line.

Q.10. Assertion : Long distance power transmission is done at high voltage.

Reason : At high voltage supply power losses are less.

ANSWERS :

1	2	3	4	5	6	7	8	9	10
D	d	c	b	c	b	d	A	A	a

II. Short answer type (Each question carries 2 marks)

1. Two metallic wires of the same material have the same length but cross-sectional area is in the ratio 1 : 2. They are connected
(i) in series and
(ii) in parallel.

Compare the drift velocities of electrons in the two wires in both the cases (i) and (ii).

Given : $l_1 = l_2 = l$

$A_1 : A_2 = 1 : 2$ or $\frac{A_1}{A_2} = \frac{1}{2}$

As $R = \rho \frac{l}{A}$, as $\rho_1 = \rho_2$

We have $\frac{R_1}{R_2} = \frac{2}{1}$

(*i*) In series current is same so from

$v_d = \frac{I}{neA}$ So, $I_1 = I_2$, $\frac{A_1}{A_2} = \frac{1}{2}$

We get $\frac{v_{d_1}}{v_{d_2}} = \frac{2}{1}$ $\therefore$ $v_{d_1} : v_{d_2} = 2 : 1$

(*ii*) In parallel current gets divided in inverse ratio of resistances

$\therefore \quad \frac{I_1}{I_2} = \frac{R_2}{R_1} = \frac{1}{2}$

As $v_{d_1} = \frac{I_1}{enA_1}$, $v_{d_2} = \frac{I_2}{enA_2}$

We have $\frac{v_{d_1}}{v_{d_2}} = \frac{I_1}{I_2} \times \frac{A_2}{A_1} = \frac{1}{2} \times \frac{2}{1} = \frac{1}{1}$

$\therefore \quad v_{d_1} : v_{d_2} = 1 : 1$

2. Derive an expression for the resistivity of a good conductor, in terms of the relaxation time of electrons.
Answer:
Drift speed gained by an electron under the effect of electric field **E** in a conductor is

$$v_d = \frac{eE}{m}\tau$$

$$v_d = \frac{eV}{ml}\tau \qquad \ldots\left(\because E = \frac{V}{l}\right)$$

We have relation, $I = neAv_d$

$$I = neA\left(\frac{eV}{ml}\tau\right), \quad R = \frac{V}{I} = \frac{ml}{ne^2\tau A} \Rightarrow R = \rho\frac{l}{A}$$

$$\frac{ml}{ne^2\tau A} = \rho\frac{l}{A}$$

$\rho = m/ne^2\tau$ between resistivity and relaxation time of electrons.

3. Using the mathematical expression for the conductivity of a material, explain how it varies with temperature for
(i) semiconductors,
(ii) good conductors.
Answer:
Conductivity $\sigma = ne^2\tau/ m$
(i) Semiconductors: With increase in temperature, conductivity of semiconductor increases. It is due to

increase in V. It dominates the effect caused by decrease in 'x'.
(ii) Good conductors : With increase in temperature, conductivity of good conductors decreases. It is due to decrease in the value of relaxation time. The effect of increased value of V is negligible.

4. Derive an expression for drift velocity of free electrons in a conductor in terms of relaxation time.
Answer:
In the absence of electric field the electrons motion is random and the net velocity is zero. In the presence of electric field, they tend to flow opposite to that of the electric field in the conduction. If an electric field 'E' is applied across a length l of the conductor, the electrons will experience an acceleration, a =eE/m.
If the average time for the acceleration is x, the velocity required is

$$\vec{v}_d = \vec{u} + \vec{a}\,\tau = \vec{a}\,\tau. \therefore v_d = -\frac{e\vec{E}}{m}\tau, \left|\vec{v}_d\right| = \frac{eE}{m}\tau$$

5.. A battery of emf 10 V and internal resistance 3Ω is connected to a resistor. If the current in the circuit is 0.5 A, find
(i) the resistance of the resistor;
(ii) the terminal voltage of the battery.
Answer:

(*i*) Since $I = \frac{V}{r+R}$ $\quad \therefore \frac{10}{r+R} = 0.5$

or $\frac{10}{3+R} = 0.5$ $\quad$ or $\frac{100}{5} = 3 + R$

$\therefore$ $R = 20 - 3 = \mathbf{17\Omega}$

(*ii*) Since $V = IR$ $\therefore$ $V = \frac{5}{10} \times 17 = \frac{85}{10} = \mathbf{8.5V}$

6. A battery of emf 6 V and internal resistance 2Ω is connected to a resistor. If the current in the circuit is 0.25 A, find
(i) the resistance of the resistors;
(ii) the terminal voltage of the battery.
Answer:

(*i*) **Given :** Current, I = 0.25 A, emf, $\varepsilon = 6V$,
internal resistance, $r = 2\ \Omega$

As $I = \frac{\varepsilon}{r+R}$ $\quad \Rightarrow 0.25 = \frac{6}{2+R}$

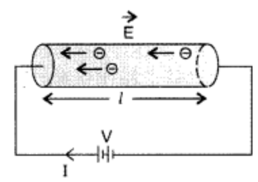
$\Rightarrow 2 + R = \frac{600}{25} = 24$

$\therefore$ *Resistance,* $R = 24 - 2 = \mathbf{22\ \Omega}$

(*ii*) As $V = IR$ $\quad \therefore V = \frac{25 \times 22}{100} = \frac{22}{4} = 5.5$ V

$\therefore$ *Terminal voltage,* **V = 5.5 V**

7. Explain the term 'drift velocity' of electrons in a conductor. Hence obtain the expression for the current through a conductor in terms of 'drift velocity'
Answer:
Definition : Drift velocity is defined as the velocity with which free electrons in a conductor get drifted in a direction opposite to the direction of the applied field. Its unit is m/s.



Expression : The magnitude of electric field set up across the conductor is given by
E = V/l
Let n be the number of free electrons per unit volume of the conductor.
Then, total number of free electrons in the conductor

= n × Volume of the conductor

Hence, Q = (nAl)e

Time taken by the charge to cross the conductor length l is given by

$$t = \frac{1}{v_d} \quad \text{where } [v_d \text{ is drift velocity of electrons}$$

$$\therefore \quad I = \frac{Q}{t} = \frac{nAle}{\frac{l}{v_d}} = neAv_d \quad \therefore \boxed{I = neAv_d}$$

8. Derive the expression for the current in a conductor of cross-sectional area A in terms of drift velocity.

Expression : Consider a conductor of length l and of uniform cross-section area A .

∴ Volume of the conductor = Al

If n is the number of the conductors, then total number of free electrons in the conductor = Aln

If e is the charge on " each electron, then

total charge on all A the free electrons in the conductor, q = Alne

The electric field set up across the conductor of potential difference V is given by,

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

Due to this field, the free electrons present in the conductor will begin to move with a drift velocity vd towards the positive terminal of the battery

∴ Time taken by free electrons to cross the conductor,

$$t = \frac{l}{v_d}$$

$$\text{Hence, Current } I = \frac{l}{v_d}\frac{q}{t} = \frac{Alne}{l / v_d} \Rightarrow I = Anev_d$$

SinceA, n and e are constants,

Hence $I \propto v_d$,Therefore, the current flowing through a conductor is directly proportional to the drift velocity.

9. State Kirchhoff's rules. Explain briefly how these rules are justified.

Kirchhoff's junction rule : At any junction, the sum of the currents entering the junction is equal to the sum of currents leaving the junction.

1.Kirchhoff's loop rule : The algebraic sum of changes in potential in any closed loop involving resistors and cells is zero.

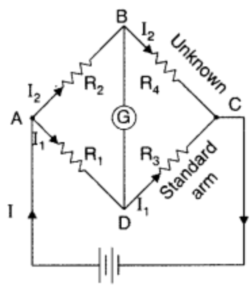
These two laws are justified on the basis of law of conservation of charge and the law of conservation of energy respectively.

10. Use Kirchhoff's rules to obtain conditions for the balance condition in a Wheatstone bridge.

Answer:

Conditions for the balance condition in a Wheatstone bridge :

Applying Kirchhoff's loop rule to closed loop ADBA,



$$-I_1R_1 + 0 + I_2R_2 = 0 \quad (I_g = 0) \qquad \ldots(i)$$

For loop CBDC,

$$-I_2R_4 + 0 + I_1R_3 = 0 \quad (I_g = 0) \qquad \ldots(ii)$$

From equation, (i)

$$\frac{I_1}{I_2} = \frac{R_2}{R_1}$$

From equation, (ii)

$$\frac{I_1}{I_2} = \frac{R_4}{R_3} \qquad \therefore \frac{R_2}{R_1} = \frac{R_4}{R_3} \quad \text{or} \quad \mathbf{\frac{R_1}{R_2} = \frac{R_3}{R_4}}$$

This is the required balance condition in a Wheatstone bridge arrangement.

III. Short answer type (3 marks)

1. Prove that the current density of a metallic conductor is directly proportional to the drift speed of electrons.

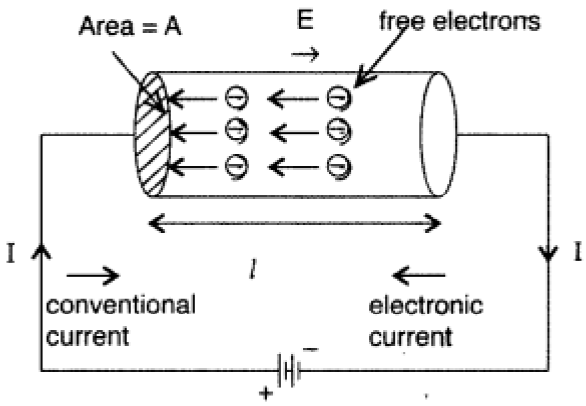
Suppose a potential difference V is applied across a conductor of length l and of uniform cross-section A. The electric field E set up inside the conductor is given by

E = V/ l

Under the influence of field **E**, the free electrons begin to drift in the opposite direction **E** with an average drift velocity vd.

Let the number of electrons per unit volume or electron density = n

Charge on an electron = e



No. of electrons in length l of the conductor = n x volume of the conductor = n × Al

Total charge contained in length l of the conductor is

q = enAl … (i)

All the electrons which enter the conductor at the right end will pass through the conductor at the left end in time,

$$t = \frac{\text{distance}}{\text{velocity}} = \frac{l}{v_d} \qquad \ldots (ii)$$

Using equations (i) and (ii), we get

$$\text{Current } I = \frac{q}{t} = \frac{l\,ne\,A}{l / v_d} = neAv_d$$

Current density 'J' is given by

$$J = \frac{I}{A} = \frac{neAv_d}{A} = nev_d \qquad \therefore \mathbf{J} \propto v_d$$

Hence the current density of a metallic conductor is directly proportional to the drift speed of electrons.

2.Define resistivity of a conductor. Plot a graph showing the variation of resistivity with temperature for a metallic conductor. How does one explain such a behaviour, using the mathematical expression of the resistivity of a material.

Answer:

(i) Resistivity of conductor : It is the resistance of a conductor of unit length and unit area of cross-section.

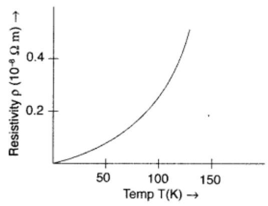
The S.I. unit of resistivity is Ω m (ohm-metre)

$$\rho = R\,\frac{A}{l}$$

(ii) Variation of resistivity with temperature :

The resistivity of a material is given by

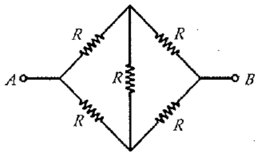
$$\rho = \frac{m}{ne^2\tau}$$



On increasing temperature, average speed of drifting electrons increases. As a result collisions are more frequent. Average relaxation time τ decreases, hence ‘ρ’ increases.

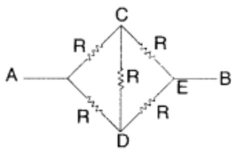
3. (i) Calculate the equivalent resistance of the given electrical network between points A and B.

(ii) Also caculate the current through CD and ACB, if a 10 V d.c. source is connected between A and B, and the value of R is assumed as 2 Ω.



(i) Equivalent circuit of the given problem is shown in the given diagram. The simplified circuit is equivalent to a balanced wheatstone bridge.

Hence there will be no current in arm CD,



(ii) Being a balanced wheatstone bridge

$I_{CD} = 0$

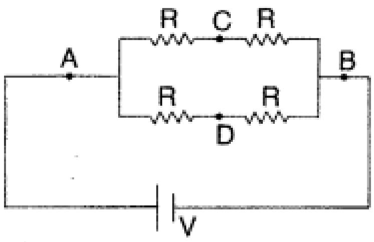
$V = 10$ volt

$R = 2\Omega$

$V_{AB} = 10$ volt

$R_{ACB} = 4\Omega$

$$\therefore\ I_{ACB} = \frac{10}{4} = \mathbf{2.5A}$$



4. Write any two factors on which internal resistance of a cell depends. The reading on a high resistance voltmeter, when a cell is connected across it, is 2.2 V. When the terminals of the cell are also connected to a resistance of 5 Ω as shown in the circuit, the voltmeter reading drops to 1.8 V. Find the internal resistance of the cell.

(a) Internal resistance of a cell depends upon :

(i) nature of electrolyte of the cell

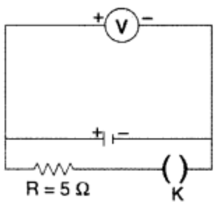
(ii) separation between the electrodes.

(b) Given: emf of cell, e = 2.2 V, R = 5 Ω, V = 1.8 V

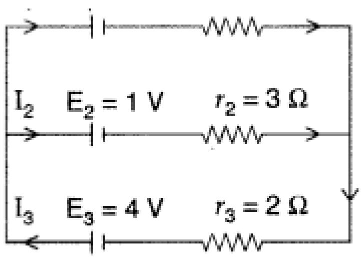
$$r = \left(\frac{\varepsilon}{V} - 1\right) R$$

$$\Rightarrow r = \left(\frac{2.2}{1.8} - 1\right) \times 5 = \left(\frac{2.2 - 1.8}{1.8}\right) \times 5$$

$$\therefore\ r = \frac{0.4}{1.8} \times 5 = \frac{2}{1.8} = \mathbf{1.1\ \Omega}$$



5. State Kirchhoff’s rules. Use these rules to write the expressions for the current I_1, I_2 and I_3 in the circuit diagram shown.



Answer:
(i) Kirchhoff's junction rule : At any junction, the sum of the currents entering the junction is equal to the sum of currents leaving the junction.
(ii) Kirchhoff's loop rule : The algebraic sum of changes in potential-in any closed loop involving resistors and cells is zero.
(b) According to Kirchhoff's junction rule,

$$I_3 = I_1 + I_2 \qquad \ldots(i)$$

Considering loop FCDEF

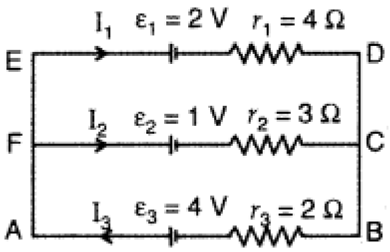
$$3I_2 - 4I_1 = 1 \qquad \ldots(ii)$$

Considering loop FCBAF

$$3I_2 + 2I_3 = 3 \qquad \ldots(iii)$$

$$3I_2 + 2(I_1 + I_2) = 3$$

$$5I_2 + 2I_1 = 3 \qquad \ldots(iv)$$



On solving equations (*i*), (*ii*) and (*iv*), we get

$$I_1 = \frac{2}{13}\,\text{A}; \qquad I_2 = \frac{7}{13}\,\text{A}; \qquad I_3 = \frac{9}{13}\,\text{A}$$

6. Define the terms
(i) drift velocity,
(ii) relaxation time.
A conductor of length L is connected to a dc source of emf e. If this conductor is replaced by another conductor of same material and same area of cross-section but of length 3L, how will the drift velocity change?
Answer:
(i) Drift velocity : It may be defined as the average velocity gained by the free electrons of a conductor in the opposite direction of the externally applied field.
(ii) Relaxation time : The average time that elapses between two successive collisions of an electron is called relaxation time.

$$V'_d = \frac{eV}{m3L} = \frac{1}{3}V_d \qquad \because\ V_d = \frac{eV}{mL}$$

When length is tripled (3L), drift velocity becomes one-third of the original.
For details :
(i) Drift velocity. Drift velocity is defined as the velocity of the free electrons with which they get drifted towards the positive terminal under the influence of the external electric field. The drift velocity of electron

is of the order of 10~5 m/ sec.

Derivation. Let 'm' be the mass of an electron and 'e' be the charge on it. When an external electric field 'E is applied, the acceleration
acquired by an electron is given by

$$F = ma \qquad \Rightarrow a = \frac{F}{m} \qquad \Rightarrow a = \frac{eE}{m}$$

Let v1 v2, v3 … vn be final velocities of electrons then average velocity of the electrons is given by

Let $v_1, v_2, v_3 \ldots v_n$ be final velocities of electrons then average velocity of the electrons is given by

$$v_d = \frac{v_1 + v_2 + v_3 \ldots v_n}{n} \qquad \ldots(i)$$

$$v_d = \frac{v_1 + v_2 + v_3 \ldots v_n}{n} = \frac{(u_1 + at_1) + (u_2 + at_2) + \ldots (u_n + at_n)}{n}$$

$$[\because v = u + at]$$

$$v_d = \frac{(u_1 + u_2 + \ldots u_n)}{n} + \frac{a(t_1 + t_2 + \ldots t_n)}{n}$$

$$v_d = 0 + a\tau \quad \Rightarrow v_d = a\tau$$

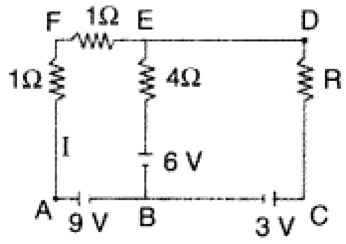
$$\therefore\ v_d = \frac{eE}{n}\tau \qquad \ldots[\text{From}(i)]$$

where $\left[\tau = \dfrac{t_1 + t_2 + \ldots t_n}{n}\right.$ is the average time between two successive collisions and called **relaxation time**.

(ii) We know that $v_D = \dfrac{e}{m}\left(\dfrac{E}{L}\right)\tau \ \therefore\ v_D \propto \dfrac{1}{L}$

Therefore, when length is tripled, the drift velocity becomes one-third.

7. Using Kirchoff's rules determine the value of unknown resistance R into circuit so that no current flows through 4Ω resistance. Also find the potential difference between A and D.



Answer: Current flows from A TO E, E to D to C to B to A.

Putting the value of current I from (*i*), we have

$$\frac{3}{2} \times R = 3 \qquad \therefore\ R = 3 \times \frac{2}{3} = 2\Omega \ \ldots(ii)$$

Potential difference between A and D through path ABCD

$$+9V - 3V - IR = V_{AD}$$

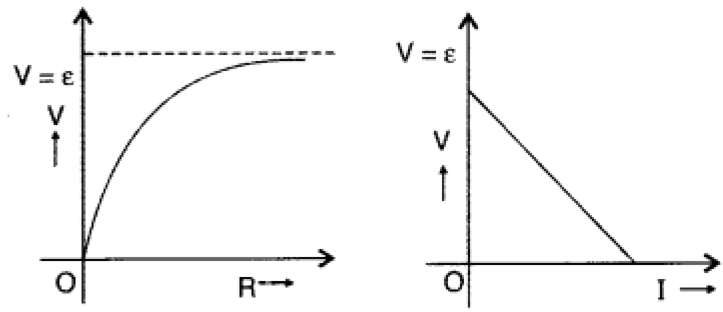
$$\Rightarrow \quad +9V - 3V - \frac{3}{2} \times 2 = V_{AD}$$

[Alternatively through path AFD]

$$\therefore \quad V_{AD} = 3V$$

8. A cell of emf 'E' and internal resistance V is connected across a variable load resistor R. Draw the plots of the terminal voltage V versus
(i) R and
(ii) the current I.
It is found that when R = 4 Ω, the current is 1 A and when R is increased to 9 Ω, the current reduces to 0.5 A. Find the values of the emf E and internal resistance r.
Answer:

(*a*) **Graph between V and I** (*b*) **Graph between V and R**



(*c*) $I = \dfrac{E}{R+r} \quad I = \dfrac{E}{4+r} \quad \Rightarrow E = 4 + r \qquad \ldots(i)$

Also $0.5 = \dfrac{E}{9+r} \qquad \Rightarrow E = 4.5 + 0.5r \ \ldots(ii)$

From equations (*i*) and (*ii*)

$$4 + r = 4.5 + 0.5r \ \therefore\ r = \mathbf{1\Omega}$$

Using this value of *r*, in equation (*i*) we get

$$\mathbf{E = 5V}$$

9. Derive the expression for the current density of a conductor in terms of the conductivity and applied electric field. Explain, with reason how the mobility of electrons in a conductor changes when the potential difference applied is doubled, keeping the temperature of the conductor constant.
Answer:
(i) Derivation of expression for current density—
Using Ohm's law,

$$V = IR = \frac{I\rho l}{A} = I\left(\frac{\rho l}{A}\right) \qquad \ldots(i)$$

Potential difference (V), across the ends of a conductor of length 'l' where field 'E' is applied, is given by

$$V = El \quad \ldots(ii)$$

From equations (*i*) and (*ii*),

$$\therefore \quad El = I\left(\frac{\rho l}{A}\right)$$

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

$$El = J\rho l = \frac{Jl}{\sigma} \qquad \left[\because \rho \frac{1}{\sigma}\right]$$

$$\Rightarrow \quad J = \sigma E$$

(*ii*) Mobility, $\mu = \frac{v_d}{E} = \frac{v_d}{\frac{V}{l}}$

So, as potential is doubled, drift velocity also gets doubled, therefore, there will be no change in mobility.

10. Potential difference V is applied across the ends of copper wire of length (l) and diameter D. What is the effect on drift velocity of electrons if
(1) V is doubled
(2) l is doubled
(3) D is doubled
Ans.

(1) Since V_d

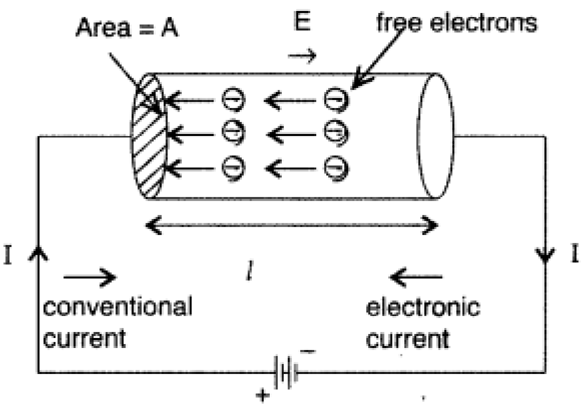
$$= V_d = \frac{I}{neA} = \frac{V}{R(neA)}$$

$$= \frac{V}{\left(P\frac{\ell}{A}\right)(neA)} = \frac{V}{nep\ell}$$

V is doubled, drift velocity gets doubled.
(2) If l is doubled, drift velocity gets halved.
(3) Since V of is independent of D, drift velocity remains unchanged.

Long answer type (5 marks)

1. (a) Derive the relation between current density '**J**' and potential difference 'V' across a current carrying conductor of length area of cross-section 'A' and the number density of free electrons.
(b) Estimate the average drift speed of conduction electrons in a copper wire of cross-sectional area 1.0×10^{-7} m^2 carrying a current of 1.5 A. [Assume that the number density of conduction electrons is 9×10^{28} m^{-3}]
(a)
Suppose a potential difference V is applied across a conductor of length l and of uniform cross-section A. The electric field E set up inside the conductor is given by
E = V/l
Under the influence of field **E** the free electrons begin to drift in the opposite direction **E** with an average drift velocity v_d.
Let the number of electrons per unit volume or electron density = n
Charge on an electron = e



No. of electrons in length l of the conductor = n x volume of the conductor = n × Al
Total charge contained in length l of the conductor is
q = enAl … (i)
All the electrons which enter the conductor at the right end will pass through the conductor at the left end in time,

$$t = \frac{\text{distance}}{\text{velocity}} = \frac{l}{v_d} \quad \text{... } (ii)$$

Using equations (*i*) and (*ii*), we get

$$\text{Current I} = \frac{q}{t} = \frac{l\,ne\,A}{l/v_d} = neAv_d$$

Current density 'J' is given by

$$J = \frac{I}{A} = \frac{neAv_d}{A} = nev_d \qquad \therefore J \propto v_d$$

Hence the current density of a metallic conductor is directly proportional to the drift speed of electrons.

(*b*) Since $I = neAv_d \Rightarrow v_d = \frac{1}{neA}$

$$\therefore \quad v_d = \frac{1.5}{9\times10^{28}\times1.6\times10^{-19}\times1.0\times10^{-7}}$$

$$= \frac{1.5}{9\times1.6}\times10^{-28+26}$$

$$= \frac{0.5}{4.8}\times10^{-2} = \mathbf{1.04\times10^{-3}\ m/s}$$

2. (i) Define the term drift velocity.
(ii) On the basis of electron drift, derive an expression for resistivity of a conductor in terms of number density of free electrons and relaxation time. On what factors does resistivity of a conductor depend?
(iii) Why alloys like constantan and manganin are used for making standard resistors?
Answer:
(i) Drift velocity may be defined as the average velocity gained by the free electrons of a conductor in the opposite direction of the externally applied field.
(ii)
Relaxation time : The average time that elapses between two successive collisions of an electron is called relaxation time.

$$\vec{V}_d = \vec{a}\,\tau = -e\frac{\vec{E}}{m}\tau$$

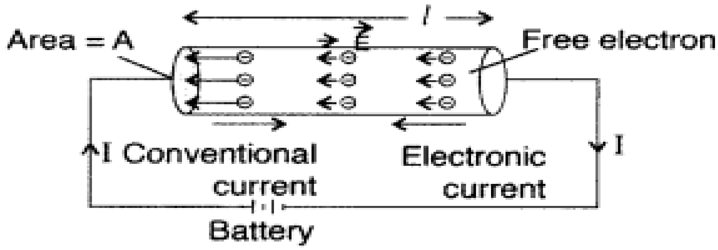
where [$\vec{V}_d$ is called drift velocity of electrons.]

Suppose a potential difference V is applied across a conductor of length T and of uniform cross-section A, then

Electric field E set up inside the conductor is given by

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

Under the influence of field E→, the free electrons begin to drift in the opposite direction E→ with an average drift velocity vd.



Let the number of electrons per unit volume or electron density = n

Charge on an electron = e

Number of electrons in length l of the conductor = n × volume of the conductor = nAl

Total charge contained in length l of the conductor, q = enAl

According to the electrons which enter the conductor at the right end will pass through the conductor at the left end in time,

$$t = \frac{\text{distance}}{\text{velocity}} = \frac{l}{v_d},$$

$$\text{Current, } I = \frac{q}{t} = \frac{enAl}{l / v_d} = enAv_d$$

$$I = enAv_d \qquad . \qquad v_d = \frac{eE\tau}{m} = \frac{eV\tau}{ml}$$

$$I = enAv_d = enA.\frac{eV\tau}{ml}$$

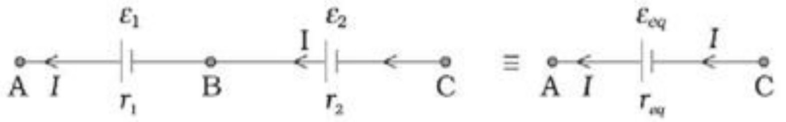
$$\frac{v}{I} = \frac{ml}{ne^2\tau A} \qquad \therefore R = \frac{ml}{ne^2\tau A}$$

where [R is electrical resistivity]

$$R = \rho\frac{l}{A}, \text{ or } \rho = \frac{AR}{l} \quad \therefore \rho = \frac{Aml}{ne^2\tau Al} = \frac{m}{ne^2\tau}$$

(iii) Because constantan and manganin show very weak dependence of resistivity on temperature. .

3. Two cells of different emfs and different internal resistances are connected in series. Find the equivalent emf and equivalent internal resistance of the combination.



Let V (A), V (B), V (C) be the potentials at points A, B and C shown in Fig. Then V (A) – V (B) is the potential difference between the positive and negative terminals of the first cell.

$V_{AB} = V(A) - V(B) = \varepsilon - I\,r$

Similarly, $V_{BC} = V(B) - V(C) = \varepsilon - I\,r$

Hence, the potential difference between the terminals A and C of the combination is

$$V_{AC} = V(A) - V(C) = [V(A) - V(B)] + [V(B) - V(C)]$$
$$V_{AC} = (\varepsilon_1 + \varepsilon_2) - I(r_1 + r_2)$$
$$or, V_{AC} = \varepsilon_{eq} - Ir_{eq}$$
$$where, \varepsilon_{eq} = \varepsilon_1 + \varepsilon_2$$
$$\text{and}, r_{eq} = r_1 + r_2$$

If we connect the two negatives of the cell, we get

$$\varepsilon_{eq} = \varepsilon_1 - \varepsilon_2 \; (\varepsilon_1 > \varepsilon_2)$$

Note: For ***n*** cells of EMF $\boldsymbol{\varepsilon}$ and internal resistance ***r***

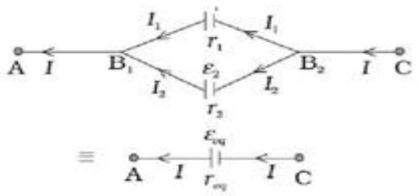
The total emf = n $\boldsymbol{\varepsilon}$

The total resistance = nr + R and

Current $I = \dfrac{n\varepsilon}{R+nr}$

If out of ***n*** cells, ***m*** cells are grouped in reverse order then, **net emf =** $n\,\varepsilon - (2m)\,\varepsilon$

4. Two cells of different emfs and different internal resistances are connected in parallel. Find the equivalent emf and equivalent internal resistance of the combination.



Consider a parallel combination of the cells. I_1 and I_2 are the currents leaving the positive electrodes of the cells. At the point B_1, I_1 and I_2 flow in whereas the current I flow out. Since as much charge flows in as out, we have

$$I = I_1 + I_2$$

Let V (B_1) and V (B_2) be the potentials at B_1 and B_2, respectively. Then, considering the first cell, the potential difference across its terminals is V (B_1) – V (B_2). Hence,

$$V = V(B_1) - V(B_2) = \varepsilon_1 - I_1 r_2$$

$$\Rightarrow I_1 = \frac{\varepsilon_1 - V}{r_1}$$

For the second cell

$$V = V(B_1) - V(B_2) = \varepsilon_2 - I_2 r_2$$

$$\Rightarrow I_2 = \frac{\varepsilon_2 - V}{r_2}$$

$$Now, I = I_1 + I_2$$

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

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

$$or, V = \varepsilon_{eq} - I r_{eq}$$

$$where\ \varepsilon_{eq} = \frac{\varepsilon_1 r_2 + \varepsilon_2 r_1}{r_1 + r_2}$$

$$and\ r_{eq} = \frac{r_1 r_2}{r_1 + r_2}$$

$$or, in\ simpler\ way \boxed{\frac{I}{r_{eq}} = \frac{1}{r_1} + \frac{1}{r_2}} \qquad and, \boxed{\frac{\varepsilon_{eq}}{r_{eq}} = \frac{\varepsilon_1}{r_1} + \frac{\varepsilon_2}{r_2}}$$

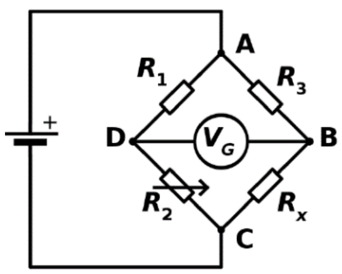
Note: For m rows of cells of emf ε and internal resistance r.

The total resistance $= \frac{r}{m} + R$

$$And\ current = I = \frac{m\varepsilon}{mR + r}, \quad If\ r \ll R, \quad I = \frac{\varepsilon}{R}$$

Case Study Questions

Q1. A **Wheatstone bridge** is an electrical circuit used to measure an unknown electrical resistance by balancing two legs of a bridge circuit, one leg of which includes the unknown component. The primary benefit of the circuit is its ability to provide extremely accurate measurements . The resistance is adjusted until the bridge is "balanced" and no current flows through the galvanometer At this point, the voltage between the two midpoints (**B** and **D**) will be zero. Therefore the ratio of the two resistances in the known leg is equal to the ratio of the two resistances in the unknown leg



1. In balanced Wheat Stone bridge, What is the potential difference between B and D?

Potential at points B and D remain same, so potential difference is zero.

2. What is the use of the Wheat bridge ?

It is used to measure unknown resistance, compare the resistances and find temperature coefficient of resistance or resistivity of the material.

3. Name the devise using in the laboratory to use Wheatstone condition to find unknown resistance?

Meter Bridge

4. Write the Condition for balanced Wheat stone bridge.

R1 / R2 = R3/ Rx

Q2. Voltage is the difference in charge between two points. **Current** is the rate at which charge is flowing. **Resistance** is a material's tendency to resist the flow of charge (current). So, when we talk about these values, we're really describing the movement of charge, and thus, the behaviour of electrons. A circuit is a closed loop that allows charge to move from one place to another. Components in the circuit allow us to control this charge and use it to do work. Ohm was a Bavarian scientist who studied electricity. Ohm starts by describing a unit of resistance that is defined by current and voltage.

1. Write the relationship gave by Ohm in the above passage.
   Voltage and Current

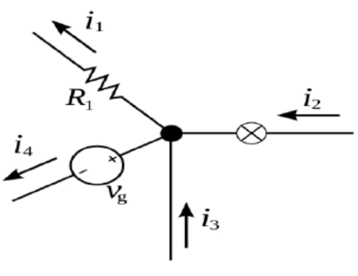
Voltage across the ends of conductor directly proportional to the current through it at constant physical condition.

2. Write SI unit of resistance.
   Ohm
3. What condition the flow of positive charge takes place?

The flow of positive charge takes place when potential difference maintained. That if from Higher to Lower Potential

4. Name the device measures Voltage.
   Voltmeter

Q3. Kirchhoff's circuit laws are two equalities that deal with the current and potential difference in the lumped element model of electrical circuits. They were first described in 1845 by German physicist Gustav Kirchhoff.



Kirchoff' Current Law This law states that, for any node in an electrical circuit, the sum of currents flowing into that node is equal to the sum of currents flowing out of that node **Kirchoff's Voltage Law** The directed sum of the potential differences (voltages) around any closed loop is zero.

1. Name the quantity conserved in Kirchhoff current law.
   Charge.
2. How will you write Kirchhoff current law in mathematical form?
   $\Sigma I = 0$
3. Name the physical quantity conserved in Kirchhoff's Voltage Law.
   Energy
4. Which circuit Kirchhoff's Voltage Law is applied?
   Any Closed-Circuit loop .

****

UNIT III -MAGNETIC EFFECTS OF CURRENT AND MAGNETISM

SL. NO	FORMULAE	SYMBOLS	APPLICATIONS
1	Biot- Savart Law $dB = \frac{\mu_0}{4\pi} \times \frac{I\, dl\, Sin\theta}{r^2}$	dB = magnetic field at a point at distance r due to a current element. μ_0 = permeability of free space I = current through wire θ = angle between current element **Idl** and position vector **r.**	To find magnetic field at a point due to current element . To find magnetic field due to a straight conductor.
2	$B = \frac{\mu_0 NI a^2}{2(a^2 + x^2)^{\frac{3}{2}}}$	B= magnetic field due to a circular coil of N turns at distance x from its centre. a = Radius of coil	Magnetic field at centre, x= 0 $B= \frac{\mu_0 N I}{2\, a}$
3	$B= \frac{\mu_0 I}{2\pi\, r}$	B = magnetic field r = perpendicular distance from wire to point of observation.	magnetic field due to a straight conductor of infinite length
4	Ampere's circuital law $\oint \vec{B} \cdot \vec{dl} = \mu_0$ I	$\oint \vec{B} \cdot \vec{dl}$ = Line integral of magnetic field in a closed path .	Magnetic field due to a solenoid B = μ_0 n I
5	$\vec{F} = q\,(\vec{v} \times \vec{B})$ F=B q v sinθ	F = Force v = velocity of charge particle q = charge of the particle	Force acting on a charge particle in magnetic field.
6	$\vec{F} = q\,[\vec{E} + (\vec{v} \times \vec{B})]$	Force on charged particle in simultaneous Electric and magnetic fields	Lorentz force
7	$\vec{F} = I\,(\vec{l} \times \vec{B})$ F = B I L Sin θ	F = Magnetic force on a current carrying conductor of length l **B** = magnetic field.	To find force acting on a current carrying conductor in a magnetic field.
8	$\frac{F}{l} = \frac{\mu_0 I_1 I_2}{2\pi\, r}$	$\frac{F}{l}$ = Force per unit length between two parallel current carrying I_1 and I_2 r = distance between the conductors.	Force per unit length between two parallel current carrying conductors.
9	**τ** = B I N A Sin θ	**τ** = torque experienced by a current loop of area **A** in magnetic field **B** **N** = Number of turns of coil. I = current	Principle of Moving coil galvanometer

10	**S =** $\left(\frac{i_g}{i - i_g}\right)$ **G**	S = shunt required , G = Galvanometer Resistance , i_g = maximum current through galvanometer (0 – i) = range of ammeter	Conversion of Galvanometer into Ammeter.
11	**R** $= (V/i_g) - G$	R = High resistance in series	Conversion of Galvanometer into Voltmeter.
12	**r** $= \frac{mv}{Bq}$	r = radius of circular path in magnetic field	To find the radius of circular path of charged particle moving perpendicular to the magnetic field.
13	**H**$=\frac{B}{\mu_0}$	Magnetic intensity	
14	**M**$=\frac{m}{V}$	Intensity of magnetism	
15	$\chi = \frac{M}{H}$	Magnetic Susceptibility	
16	$\mu = 1 + \chi$	Magnetic permeability	
17	**m = NIA**	Magnetic Moment of a current carrying loop	
18	**B =** $(\mu_0/4\pi)\, 2m/r^3$	Magnetic field on the axis of the magnet	
19	**B=**$(\mu_0/4\pi)\, m/r^3$	Magnetic field on the equatorial axis of the magnet	
20	**U= -mB cos θ**	**Potential energy of a magnetic dipole**	

MINIMUM LEARNING MATERIALS

1. BIOT – SAVART'S LAW:-

Magnetic field due to current carrying element, at a point at a distance r from it is given by:

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

Direction of **dB** is that of I**dl** x **r** and is given by **Right hand thumb rule**.

2. RIGHT HAND THUMB RULE:-

The rule states that if we hold the conductor in palm of our right hand such that thumb gives direction of current then curling of fingers gives the direction of magnetic field.

3. MAGNETIC FIELD DUE TO CURRENT CARRYING CIRCULAR COIL

$$B = \frac{\mu_0 N I R^2}{2(R^2 + x^2)^{3/2}}$$ on its axis

$$B = \frac{\mu_0 N I}{2R}$$ at its centre

A current loop of N turns having area A carrying current I behaves like magnetic dipole.

Magnetic moment **m**= N I A ; Unit = (A m^{-2})

4. MAGNETIC LORENTZ FORCE:-

It is the force experienced by moving charge in magnetic field (**B**); **F** = q **(V** x **B**)

i.e., F = q V B sin θ [F perpendicular to V and B]

F = Maximum when sin θ = 1 or θ = 90^0

F = Minimum when sin θ = 0 or θ = 0^0 (or) 180^0

F = 0, when V = 0, charged particle is at rest.;

S.I unit of Magnetic Field (B) is Tesla (T); C.G .S unit of B is Gauss (G); 1 T = 10^4 G

5. LORENTZ FORCE:-

Total force experienced by moving charge inside electric field (E) and magnetic field (B)

F = q [**E** + **V** x **B**]

Velocity selector : Electric force =magnetic force

i.e qE = qvB ; v = E/B This condition can be used to select charged particles of a particular velocity out of a beam containing charges moving with different speeds.The crossed E and B fields, therefore, serve as a **velocity selector**

6. Work done by magnetic Lorentz force on moving charge = 0

7. FORCES BETWEEN TWO INFINITELY LONG PARALLEL CURRENT CARRYING CONDUCTORS:

$$F = \frac{\mu_0 I_1 I_2}{2 \pi r}$$

Force is **attractive** if currents are in the same direction and **repulsive** if current are in the opposite direction.

8. AMPERES CIRCUITAL LAW:

It states that line integral of magnetic field **B** around a closed circuit is μ_0 times the current threadlike the closed circuit..ei.e $\int B.\, dl = \mu_0 I$

9. MAGNETIC FIELD DUE TO STRAIGHT SOLENOID : B = μ_0 nI, (inside the solenoid)

B = 1/2μ_0 nI, (at its ends) & B= 0 (outside the core of the solenoid)

10. Force per unit length between two parallel current carrying conductors **&DEFINITION OF AMPERE:**

$$F = \frac{\mu_0 I_1 I_2}{2 \pi r}$$

If $I_1 = I_2 = 1$ A & r = 1 m Then,

F = 2 x 10^{-7} N/m

One ampere is the current which when flowing through each of two parallel wires of infinite length (in free space) and separated by a distance of 1 m attracts or repels each other by a force of 2 x 10^{-7} N/m per metre.

11. TORQUE ON A CURRENT CARRYING COIL PLACED IN MAGNETIC FIELD

$\tau = N\,B\,I\,A \sin\theta$ Where θ = Angle between magnetic field and normal to the plane of coil.

12. PRINCIPLE OF GALVANOMETER

A rectangular current carrying coil placed in magnetic field (B) experiences a torque.

$$\phi = \frac{N\,B\,A\,I}{k}$$

Where k= Torsional constant of spring,

Current is directly proportional to ϕ

13. SENSITIVTY OF A GALVANOMETER:-

A Galvanometer is said to be sensitivity, if it gives a large deflection, even when a small current is passed through it (or) when a small voltage is applied across its coil.

14. CURRENT SENSITIVITY:-

It is defined as the deflection produced in the Galvanometer on passing unit current through its coil.

Current sensitivity of Galvanometer = $\dfrac{\phi}{I} = \dfrac{N\,B\,A}{k}$ Unit = rad A^{-1}

. 16. **VOLTAGE SENSITIVITY:-**

It is defined as the deflection produced in the Galvanometer, when a unit voltage is applied across its coil.

Voltage sensitivity of Galvanometer = $= \dfrac{\phi}{V} = \dfrac{N\,B\,A}{k\,R}$ Unit = rad V^{-1}

$$\text{Voltage sensitivity} = \frac{\text{current sensitivity}}{\text{Resistance (R)}}$$

For a Galvanometer to be sensitive the conditions are:

1. Number of turns -large , 2. Area of the coil-large ,3. Magnetic field (B)-large & 4. k-small

15. A small resistance usually put in parallel to the coil of a galvanometer is called Shunt. The most part of the current in the circuit passes through the shunt and thus shunt allows only a very small part of current to pass through the Galvanometer.

➢ **Ammeter: -**

It is an instrument used to measure current. A Galvanometer is converted into an Ammeter by placing a small resistance (shunt) in parallel with it.

$S = \dfrac{I_g \times G}{I - I_g}$, $R = \dfrac{G \times S}{G + S}$ is the resistance of the ammeter.

Ammeter is always connected in series due to its small resistance. Resistance of ideal ammeter is 0.

16. VOLTMETER: -

It is used to measure potential difference. A Galvanometer is converted into Voltmeter by placing a high resistance (R) in series with it. $R = V / I_g - G$

It is the current for full-scale deflection in Galvanometer. $R_v = R + G$ is resistance of Voltmeter.

Because of this high resistance, Voltmeter is always connected in parallel.Resistance of ideal Voltmeter is infinity.

17. MOTION OF CHARGE PARTICLE UNDER MAGNETIC FIELD (B),
F = q (V x **B**)

➢ SPECIAL CASES: -
Trajectory is Circular if **V** is perpendicular to B**,**

Radius (r) = $\frac{mV}{Bq}$

$T = \frac{2\pi m}{Bq}$

Trajectory is helical if V is inclined at an arbitrary angle with B,

Radius (r) = $\frac{mV\sin\theta}{Bq}$

. 19 . MAGNETIC DIPOLE:-

It is a system of two unlike poles of equal strength and separated by some distance.

Magnetic dipole moment **(m)** =q .2 **l,**

Where, q = pole strength. Unit = A m

MAGNETIC FIELD DUE TO BAR MAGNET:-

At a point on the axial line:

$B = \frac{2\mu_0 m}{4\pi(r^2 - l^2)^2}$

At a point on the equatorial line:

$B = \frac{\mu_0 m}{4\pi(r^2 + l^2)^{3/2}}$

18. TORQUE ACTING ON MAGNET IN A UNIFORM MAGNETIC FIELD

τ =m x **B;** i.e. $\tau = m.B.\sin\theta$ where m = NIA

20 . POTENTIAL ENERGY OF A MAGNETIC DIPOLE IN A UNIFORM MAGNETIC FIELD.: U = - M.B.sin θ

21. CURRENT LOOP AS A MAGNETIC DIPOLE:-

Magnetic moment = current x area of the loop; **m** = I **A**

22.. **GAUSS THEOREM IN MAGNETISM**:-∫ **B.ds** = 0

It implies that “No magnetic monopole can exist”.

MULTIPLE CHOICE QUESTIONS AND ASSERTION, REASONING QUESTIONS

1. Inside the magnet, the field lines moves

a) From North to South b) from South to North

c) Away from south pole d) Away from North pole

2. which of the following statement is not correct about the magnetic field?

a) Magnetic field lines form a continuous closed curve.

b) Magnetic field line do not interest each other.

c) Direction of tangent at any point on the magnetic field line curve gives the direction of magnetic field at that point.

d) Outside the magnet, magnetic field lines go from South pole North pole of the magnet.

3. Two thin, long parallel wires, separated by a distance (d) carry a current of (i) in the same direction. They will

(a) Attract each other with a force of $\mu_0 i^2/2\pi d$ (b)repel each other with a force of $\mu_0 i^2/\pi 2d$

(c) attract each other with a force of $\mu_0 i^2/2\pi d^2$ (d)repel each other with a force of $\mu_0 i^2/2\pi d^2$

4.The coil of a moving coil galvanometer is wound over a metal frame in order to

(a) reduce hysteresis (b) increase sensitivity

(c) increase moment of inertia (d) provide electromagnetic damping

5. **The most suitable material for making the core of an electromagnet is :**

a) Steel b) Iron c) Soft iron d) Aluminium

6. Which of the following is not attracted by a magnet?

(a) steel (b) cobalt (c) brass (d) nickel

Answer: Option (c)

7. Two magnetic field lines:

a) Intersect at neutral point b) Never intersect each other

c) Intersect near north-pole or south pole d) Intersect at the mid point of the magne

8.. **The front face of a circular loop of a wire is North-pole, the direction of current in this face of the loop will be:**

a) Clockwise b) Anticlockwise c) Towards North d) Towards South

9. The magnetic field inside a long straight solenoid carrying current:

a) Is zero b) Decrease as we move towards its end

c) Is same at all points d) Increase as we move towards its end

10. The force on a current-carrying conductor when placed perpendicular in a uniform magnetic field.

a) F=BIL b) F=B/IL c) F=L/BI d) F=I/BL

11. The magnetic field at the centre of a current carrying circular loop is B. If the radius of the loop is doubled keeping the current unchanged, the magnetic field at the centre of loop will become:
(a) B/2 (b) B/4 (c) 2B (d) 4B

12. The force between two parallel wire 2×10^{-7} Nm-1, placed 1 m apart to each other in vacuum. The electric current flowing through the wires is:

(a) 1 A (b) zero (c) 5 × 106 A (d) 2 × 10-7 A

13 . A magnetic dipole moment is a vector quantity directed from:

(a) S to N (b) N to S (c) E to W (d) W to E

14. In a moving coil galvanometer, we use a radial magnetic field so that the galvanometer scale is:

(A) Exponential (b) linear (c) algebraic (d) logarithmic

15. The magnetic field strength due to a short bar magnet directed along its axial line at a distance r is B. What is its value at the same distance along the equatorial line?

(a) B (b) 2B (c) B/2 (d) B/4

16. Which of the following has higher magnetic susceptibility?

(a) Diamagnetic (b) paramagnetic (c) ferromagnetic (d) none of these

17 . The radius of curvature of the path of charged particle in a uniform magnetic file is directly proportional to the

(a) Charge on fie particle (b) Momentum of particle

(c) Energy of particle (d) Strength of field

18. A 100 turns coil having area $0.008m^2$carries a current of 2 A in a magnetic field of 0.2 . –2 Wb – m-2 The torque acting on the coil is

(a) 0.32 N-m tending to rotate the coil (b) 3.2N-m tending to rotate the coil
(c) 0.64 N-m tending to rotate the coil (d) 6.4 N-m tending to rotate the coil

19. Currents of 10 A and 2 A are flowing in opposite directions through two parallel wires A and B respectively. If the wire A is infinitely long and wire B is 2 m long, then force on wire B which is situated at 10 cm from A, is

(a) 8×10^{-5} N (b) 6×10^{-5} N (c) 4×10^{-5} N (d) 5×10^{-5} N

20. A wire in the form of a circular loop, of one turn carrying a current, produces magnetic induction B at the centre. If the same wire is looped into a coil of two turns and carries the same current, the new value of magnetic induction at the centre is

(a) B (b) 2 B (c) 4 B (d) 8 B

1	2	3	4	5	6	7	8	9	10
B	b	a	D	c	c	b	B	c	a
11	12	13	14	15	16	17	18	19	20
A	a	a	A	c	c	b	A	a	c

ASSERTON AND REASONING QUESTION Instructions: Two statements are given-one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below.
(a) Both A and R are true and R is the correct explanation of A
(b) Both A and R are true but R is not the correct explanation of A
(c) A is true but R is false
(d) A is false and R is also false

1. Assertion (A): The magnetic field at the centre of the current carrying circular coil shown in the fig. is zero.
   Reason (R): The magnitudes of magnetic fields are equal and the directions of magnetic fields due to both the semicircles are opposite.
2. Assertion (A): The voltage sensitivity may not necessarily increase on increasing the current sensitivity
   Reason (R): Current sensitivity increases on increasing the number of turns of the coil
3. Assertion (A): If a proton and an α-particle enter a uniform magnetic field perpendicularly with the same speed, the time period of revolution of α-particle is double than that of proton.
   Reason (R): In a magnetic field, the period of revolution of a charged particle is directly proportional to the mass of the particle and inversely proportional to the charge of the particle.
4. Assertion (A): The magnetic field at the ends of a very long current carrying solenoid is half of that at the centre.
   Reason (R): If the solenoid is sufficiently long, the field within it is uniform.
5. Assertion (A): If an electron and proton enter a magnetic field with equal momentum, then the paths of both of them will be equally curved.
   Reason (R): The magnitude of charge on an electron is same as that on a proton.
6. Assertion (A): The coils of a spring come close to each other, when current is passed through it.
   Reason (R): It is because, the coils of a spring carry current in the same direction and hence attract each other
7. Assertion (A): The range of a voltmeter can be both increased and decreased.
   Reason (R): The required resistance (to be connected in series) can be calculated by using the relation,
8. Assertion (A): An electron projected parallel to the direction of magnetic force will experience maximum force.
   Reason (R): Magnetic force on a charge particle is given by F = (IL x B).
9. Assertion (A): The torque acting on square and circular current carrying coils having equal areas, placed in uniform magnetic field, will be same.
   Reason (R): Torque acting on a current carrying coil placed in uniform magnetic field does not depend on the shape of the coil, if the areas of the coils are same.
10. Assertion (A): Magnetic field due to an infinite straight conductor varies inversely as the distance rom it.
    Reason (R): The magnetic field due to a straight conductor is in the form of concentric circles.

11. **Assertion (A):** The electrostatics force increases with decrease the distance between the charges.

Reason (R): The electrostatic force of attraction or repulsion between any two stationary point charges is inversely proportional to the square of the distance between them.

12. **Assertion (A):** A proton is placed in a uniform electric field, it tend to move along the direction of electric field.

Reason(R): A proton is placed in a uniform electric field it experiences a force.

13. **Assertion:** Magnetic Resonance Imaging (MRI) is a useful diagnostic tool for producing

Images of various parts of human body.

Reason: Protons of various tissues of the human body play a role in MRI.

14. **Assertion:** Ferro-magnetic substances become paramagnetic above Curie temp.

Reason: Domains are destroyed at high temperature.

15. **Assertion:** The ferromagnetic substance do not obey Curie’s law.

Reason: At Curie point a ferromagnetic substance start behaving as a paramagnetic substance.

16. **Assertion:** The sensitivity of a moving coil galvanometer is increased by placing a suitable magnetic material as a core inside the coil.

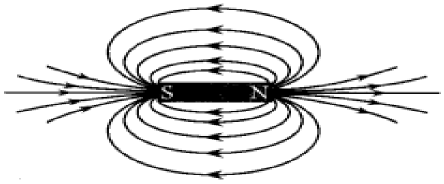
Reason: Soft iron has high magnetic permeability and cannot be easily magnetized or demagnetized.

ASSERTION AND REASONING QUESTION: ANSWERS

1. (a)	**2. (b)**	**3. (a)**	**4. (b)**	**5.(a)**	**6.(a)**	**7.(a)**	**8. (d)**	**9. (a)**	**10.(b)**
11.(a)	**12.(b)**	**13.(a)**	**14.(a)**	**15.(b)**	**16.(c)**				

2 Mark Questions

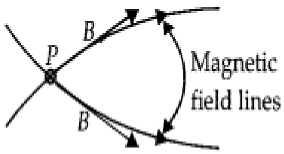
1. What are magnetic field lines? Justify the following statements:
(a) Two magnetic field lines never intersect each other.
(b) Magnetic field are closed curves



Magnetic field lines around a bar magnet

Imaginary continuous closed curves used to represent the magnetic field in a region is known as magnetic field lines. It is directed from North Pole to South Pole outside the magnet and South Pole to North Pole inside the magnet.

(a) The direction of magnetic field (B) at any point is obtained by drawing a tangent to the magnetic field line at that point. In case, two magnetic field lines intersect each other at the point P as shown in figure, magnetic field at P will have two directions, shown by two arrows, one drawn to each magnetic field line at P, which is not possible.



(b) It is taken by convention that the field lines emerges from North Pole and merge at the South Pole. Inside the magnet, the direction of field lines is from its south pole to its north pole. Thus, the magnetic field lines are closed curves.

2.(a) State three factors on which the strength of magnetic field produced by a current carrying solenoid depends.

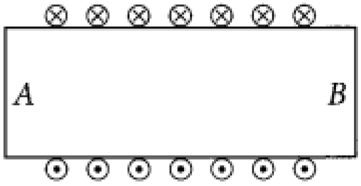
(b) Draw circuit diagram of a solenoid to prepare an electromagnet.

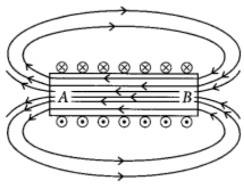
(a) Strength of magnetic field produced by a current carrying solenoid depends upon the following factors:(i).number of turns in the coil, (ii).amount of current flowing through it &
(iii). Material of core of the solenoid.

(b) A strong magnetic field produced inside a solenoid can be used to magnetize a piece of magnetic material, like soft iron, when placed inside the coil. The magnet so formed is called an electromagnet.

An electromagnet-A current-carrying solenoid coil which is used to magnetise steel rod inside it.

3 .Diagram shows the lengthwise section of a current carrying solenoid. ⊗ indicates current entering into the page, ⊙ indicates current emerging out of the page. Decide which end of the solenoid A or B, will behave as North Pole. Give reason for your answer. Also draw field lines inside the solenoid.





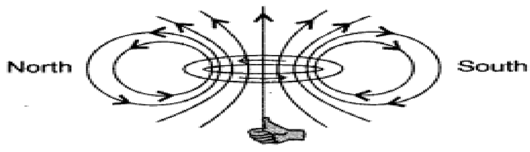
Using right hand thumb rube we can draw the magnetic field lines around the conductor as shown. From figure, end A of solenoid act as North Pole and end B will act as South Pole. Inside the solenoid field lines are in the form of parallel straight lines.

3. What is the magnetic potential energy of a dipole when it is perpendicular to the magnetic Field?

PE = - mBCos θ = mB cos 90 = Zero

4.Current flows through a circular loop. Depict the north and south pole of its equivalent magnetic dipole?

Direction of the magnetic field lines is given by right hand thumb rule.



Magnetic field lines

5.Define magnetic susceptibility of a material. Name two elements, one having positive susceptibility and the other having negative susceptibility. What does negative susceptibility signify?

(i) Magnetic susceptibility (χm): It is the property of a material which determines how easily it can be magnetized when kept in a magnetizing field.

Also, it is the ratio of intensity of magnetization (I) produced in the material to the intensity of magnetizing field (H). $\chi_m = \frac{I}{H}$

(ii)Positive susceptibility: para-magnetic material & Example: Al, Ca.

Negative susceptibility : diamagnetic material- Example: Bi, Cu.

(iii)Negative susceptibility signifies that the material is diamagnetic in nature.

6. (a) How does a diamagnetic material behave when it is cooled to very low temperatures?

(b) Why does a paramagnetic sample display greater magnetization when cooled? Explain.

(a) When diamagnetic material is cooled to very low temperature then it exhibits both perfect conductivity and perfect diamagnetism.

(b) This is because at lower temperature, the tendency to disrupt the alignment of dipoles (due to magnetizing field) decreases on account of reduced random thermal motion.

7.Two long parallel wires are hanging freely. if they are connected to a Battery (i) series (ii) parallel. what would be the effect on their position.?

when connected in series I is in opposite direction therefore force of Repulsion. When connected with parallel I is in same direction force of attraction & they will move close to each other.

8. An electron with charge **-e** and mass **m** travels at a speed **v** in a plane perpendicular to a magnetic field of magnitude **B** .The electron follows a circular path of radius **R**. In a time **t** the electron travels halfway around the circle. What is the amount of work done by the magnetic field.

Ans: Work done is zero. Since the magnetic field is perpendicular to the velocity, so there will be no work on the charged particle

9.Write an expression for the force $\vec{F}$ acting on a particle of mass m and charge q moving with velocity $\vec{V}$ in a magnetic filed $\vec{B}$. Under what condition will it move in (i) a circular path (ii) a helical path?

b.) Show that kinetic energy of the particle moving in magnetic remains constant.

Ans: a) $F = q(V \times B)$

(i) When velocity of charge particle and magnetic field are perpendicular to each other.

(ii)When velocity is neither parallel nor perpendicular to the magnetic field.

b) The force, experienced by the charged particle, is perpendicular to the instantaneous velocity $\vec{V}$,

at all instants. Hence, the magnetic force cannot bring any change in the speed of the charged particle. Since speed remains constant, the kinetic energy also stays constant.

10..Two protons of equal kinetic energies enter a region of uniform magnetic field. The first proton enters normal to the field direction while the second enters at 30 degree to the field direction. Name the trajectories followed by them.

Normal: Circular & At an angle 30 degree: it will follow helical path.

11.(a). Define the term magnetic susceptibility and write its relation in terms of relative magnetic permeability.(b). Two magnetic materials A and B have relative magnetic permeabilities of 0.96 and 500. Identify the magnetic materials A and B.

ANS (a): It refers to the ease with which a substance can be magnetised. It is defined as the ratio of intensity of magnetisation to the magnetising field. The required relation is

$\mu_r = 1 + X_m$.;(a) A; Paramagnetic , B; Ferromagnetic .

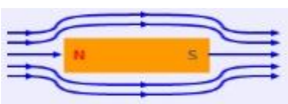
SHORT ANSWER TYPE QUESTION(3-Marks)

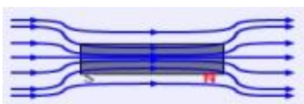
1.A proton and an α-particle enter a number magnetic field perpendicularly with the same speed. How many times in the time period of the α particle than that of the proton? Deduce an expression for the ratio of the radii of the circular path of the two particles.

$T = \dfrac{2\pi m}{Bq}$; For proton $T = \dfrac{2\pi m}{Bq}$ & For α particle $T = \dfrac{2\pi 4m}{B2q} = 2T_p$

$r = \dfrac{mv}{Bq}$ $\dfrac{rp}{r\alpha} = \dfrac{1}{2}$

2.A uniform magnetic field sets modified as shown when two specimens X & Y are place in it.





a) identify the specimen X & Y

b) state the reason for their behaviour

a) X -> diamagnetic , Y -> Ferro magnetic

b) This is because magnetic lines of force prefer not to pass through diamagnetic materials as its permeability being less than one.

On the other hand, magnetic field lies prefer to pass as permeability is more than one.

3. Write the expression for the force acting on a charged particle of charge q moving with velocity is in the presence of magnetic field B. Show that in the presence of this force.
(a) The K.E. of the particle does not change.
(b) Its instantaneous power is zero.

Ans. Since F = q ($\vec{v} \times \vec{B}$)

(a) Since direction of force is perpendicular to the plane containing ($\vec{v} \times \vec{B}$)

=> w = Fs cos θ $(= 90^0)$

w = Fs $cos 90^0$ = 0

=> KE = 0; $\therefore$ KE will not – change

(b) since p = Fvcos θ = Fv $cos 90^0$ = 0

=> Instantaneous power is also zero.

4. An electron of kinetic energy 25KeV moves perpendicular to the direction of a uniform magnetic field of 0.2 millitesla calculate the time period of rotation of the electron in the magnetic field?

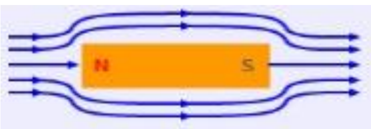
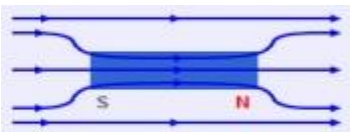
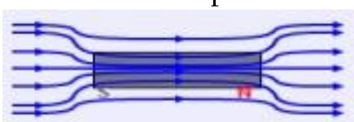
Ans. B = 0.2 T = 0.2×10^{-3}T

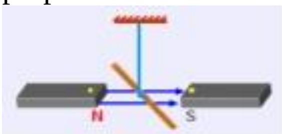
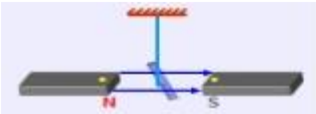
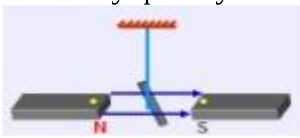
Time Period T = $\dfrac{2\pi M}{QB}$

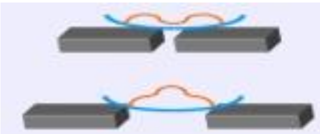
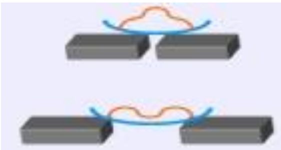
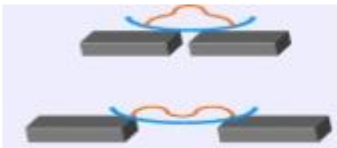
$$T = \frac{2 \times 3.14 \times 9.1 \times 10^{-31}}{1.6 \times 10^{-17} \times 0.2 \times 10^{-3}}$$

$T = 1.787 \times 10^{-7}$ second

5.Distinguish between dia, para, ferro magnetic substance.

DIA	PARA	FERRO
1.Diamagnetic substances are those substances which are feebly repelled by a magnet Eg. Antimony, Bismuth, Copper, Gold, Silver, Quartz, Mercury, Alcohol, water,Hydrogen,Air, Argon, etc.	Paramagnetic substances are those substances which are feebly attracted by a magnet. Eg.Aluminium, Chromium, Alkali and Alkaline earth metals,Platinum, Oxygen, etc.	Ferromagnetic substances are those substances which are strongly attracted by a magnet. Eg. Iron, Cobalt, Nickel, Gadolinium, DysprosiumETC
2. When placed in magnetic field, the lines of force tend to avoid the substance. 	The lines of force prefer to pass through the substance rather than air. 	The lines of force tend to crowd into the specimen. 
3. When placed in non-uniform magnetic field, it	Whenplaced in non-uniform magnetic field, it	Whenplaced in non-uniform magnetic field, it

moves from stronger to weaker field (feeble repulsion).	moves from weaker to stronger field (feeble attraction).	moves from weaker to stronger field (strong attraction).
4. When a diamagnetic rod is freely suspended in a uniform magnetic field, it aligns itself in a direction perpendicular to the field. 	When a paramagnetic rod is freely suspended in a uniform magnetic field, it aligns itself in a direction parallel to the field. 	When a paramagnetic rod is freely suspended in a uniform magnetic field, it aligns itself in a direction parallel to the field very quickly. 

5. If diamagnetic liquid taken in a watch glass is placed in uniform magnetic field, it collects away from the centre when the magnetic poles are closer and collects at the centre when the magnetic poles are farther. 	If paramagnetic liquid taken in a watch glass is placed in uniform magnetic field, it collects at the centre when the magnetic poles are closer and collects away from the centre when the magnetic poles are farther. 	If ferromagnetic liquid taken in a watch glass is placed in uniform magnetic field, it collects at the centre when the magnetic poles are closer and collects away from the centre when the magnetic poles are farther. 
6. Induced Dipole Moment (M) is a small – ve value.	Induced Dipole Moment (M) is a small + ve value.	Induced Dipole Moment (M) is a large + ve value.
7. Intensity of Magnetisation (I) has a small – ve value.	Intensity of Magnetisation (I) has a small + ve value.	Intensity of Magnetisation (I) has a large + ve value.
8. Intensity of Magnetisation (I) has a small – ve value.	Intensity of Magnetisation (I) has a small + ve value.	Intensity of Magnetisation (I) has a large + ve value.
9. Magnetic permeability μ is always less than unity.	Magnetic permeability μis more than unity.	Magnetic permeability μ is large i.e. much more than unity.
10.Magnetic susceptibility has asmall – ve value.	Magnetic susceptibility has a small +ve value.	Magnetic susceptibility has a large + ve value.
11.They do not obey Curie's Law. i.e. their properties do not change	They obey Curie's Law. They lose their magnetic properties with rise in	They obey Curie's Law. At a certain temperature called Curie Point, they

with temperature.	temperature.	and behave like paramagnetic substances.

6. (a) Why do we use a shunt to convert a galvanometer into an ammeter?

(b) A galvanometer of resistance of 15 ohm shows a full scale deflection on the meter scale for a current of 6 mA. calculate the value of the shunt resistance required to convert the galvanometer into an ammeter of range 0-6 A.

ANS (a): since ammeter is an instrument used to measure the current in the circuit, so it has to be connected in series in the circuit to measure whole current. Hence its resistance makes it suitable for measuring current.

(b): given G=15 ohm, I_g=6 mA=6×10^{-3} A, I=6 A,S=?

$S = I_g G / I - I_g = 6\times10^{-3} \times 15 / 6 - 6\times10^{-3}$

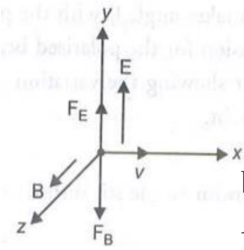
$S = 6\times10^{-3} \times 15/5.99 = 0.015$ ohm.

7. Find the condition under which the charged particle moving with different speeds in the presence of electric and magnetic field vectors can be used to select charged particles of a particular speed.

Ans: Condition

(i) For direction of $\vec{E}, \vec{B}, \vec{v}$

(ii) For magnitudes of $\vec{E}, \vec{B}, \vec{v}$

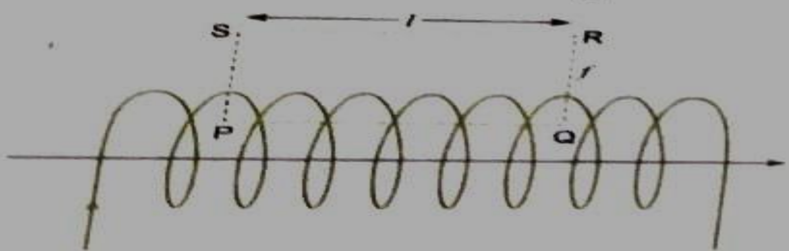


(i) The velocity $\vec{v}$, of the charged particles , and the $\vec{E}$ and $\vec{B}$ vectors, must be mutually perpendicular. Also the forces on q, due to $\vec{E}$ and $\vec{B}$, must be oppositely directed.
(ii) If magnetic force= electrostatic force
Fm=Fe
qvB = qE
v=E/B

8. Using Ampere's Circuital Law, Obtain an expression for magnetic field on the axis of current carrying very long solenoid.

(b) On applying Ampere's circuital law $\oint \vec{B}\cdot\vec{dl} = \mu_0$ [Total current]

$$\Rightarrow \int_{PQ} \oint \vec{B}\cdot\vec{dl} + \int_{QR} \vec{B}\cdot\vec{dl} + \int_{RS} \vec{B}\cdot\vec{dl} + \int_{SP} \vec{B}\cdot\vec{dl} = \mu_0 \; [n\ell I]$$



As no magnetic field exists in direction QR, RS and SP, so

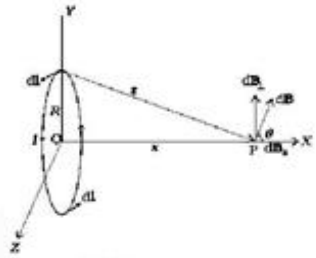
$$\int_0^l |\vec{B}| \; dl + 0 + 0 + 0 = \mu_0 n\ell I$$

$$\Rightarrow |\vec{B}| \; \ell = \mu_0 n\ell I \quad \Rightarrow \quad B = \mu_0 nI$$

LONG ANSWERS QUESTION(5Marks)

1. Using Biot-Savart's law, derive the expression for the magnetic field due to a current carrying loop of radius '*R*', at a point which is at a distance '*x*' from its centre along the axis of the loop.

Figure depicts a circular loop carrying a steady current I. The loop is placed in the y-z plane with its centre at the origin O and has a radius R. The x-axis is the axis of the loop. Let x be the distance of P from the centre O of the loop.



Consider a conducting element dl of the loop. This is shown in Fig. The magnitude dB of the magnetic field due to dl is given by the Biot-Savart law,

$$dB = \frac{\mu_0}{4\pi}\frac{I|d\vec{l}\, x\, \vec{r}|}{r^3}$$

Now $r^2 = x^2 + R^2$. Further, any element of the loop will be perpendicular to the displacement vector from the element to the axial point.

Hence $|d\vec{l}\, x\, \vec{r}| = rdl$. Thus $dB = \frac{\mu_0}{4\pi}\frac{Idl}{x^2+R^2}$

The direction of $d\vec{B}$ is shown in Fig. It is perpendicular to the plane formed by $d\vec{l}$ *and* $\vec{r}$. It has an x-component $d\vec{B}_x$ and a component perpendicular to x-axis, $d\vec{B}_\perp$. When the components perpendicular to the x-axis are summed over, they cancel out and we obtain a null result. The net contribution along x-direction can be obtained by integrating $dB_x = dB\cos\theta$ over the loop.

Now from above fig,

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

From above two equations

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

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

The summation of elements dl over the loop yields 2πR, the circumference of the loop. Thus, the magnetic field at P due to entire circular loop is

$$\boxed{\vec{B} = B_x\hat{\imath} = \frac{\mu_0 IR^2}{2(x^2+R^2)^{\frac{3}{2}}}\hat{\imath}} \quad or\ for\ coil\ having\ N\ turns, B = \frac{\mu_0 NIR^2}{2(x^2+R^2)^{\frac{3}{2}}}$$

Special cases

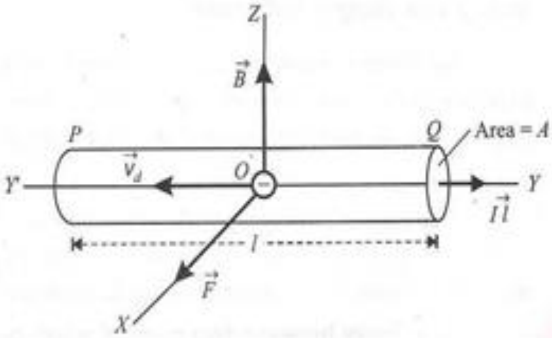
At the centre of the current loop, $x = 0$

$$\therefore B = \frac{\mu_o NIA}{2\pi R^3}, \qquad where\ A = \pi R^2, area\ of\ circular\ current\ loop$$

At the axial points lying far away from the coil, $x \gg R$, $B = \frac{\mu_o NIR^2}{2x^3} = \frac{\mu_o NIA}{2\pi x^3}$

At an axial point at a distance equal to the radius of the coil i.e. $x = R$, we get $B = \frac{\mu_o NIR^2}{2(R^2+R^2)^{3/2}} = \frac{\mu_o NI}{2^{5/2} R}$

2. Derive a mathematical expression for the force acting on a current carrying straight conductor kept in a magnetic field. Under what condition is this force (i) zero and (ii) maximum?



Consider a conductor PQ of length *l*, area of cross section *A*, carrying current *I*, along +ve Y-direction. The field $\vec{B}$ acts along +ve Z-direction. The electrons drift towards left with velocity $\vec{v}_d$. Each electron experiences a magnetic Lorentz force along +ve X-axis, which is given by

$$\vec{f} = -e(\vec{v}_d \times \vec{B})$$

If *n* is the number of free electrons per unit volume, then total number of electrons in the conductor is $N = n \times volume = nAl$

The total force on the conductor is

$$\vec{F} = N\vec{f} = nAl[-e(\vec{v}_d \times \vec{B})] = enA[-l\vec{v}_d \times \vec{B}]$$

If $I\vec{l}$ represents a current element vector in the direction of current, then vectors $\vec{l}\ and\ \vec{v}_d$ will have opposite directions and we can take

$$-l\vec{v_d} = v_d\vec{l}$$

$$\therefore \vec{F} = enAv_d(\vec{l} \times \vec{B})$$

$$or, \vec{F} = I(\vec{l} \times \vec{B}) \quad magnitude\ of\ force, F = IlB\sin\theta$$

where θ is the angle between the direction of the magnetic field and the direction of flow of current.

(i) If θ = 0° or 180°, then $F = IlB\ (0) = 0$

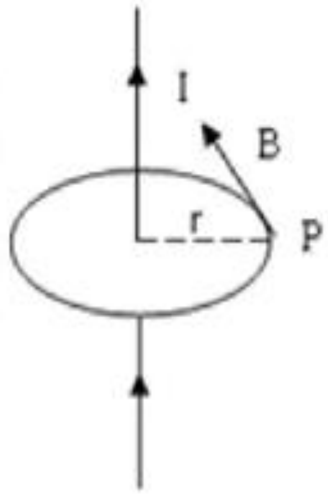
Thus, a current carrying conductor placed parallel to the direction of the magnetic field does not experience any force.

(ii) If θ = 90°, then $F = Ilb \sin 90° = IlB = F_{max}$

Thus, a current carrying conductor placed perpendicular to the direction of the magnetic field does not experience a maximum force.

3. State Ampere's circuital law. Derive an expression for the magnetic intensity at a point due to a current carrying straight wire of infinite length.

Ampere's law states that the line integral of the magnetic field around any closed path in free space is equal to μ_o times the total current passing through the surface. i.e. $\boxed{\oint \vec{B} . d\vec{l} = \mu_o I}$



Let a long straight conductor of infinite length carry current *I*.

Now, to find the magnetic intensity at a point 'P' due to this current carrying straight wire let us consider a circular amperian loop of radius '*r*' through point 'P'.

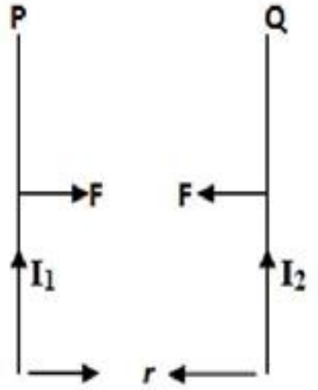
Applying Ampere's circuital law for this closed circular surface we get

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

$$B \oint dl = \mu_o I or B . 2\pi r = \mu_o I$$

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

4. Derive an expression for the force acting per unit length between two long straight parallel metallic conductors, carrying current in the same direction and kept near each other. Hence define an ampere.



(a) Consider two long straight conductors P and Q, placed parallel to each other, at a distance r apart. The currents through the two conductors are I_1 and I_2 respectively in the same direction.

The magnitude of the magnetic field due to current I_1 in P, at any point of Q, is given by

$$B = \frac{\mu_o I_1}{2\pi r} \quad \ldots\ldots(1)$$

The direction of magnetic field is into the plane of the paper. The current carrying conductor Q is placed in the magnetic field B. Since Q is placed perpendicular to the magnetic field B, the force acting per unit length l of Q is given by

$$F = BI_2 l,$$

directed towards P. Using eq (1), we get

$$F = \frac{\mu_o}{2\pi}\frac{I_1}{r} I_2 l = \frac{\mu_o}{2\pi}\frac{I_1 I_2}{r}\, l$$

$$or, \boxed{f = \frac{F}{l} = \frac{\mu_o}{2\pi}\frac{I_1 I_2}{r}}$$

When $I_1 = I_2 = 1\,A$ and $r = 1m$, we get

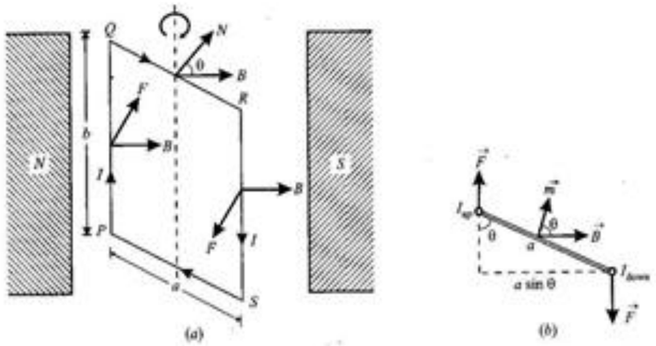
$$f = \frac{\mu_o}{2\pi} = 2 \text{ x } 10^{-7} Nm^{-1}$$

One ampere is that value of steady current, which on flowing in each of the two parallel infinitely long conductors of negligible cross-section placed in vacuum at a distance of 1m from each other, produces between them a force of $2 \times 10^{-7} Nm^{-1}$ *of their length.*

Note : For information only- The standard definition of one ampere is now modified

The ampere is defined by taking the fixed numerical value of the elementary charge e to be $1.602\,176\,634 \times 10^{-19}$ *when expressed in the unit C, which is equal to As, where the second is defined in terms of* $\Delta\nu_{Cs}$. *(2019)*

5. Derive an expression for the torque on a rectangular coil of area *A*, carrying a current *I* and placed in a magnetic field *B*. The angle between the direction of *B* and vector perpendicular to the plane of the coil is θ.



As shown in the figure, consider a rectangular coil PQRS suspended in a uniform magnetic field $\vec{B}$, with its axis perpendicular to the field.

Let I =current flowing through the coil, a, b = sides of the coil PQRS, $A = ab$=area of the coil and θ =angle between the direction of $\vec{B}$ and normal to the plane of the coil.

According to the Fleming's left hand rule, the magnetic forces on sides PS and QR are equal, opposite and collinear (along the axis of the loop), so their resultant is zero.

The sides PQ experiences a normal inward force equal to IbB while the side RS experiences an equal normal outward force. These two forces from a couple which exerts a torque given by

$$\tau = Force \text{ x } perpendicular\ distance = IbB\ x\ a \sin\theta = IBA \sin\theta$$

If the rectangular loop has N turns, the torque increases N times, i.e.

$$\tau = NIBA \sin\theta$$

But $NIA = m$, the magnetic moment of the loop, so

$$\tau = mB \sin\theta \ \ or\ in\ vector\ notation \boxed{\vec{\tau} = \vec{m} \text{ x } \vec{B}}$$

The direction of the torque is such that it rotates the loop clockwise about the axis of suspension.

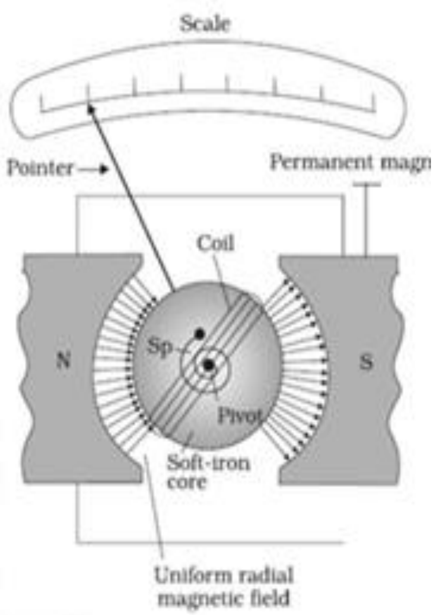
Special cases:

When θ = 0°, τ =0, i.e. the torque is minimum when the plane of the loop is perpendicular to the magnetic field.

When θ =90°, $\tau = NIBA$, i.e. the torque is maximum when the plane of the loop is parallel to the magnetic field.

6. Describe the principle, construction and working of a moving coil galvanometer. Define its figure of merit, current sensitivity and voltage sensitivity.

A galvanometer is a device to detect the presence of current in a circuit.



Principle: A Weston type moving coil galvanometer is based on the fact that when a current carrying loop or coil is placed in the uniform magnetic field, it experiences a torque.

Construction: A Weston type moving coil galvanometer is shown in the figure. It consists of a coil wound on a non metallic frame. The coil is suspended between two poles of a permanent cylindrical magnet. The motion of the coil is controlled by a pair of hair springs (usually of phosphor- bronze). The inner ends of the springs are soldered to the ends of the coil and the outer ends are connected to the binding screws. The spring provides the restoring torque and also serves as current leads. A light aluminum pointer attached to the coil measures its deflection. There is a cylindrical soft iron core which not only makes the field radial but also increases the strength of the magnetic field.

Working: Let $B = Intensity\ of\ magnetic\ field, I = current\ flowing\ through\ the\ coil, A = area\ of\ the\ coil\ and\ N = number\ of\ turns\ in\ the\ coil.$

When current flows through the coil, it experiences a torque, which is given by

$$\tau = NIAB \sin\theta = NIAB \quad (\because \sin\theta = 1)$$

This torque is called ***deflecting torque***.

As the coil is deflected, the spring gets twisted and a restoring torque is developed, which is given by $= \boldsymbol{k\phi}, where\ k = restoring\ torque\ per\ unit\ twist\ and\ \phi = deflection.$

For equilibrium of the coil, ***Deflecting torque = Restoring torque***

$$i.e. NIAB = k\phi$$

$$or, I = \left(\frac{k}{NAB}\right)\phi = G\phi$$

$$where\ G = \frac{k}{NAB}\ is\ called\ Galvanometer\ constant.$$

$$or\ I\ \alpha\ \phi$$

Thus, deflection of the coil is directly proportional to the current flowing through it. Hence a linear scale in the galvanometer can be used to detect the current in the circuit.

...

Figure of merit: It is defined as the current which produces a unit deflection in the galvanometer. It is given by

$$G = \frac{I}{\phi} = \frac{k}{NAB}$$

This is equal to the galvanometer constant.

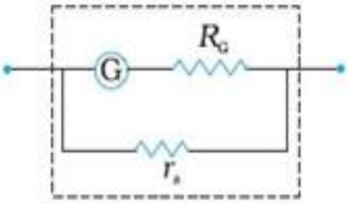
Current Sensitivity: It is defined as the deflection produced in the galvanometer, when a unit current flows through it. It is given by

$$I_s = \frac{\phi}{I} = \frac{NAB}{k}$$

Voltage sensitivity: It is defined as the deflection produced in the galvanometer, when a unit potential difference is applied across its ends. It is given by,

$$V_s = \frac{\phi}{V} = \frac{\phi}{IR} = \frac{NAB}{IR} = \frac{I_s}{R} \quad i.e.\, voltage\ sensitivity = \frac{current\ sensitivity}{R}$$

7. Explain how a galvanometer can be converted into an ammeter of given range.



Ammeter

An ammeter is an instrument used to measure electric current in an electric current. An ideal ammeter should have zero resistance.

A galvanometer can be converted into an ammeter by connecting a low resistance called shunt parallel to the galvanometer. The value of shunt resistance depends on the range of the current required to be measured.

$let\ G = galvanometer\ resistance,$

$I_g = current\ for\ which\ galvanometer\ gives\ full\ scale\ deflection$

$0\ to\ I = required\ range\ of\ current, \qquad S = shunt\ resistance$

As $G\ and\ S\ are\ connected\ parallel$

$$potential\ difference\ across\ the\ galvanometer$$
$$= potential\ diff.across\ the\ shunt$$

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

$$or, S = \frac{I_g}{I - I_g} G \qquad also\ I_g = \frac{S}{G + S} I$$

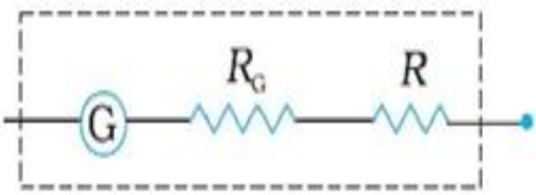
An ammeter is a shunted or low resistance galvanometer. Its effective resistance is

$$R = \frac{GS}{G + S}\ \ which\ is < S$$

8. Explain how a galvanometer can be converted into a voltmeter of given range.

Voltmeter is a device for measuring potential difference across any two points in a circuit.

Ideal voltmeter should have infinite resistance.



Voltmeter

A galvanometer can be converted into a voltmeter by connecting a high resistance in series with it.

$let\ G = galvanometer\ resistance,$
$I_g = current\ for\ which\ galvanometer\ gives\ full\ scale\ deflection$
$0\ to\ V = required\ range\ of\ voltage, \qquad R = High\ resistance$

Total resistance of the circuit = $R + R_G$

By ohm's law

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

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

A voltmeter is a high resistance galvanometer. Its effective resistance is $R_V = R + R_G \gg R_G$

9. Show that a current carrying circular loop behaves as a magnetic dipole. Hence derive an expression for the magnetic dipole moment of the loop.

The magnetic field due to a circular current loop of radius *r* at a distance *x* from its centre is given by

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

$$Or, B = \frac{\mu_o}{4\pi} \frac{2\pi I r^2}{(r^2 + x^2)^{\frac{3}{2}}}$$

πr^2 is the area of the plane of the loop, say *A*.

$$\therefore B = \frac{\mu_o}{4\pi} \frac{2IA}{(r^2 + x^2)^{\frac{3}{2}}}$$

$for\ x \gg r,$

$$B = \frac{\mu_o}{4\pi} \frac{2IA}{(x)^3}$$

Now, the electric field due to an electric dipole along the dipole axis, at a distance *x* from the centre of the dipole is given by

$$E = \frac{1}{4\pi\varepsilon_o} \frac{2p}{x^3}$$

Comparing the two equations, we conclude that a current loop behaves like a magnetic dipole whose magnetic dipole moment is equal to the product of the current and the area of plane of coil. It is denoted by *M*. Thus,

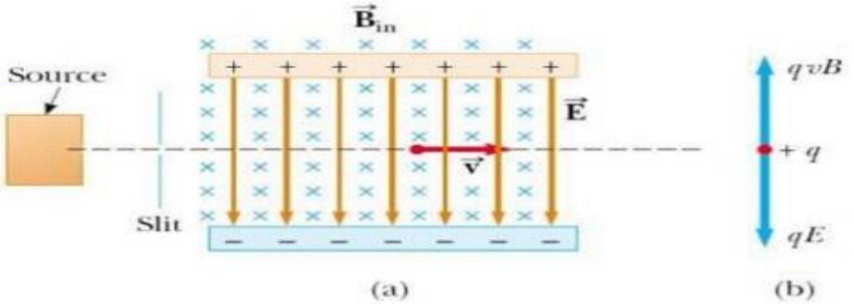
$$\boxed{M = IA}$$

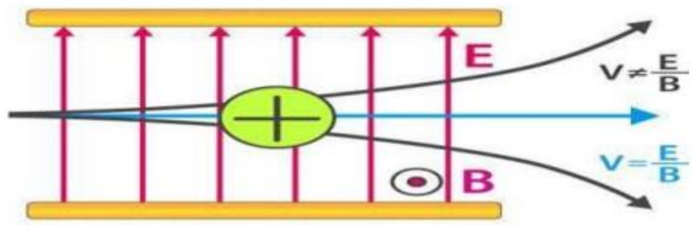
SECTION: E

CASE STUDY QUESTIONS

Read the following case/passage and answer the following questions:

1)A charge q moving with a velocity v in presence of both electric and magnetic fields experience a force F = q [E + v x B]. If electric and magnetic fields are perpendicular to each other and also perpendicular to the velocity of the particle, the electric and magnetic forces are in opposite directions. If we adjust the value of electric and magnetic field such that magnitude of the two forces is equal. The total force on the charge is zero and the charge will move in the fields UN deflected.





1.What will be the value of velocity of the charge particle, when it moves un deflected in a region where the electric field is perpendicular to the magnetic field and the charge particle enters at right angles to the fields.

(a) v = E/B (b) v = B/E (c) v = EB (d) v = EB/q

2. Proton, neutron, alpha particle and electron enter a region of uniform magnetic field with same velocities. The magnetic field is perpendicular to the velocity. Which particle will experience maximum force?

(a) Proton (b) Electron (c) Alpha particle (d) Neutron

3. A charge particle moving with a constant velocity passing through a space without any change in the velocity. Which can be true about the region?

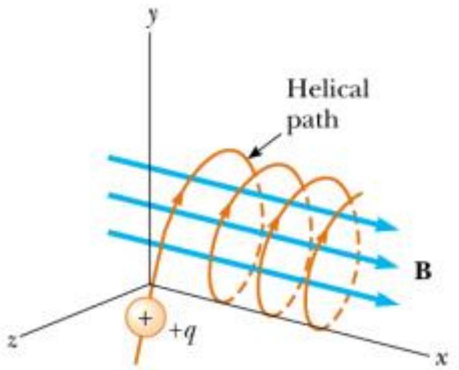
(a) E = 0, B = 0 (b) E ≠ 0, B ≠ 0 (c) E = 0, B ≠ 0 (d) All of these

4. Proton, electron and deuteron enter a region of uniform magnetic field with same electric potential-difference at right angles to the field. Which one has a more curved trajectory?

(a) Electron (b) Proton (c) Deuteron (d) All will have same radius of circular path

1. (a)	**2. (c)**	**3. (d)**	**4. (a)**

2) If velocity has a component along B, this component remains unchanged as the motion along the magnetic field will not be affected by the magnetic field. The motion in a plane perpendicular to magnetic field is a circular one, thereby producing a helical motion.



1. The radius of the charge particle, (when v is perpendicular to B) placed in a Uniform magnetic field is given by

(a) R = mv/qB (b) R = qB/mv (c) R = Bqm/v (d) R = vq/mB

2. An electron, proton, He+ and Li++ are projected with the same velocity perpendicular to a uniform magnetic field. Which one will experience maximum Magnetic force?

(a) Electron (b) Proton (c) He+ (d) Li++

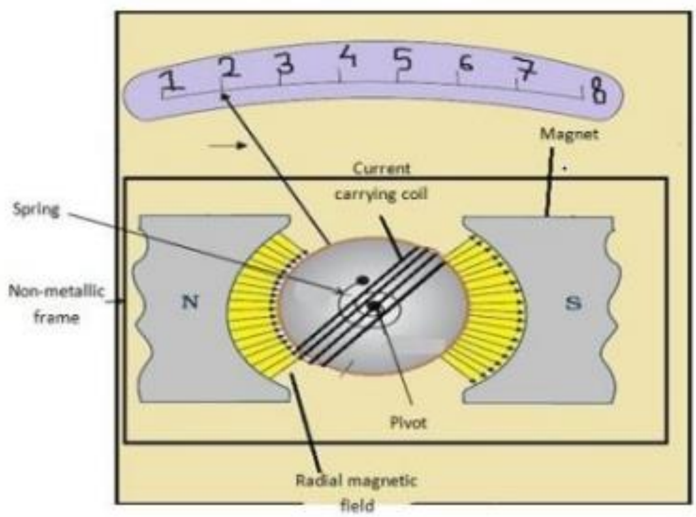
3. The work done by the magnetic field on the charge particle moving perpendicular to a uniform magnetic field is

(a) Zero (b) q (v x B). S (c) Maximum (d) qBS/v

CASE STUDY- BASED QUESTION:
ANSWER:

1. (A)	**2. (D)**	**3. (A)**

3) The galvanometer is a device used to detect the current flowing in a circuit or a small potential difference applied to it. It consists of a coil with many turns, free to rotate about a fixed axis, in a uniform radial magnetic field formed by using concave pole pieces of a magnet. When a current flows through the coil, a torque acts on it.



1. What is the principle of moving coil galvanometer?

(a) Torque acting on a current carrying coil placed in a uniform magnetic field.

(b) Torque acting on a current carrying coil placed in a non-uniform magnetic field.

(c) Potential difference developed in the current carrying coil.

(d) None of these.

2. If the field is radial, then the angle between magnetic moment of galvanometer Coil and the magnetic field will

be

(A) 0°　　(b) 30°　　(c) 60°　　(D) 90°

3. Why pole pieces are made concave in the moving coil galvanometer?

(a) To make the magnetic field radial.　　(b) To make the magnetic field uniform.

(c) To make the magnetic field non-uniform.　　(d) None of these.

4. What is the function of radial field in the moving coil galvanometer?

(a) To make the torque acting on the coil maximum.　　(b) To make the magnetic field strong.

(c) To make the current scale linear.　　(d) All the above.

5. If the rectangular coil used in the moving coil galvanometer is made circular, then what will be the effect on the maximum torque acting on the coil in magnetic field for the same area of the coil?

(a) Remains the same　　(b) Becomes less in circular coil

(C) becomes greater in circular coil　　(d) Depends on the orientation of the coil

1.(A)	**2.(D)**	**3.(A)**	**4.(D)**	**5.(A)**

****

Unit IV: Electromagnetic Induction and Alternating Currents

IMPORTANT FORMULAE IN EMI & AC

S:No	Formula Name	Formula
1	Faraday's Laws of Electromagnetic Induction	$E \propto d\varphi / dt \Rightarrow E = -d\varphi / dt$
2	Induced EMF and Current	Induced e.m.f = Rate of change of flux link = $d\varphi/dt$ Magnitude of induced emf $E = -d\varphi/dt$ $E = -d/dt\,(NBA \cos \omega t)$ $E = NAB\omega \sin \omega t$ $E = E_o \sin \omega t$ $I = [NBA\omega]\sin \omega t / R$ $I = I_o \sin \omega t$
3	Coefficient of Self-Induction	$\varphi = LI$
4	Induced emf in the coil	$E = -L\,(dI/dt)$
5	Self – inductance of a long solenoid	$L = \mu_o N^2 A/L = \mu_o n^2 Al$
6	core of the solenoid is of any other magnetic material	$L = \mu_o \mu_r N^2 A/L$
7	Energy stored in an inductor	$E = (½)\, LI^2$
8	If two coils are coupled with each other then magnetic flux linked with a Coil (secondary coil)	$\varphi = MI$
9	induced emf in the secondary coil	$E = -M\,(dI/dt)$
10	Coefficient of coupling	$K = \sqrt{}M / L_1 L_2$
11	Mutual Inductance	$M = \sqrt{L_1 L_2}$
12	Mutual inductance of two long coaxial solenoids	$M = \mu_o N_1 N_2 A/L = \mu_o n_1 n_2 AL$

S:No	Formula Name	Formula
1	Instantaneous emf Instantaneous current	$V = V_0 \sin\omega t$ $I = I_0 \cos\omega t$
2	Average Value of Alternating Current	$I_m = \frac{2}{\pi} I_0 = 0.637 I_0$
3	RMS value of alternating current	$I_{r.m.s} = \frac{I_0}{\sqrt{2}} = 0.707\, I_0$
4	Inductive Reactance	$X_L = \omega L$

5	Capacitive Reactance	$X_c=1/\omega C$
6	**Phase difference Between the EMF (Voltage) and the Current in an AC Circuit**	**$V=V_0\sin(\omega t)$**
6a)	**For pure resistance:** **The voltage and the current are in same phase i.e. phase difference $\phi = 0$**	**$I=I_0\sin(\omega t)$**
6b)	**For pure inductance:** **The voltage is ahead of current by $\pi/2$ i.e. phase difference $\phi = +\pi/2$.**	**$I=I_0\sin(\omega t-\pi/2)$**
6c)	**For pure capacitance:** **The voltage lags behind the current by $\pi/2$ i.e. phase difference $\phi = -\pi/2$**	**$I=I_0\sin(\omega t+\pi/2)$**
7	**SERIES LCR CIRCUIT**	
7a	**Instantaneous emf**	**$V=V_0\sin(\omega t)$**
7b	**Instantaneous current**	**$I=I_0\sin(\omega t \pm \phi)$**
7c	**Impedance**	$Z = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}$ $Z = \sqrt{R^2 + (X_L - X_C)^2}$
7d	**Phase**	$\phi = \tan^{-1}\left[\frac{X_L - X_C}{R}\right]$
8	**Resonant frequency** $X_L = X_c$	$\omega_0 = \frac{1}{\sqrt{LC}}$ $f_o = \frac{1}{2\pi\sqrt{LC}}$
S.No	**Formula Name**	**Formula**
9	**Average Value of Power of an A.C. Circuit**	**$P_{av}= (½)E_0 I_0 \cos\phi$** **$P_{av}=E_{rms} I_{rms} \cos\phi$**
10	**Power Factor**	$\text{Power Factor} = \frac{\text{True power}}{\text{Apparent power}}$
		$\cos\phi=R/Z/Z$

11	**Transformer**	$\frac{E_s}{E_P} = \frac{N_s}{N_p} = \frac{I_P}{I_S} = k$ where k is called transformer ratio. (for step up transformer k > 1 and for step down transformer k < 1)
12	**Step-Up transformer**	**($N_s > N_P$), ($V_s > V_P$), ($I_s < I_P$).**
13	**Step-Down transformer**	**($N_s < N_P$), ($V_s < V_P$), ($I_s > I_P$).**
14	**Efficiency of a transformer**	$\eta = \frac{output\ power}{input\ power} = \frac{E_s I_s}{E_P I_P}$

MINIMUM LEARNING MATERIALS-EMI

1. Electromagnetic Induction

Whenever the magnetic flux linked with an electric circuit change, an emf is induced in the circuit. This phenomenon is called electromagnetic induction.

2.Faraday's Laws of Electromagnetic Induction

(i) Whenever the magnetic flux linked with a circuit changes, an induced emf is produced in it. (ii) The induced emf lasts so long as the change in magnetic flux continues. (iii) The magnitude of induced emf is directly proportional to the rate of change in magnetic flux, i.e.,

$E \propto d\varphi / dt \Rightarrow \mathbf{E = -d\varphi / dt}$

where constant of proportionality is one .Here, **flux = NBA cos θ,**

SI unit of φ = weber, CGS unit of φ = maxwell, 1 weber = 10^8 maxwell,
Dimensional formula of magnetic flux [φ] = $[ML^2T^{-2}A^{-2}]$

3.Lenz's law

The direction of induced emf or induced current is always in such a way that it opposes the cause due to which it is produced.

Lenz's law is in accordance with the conservation of energy.

3a.Fleming's Right Hand Rule

If we stretch the thumb, the forefinger and the central finger of right hand in such a way that all three are perpendicular to each other, i.e if thumb represent the direction of motion, the forefinger represent the direction of magnetic field, then central finger will represent the direction of induced current.

4.**Induced EMF and Current:**Induced e.m.f = Rate of change of flux link = **dφ/ dt**
Magnitude of induced emf **E = – dφ/ dt ;** E = – d/ dt (NBA cos ωt); **E=NABω sin ωt**

$E=E_o$ sin ωt where, E_o =NABω

If R is the electrical resistance of the circuit, then induced current in the circuit is given by **I = E/R**

If induced current is produced in a coil rotated in uniform magnetic field, then I = [NBAω]sin ωt /R

$I = I_o \sin \omega t$; where, **$I_o = NBA\omega/R$** = peak value of induced current,

N = number of turns in the coil , B= magnetic induction, ω = angular velocity of rotation and A = area of cross-section of the coil.

5.Self-Induction

The phenomena of production of induced emf in a circuit due to change in current flowing in its own, is called self-induction.

Coefficient of Self-Induction

The magnetic flux linked with a coil **$\varphi = LI$** where, L = coefficient of self-induction.
The induced emf in the coil **$E = - L\,(dI/dt)$** ; Unit of self-induction is henry (H) and its

Dimensional formula is $[ML^2T^{-2}A^{-2}]$.
Self – inductance of a long solenoid is given by

$$L = \mu_o N^2A/L = \mu_o n^2Al$$

where, N = total number of turns in the solenoid, L = length of the coil,
n = number of turns per unit length in the coil and A = area of cross-section of the coil.
If core of the solenoid is of any other magnetic material, then

$$L = \mu_o\mu_r N^2A/L$$

Energy stored in an inductor **$E = (½)\, LI^2$**

6.Mutual Induction The phenomena of production of induced emf in a circuit due to the change in magnetic flux in its neighbouring circuit, is called mutual induction.

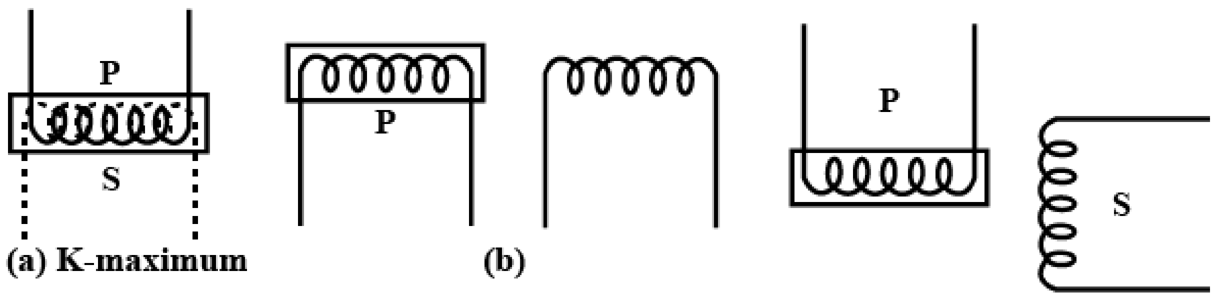
Coefficient of Mutual Induction

If two coils are coupled with each other then magnetic flux linked with a Coil (secondary coil) **$\varphi = MI$** where M is coefficient of mutual induction and
I is current flow in through primary coil.
The induced emf in the secondary coil **$E = - M\,(dI/dt)$**

where dI/dt is the rate of change of current through primary coil.

The unit of coefficient of mutual induction is henry (H)

The coefficient of mutual induction depends on geometry of two coils, distance between them and orientation of the two coils. Coefficient of Coupling Two coils are said to be coupled if full a part of the fuse produced by one links with the other.



(a) K-maximum (b) (c) K-minimum

.

.Mutual inductance of two long coaxial solenoids is given by

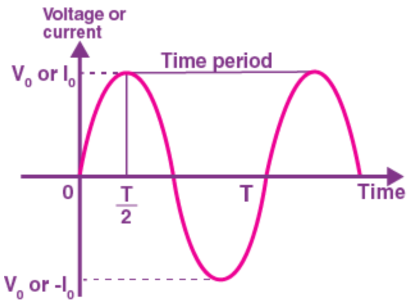
$$M = \mu_o N_1 N_2A/L = \mu_o n_1n_2AL$$

where N_1 and N_2 are total number of turns in both coils, n_1 n_2 are number of turns per unit length in coils, A is area of cross-section of coils and L is length of the coils.

MINIMUM LEARNING MATERIALS-ALTERNATING CURRENT

1. The Alternating Current

The magnitude of alternating current changes continuously with time and its direction is reversed periodically. It is represented by



$I=I_0\sin\omega t$ or

$I=I_0\cos\omega t$

where, I_0 is termed as peak value of an alternating current and $\omega=2\pi/T=2\pi v$

2. Average Value of Alternating Current

The mean or average value of alternating current over any half cycle is defined as that value of steady current which would send the same amount of charge through a circuit in the time of half cycle (i.e.T/2) as is sent by the alternating current through the same circuit, in the same time.

$$I_m = \frac{2}{\pi} I_0 = 0.637 I_0$$

Hence, mean or average value of alternating current over positive half cycle is 0.637 times the peak value of alternating current, i.e., 63.7%63.7% of the peak value.

3.RMS value of alternating current

The steady current which, when flows through a resistor of known resistance for a given period of time than as a result the same quantity of heat is produced by the alternating current when flows through the same resistor for the same period of time is called **R.M.S** or effective value of the alternating current.

In other words, the R.M.S value is defined as the square root of means of squares of instantaneous values.

$$I_{r.m.s} = \frac{I_0}{\sqrt{2}} = 0.707\, I_0$$

4.Reactance & Impedance

Reactance

Reactance is the opposition offered to flow of alternating current. This opposition may either be due to inductor (L) and or capacitor (C). The value of reactance due to inductor having inductance L is **ωL** whereas its value is **(1/ωC)** for capacitor having capacitance C.

Impedance:

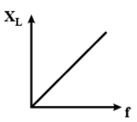
Impedance in alternating current circuit is defined as the net opposing factor to flow of current. This opposition may be due to Resistance & Inductance or Resistance & Capacitance or Resistance, Inductance and Capacitance.

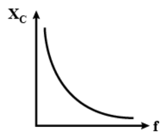
It is denoted by symbol Z.

Reactance values depend on frequency while resistances don't. Reactance resist currents without dissipating power, unlike resistors.

Inductive reactance increases with frequency and inductance($X_L=\omega L=2\pi fL$)

Capacitive reactance decreases with frequency and capacitance($X_C=1/\omega C=1/2\pi fC$)





Impedance represents total opposition provided by reactance and resistance.

5.Phase difference Between the EMF (Voltage) and the Current in an AC Circuit

Alternating source of voltage **$V = V_0 \sin\omega t$** is applied across

a)For pure resistance:

The voltage and the current are in same phase i.e. phase difference $\phi = 0$; **$I = I_0 \sin(\omega t)$**

b) For pure inductance:

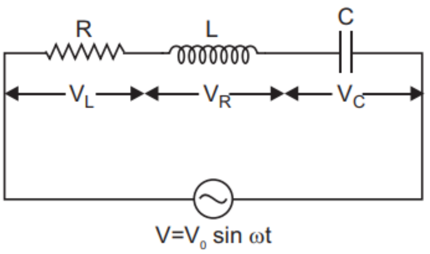
The voltage is ahead of current by $\pi/2$ i.e. phase difference $\phi = +\pi/2$; **$I = I_0 \sin(\omega t - \pi/2)$**

c) For pure capacitance:

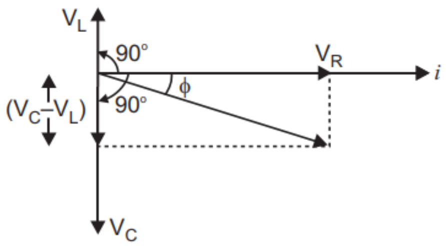
The voltage lags behind the current by $\pi/2$ i.e. phase difference $\phi = -\pi/2$; **$I = I_0 \sin(\omega t + \pi/2)$**

6.SERIES LCR CIRCUIT :

Suppose resistance R, inductance L and capacitance C are connected in series and an alternating source of voltage $V = V_0 \sin\omega t$ is applied across it. (fig. a)On account of being in series, the current (i) flowing through all of them is the same. Suppose the voltage across resistance R is V_R, voltage across inductance L is V_L and voltage across capacitance C is V_C.



(a)



(b)

The voltage V_R and current i are in the same phase, the voltage V_L will lead the current by angle 90° while the voltage V_C will lag behind the current by angle 90° (fig. b). Clearly V_C and V_L are in opposite directions, therefore their resultant potential difference $= V_C - V_L$ (if $V_C > _{CL}$). Thus V_R and (V_C - V_L) are mutually perpendicular and the phase difference between them is 90°. As applied voltage across the circuit is V, the resultant of VR and (VC - VL) will also be V.

$$V^2 = V_R^2 + (V_C - V_L)^2 \Rightarrow V = \sqrt{V_R^2 + (V_C - V_L)^2} \qquad ...(i)$$

But $\quad V_R = R\,i,\; V_C = X_C\, i$ and $V_L = X_L\, i \qquad ...(ii)$

where $X_C = \dfrac{1}{\omega C}$ = capacitance reactance and $X_L = \omega L$ = inductive reactance

$$\therefore \qquad V = \sqrt{(R\,i)^2 + (X_C\, i - X_L\, i)^2}$$

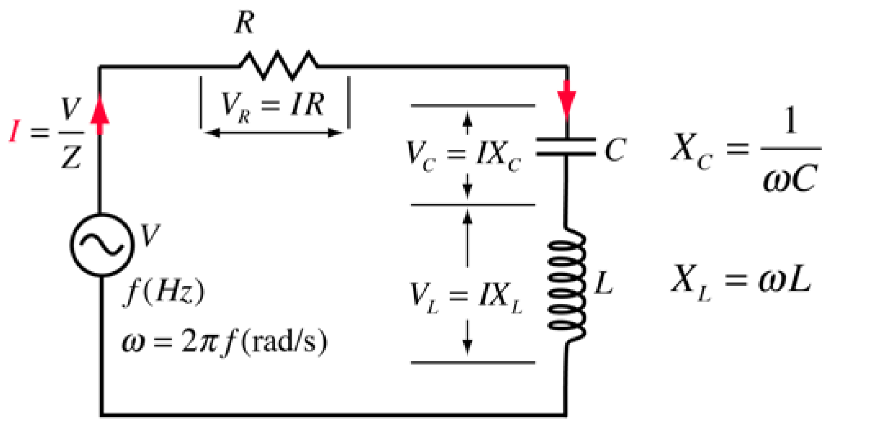
$$\therefore \quad \text{Impedance of circuit,} \quad Z = \frac{V}{i} = \sqrt{R^2 + (X_C - X_L)^2}$$

$$i.e. \qquad Z = \sqrt{R^2 + (X_C - X_L)^2} = \sqrt{R^2 + \left(\frac{1}{\omega C} - \omega L\right)^2}$$

7.Series Resonant Circuit

A circuit in which inductance L capacitance C and resistance R are connected in series, and the circuit admits maximum current corresponding to a given frequency of a.c., is called series resonance circuit.

The impedance (Z) of a LCR circuit is given by



$Z = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}$ $\quad Z = \sqrt{R^2 + (X_L - X_C)^2}$ $\quad Phase = \phi = \tan^{-1}\left[\frac{X_L - X_C}{R}\right]$

i)When the inductive reactance (X_L) becomes equal to the capacitive reactance (X_C) in the circuit, the total impedance becomes purely resistive (Z=R).In this state voltage and current are in same phase ($\phi = 0$), the current and power are maximum and impedance is minimum. This state is called resonance.

ii) At resonance,

$$\mathrm{X_L} = \mathrm{X_c}$$

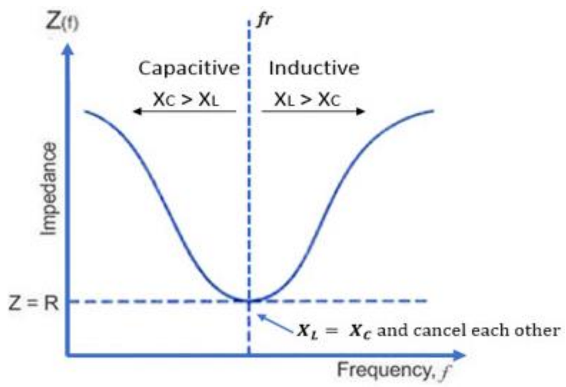
i.e., $\omega_r \mathrm{L} = \frac{1}{\omega_\mathrm{r}\mathrm{C}}$ or $\omega_\mathrm{r} = \frac{1}{\sqrt{\mathrm{LC}}}$

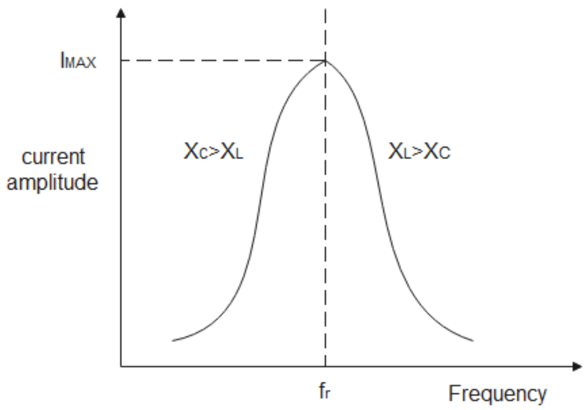
$2\pi \mathrm{v_r} = \frac{1}{\sqrt{\mathrm{LC}}}$ or $\mathrm{v_r} = \frac{1}{2\pi\sqrt{\mathrm{LC}}}$

At this particular frequency v_f as $\mathrm{X_L} = \mathrm{X_c}$,

$Z = \sqrt{R^2 + 0} = R = \text{minimum}$

iii) In resonance the power factor of the circuit is one.





8.Average Value of Power of an A.C. Circuit

Average power/cycle in an inductive circuit is

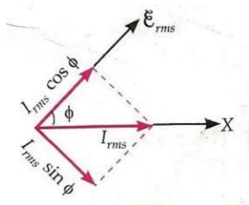
$P = E_{rms} I_{rms} \cos\phi$

$$P_{av} = \frac{1}{2} E_0 I_0 \cos\phi = E_{rms} I_{rms} \cos\phi$$

9.Power Factor

- The power factor of an alternating current is defined as the ratio of the true power flowing through the circuit to the apparent power present in the circuit.
- It is usually in the interval of -1 to 1 and is dimensionless.

$$\text{Power Factor} = \frac{\text{True power}}{\text{Apparent power}}$$

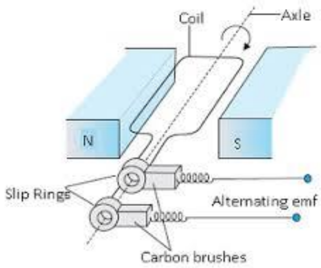


Also, cosΦ =R/Z

10.Wattless Current The current in an AC circuit when average power consumption in AC circuit is zero, is referred as wattless current or idle current.

The component **I_{rms} sinϕ** is called wattless current because it does not consume any power in a.c. circuit.

11.AC Generator:



$P_{av} = E_{rms}\,(I_{rms}\sin\phi)\cos\frac{\pi}{2} = 0$ AC generator is the one which produces a current that alternates or changes its direction regularly after a fixed interval of time, i.e., it is a device which converts mechanical energy into the alternating form of electrical energy.AC generators work on the principle of Faraday's law of electromagnetic induction, which states that electromotive force – EMF or voltage – is generated in a current-carrying conductor that cuts a uniform magnetic field.

Parts of an AC Generator

An Ac generator consists of two poles i.e is the north pole and south pole of a magnet so that we can have a uniform magnetic field. There is also a coil which is rectangular in shape that is the armature. These coils are connected to the slip rings and attached to them are carbon brushes.The slip rings are made of metal and are insulated from each other. The brushes are carbon brushes and one end of each brush connects to the ring and other connects to the circuit. The rectangular coils rotate about an axis which is perpendicular to the magnetic field. There is also a shaft which rotates rapidly.

Working of an AC Generator

When the armature rotates between the poles of the magnet upon an axis perpendicular to the magnetic field, the flux which links with the armature changes continuously. Due to this, an emf is induced in the armature. This produces an electric current through the galvanometer and the slip rings and brushes.
The galvanometer swings between the positive and negative values. This indicates that there is an alternating current flowing through the galvanometer. The direction of the induced current can be identified using **Fleming's Right-Hand Rule**.

12.Transformer

A transformer is an electrical device used for converting low alternating voltage into a high alternating voltage and vice versa. It transfers electric power from one circuit to another. The transformer is based on the principle of electromagnetic induction.

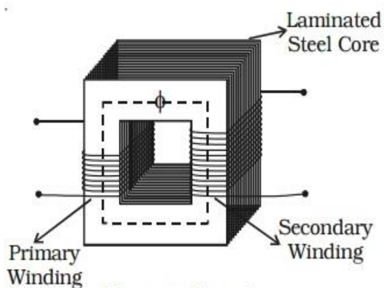


Fig Transformer

A transformer consists of primary and secondary coils insulated from each other, wound on a soft iron core To minimize eddy currents a laminated iron core is used. The a.c. input is applied to the primary coil. The continuously varying current in the primary coil produces a varying magnetic flux in the primary coil, which in turn produces a varying magnetic flux in the secondary. Hence, an induced emf is produced across the secondary.

One of the coils called the **primary coil** has $\mathbf{N_p}$ turns. The other coil s called the **secondary coil**; it has $\mathbf{N_s}$ turns. Often the primary coil is the **input coil** and the secondary coil is the **output coil** of the transformer. Since same flux links with the primary and secondary, the emf induced per turn of the two coils must be the same.

(i.e) $$\frac{E_p}{N_p} = \frac{E_s}{N_s}$$

or $$\frac{E_s}{E_p} = \frac{N_s}{N_p} \qquad \text{...(1)}$$

For an ideal transformer, input power = output power

$$E_p I_p = E_s I_s$$

where I_p and I_s are currents in the primary and secondary coils.

(i.e.) $$\frac{E_s}{E_p} = \frac{I_p}{I_s} \qquad \text{...(2)}$$

From equations (1) and (2)

$$\frac{E_s}{E_p} = \frac{N_s}{N_p} = \frac{I_p}{I_s} = k$$

where k is called transformer ratio.

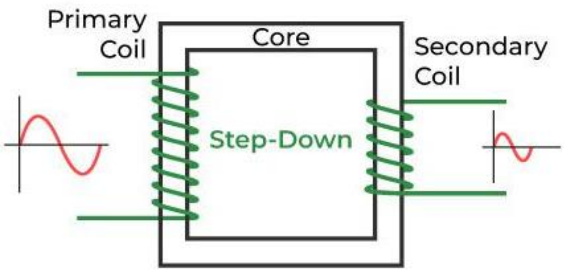
(for step up transformer k > 1 and
for step down transformer k < 1)

Step-Up transformer:

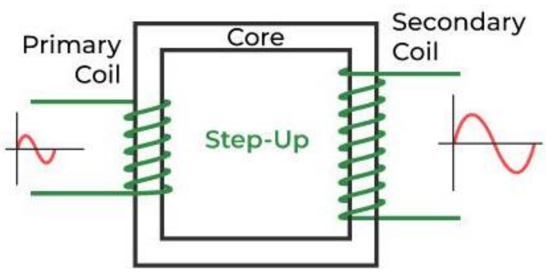
if the secondary coil has a greater number of turns than the primary ($N_s > N_p$), the voltage is stepped up ($V_s > V_p$). This type of arrangement is called a *step-up transformer*. However, in this arrangement, there is less current in the secondary than in the primary ($N_p/N_s < 1$ and $I_s < I_p$).

Step-Down transformer:

If the secondary coil has less turns than the primary ($N_s < N_p$), we have a *step-down transformer*. In this case, $V_s < V_p$ and $I_s > I_p$. That is, the voltage is stepped down, or reduced, and the current is increased.



Step-Down Transformer



Step-Up Transformer

Efficiency of a transformer

The efficiency of a transformer is defined as the ratio of output power to the input power.

The efficiency η = 1 (ie. 100%), only for an ideal transformer where there is no power loss. But practically there are numerous factors leading to energy loss in a transformer and hence the efficiency is always less than one.

Reasons -Energy Loss in Transformer:

i. **Copper loss**: It is due to the resistance of copper wire.
ii. **Iron loss** : It is due to the formation of eddy current.
iii. **Leakage of magnetic flux** : It occur due to lose winding of primary or secondary coil.
iv. **Hysteresis loss** : It is due to the continuous magnetization and demagnetization of the iron.
v. Humming noise.

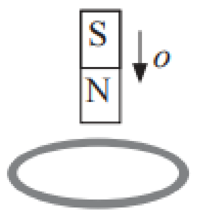
Applications Of Transformer

- The transformer transmits electrical energy through wires over long distances.
- Transformers with multiple secondary's are used in radio and TV receivers which require several different voltages.
- Transformers are used as voltage regulators.

MULTIPLE CHOICE QUESTIONS

1. A moving conductor coil in a magnetic field produces an induced emf. This is in accordance with:
(a) Lenz's Law (b) Coulomb's Law (c) Faraday's Law (d) Ampere's Law

2.A metallic ring is attached with the wall of a room. When the north pole of a magnet is brought near to it, the induced current in the ring will be:



(a) In clockwise direction (b) In anticlockwise direction
(c) First clockwise then anticlockwise (d) First anticlockwise then clockwise

3.Whenever the flux linked with a circuit changes, there is an induced emf in the circuit. This emf in the circuit lasts
(a) for a very short duration (b) for a long duration
(c) forever (d) as long as the magnetic flux in the circuit changes.

4. The magnetic flux through a coil is inversely proportional to:
(a) magnetic field (b) number of turns (c) area (d) none of these

5. A coil of insulated wire is connected to a battery. If it is taken to galvanometer, its pointer is deflected, because:
(a) the number of turns in the coil of the galvanometer are changed (b) the coil acts like a magnet
(c) the induced current is produced (d) none of these

6. Lenz's law gives:

(a) the direction of the induced current (b) the magnitude of the induced emf
(c) the magnitude of the induced current (d) both the magnitude and direction of the induced Current

7. To induce an emf in a coil, the linking magnetic flux:
(a) must remain constant (b) can either increase or decrease
(c) must increase (d) must decrease

8. Which of the following phenomena makes use of electromagnetic induction?
(a) Magnetising an iron piece with a bar magnet (b) Generation of hydroelectricity
(c) Magnetising a soft iron piece by placing inside a current carrying solenoid
(d) Charging a storage battery

9. The magnetic flux linked with a coil of N turns of area of cross section A held with its plane parallel to the field B is:
(a) NAB (b) Zero (c) NAB (d) NAB

10. Flux of magnetic field through an area bounded by a closed conducting loop can be changed by changing:
(a) magnetic field B (b) area of the loop
(c) angle between area vector and B (d) All of the above

11 The laws of electromagnetic induction have been used in the construction of a
(a) galvanometer (b) voltmeter (c) electric motor (d) generator

12.Two coils are placed closed to each other. The mutual inductance of the pair of coils depends upon
(a) the rate at which currents are changing in the two coils. (b) relative position and orientation of two coils.
(c) the material of the wires of the coils. (d) the currents in the two coils.

13.When current in a coil changes from 5 A to 2 A in 0.1 s, average voltage of 50 V is produced. The self-inductance of the coil is
(a) 1.67 H (b) 6 H (c) 3 H (d) 0.67 H

HINT: (a) $\because\ \varepsilon = -L\frac{dI}{dt}$, $50 = -L\frac{(2-5)}{0.1}$

$L = \frac{50\times 0.1}{3} = \frac{5}{3} = 1.67\text{ H}$

14.The frequency of A.C. mains in India is
(a) 30 c/s (b) 50 c/s (c) 60 c/s (d) 120 c/s

15. A.C. power is transmitted from a power house at a high voltage as
(a) the rate of transmission is faster at high voltages (b) it is more economical due to less power loss
(c) power cannot be transmitted at low voltages (d) a precaution against theft of transmission lines

16.An A.C. source is connected to a resistive circuit. Which of the following is true?
(a) Current leads ahead of voltage in phase (b) Current lags behind voltage in phase
(c) Current and voltage are in same phase
d) Any of the above may be true depending upon the value of resistance.

17.If the frequency of an A.C. is made 4 times of its initial value, the inductive reactance will
(a) be 4 times (b) be 2 times (c) be half (d) remain the same
[HINT: Inductive reactance $X_L = 2\pi fL$
therefore when f is made 4 times, inductive reactance also becomes 4 times].

18.A capacitor has capacitance C and reactance X, if capacitance and frequency become double, then reactance will be
(a) 4X (b) X/2 (c) X/4 (d) 2X

HINT: $X = \frac{1}{C\omega}$ $X' = \frac{1}{4C\omega}$ $\therefore\ X' = \frac{X}{4}$

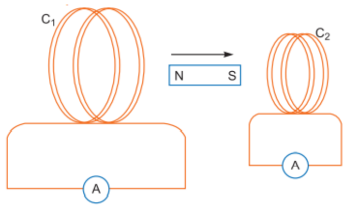
19. A metallic cylinder is held vertically and then or small magnet is dropped along its axis. It will fall with-
(a) constant velocity a=0 (b)acceleration a=g
(c) acceleration a>g (d) acceleration a<g

20.A power transmission line needs input power at 2300 V to a step down transformer with its primary windings having 4000 turns. What should be the number of turns in the secondary windings in order to get output power at 230 V?

(a) 2000 (b)200 (c)4000 (d) 400

$$N_S = \frac{V_S}{V_P} \times N_P = \frac{230}{2300} \times 4000 = \textbf{400 turns}$$

21.A magnet is quickly moved in the direction indicated by an arrow between two coils C1 and C2 as shown in the figure. What will be the direction of induced current in each coil as seen from the magnet?



(a)C1--clockwise. C2-- anti clockwise. (b)C1--anti clockwise, C2-- clockwise.
(c)C1-- anticlockwise. C2-- anticlockwise. (d) C1--clockwise. C2-clockwise.

22. The area of a square shaped coil is 10^{-2} m^2.Its plane is perpendicular to a magnetic field of strength 10^{-3} T. The magnetic flux linked with the coil is

(a) 10 Wb (b) 10^{-5} Wb (c) 10^5 Wb (d) 100 Wb

ANS to MCQ: 1-c, 2-b, 3-d, 4-d, 5-c, 6-a,7-b, 8-b, 9-c, 10-d , 11-d, 12-b,13-a,14-b,15-b, 16-c, 17-a, 18-c,19-d, 20-d, 21-d, 22-b.

ASSERTION AND REASON TYPE QUESTIONS

Directions: In the following questions, a statement of assertion is followed by a statement of reason. Mark the correct choice as:

(A) If both assertion and reason are true and reason is the correct explanation of assertion.

(B) If both assertion and reason are true but reason is **not** the correct explanation of assertion.

(C) If assertion is true but reason is false.

(D) If both assertion and reason are false.

1. **Assertion:** Two identical loops, one of copper and another of aluminium are rotated with the same speed in the same magnetic field. The emf induced in both the loop will be same.
Reason: The magnitude of induced emf is directly proportional to the rate of change of magnetic flux linked with the circuit.

2. **Assertion:** Only a change in magnetic flux will maintain an induced current the coil.
Reason: The presence of large magnetic flux through a coil maintains a current in the coil if the circuit is continuous

3. **Assertion**: Induced emf will always occur whenever there is change in magnetic flux.
Reason: Current always induces whenever there is change in magnetic flux.
(Emf will always induces whenever, there is change in magnetic flux. The current will be induced only in closed loop.)

4. **Assertion:** Lenz's law does not violate the principle of conservation of energy.
Reason: Induced emf always opposes the change in magnetic flux responsible for its production.

5. **Assertion:** Mutual inductance of a pair of coils depends on their separation as well as their relative orientation.
Reason: Mutual inductance depend upon the length of the coil only.

6. **Assertion:** When two coils are wound on each other, the mutual induction between the coils is maximum.
Reason: Mutual induction does not depend on the orientation of the coils.

7.Assertion: Average value of a.c. over a complete cycle is always zero.
Reason: Average value of a.c. is always defined over half cycle.

8.Assertion: In a series LCR circuit, at resonance condition power consumed by circuit is maximum.
Reason: At resonance condition effective resistance of circuit is maximum.

9.Assertion: In series LCR circuit resonance can take place.
Reason: Resonance takes if inductance and capacitive reactance are equal.
10.Assertion: When frequency is greater than resonance frequency in a series LCR circuit, it will be an inductive circuit.
Reason: Resultant voltage will lead the current
11.Assertion: When capacitive reactance is smaller than the inductive reactance in LCR circuit, e.m.f. leads the current.
Reason: The phase angle is the angle between the alternating e.m.f. and alternating current of the circuit.
12 **Assertion:** An induced current has a direction such that the magnetic field due to the current opposes the change in the magnetic flux that induces the current.
Reason : Above statement is in accordance with conservation of energy.

Ans : 1-a, 2-c, 3-c,4-a,5-c,6-a,7-b, 8-c, 9-a,10-a, 11-c,12 –b.

2-MARKS QUESTIONS with Answers

1.State Faraday's law of electromagnetic induction

(i) Whenever there is a change in magnetic flux linked with a coil, an emf is induced in the coil. Emf is induced when the magnetic flux across the coil changes with time.

(ii)The induced emf is proportional to the rate of change of magnetic flux linked with the coil.

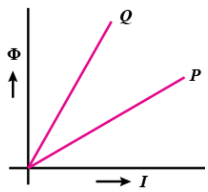
2.State Lenz's Law. A metallic rod held horizontally along east-west direction, is allowed to fall under gravity. Will there be an emf induced at its ends? Justify your answer

Ans. Lenz's law: According to this law "the direction of induced current in a closed circuit is always such as to oppose the cause that produces it

Yes, an emf will be induced at its ends.

Justification: When a metallic rod held horizontally along east-west direction is allowed to fall freely under gravity i.e., fall from north to south, the intensity of earth magnetic field changes through it i.e., the magnetic flux changes and hence the emf is induced at it ends

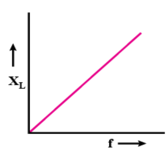
3.(i)If the rate of change of current 2 A/s, induces an emf of 40 mV in the solenoid, what is the self-inductance of the solenoid? (ii) The given graph shows a plot of magnetic flux(φ) and the electric current(I) following through two inductors P and Q. Which of the two inductors has smaller value of self-inductance.



[**Ans:** -(i) L = 20mH. (ii) L = slope, P is having smaller resistance,
Inductor P, $\varphi=LI \Rightarrow L=\varphi/I$
For P, φ/I is lesser so, it has smaller value of self-inductance.]

4.(i)Define the term inductive reactance. Write its S.I. unit. (ii) Show graphically the variation of inductive reactance with frequency of the applied alternating voltage.

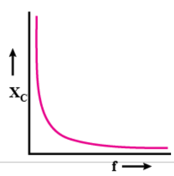
[Ans. Inductive reactance: The opposition/obstruction offered by an inductor to the flow of alternating current through it, is called inductive reactance



⇨ Its S. I. unit is ohm

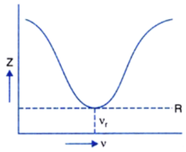
5. (i)Define the term capacitive reactance. Write its S.I. unit. (ii) Show graphically the variation of capacitive reactance with frequency of the applied alternating voltage.

[Ans. Capacitive reactance : The opposition/obstruction offered by a capacitor to the flow of alternating current through it, is called capacitive reactance



⇨ Its S. I. unit is ohm.

6.What is meant by impedance? Write an expression for impedance of L-C-R circuit. What is it's S.I. unit? (ii) Show graphically the variation of impedance of LCR circuit with frequency of the applied alternating voltage.



[Ans. Impedance : The opposition /obstruction offered by the combination of resistance and effective reactance to the flow of alternating current through it, is called impedance. $Z = \sqrt{R^2 + (X_L - X_C)^2}$ Its S. I. unit is ohm

7.Define the term power factor. State the condition under which it is (i) maximum and (ii) minimum.

Power factor : It is the ratio of resistance to the impedance of an a.c. circuit i,e, Power factor $\cos\phi$= R/Z.(i) Power factor is maximum when, **Z=R, $\cos\phi$= R/ Z=1**

when either the a.c. circuit is pure resistive circuit or is in resonance condition.

(ii) Power factor is minimum when, **R=0, $\cos\phi$= R/ Z=0** when a.c. circuit is either when circuit is purely inductive or capacitive.]

8.An a.c. source of voltage is connected one by one, to three circuit elements and . It is observed that the current flowing in them,

(i) is in phase with the applied voltage for element
(ii) lags the applied voltage in phase by , for element

(iii) leads the applied voltage in phase by , for element . Identify the three circuit elements.

[**Ans.** (i) X-Resistor (ii) Y- Inductor (iii) Z- capacitor]

9.Describe briefly any two energy losses, giving the reason of their occurrence in actual transformer. How are these reduced?

[**Ans.** Energy losses in a transformer :

(i) Copper loss : Energy loss as heat due to resistance of primary and secondary is called copper loss and can be minimized by using thick copper wires

(ii) Iron loss : Energy loss as heat due to eddy currents in the iron core is called Iron loss and can be reduced by using a laminated iron core

(iii) Hysteresis loss: Magnetisation of iron core is repeatedly reversed by the alternating magnetic field and energy is lost in the form of heat in the core. This is called hysteresis loss and can be minimized by using a core of a material having low hysteresis loop.

(iv) Flux leakage : There is always some flux leakage; i,e, all of the flux due to primary does not passes through the secondary. It can be minimized by winding primary and secondary coils one over the other

10.How is the transformer used in large scale transmission and distribution of electrical energy over long distances ?

[Ans. (a) output voltage of the power generator is stepped-up so that current is reduced and as a result, line loss I^2R is also reduced

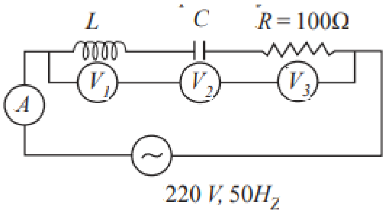
(b) It is then transmitted over long distances to an area sub-station, where voltage is stepped down.]
11.A power transmission line feeds input power at 2200 V to a step-down transformer with its primary windings having 300 turns. Find the number of turns in the secondary to get the power output at 220 V.
[Ans $N_p = 3000$, $E_p = 2200\ V$, $E_s = 220\ V$, $N_s = ?$

Since, Es/Ep = Ns/Np =220/ 2200 = Ns/3000 ; Ns = 300 ;

12.Obtain the resonant frequency ω_r of a series LCR circuit with L = 2.0H, C=32 μF and $R = 10\ \Omega$. What is Q-value of this circuit?

[Ans. Here $L = 2.0H$, C = 32 μF = × 32 × $10^{-6}F$ $R = 10\ \Omega$
∴ Resonant frequency is given by, $\omega_r = 1/\sqrt{LC} = 1/\sqrt{2.0 \times 32 \times 10^{-6}}$
= 1000/ 8 =125 Hz.
Quality factor is q-value = $(\omega_r.L)/R$ = 125 × 2.0/10 = 25]

13.In the given circuit the reading of voltmeter V_1 and V_2 are 300 V each. What will be the reading of the voltmeter V_3 and ammeter A



[Ans. As $V_1 = V_2$ = 300 V,, resonance will take place.
V_3 = 220 V Current, I = 220 /100= 2.2A
reading of V_3 = 220 V and reading of A = 2 2. A

PART- C
3-MARKS QUESTIONS with Answers

1.Derive expression for self inductance of a long air-cored solenoid of length l, cross-sectional area A and having number of turns N (OR)
Derive the expression for the self-inductance of a long solenoid of cross sectional area A , length l , and having n turns per unit length.

[**Ans.** Self-inductance of a long solenoid :
Let a current I is flowing through a long solenoid, then magnetic field at its centre
Let a current I is flowing through a long solenoid, then magnetic field at its centre

$$B = \mu_0\, n\, I = \frac{\mu_0\, N\, I}{l} \qquad [\because n = \frac{N}{l}]$$

⇨ magnetic flux linked with each turn of the solenoid

$$\phi = BA = \left(\frac{\mu_0 NI}{l}\right) A = \frac{\mu_0\, N\, IA}{l}$$

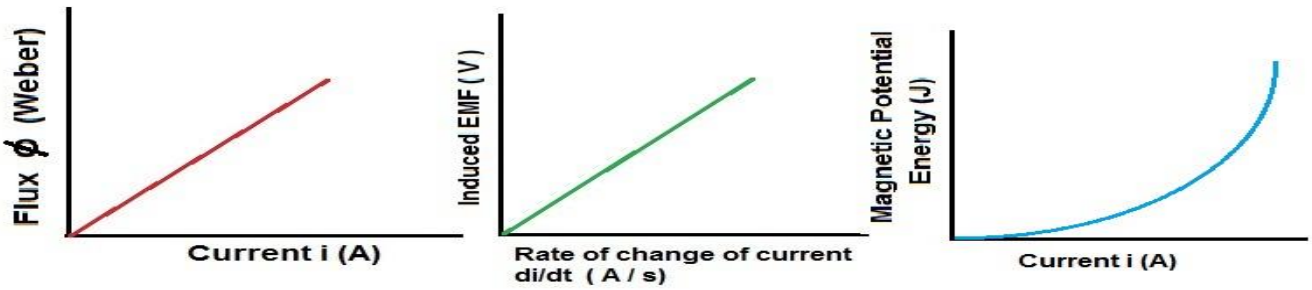
⇨ $$L = \frac{N\phi}{I} = \frac{N}{I}\left(\frac{\mu_0\, N\, IA}{l}\right) = \frac{\mu_0\, N^2 A}{l}$$

⇨ $$L = \frac{\mu_0\, (nl)^2 A}{l} = \mu_0\, n^2 Al$$

If we fill the inside of the solenoid with a material of relative permeability μ_r, then

$$L = \mu_0\, \mu_r\, n^2 Al = \mu_0\, \mu_r\, n^2 \pi r^2 l$$

2.The current flowing through an inductor of self inductance L is continuously increasing. Plot a graph showing the variation of (i) Magnetic flux versus the current (ii) Induced emf versus dI/dt (iii) Magnetic



potential energy stored versus the current.

3.How is the mutual inductance of a pair of coils affected when (i) separation between the coils is increased? (ii) the number of turns in each coil is increased? (iii) a thin iron sheet is placed between the two coils, other factors remaining the same? Justify your answer in each case.'

(i) When the relative distance between the coil is increased, the leakage of flux increases which reduces the magnetic coupling of the coils. So magnetic flux linked with all the turns decreases. Therefore, mutual inductance will be decreased.

(ii) Mutual inductance for a pair of coil is given by

$$M = \frac{\mu_0 N_1 N_2 \pi r^2}{L}$$

Therefore, when the number of turns in each coil increases, the mutual inductance also increases.(iii)When a thin iron sheet is placed between the two coils, the mutual inductance increases because $M \propto \mu_r$ (Relative permeability of material).

The permeability of the medium between coils increases.

4.(i)Write the principle of which a transformer works. (ii)Why is the core of a transformer made of a magnetic material of high permeability?(iii) Does a step up transformer violets the principle of conservation of energy ?

[Ans. (i)It is based on the principle of mutual induction i,e, whenever there is change in magnetic flux linked with a coil, an emf is induced in the neighbouring coil

(ii)To increase the magnetic flux in the core, due to which flux leakage decreases & efficiency increases

(iii)No, In an ideal transformer input power is always equal to output power, due to which if voltage increases, current is reduced in same proportion]

5-MARKS QUESTIONS with Answers

1.Draw a schematic diagram of a step up/step down transformer. Explain its working principle. Deduce the expression for the secondary to primary voltage in terms of the number of turns in the two coils. In an ideal transformer, how is this ratio related to the currents in the two coils?

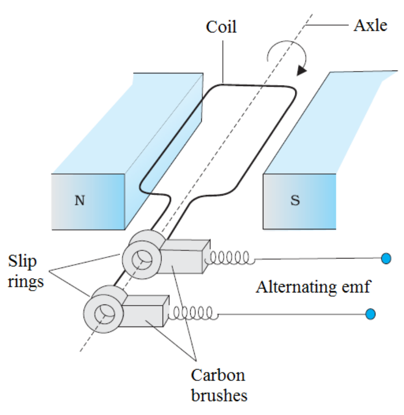
Refer Minimum Learning Material

2.Explain with the help of a labelled diagram, the principle and working of an ac generator and obtain expression for the emf generated in the coil. (ii) Draw a schematic diagram showing the nature of the alternating emf generated by the rotating coil in the magnetic field during one cycle. (iii)What is the source of energy generation in this device?

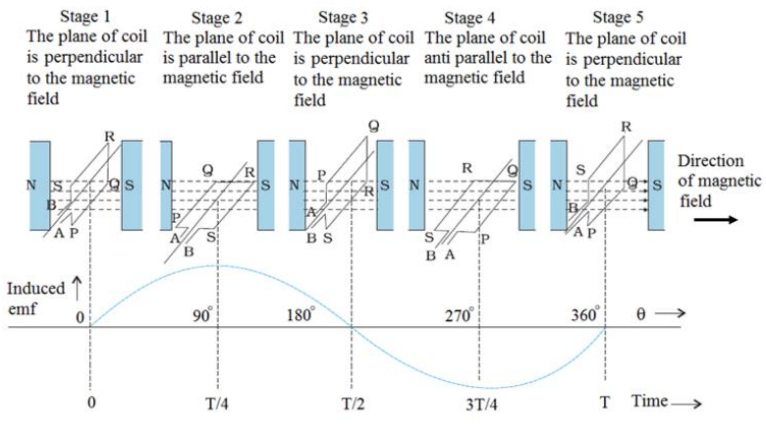
It is a device which converts mechanical energy in to electrical energy.

Principle: It is based on the principle of electromagnetic induction, i,e, whenever there is change in magnetic flux linked with a coil, an emf is induced in the coil

Working : When the armature coil is rotated in a uniform magnetic field, effective area of coil changes continuously due to which magnetic flux linked with it changes. Hence an emf is induced in the circuit and a current flow through the coil



AC GENERATOR



Different orientations of armature and magnetic field in an AC GENERAOR

The magnetic flux linked with the coil at any instant is $\phi = NB\ A \cos \omega t$

Induced emf will be e = $- d\phi\ dt$

$= - d/dt\ (NBA \cos \omega t)$

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

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

$e = NAB\omega \sin \omega t$ …(i) the induced emf will be maximum,

when $\sin \omega\ t$ = maximum = 1

$\therefore e_{max} = e_0 = NAB\omega \times 1$ …(iii)

Put in (ii) $e = e_0 \sin \omega t$

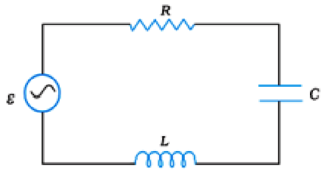
(c) Mechanical energy is converted into electric energy.

3.A voltage $V=V_0 \sin \omega t$ is applied to a series LCR circuit. Derive the expression for average power dissipated over a cycle. Under what condition is –

(i)no power is dissipated even though the current flows through the circuit,

(ii) maximum power dissipated in the circuit.

[**Ans.** We have the applied voltage



$V = V_0 \sin \omega t$

& $I = I_0 \sin(\omega t + \phi)$ Where, $\phi = \tan^{-1}\left(\frac{X_C - X_L}{R}\right)$

⇨ $P = V \text{ X } I = V_0 \sin \omega t \text{ X } I_0 \sin(\omega t + \phi)$

⇨ $P = V_0\ I_0 \sin \omega t \text{ X } (\sin \omega t\ \cos \phi + \cos \omega t\ \sin \phi)$

⇨ $P = V_0\ I_0 \left[\sin^2 \omega t\ \cos \phi + \frac{1}{2} \sin 2\omega t\ \sin \phi\right]$

Average power per cycle

$\bar{P} = \frac{1}{T}\int_0^T P\, dt = \frac{1}{T}\int_0^T V_0\, I_0 \left[\sin^2 \omega t\ \cos \phi + \frac{1}{2}\sin 2\omega t\ \sin \phi\right] dt$

⇨ $\bar{P} = \frac{V_0\, I_0\ \cos \phi}{T}\int_0^T \sin^2 \omega t\ dt + \frac{V_0\, I_0\ \sin \phi}{2T}\int_0^T \sin 2\omega t\ dt$

⇨ $\bar{P} = \frac{V_0\, I_0\ \cos \phi}{T}\ \frac{T}{2} + 0$ $\left[\because \int_0^T \sin^2 \omega t\ dt = \frac{T}{2}\ \&\ \int_0^T \sin 2\omega t\ dt = 0\right]$

⇨ $\bar{P} = \frac{V_0\, I_0}{2} \cos \phi = \frac{V_0}{\sqrt{2}} \text{ X } \frac{I_0}{\sqrt{2}} \text{ X } \cos \phi$

⇨ $\boxed{\bar{P} = V_{rms} \text{ X } I_{rms} \text{ X} \cos \phi}$ Where, $\cos \phi = R/Z$ is called power factor

(i) For a pure inductive or capacitive circuit, $\phi = \frac{\pi}{2}$

⇨ $\bar{P} = V_{rms}\ X\ I_{rms}\ X \cos \frac{\pi}{2} = 0$ which shows that, no power is dissipated even current flows through the circuit

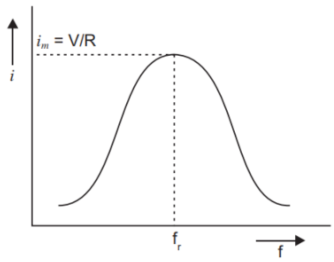
(ii) at resonance when $X_L = X_C$, $\phi = 0$

⇨ $\bar{P} = V_{rms}\ X\ I_{rms}\ X \cos 0 = V_{rms}\ X\ I_{rms}$ = maximum Which shows that at resonance max power is dissipated

4.Derive an expression for the impedance of a series LCR circuit connected to an AC supply of variable frequency. Plot a graph showing variation of current with the frequency of the applied voltage

Ans : Refer Minimum learning material

Graph showing variation of current with the frequency of the applied voltage



CASE STUDY BASED QUESTIONS

I.Read the following paragraph and answers the questions:

In year 1820 Oersted discovered the magnetic effect of current. Faraday gave the thought that reverse of this phenomenon is also possible i.e., current can also be produced by magnetic field. Faraday showed that when we move a magnet towards the coil which is connected by a sensitive galvanometer. The galvanometer gives instantaneous deflection showing that there is an electric current in the loop. Whenever relative motion between coil and magnet takes place an emf induced in coil. If coil is in closed circuit, then current is also induced in the circuit. This phenomenon is called electromagnetic induction.

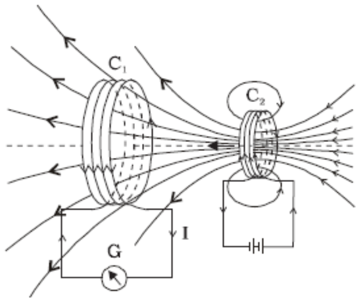
1.State the law that gives the polarity of the induced emf.

2. Two identical loops, one of copper and the other of aluminium are rotated with the same angular speed in the same magnetic field. Compare the induced emf . Justify your answer

3.A current is induced in coil C_1 due to the motion of current carrying coil C_2.

(i)Write any one method by which a large deflection can be obtained in the galvanometer G

(ii)Suggest an alternative device to demonstrate the induced current in place of a galvanometer.



[ANS:1. **The direction of induced emf or induced current is always in such a way that it opposes the cause due to which it is produced.**

2.The induced emf in both the loops will be same as areas of the loop and time periods are same as they are identical and rotated with same angular speed.

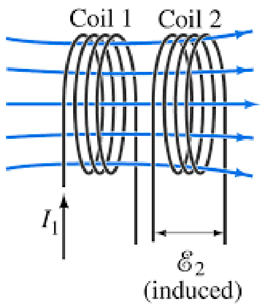
3. (i)(a)by moving quickly, the coil C_2 towards C_1, or by moving quickly the coil C_2 away from C,.

(b)by switching off and on the key.

(ii) Alternating device in place of galvanometer can be LED or bulb.

II. Read the following paragraph and answers the questions:

Mutual inductance is the phenomenon of inducing emf in a coil, due to a change of current in the neighbouring coil. The amount of mutual inductance that links one coil to another depends very much on the relative positioning of the two coils, their geometry and relative separation between them. Mutual inductance between the two coils increases μ_r times if the coils are wound over an iron core of relative permeability μ_r



1.Name two factors which affect the mutual inductance of a pair of coils

2. A short solenoid of radius a, number of turns per unit length n_1' and length L is kept coaxially inside a very long solenoid of radius b, number of turns per unit length n_2. What is the mutual inductance of the system?

3.How does the magnitude of the induced emf change in coil C1

4.If a change in current of 0.01 A in one coil produces a change in magnetic flux of 2 x 10^{-2} weber in another coil, then what is the mutual inductance between coils?

[ANS:1 **(i)**distance between the coils/relative orientation of the coils (ii) number of turns in the coils (iii)Permeability of the medium [any other answer]

2. $M_{12} = \mu_0 n_1 n_2 \pi a^2 L$

3. Due to the rate of change of current and mutual inductance of the two coils.

4.Mutual inductance between two coils is. $M = \frac{\phi_B}{I} = \frac{2\times10^{-2}\ \mathrm{Wb}}{0.01\ \mathrm{A}} = 2\mathrm{H}$]

III. Read the following paragraph and answers the questions:

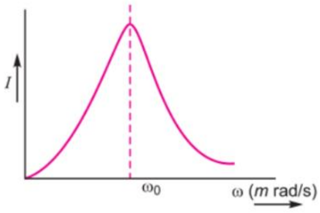
Resonant Series LCR Circuit. When the frequency of ac supply is such that the inductive reactance and capacitive reactance become equal, the impedance of the series LCR circuit is equal to the ohmic resistance in the circuit. Such a series LCR circuit is known as resonant series LCR circuit and the frequency of the ac supply is known as resonant frequency. Resonance phenomenon is exhibited by a circuit only if both L and C are present in the circuit. We cannot have resonance in a RL or RC circuit.

1. Plot a graph showing the variation of current with frequency of a.c. sources in a series LCR circuit.
2. **At resonance which physical quantity is maximum, minimum value?**

3. Show that in a series LCR circuit connected to an a.c. source exhibits resonance at its natural frequency equal to $\omega_r = 1/\sqrt{LC}$

4.A series LCR circuit with L = 5.0 H, C = 80 μF, R = 40 Ω connected to a variable frequency 240 V source. Calculate the current at the resonating frequency

[ANS:1.



2.

Maximum ---Current

Minimum ---Impedance

3. For electrical resonance,

$$X_L = X_C$$

$$\omega L = \frac{1}{\omega C} \text{ or } \omega^2 = \frac{1}{LC}$$

$$\therefore \omega = \frac{1}{\sqrt{LC}}$$

where ω is the natural frequency of the circuit.

4.

$$I_{rms} = \frac{V_{rms}}{R} = \frac{240}{40} = \mathbf{6\ A}$$

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UNIT 5 ELECTRO MAGNETIC WAVES

UNIT—V-ELECTROMAGNETIC WAVES

GIST ,FORMULAE AND SHORTCUT FOURMULAE

1. **Concept of displacement current**

Displacement current is that current which appears in a region in which the electric field (and hence electric flux) is changing with time.

Note- We have $I_D = \varepsilon_0 \frac{d\phi_E}{dt} = \varepsilon_0 \frac{d}{dt}(EA) == \varepsilon_0 \frac{d}{dt}(\frac{q}{\varepsilon_{0A}} A) =$ $= \frac{dq}{dt} = I$

2. **Modified Ampere's circuital Law**

$$\oint B.dl = \mu_0 (I + \varepsilon_0 \frac{d\phi_E}{dt})$$

3. **Electromagnetic Waves**

We know, Maxwell's equations in vacuum

$$\oint \vec{E}.\vec{dl} = -\frac{d\vec{\phi}_B}{dt} \quad \& \quad \oint B.dl = \mu_0 \varepsilon_0 \frac{d\phi_E}{dt}$$

These equations leads to the conclusion that, either of the electric or magnetic fields change with time, the other field is induced in space. The net result of these interacting changing fields is the generation of electromagnetic disturbance, called electromagnetic waves which travel with the speed of light.

4. **Mathematical Expression of EM waves**

$E_y = E_0 \sin 2\pi(\frac{x}{\lambda} - \frac{t}{T})$ j	$B_z = B_0 \sin 2\pi(\frac{x}{\lambda} - \frac{t}{T})\, k$

5. **Properties of em waves**

(i) E. M. waves are produced by accelerated charged particles.

(ii) E.M. waves do not require any medium for their propagation. These waves can propagate in vacuum as well as in a medium.

velocity of em waves in a free space is given by

$$v = c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}} = 3 \text{ X } 10^8 \text{ m/s}$$

Velocity of em waves in a medium is given by

$$v = \frac{c}{\sqrt{\mu_r K}}$$

(iii) E.M. waves are transverse in nature i,e, $\overleftrightarrow{E \ \& \ B}$ are perpendicular to each other as well as perpendicular to the direction of

propagation of the wave. E & B are related as follows -

$$\frac{E_0}{B_0} = c \text{ or } \frac{E}{B} = c$$

(iv) E.M. waves carry energy, which is shared equally by electric and magnetic fields.

The average energy density of an em wave is given by

$$u = u_E + u_B = 2\,u_E = 2\,u_B$$

Where $u_E = \frac{1}{2}\varepsilon_0 E^2 = \frac{1}{2}\varepsilon_0 (Bc)^2$ $[\because \frac{E}{B} = c\,]$

$= \frac{1}{2}\varepsilon_0 B^2 (\frac{1}{\sqrt{\mu_0\varepsilon_0}})^2$ $[\because c = \frac{1}{\sqrt{\mu_0\varepsilon_0}}]$

⇨ $u_E = \frac{B^2}{2\mu_0} = u_B$

(v) E.M. waves carry momentum & exert a radiation pressure $P = \frac{F}{A} = \frac{1}{A}\frac{dp}{dt}$ & momentum $p = \frac{U}{c}$

(vi) E.M. waves transport energy. The rate of energy of em wave transported per unit area is represented by a quantity called

Pointing vector (S) and is given by

$$\vec{S} = \frac{1}{\mu_0}(\vec{E} \times \vec{B})$$

(Vii) Electric vector of an em wave is responsible for optical effects, as $E_0 >> B_0$.

(viii) Intensity of an em wave is given by

$$I = \frac{1}{2}\,c\,\varepsilon_0 E = \frac{B\,c}{2\mu_0}$$

ELECTRO MAGNETIC SPECTRUM, ITS PRODUCTION, DETECTIONAND USES IN GENERAL

Type	Wave lengthRange Frequency Range	Production	Detection	Uses
Radio	10^{-1} to 1 x 10^{4}m 10^{9} to 10^{5}Hz	Rapid acceleration / deceleration of electrons in aerials	Receiver's aerials	Radio, TV Communi cation
Micro-wave	10^{-1}-10^{-3} m 10^{12} to10^{10} Hz	Klystron valve or magnetron valve	Point contact diodes	Radar, TV communication
Infrared	10^{-4}-10^{-6} m 10^{12} to 10^{14}Hz	Vibration of atomor molecules	Thermopiles, Bolometer Infrared PhotographicFilm	Green House effect, looking through haze, fog and mist, Ariel mapping.
Light	700nm to 400nm 8x10^{14} Hz	Electron in an atom during transition	Eye, Photocell, Photographic Film	Photography, Illuminations,Emit & reflect by the objects.
Ultra-violet	10^{-6}-10^{-9} m 10^{15} to 10^{17}Hz	Inner Shell electron in atom moving from one energy level to a lower energy level	Photocell & photographic film	Preservation of food items, Detection of invisible writing, finger print in forensic laboratory. Determination of Structure of molecules& atoms.
X-rays	10^{-8}-10^{-12} m 10^{16} to 10^{21}Hz	X-ray tube or inner shell Electrons	Photographic film, Geiger tube, ionization chamber.	Study of crystal structure& atom, fracture of bones.
Gamma ray	<10^{-11} 10^{18} to 10^{26}Hz	Radioactive decay of the nucleus	Photographic film, Geiger tube, ionization chamber	Nuclear reaction & structure of atoms & Nuclei. To destroy cancer cells.

ElectromagneticWaves -Minimum Learning material

Maxwell put together the basic laws of electricity and magnetism is that, Gauss' law of electricity, Gauss' law of magnetism, Faraday's law of electromagnetic induction, and Ampere- Maxwell's Circuital law in the form of four fundamental equations, known as Maxwell's equations.

On the basis of these equations, Maxwell anticipated the existence of electromagnetic waves.

1. **Gauss' law of electricity:-** It states that the electric flux through any closed surface is equal to the $1/\epsilon_0$ times the net charge enclosed by the surface.

$$\oint \vec{E}.d\vec{s} = \frac{q}{\epsilon_0}$$

This equation is called Maxwell's first equation. This equation is true for both moving and stationary charges.

2. **Gauss's law of magnetism:-** It states that the magnetic flux through any closed surface is zero.

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

This equation is called Maxwell's second equation. It signifies that free magnetic poles do not exist. This equation also signifies that magnetic lines of force cannot start from a point nor end at a point, that is they are closed curves.

3. **Faraday's laws of Electromagnetic induction:-** It asserts that the negative rate of change of magnetic flux across a circuit is equal to the induced emf set up in the circuit.

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

Since emf can be defined as the line integral of the electric field, the above relation can be expressed as

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

The line integral of the electric field along a closed channel is therefore equal to the rate of change of magnetic flux through the surface bounded by that closed path, according to the law.

This equation is called Maxwell's third equation. It signifies that the electric field is produced by a changing magnetic field.

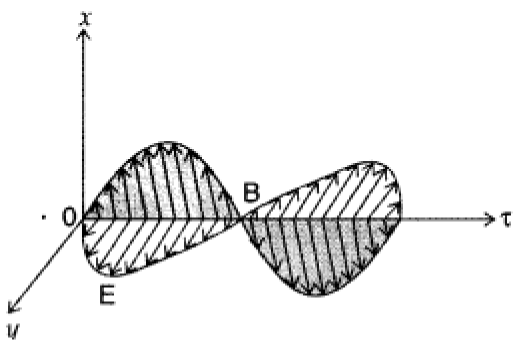
4. **Ampere-Maxwell's Circuital law:-** It states that the line integral of the magnetic field along a closed is equal to μ_0 times the total current linked with the surface bounded by that closed path.

$$\oint \vec{B}.d\vec{l} = \mu_0(i + i_d) \text{ Where } i_d = \epsilon_0 A\frac{dE}{dt}$$

This equation is known as Maxwell's fourth equation. It signifies that a conduction current, as well as a changing electric field, produces a magnetic field.

Electromagnetic Waves

From the Maxwell third equation is that a changing magnetic field produces an electric field whereas Maxwell's fourth equation is, a changing electric field produces a magnetic field. It means that change in either field produces the other field. Maxwell worked out from his quotations that variation in electric and magnetic fields would lead to a wave consisting of fluctuating electric and magnetic fields perpendicular to each other and also perpendicular to the propagation of the wave. Such waves can actually propagate in space without any material medium called electromagnetic waves.



A graphical representation of electromagnetic waves is shown in fig. In this electric field vector E and the magnetic field, vectors B are vibrating along the Y- and Z- directions respectively and the wave is propagating along the X-direction. Both vector E and vector B are varied with time and space and have the same frequency. Some examples of electromagnetic waves are radio waves, microwaves, infrared rays, ultraviolet rays, X-rays, and γ-rays.

Relation Between Magnitudes of Vector E and Vector B in Free Space

Let a sinusoidal electromagnetic wave is propagating in free space along with the positive directions o the X-axis with wave no. k and angular frequency ω. Then, the magnitudes of vector E and vector B acting along Y- and Z-axis respectively, vary with x and t and can be written as

$$E = E_0 \sin(\omega t - kx) \quad .....(i)$$
$$B = B_0 \sin(\omega t - kx) \quad ......(ii)$$

Where E_0 and B_0 are the maximum values of E and B respectively.

$$k = \frac{2\pi}{\lambda}, \omega = 2\pi v$$

Here λ is wavelength and v is the frequency of the wave.

$$\therefore \frac{\omega}{k} = \frac{2\pi v}{2\pi/\lambda} = v\lambda = c$$

c is the speed of the electromagnetic wave which is the speed of light in free space.

$$\frac{E_0}{B_0} = \frac{\omega}{k} = c$$

Since E and B are in the same phase.

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

At any point in space. Thus, the ratio of the magnitude of electric field and magnetic field equals the speed of light in free space.

Energy Density in Electromagnetic Waves

The energy density in an electric field E in a vacuum is $\epsilon_0 E^2/2$, and that in a magnetic field B is $B^2/2\mu_0$. Thus, the energy density is associated with an electromagnetic wave is

$$u = \frac{1}{2}\epsilon_0 E^2 + \frac{1}{2}\frac{B^2}{\mu_0} \quad .....(i)$$

An electromagnetic wave propagating along the X-axis and the magnitude of vector E and vector B, acting along the Y- and Z- axis respectively can be written as

$$E = E_0 \sin(\omega t - kx) \ \ and\, B = B_0 \sin(\omega t - kx)$$

Where E_0 and B_0 are the maximum values of E and B respectively. Putting these values in eqn (i), we get

$$u = \frac{1}{2}\epsilon_0 E_0^2 \sin^2(\omega t - kx) + \frac{1}{2}\frac{B_0^2}{\mu_0} \sin^2(\omega t - kx)$$

The time average of $\sin^2$ over any whole number of cycles is ½. Therefore the average energy density of an e.m. wave is

$$\bar{u} = \frac{1}{2}\epsilon_0 E_0^2 + \frac{1}{2}\frac{B_0^2}{\mu_0}$$

Here $\epsilon_0 E^2/2$ is the average kinetic energy density u_e and $B^2/2\mu_0$ is the average magnetic density u_m.

IMPORTANT CHARACTERISTICS OF ELECTROMAGNETIC WAVES

1. The electromagnetic waves are produced by accelerated charge.
2. In free space, these waves travel with the speed of light.
3. No medium is required for the propagation of Electromagnetic waves.
4. The electric and magnetic fields have perpendicular variations in their direction of variation.
5. The electromagnetic waves are transverse in nature.
6. The variations in the electric and magnetic fields occur simultaneously and the field acquires their maximum values E_0 and B_0 at the same place and same time.
7. In free space, the magnitudes of the electric and magnetic fields in electromagnetic waves are related by $E/B = c$.
8. Electromagnetic waves, being uncharged, are not deflected by electric and magnetic fields.

MCQ AND ASSERTION AND REASONING QUESTIONS IN EM WAVES

1) **Which of the following laws was modified by Maxwell by introducing the displacement current?**

(a) Gauss's law (b) Ampere's law (c) Biot-Savart's law (d).None of these

2) **Electromagnetic waves have a speed of**

(a) 3 × 105 kms-1 (b)3 × 106 kms-1 (c) 3 × 107 kms-1 (d) 3 × 108 kms-1

3) **Which of the following EMW has highest wavelength?**

(a) X-ray (b) ultraviolet rays (c) infrared rays (d) microwaves

4) **Displacement current is due to:**

(a) the flow of electrons (b) the Varying electric field (c) the ionization of atmosphere

(d) the flow of protons

5) **Displacement current is always :**

(a) equal to conduction current (b) less than conduction current (c) greater than conduction current

(d) the sum of current due to flow of positive and negative ions

6) **EMW are produced by:**

(a) charge in uniform motion only (b) charge at rest only (c) accelerated or decelerated charge only

(d) all of the above

7) **If $\vec{B}$ is the magnetic field vector and $\vec{E}$ is the electric field vector in an em wave, then which of the following relations is correct? Here c is the speed of fight:**

(a) $c = E/B$ (b) $c = BE$ (c) $c = B/E$ (d) $c = 1/EB$

8) **Name the law which states that a varying electric field produces a magnetic field:**

(a) Biot-Savart's law (b) Faraday's law (c) Modified Ampere's law (d) None of these

9) **Frequency of a wave is 6 × 1015. Hz. The wave is :**

(a) Radiowave (b) Microwave (c) X-ray (d) Ultra violet

10) **Choose the wrong statement?**
(a) Electromagnetic waves are transverse
(b) Electromagnetic waves travel with the speed of light in free space
(c) Electromagnetic waves are produced by accelerating charges
(d) Electromagnetic waves travel with the same speed in all media

11) **If u_e and u_m arc the electric and magnetic field densities in an electromagnetic wave, then (c is the speed of light):**

(a) $u_e = u_m$ (b) $u_e = c/ u_m$ (c) $u_e = u_m/c$ (d) None of these

12) **In electromagnetic waves the phase difference between electric and magnetic field vectors are**

(a) zero (b) $\pi/4$ (c) $\pi/2$ (d) π

13) **The correct option, if speeds of gamma rays, X-rays and microwave are Vg, Vx an Vm respectively will be**.

(a) Vg > Vx > Vm (b) Vg < Vx < Vm (c) Vg > Vx > Vm (d) Vg = Vx = Vm

14) **Which of the following has minimum wavelength?**

(a) Blue light (b) γ-rays (c) infrared rays (d) microwave

15) **Which of the following has maximum penetrating power?**

(a) Ultraviolet radiation (b) Microwaves (c) γ-rays (d) Radio waves

16) **The quantity $\sqrt{\mu 0 \varepsilon 0}$ represents**

(a) speed of sound (b) speed of light in vacuum
(c) speed of e.m. waves (d) inverse of speed of light in vacuum

17) **Which of the following is called heat radiation?**

(a) X-rays (b) γ-rays (c) Infrared radiation (d) Microwave

18) **Which of the following are not electromagnetic waves?**

(a) Cosmic ray (b) γ-rays (c) β-rays (d) X-rays

19) **If $\vec{E}$ and $\vec{B}$ represent electric and magnetic field vector of the electromagnetic waves then the direction of propagation of the em wave is that of**

(a) $\vec{E} . \vec{B}$ (b) $\vec{B} . \vec{E}$
(c) $\vec{E} \times \vec{B}$ (d) $\vec{B} \times \vec{E}$

20) **The structure of solids is investigated by using**

(a) cosmic rays (b) X-rays (c) γ-rays (d) infrared rays

Answer: (b) X-rays are used to investigate structure of solids.

21) **Which radiations are used in treatment of muscle ache?**

(a) Infrared (b) Ultraviolet (c) Microwave (d) X-rays

22) **Waves in decreasing order of their wavelength are**

(a) X-rays, infrared rays, visible rays, radio waves (b) radio waves, visible rays, infrared rays, X-rays.

(c) radio waves, infrared rays, visible rays, X-rays. (d) radio waves, ultraviolet rays, visible rays, X-rays

23) **The conduction current is same as displacement current when source is**

(a) ac only (b) dc only (c) either ac or dc (d) neither dc nor ac

Ans :1-b, 2-a, 3-c , 4-b ,5-a,6-c, 7-c, 8-c,9-d,10-d,11-a,12-a ,13-d,14 –b,15-c, 16-d, 17-c, 18-c,19-c , 20-b, 21-a, 22-c,23-c.

ASSERTION AND REASONING QUESTIONS

Directions: These questions consist of two statements, each printed as Assertion and Reason. While answering these questions, you are required to choose any one of the following four responses.

(a) If both Assertion and Reason are true and the Reason is a correct explanation of the Assertion.

(b) If both Assertion and Reason are true but Reason is not a correct explanation of the Assertion.

(c) If the Assertion is true but Reason is false.

(d) If both the Assertion and Reason are false..

1. **Assertion (A) :** Electromagnetic wave are transverse in nature.
Reason (R) : The electric and magnetic fields in electromagnetic waves are perpendicular to each other and the direction of propagation.
2 **Assertion (A):** Electromagnetic waves interact with matter and set up oscillations.
Reason (R) : Interaction is independent of the wavelength of the electromagnetic wave.
3. **Assertion (A) :** Electromagnetic waves carry energy and momentum.
Reason (R) : Electromagnetic waves can be polarised.
4. **Assertion (A):** Electromagnetic waves exert radiation pressure.
Reason (R) : Electromagnetic waves carry energy.
5. **Assertion (A)**: The electromagnetic wave is transverse in nature.
Reason (R) : Electromagnetic wave propagates parallel to the direction of electric and magnetic fields.
6. **Assertion (A):** The velocity of electromagnetic waves depends on electric and magnetic properties of the
medium.
Reason (R) : Velocity of electromagnetic waves in free space is constant.
7. **Assertion (A):** The basic difference between various types of electromagnetic waves lies in their wavelength or frequencies.
Reason (R): Electromagnetic waves travel through vacuum with the same speed.
8. **Assertion (A):** Microwaves are better carrier of signals than optical waves.
Reason (R) : Microwaves move faster than optical waves.
9. **Assertion (A):** Infrared radiation plays an important role in maintaining the average temperature of earth.
Reason (R) : Infrared radiations are sometimes referred to as heat waves
10) **Assertion (A)** : Radio waves cannot be diffracted by the buildings.
Reason (R) : The wavelength of radio waves is very small.
11) **Assertion(A)** : Only microwaves are used in radar.
Reason : Because microwaves have very small wavelength.
12) **Assertion (A)**: Velocity of light is constant in all media.
Reason (R): Light is an electromagnetic wave which has constant velocity in all media.
13) **Assertion (A):** Infrared waves sometimes referred as heat waves.
Reason (R): Infrared waves heat up the earth surface.

14) **Assertion (A):** X-ray astronomy is possible only from satellites orbiting the earth.
Reason (R) : Efficiency of X-rays telescope is large as compared to any other telescope.
15) **Assertion (A)** : Light can travel in vacuum whereas sound cannot do so.
Reason (R) : Light has an electromagnetic wave nature whereas sound is mechanical wave.
Answer : 1-a,2-c,3-b,4-a,5-c,6-b,7-a,8-d, 9-b,10-d,11-a,12-d,13-b,14-c,15-a

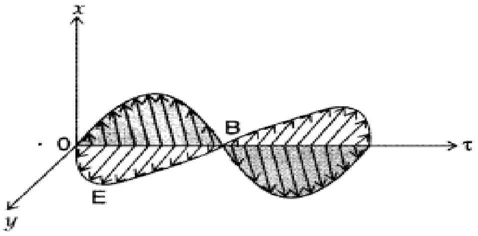
SHORT ANSWER TYPE QUESTIONS (Two marks each)

1. The oscillating magnetic field in a plane electromagnetic wave is given by
   By = $(8 \times 10^{-6}) \sin [2 \times 10^{-11} t + 300 \pi x]$ T
   (i) Calculate the wavelength of the electo-magnetic wave.
   (ii) Write down the expression for the oscillating electric field.
   Answer:
   Given: $B_y = 8 \times 10^{-6} \sin [2 \times 10^{11} t + 300 \pi x]$ T
   (i) Standard equation is,
   $$B_y = B_0 \sin \left[2\pi\left(\frac{x}{\lambda} + \frac{t}{T}\right)\right]$$
   $$\Rightarrow B_y = B_0 \sin \left[\frac{2\pi t}{T} + \frac{2\pi x}{\lambda}\right]$$
   Comparing it with the given expression:
   $$\frac{2\pi}{\lambda} = 300\pi \quad \therefore \lambda = \frac{1}{150} \text{ m} = \mathbf{0.67\ cm}$$
   (*ii*) Speed of light, $C = \frac{E_0}{B_0}$
   $$\therefore E_0 = C \times B_0 = 3 \times 10^8 \times 8 \times 10^{-6}$$
   $$= 2400\ \text{Vm}^{-1}$$
   $$E_z = E_0 \sin (2 \times 10^{11} t + 300 \pi x)\ \text{Vm}^{-1}$$
   $$\therefore E_z = 2400 \sin (2 \times 10^{11} t + 300 \pi x)\ \text{Vm}^{-1}$$
   The oscillations of $\vec{E}$ and $\vec{B}$ fields are perpendicular to each other as well as to the direction of propagation of the wave. So we take electric field in z-direction because oscillating magnetic field is in y-direction and propagation of the wave is in x-direction.
2. The oscillating electric field of an electromagnetic wave is given by :
   $E = 30 \sin [2 \times 10^{11} t + 300 \pi x]\ \text{Vm}^{-1}$
   (a) Obtain the value of the wavelength of the electromagnetic wave.
   (b) Write down the expression for the oscillating magnetic field
   Answer:
   (a) We compare the given expression with
   $$E_y = E_0 \sin \left(\frac{2\pi}{T} t + \frac{2\pi}{\lambda} x\right)$$
   $$\frac{2\pi}{\lambda} = 300\pi \quad \Rightarrow \lambda = \frac{2\pi}{300\pi}$$
   $$\Rightarrow \lambda = \frac{1}{150} \text{ m} \quad \therefore \boldsymbol{\lambda} = \mathbf{\frac{2}{3}\ cm}$$
   (*b*) $B_Z = B_0 \sin (2 \times 10^{11} t + 300 \pi x)$, $C = \frac{E_0}{B_0}$
   $$B_0 = \frac{E_0}{C} = \frac{30}{3 \times 10^8} = 10^{-7}\ \text{T}$$
   $$\therefore \mathbf{B_Z = 10^{-7} \sin (2 \times 10^{11} t + 300 \pi x)\ T}$$

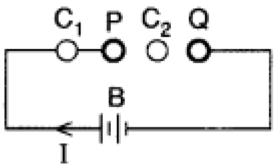
3. How does a charge q oscillating at certain frequency produce electromagnetic waves? Sketch a schematic diagram depicting electric and magnetic fields for an electromagnetic wave propagating along the Z-direction.
   Answer:
   As the charge q moves accelerating, the electric field and magnetic field produced will change the space and time E and B varying with time produced the other field B and E respectively and sustain the E.M. pattern.

This is from the interpretation of Maxwell supported by

$$-\int \vec{E}.d\vec{l} = \frac{d\phi}{dt} \text{ B and } \oint \vec{B}.d\vec{l} = \mu_0 I + \mu_0 I_d$$



4. Arrange the following electromagnetic radiations in ascending order of their frequencies:
   (i) Microwave (ii) Radiowave (iii) X-rays (iv) Gamma rays
   Write two uses of any one of these
   Answer:
   In ascending order of their frequencies :
   Radiowave < Microwave < X-rays < Gamma rays.
   Two uses of microwaves are :
   1. In microwave ovens.
   2. In aircraft navigation.
5. How are infrared waves produced? Why are these referred to as 'heat waves'? Write their one important use.
   Answer:
   Infrared rays are produced by hot bodies and molecules. This may involve vibration and bending of molecules. Infrared band lies adjacent to low-frequency or long-wavelength end of the visible spectrum. Infrared waves are sometimes referred to as heat waves.
   Use: Infrared rays are used to take photographs in darkness. These are also used to study secret writing. They are also used in physical therapy.
6. A parallel plate capacitor is being charged by a time varying current. Explain briefly how Ampere's circuital law is generalized to incorporate the effect due to the displacement current.
   Answer:
   Maxwell's displacement current : According to Ampere's circuital law, the magnetic field B is related to steady current I as



Maxwell showed that this relation is logically in-consistent. He accounted this inconsistency as follows

Ampere's circuital law for loop C_1 gives

$$\oint_{C_1} \vec{B}.d\vec{l} = \mu_o I \quad \ldots(ii)$$

Loop C_2 lies in the region between the plates

$$\therefore \oint_{C_2} \vec{B}.d\vec{l} = 0 \quad \ldots(iii)$$

It is expected that, $\oint_{C_1} \vec{B}.d\vec{l} = \oint_{C_2} \vec{B}.d\vec{l} \quad \ldots(iv)$

which is logically inconsistent. So, Maxwell gave idea of displacement current.

Thus displacement current is that current which comes into play in the region in which the electric field and hence the electric flux is changing with time.

$$I_D = \varepsilon_o \frac{d\phi E}{dt}$$

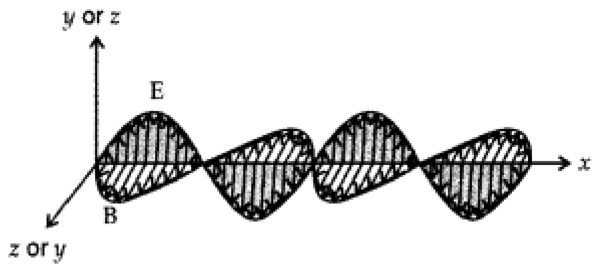
where [I_D is displacement current and ϕE is electric flux.

$$= \mu_o\left(I + \varepsilon_o \frac{d\phi E}{dt}\right)$$

It is now called Ampere-Maxwell law. This is the generalization of Ampere's circuital law.

7. (a) An em wave is travelling in a medium with a velocity v→=vi^. Draw a sketch showing the propagation of the em wave, indicating the direction of the oscillating electric and magnetic fields. (b) How are the magnitudes of the electric and magnetic fields related to the velocity of the em wave?
Answer:

(a)

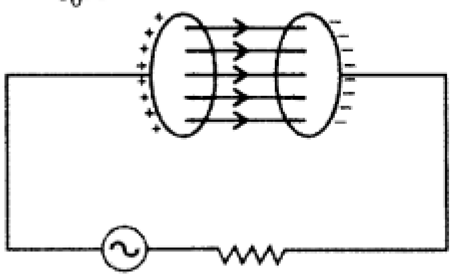


(b) $\frac{E_0}{B_0} = c$

8. A capacitor, made of two parallel plates each of plate area A and separation d, is being charged by an external ac source. Show that the displacement current inside the capacitor is the same as the current charging the capacitor.
Answer:

The displacement current arises due to varying electric field

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



ϕ (flux between the capacitors)

$$= \left(\frac{q}{\varepsilon_0 A}\right) \times A = \frac{q}{\varepsilon_0}$$

$$I_D = \varepsilon_0 \frac{d}{dt}\left(\frac{q}{\varepsilon_0}\right) = \frac{dq}{dt} \Rightarrow I_D = \frac{dq}{dt} \quad \ldots(i)$$

$$\text{Conduction current } I_C = \frac{dq}{dt} \quad \ldots(ii)$$

From (i) and (ii) $\boxed{I_C = I_D}$ $\quad \therefore \quad I_D = \varepsilon_0 \left(\frac{d\phi}{dt}\right)$

If q be instantaneous charge, then E is electric field between the plates of capacitor at that time and A is area of plate; then

9. . (a) How are electromagnetic waves produced?

(b) How do you convince yourself that electromagnetic waves carry energy and momentum?

Answer:

(a) Electromagnetic Waves : Accelerating electric charge produces electromagnetic waves.

(b) Einstein's explanation of photoelectric effect led de Broglie to the wave-particle duality, i.e., matter exhibits wave as well as particle properties. Electromagnetic waves are characterised by wave properties, such as periodicity in space-time, wavelength, amplitude, frequency, wave velocity etc. It transports energy but no matter.

The term wave-particle duality refers to the behaviour where both wave-like and particle-like properties are exhibited under different conditions by the same entity. Hence electromagnetic waves show particle properties such as definite position, size, mass, velocity, momentum, energy etc.
For a photon of momentum (p), an associated wavelength is given by λ=hp.

10. (a) Arrange the following electromagnetic waves in the descending order of their wavelengths :

Microwaves, Infra-red rays, Ultra-violet radiation, Gamma rays

(b) Write one use each of any two of them.

Answer:(a) Arrangement: Microwaves, Infra-red rays, Ultra-violet radiation, Gamma rays

(b) Uses :Microwaves are used in radar system.

Infra-red rays are used for protecting dehydrated fruits.

Ultra-violet rays are used in the study of molecular structure.

Gamma rays are used to kill micro-organisms in food industry.

11.Name the types of e.m. radiations which are used in destroying cancer cells, cause tanning of the skin and

maintain the earth's warmth. Write briefly a method of producing any one of these waves.
Answer: γ-rays, Ultraviolet rays, Infrared rays

Mode of production: γ-rays are produced by radioactive decay of nucleus.

Ultraviolet rays are produced when inner shell electrons in atoms move from one energy level to an other energy level.

Infrared rays are produced due to vibration of atoms and molecules.

SHORT ANSWER TYPE QUESTIONS (Three marks each)

1.**Identify the following electromagnetic radiations as per the wavelengths given below. Write one application of each.**
(a) 10^{-3} nm (b) 10^{-3} m (c) 1 nm
Answer:
(a) 10^{-3} nm : γ-rays
Application : (i). γ-rays are used in the treatment of cancer and tumour.

(ii) γ-rays are used in radiation therapy. (any one)

b) 10^{-3}m : Microwave
Application : Microwaves are used in Radar systems for aircraft navigation.
(c) 1 nm : X-rays Application : (i) Infra-red waves are used for taking photographs during the conditions of fog, smoke etc. (ii)These are also used as a diagonostic tool for the detection of fractures, (any one)

2. (a) How does an oscillating charge produce electromagnetic wave? Explain.
(b) Draw a sketch showing the propagation of a plane em wave along the Z-direction, clearly depicting the directions of oscillating electric and magnetic field vectors.
Answer: (a) Consider a charge oscillating with same frequency. This produces an oscillating electric field in space, which produces an oscillating magnetic field which in turn is a source of oscillating electric field and so on. The oscillating electric and magnetic fields thus regenerate each other, as the waves propagate through the space. The frequency of the electromagnetic wave naturally equals the frequency of the oscillation of the charge.
(b) Sketch of a plane electromagnetic wave propagating along the z-direction with oscillating electric field E along the x-direction and the oscillating magnetic field B along the y-direction.

3**. Answer the following :**
(a) Name the em waves which are suitable for radar systems used in aircraft navigation. Write the range of frequency of these waves.
(b) If the. earth did not have atmosphere, would its average surface temperature be higher or lower than what it is now? Explain.
(c) An em wave exerts pressure on the surface on which it is incident. Justify.
Answer:
(a) Microwaves are used in radar systems. Its frequency range : 10^{10} to 10^{12} Hz

(b) In the absence of earth's atmosphere, there would have no ozone layer to prevent ultraviolet radiations reaching the earth, the temperature on earth's surface would have been lower due to green house effect, making it difficult for human survival.

(c) Since em wave carries both energy and momentum, hence exerts pressure on the surface on which it is incident.

An em wave exerts negligibly very small pressure on the surface on which it is incident.

It is due to the fact that momentum of the photon is extremely small, which can be calculated by de-Broglie relation (λ=hp)

$$\text{or } p = \frac{h}{\lambda} = \frac{6.63\times10^{-34}}{10^{-9}}$$
$$= \mathbf{6.63 \times 10^{-25}\ kg\ ms^{-1}}$$

4. Answer the following :
(a) Name the em waves which are used for the treatment of certain forms of cancer. Write their frequency range.
(b) Thin ozone layer on top of stratosphere is crucial for human survival. Why?
(c) Why is the amount of the momentum transferred by the em waves incident on the surfrace so small?
Answer:
(a) Gamma (γ) rays are used for the treatment of certain forms of cancer. Their frequency range is 10^{18} Hz to 10^{22} Hz.

(b) The thin ozone layer on top of stratosphere absorbs most of the harmful ultraviolet rays coming from the Sun towards the Earth. They include UVA, UVB and UVC radiations, which can destroy the life system on the Earth.
Hence, this layer is crucial for human survival.

(c) Thus, the amount of the momentum transferred by the em waves incident on the surface is very small, because of small value of planks constant. For example, an electromagnetic wave of wavelength 1.00 nm will provide momentum (p) according to de-Broglie's relation,

$$p = \frac{h}{\lambda} = \frac{6.63\times10^{-34}}{1\times10^{-9}} = 6.63 \times 10^{-25}\ \text{kg ms}^{-1}$$

It is extremely small value of the momentum.

5. **Name the parts of the electromagnetic spectrum which is**
(a) suitable for radar systems used in aircraft navigation.
(b) used to treat muscular strain.
(c) used as a diagnostic tool in medicine.
Write in brief, how these waves can be produced.
Answer:
(a) Microwaves
Production : Klystron/magnetron.

(b) Infrared Radiations
Production ; Hot bodies/vibrations of atoms and molecules.

(c) X-Rays
Production : Bombarding high energy electrons on a metal target.

CASE STUDY PASSAGE (Each one mark)

READ THE FOLLWING PASSAGE AND ANSWER ANY FOUR QUESTIONS ONLY

In an electromagnetic wave both the electric and magnetic fields are perpendicular to the direction of propagation, that is why electromagnetic waves are transverse in nature. Electromagnetic waves carry energy as they travel through space and this energy is shared equally by the electric and magnetic fields. Energy density of an electromagnetic waves is the energy in unit volume of the space through which the wave travels.

(i) The electromagnetic waves propagated perpendicular to both $\vec{E}$ and $\vec{B}$. The electromagnetic waves travel in the direction of

(a) $\vec{E}\cdot\vec{B}$ (b) $\vec{E}\times\vec{B}$ (c) $\vec{B}\cdot\vec{E}$ (d) $\vec{B}\times\vec{E}$

ii) Fundamental particle in an electromagnetic wave is

(a) photon (b) electron (c) phonon (d) proton

(iii) Electromagnetic waves are transverse in nature is evident by

(a) polarization (b) interference (c) reflection (d) diffraction

(iv) For a wave propagating in a medium, identify the property that is independent of the others.

(a) velocity (b) wavelength (c) frequency (d) all these depend on each other

(v) The electric and magnetic fields of an electromagnetic waves are

(a) in opposite phase and perpendicular to each other (b) in opposite phase and parallel to each other

(c) in phase and perpendicular to each other (d) in phase and parallel to each other.

ANSWERS

(i) (b): Electromagnetic waves propagate in the direction of (b) $\vec{E}\times\vec{B}$

(ii) (a): Photon is the fundamental particle in an electromagnetic wave.

(iii) (a): Polarisation establishes the wave nature of electromagnetic waves.

(iv) (c): Frequency D remains unchanged when a wave propagates from one medium to another. Both wavelength and velocity get changed.

(v) (c): The electric and magnetic fields of an electromagnetic wave are in phase and perpendicular to each other.

CASE STUDY PASSAGE II

All the known radiations from a big family of electromagnetic waves which stretch over a large range of wavelengths. Electromagnetic wave include radio waves, microwaves, visible light waves, infrared rays, UV rays, X-rays and gamma rays. The orderly distribution of the electromagnetic waves in accordance with their wavelength or frequency into distinct groups having widely differing properties is electromagnetic spectrum.

(i) Which wavelength of the Sun is used finally as electric energy?

(a) radio waves (b) infrared waves (c) visible light (d) microwaves

(ii) Which of the following electromagnetic radiations have the longest wavelength?

(a) X-rays (b) gamma rays (c) microwaves (d) radio waves

(iii) Which one of the following is not electromagnetic in nature?

(a) X-rays (b) gamma rays (c) cathode rays (d) infrared rays

(iv) Which of the following has minimum wavelength?

(a) X-rays (b) ultraviolet rays (c) Y-rays (d) cosmic rays

(v) The decreasing order of wavelength of infrared, microwave, ultraviolet and gamma rays is

(a) microwave, infrared, ultraviolet, gamma rays

(b) gamma rays, ultraviolet, infrared, microwave

(c) microwave, gamma rays, infrared, ultraviolet

(d) infrared, microwave, ultraviolet, gamma rays

ANSWERS

(v) (a): λmicro >λinfra >λultra >λgamma

(i) (d): All electromagnetic waves travel in vacuum with the same speed.

(ii) (c): Cathode rays (beam of electrons) get deflected in an electric field.

(iii) (c) : Y-rays are detected by ionization chamber.

(iv) (b): Size of particle =λ=cv

v=cλ=3×1010 cm s−13×10−4 cm=3×1014 Hz

(v) (a) Any body at a temperature T > 0 K emits radiation in the infrared region.

UNIT VI - OPTICS

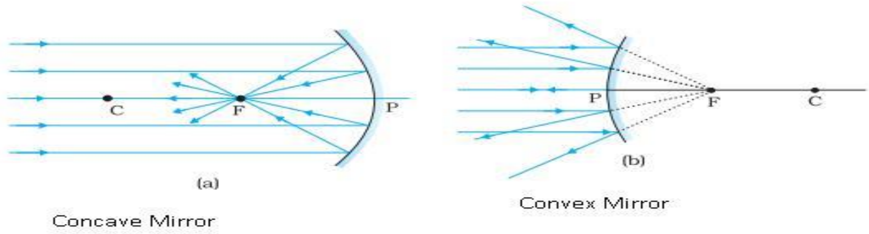
CHAPTER -9 –RAY OPTICS & OPTICAL INSTRUMENTS

RTANT FORMULAE IN RAY OPTICS AND OPTICAL INSTRUMENTS			
S.NO	**FORMULAE**	**SYMBOL**	**APPLICATIONS**
1	**Mirror formula** $\frac{1}{f}=\frac{1}{v}+\frac{1}{u}$ **Convex produces only virtual For real image u is negative and v is negative. For virtual image u is negative and v is positive**	**f -focal length, u is object distance and v is image distance (For concave mirror f is negative) (For convex mirror f is positive) Concave produces both real and virtual image.**	**To find the focal length of a mirror if u and v are known.**
2	$m=\frac{I}{o}=-\frac{v}{u}$ $m=\frac{f-v}{f}, m=\frac{f}{f-u}$	**m- magnification, I- size of the image, O- size of the object f – focal length, u – object distance, v – image distance**	**To find the magnification of the mirror**
3	$\mu=\frac{c}{v}=\frac{\lambda}{\lambda_m}$	**μ- absolute refractive index, c- speed of light in air, v- speed of light in medium λ is the wavelength of light in air λ_m is the wavelength of light in medium**	**To find the absolute refractive index. (refractive index of the medium with respect to air)**
4	${}^1\mu_2=v_2/v_1$	**Refractive index of medium 2 with respect to medium 1. V_2 speed of light in medium 2,V_1 speed of light in medium 1**	**To find the relative refractive index of a one medium with respect to another**
5	${}_2^1\mu$ **= real depth/ apparent depth**	**${}^1\mu_2$ it is the refractive index of the medium2 with respect to medium 1**	**To find the refractive index of the medium using real depth and apparent depth**
6	**Normal shift** **N = t** $(1-\frac{1}{\mu})$	**t is the thickness of the medium and μ is the refractive index.**	**To find the normal shift (how much image appears to shifted)**
7.	${}_2^1\mu=\frac{1}{\sin i_c}$	**I_c is the critical angle and μ is the refractive index**	**To find the value of refractive index if the critical angle is known in total internal reflection.**
8	$\frac{\mu_2}{v}-\frac{\mu_1}{u}=\frac{\mu_2-\mu_1}{R}$	**μ_2 and μ_1 are the refractive indices and R is the radius of curvature.**	**Refraction in a convex spherical surface when the object lies in a rarer medium and the image formed is real.**

9	$\frac{1}{f} = (\mu - 1)(\frac{1}{R_1} - \frac{1}{R_2})$	f is the focal length μ is the refractive index and R_1 and R_2 are the radius of curvature	Lens marker's formula
10	$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$ For concave lens f is negative For convex lens f is positive For real image u is negative and v is positive For virtual image u is negative and v is negative	f is the focal length and v is the distance from the lens to the image (image distance) and u is the distance from the lens to the object (Object distance)	Lens formula To find the focal length if u and v are known
11	$\mu = \frac{\sin\frac{(\delta_{min} + A)}{2}}{\sin A/2}$	δ_{min} is the angle of minimum deviation and A is the angle of prism and μ is the refractive index	Prism formula to find the refractive index
12	$\delta_m = (\mu - 1)A$	δ_m is the minimum deviation , A is the angle of the prism and μ is the refractive index	Relation between angle of deviation , refractive index and angel of the prism
13	$M = M_o \times M_e = \frac{v_o}{u_o}\left(1 + \frac{D}{f_e}\right)$	M_o is the magnification of objective ,M_e is the magnification of eyepiece,v_0 is the image distance of the objective and u_o is the object distance of the objective D is 25 cm ,least distance of distinct vision f_e is the focal length of the eyepiece	Magnification formula for compound microscope.(when the final image is formed at D)
14	NORMAL ADUJSTMENT POSITION (when the final image is formed at infinity $M = M_o \times M_e = -\frac{L}{f_o} \times \frac{D}{f_e}$	M_o is the magnification of objective, M_e is the magnification of eyepiece L is the length of the compound microscope(L= v_o+u_e) f_e is the focal length of the eyepiece, f_o is the focal length of the objective	Magnification formula for compound microscope
15	$M = -\frac{f_0}{f_e}$ (NORMAL ADJUSTMENT POSITION) (when the final image is formed at infinity	f_e is the focal length of the eyepiece, f_o is the focal length of the objective	Magnification for Astronomical telescope when the final image is formed at infinity
16	$M = -\frac{f_0}{f_e}(1 + \frac{f_e}{D})$	f_e is the focal length of the eyepiece, f_o is the focal length of the objective D is 25 cm ,least distance of distinct vision	Magnification for Astronomical telescope when the final image is formed at D

IMPORTANT TOPICS TO BE REVISED(MINIMUM LEARNING MATERIAL)

Spherical Mirrors are of two types:-



Pole:

The centre of the reflecting surface of a spherical mirror.It lies on the surface of the mirror.

Centre of curvature:

The reflecting surface of a spherical mirror forms a part of a sphere. The sphere's centre is called as centre of curvature.The centre of curvature is not a part of the mirror. It lies outside its reflecting surface.

The centre of curvature of a concave mirror lies in front of it.

However, it lies behind the mirror in case of a convex mirror.

Radius of curvature

The radius of the sphere of which the reflecting surface of a spherical mirror forms a part

Principal axis

A straight line passing through the pole and the centre of curvature of a spherical mirror.

Principal axis is normal to the mirror at its pole.

Principal Focus

Rays parallel to the principal axis falling on a concave mirror meet/intersect at the point on the principal axis. The point is called principal focus of concave mirror.

The reflected rays appear to come from a point on the principal axis when rays parallel to the principal axis fall on a convex mirror, that point is called principal focus of convex mirror.

The principal focus is represented by the letter F.

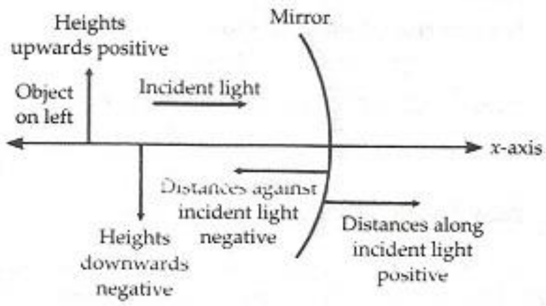
The distance between the pole and the principal focus of a spherical mirror is called the focal length. It is represented by the letter f.

Aperture

The diameter of the reflecting surface of spherical mirror is called its aperture.

Mirrors whose aperture is much smaller than its radius of curvature, we use R=2f.

Sign Convention: Following sign conventions are the new cartesian sign convention:-
(i) All distances are measured from the pole of the mirror & the distances measured in the direction of the incident light is taken as positive. In other words, the distances measured toward the right of the origin are positive.
(ii) The distance measured against the direction of the



incident light are taken as negative. In other words, the distances measured towards the left of origin are taken as negative.
(iii) The distance measured in the upward direction, perpendicular to the principal axis of the mirror, are taken as positive & the distances measured in the downward direction are taken as negative.

- **Focal Length of a Spherical Mirror:**
  a) The distance between the focus and the pole of the mirror is called focal length of the mirror and is represented by *f*.
  b) The focal length of a concave mirror is negative and that of a convex mirror is positive.
  c) The focal length of a mirror (concave or convex) is equal to half of the radius of curvature of the mirror, i.e., $f = \frac{R}{2}$.
- **Principal Axis of the Mirror:** The straight line joining the pole and the centre of curvature of spherical mirror extended on both sides is called principal axis of the mirror.
- **Mirror Formula:** $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$
  Where u = distance of the object from the pole of mirror
  v = distance of the image from the pole of mirror
  f = focal length of the mirror
  $f = \frac{R}{2}$ Where R is the radius of curvature of the mirror.
- **Magnification:** It is defined as the ratio of the size of the image to that of the object.
  Linear magnification, $m = \frac{I}{O} = -\frac{v}{u} = \frac{f-v}{f} = \frac{f}{f-u}$
  Where *I* = size of image and *O* = size of obje
- Magnification, m is positive, implies that the image is real and inverted.
- Magnification, m is negative, implies that the image is virtual and erect.

Image formation by a concave mirror:-

S.No.	Position of object	Position of image	Nature of image	Size of image
1	Infinity	At F	Real and inverted	Highly diminished
2	Beyond C	Between F & C	Real and inverted	Diminished
3	At C	At C	Real and inverted	Same size
4	Between C & F	Beyond C	Real and inverted	Magnified
5	At F	At infinity	Real and inverted	Highly magnified
6	Between F & P	Behind the mirror	Virtual & erect	Magnified

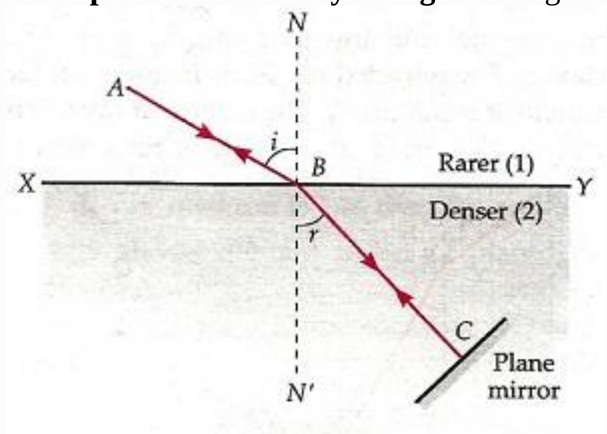
Image formation by a convex mirror:-

S.No.	Position of object	Position of image	Nature of image	Size of image
1	Infinity	At F	Virtual & erect	Highly diminished
2	Between ∞ and P	Between P and F	Virtual & erect	Diminished

- **Refraction:** The phenomenon of the change in the path of light as it passes obliquely from one transparent medium to another is called refraction of light.
- **Laws of Refraction:**
  (i) The incident ray, normal at the point of incidence and refracted ray all lies in the same plane.

(ii) For the same pair of media and the same colour of light, the ratio of the sine of the angle of incidence to the sine of the angle of refraction is constant i.e., $\frac{\sin i}{\sin r} = {}_a\mu_b$
Where ${}_a\mu_b$ is a constant known as Refractive Index of the medium b with respect to the medium a, i is the angle of incidence in medium a and r is the angle of refraction in medium b.

- **Refractive index:-** It is defined as the ratio of the speed of light in vacuum to its speed in that medium.
$$\mu = \frac{c}{v} = \frac{\lambda_{vac}}{\lambda_{med}}$$
- **Principle of Reversibility of Light:** As light follows a reversible path, ${}_2\mu_1 = \frac{\sin r}{\sin i}$



Multiplying we get,

- **Methods to Determine Refractive Index of a Medium:** Refractive index of a medium can also be determined from the following:
(i) $\mu = \frac{\text{Velocity of light in air}}{\text{Velocity of light in the medium}}$
(ii) $\mu = \frac{1}{\text{sinc}}$
Where *c* is the critical angle.
- **Critical Angle:** The Critical angle is the angle of incidence in a denser medium corresponding to which the refracted ray just grazes the surface of separation.

Total internal reflection: When light travels from an optically denser medium to a rarer medium at the interface, it is partly reflected back into the same medium and partly refracted to the second medium. **This reflection is called the internal reflection**.

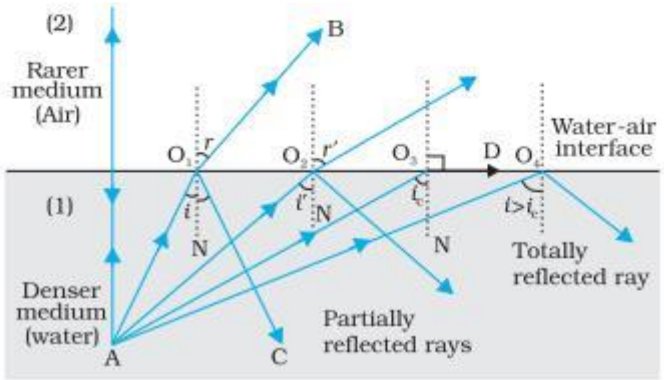
In total internal reflection phenomenon there is no refraction and the entire incident ray will get reflected.

Conditions for Total Internal Reflection are as follows:-

- Light ray travels from denser to rarer medium.
- The angle of incidence should be greater than the critical angle.

The angle of incidence corresponding to angle of refraction = 90^0 is called

Critical angle.



Applications of Total Internal Reflection

Optical Fibres:-

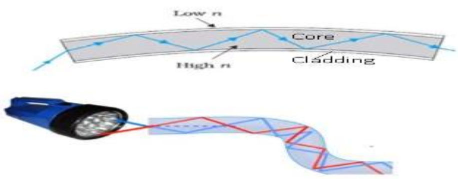
They are used in telecommunication industries.

Optical fibres work on the phenomenon of total internal reflection.

Working of Optical fibres:

Optical fibres are fabricated with high quality composite glass/quartz fibres.

Each fibre consists of a core and cladding. The refractive index of the material of the core is higher than that of the cladding.



As there is difference in the refractive index of core and denser; core acts as a denser medium and cladding acts as a rarer medium.

When a signal in the form of light is directed at one end of the fibre at a suitable angle, it undergoes repeated total internal reflections along the length of the fibre and finally comes out at the other end.

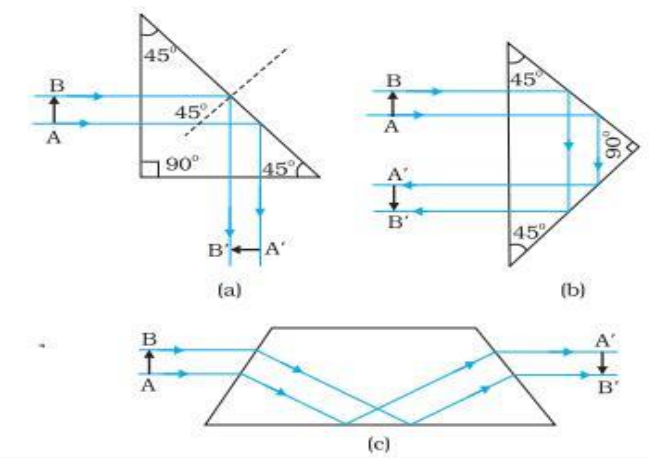
Since light undergoes total internal reflection at each stage, there is no appreciable loss in the intensity of the light signal.

Prisms make use of total internal reflection which makes it useful in binoculars.

Prisms designed to bend light by 90º or by 180º make use of total internal reflection.

Such a prism is also used to invert images without changing their size.

In the first two cases, the critical angle i_c for the material of the prism must be less than 45º.



- **Apparent Depth of a Liquid:** If the object be placed at the bottom of a transparent medium, say water, and viewed from above, it will appear higher than it actually is.
  The refractive index μ in this case is:
  Refractive index of the medium, $\mu = \dfrac{\text{Real Depth}}{\text{Apparent Depth}}$
- **Normal shift:** The height through which an object appears to be raised in a denser medium is called normal shift.
  $d = t\left(1 - \dfrac{1}{\mu}\right)$
- **Refraction through a Single Surface:** If μ_1, μ_2 are refractive indices of rare and denser media respectively, R is the radius of curvature of spherical surface.
  When object is in rare medium: $\dfrac{\mu_2}{v} - \dfrac{\mu_1}{u} = \dfrac{(\mu_2 - \mu_1)}{R}$
  When object is in denser medium: $\dfrac{\mu_1}{v} - \dfrac{\mu_2}{u} = \dfrac{\mu_1 - \mu_2}{R}$
  where u and v are the distances of the object and the image from the centre of the refracting surface of radius of curvature R respectively.
- **Refraction through a Thin Lens (Lens maker's formula):** If R_1 and R_2 are radii of curvature of first and second refracting surfaces of a thin lens of focal length f, then lens-makers formula is $\dfrac{1}{f} = \left(\dfrac{\mu_2 - \mu_1}{\mu_1}\right)\left(\dfrac{1}{R_1} - \dfrac{1}{R_2}\right)$
  If the lens is surrounded by air, $\mu_1 = 1$ and $\mu_2 = \mu$, then $\dfrac{1}{f} = (\mu - 1)\left(\dfrac{1}{R_1} - \dfrac{1}{R_2}\right)$

Image formation by a convex lens:-

S.No.	Position of object	Position of image	Nature of image	Size of image
1	Infinity	At F	Real and inverted	Highly diminished
2	Beyond 2F	Between F & 2F	Real and inverted	Diminished
3	At 2F	At 2F	Real and inverted	Same size
4	Between 2F & F	Beyond 2F	Real and inverted	Magnified
5	At F	At infinity	Real and inverted	Highly magnified
6	Between F & O	Same side	Virtual & erect	Magnified

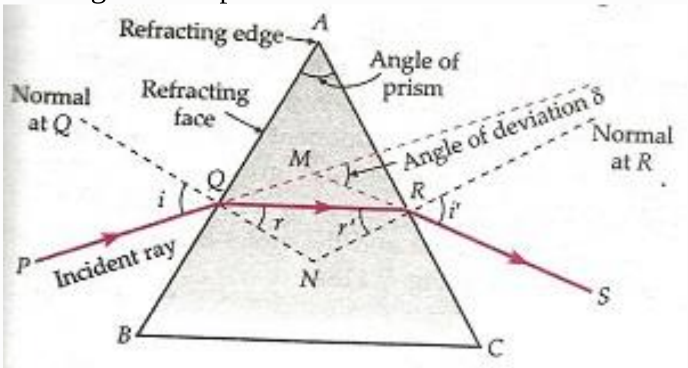
Image formation by a concave lens:-

S.No.	Position of object	Position of image	Nature of image	Size of image
1	Infinity	At F	Virtual & erect	Highly diminished
2	Between ∞ and O	Same side	Virtual & erect	Diminished

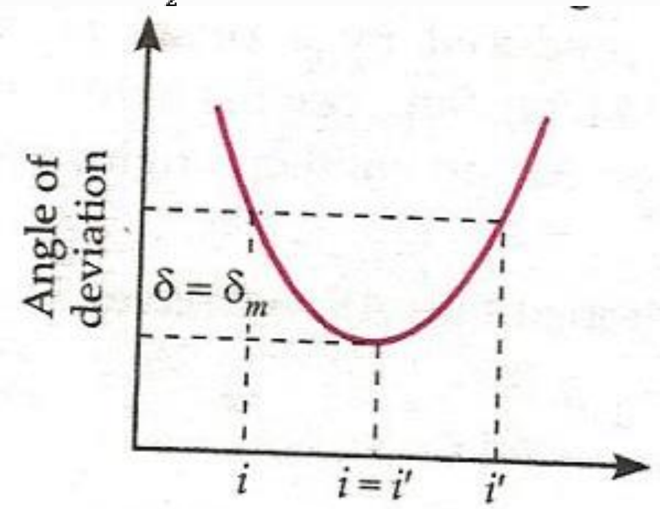
- **Thin lens formula:** $\dfrac{1}{f} = \dfrac{1}{v} - \dfrac{1}{u}$
- **Magnification Produced by a Lens:**
  Where I is the size of image and O is the size of object.

- **Power of a Lens:** The power of a lens P is its ability to deviate the ray towards axis.

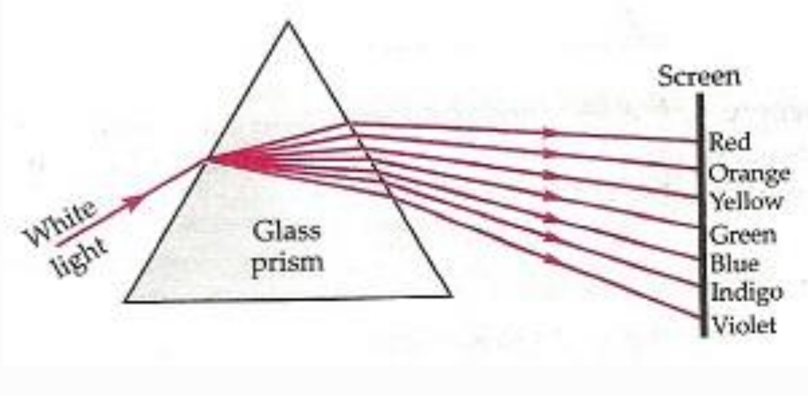
- **Focal Length of Thin Lenses:** The focal length (f) of thin lenses of focal lengths $f_1, f_2, f_3,$ ....placed in contact of each other is $\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} + \frac{1}{f_3} + ...$
- **Refraction Through Prism**: When a ray of monochromatic light is refracted by a prism, the deviation δ produced by the prism is $\delta = i + e - A$
  Where i = angle of incidence
  e = angle of emergence
  A = angle of the prism



- **Angle of Deviation:** The minimum value of the angle of deviation suffered by a ray on passing through a prism is called the angle of minimum deviation and is denoted by δ_m.
  $\mu = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin\frac{A}{2}}$



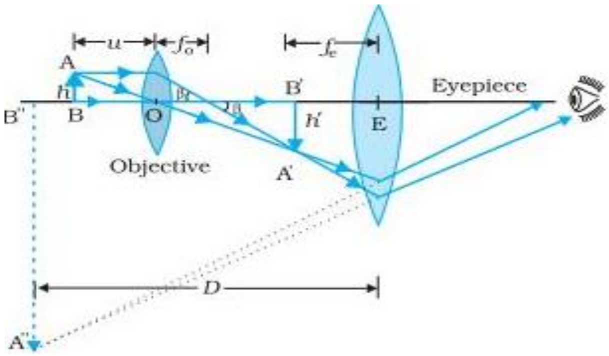
- **Dispersion:** The splitting of white light into constituent colours is called the dispersion of light. A prism causes deviation as well as dispersion.
- The pattern of the coloured bands obtained on the screen is called spectrum.



- **Angular dispersion:** The angular seperation between the two extreme colours (violet and red) in the spectrum is called the angular dispersion.
  $Angular\ dispersion = \delta_V - \delta_R = (\mu_V - \mu_R)\,A$
- **Dispersive Power:** It is defined as the ratio of the angular dispersion to the mean deviation.
  $\omega = \dfrac{\mu_V - \mu_R}{\mu - 1}$
- **Optical Instruments**: Optical instruments are the devices which help human eye in observing highly magnified images of tiny objects, for detailed examination and in observing very far objects whether terrestrial or astronomical.
- **Microscope**:
  a) A simple microscope is a short focal length convex lens.
  b) The magnifying power of a simple microscope is $M = 1 + \dfrac{D}{f}$

Compound Microscope

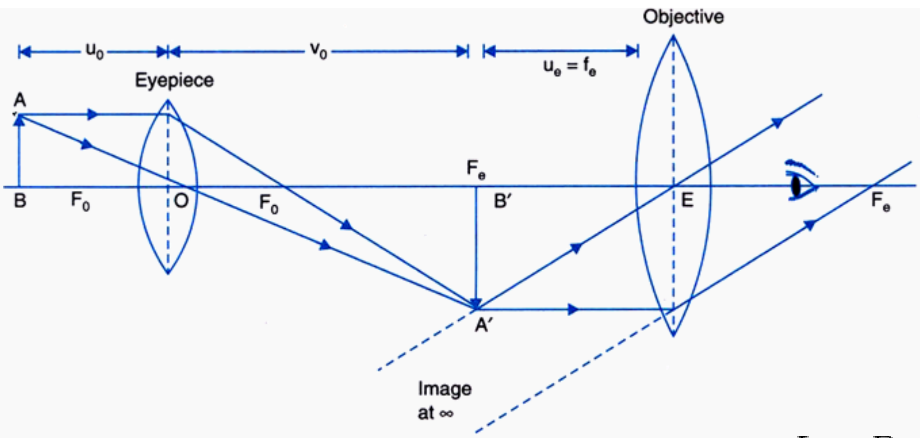
In order to have large magnifications compound microscope is used.



The lens nearest the object, called the objective, forms a real, inverted, magnified image of the object. This serves as the object for the second lens, the eyepiece, which functions essentially like a simple microscope or magnifier, produces the final image, which is enlarged and virtual.

- The first inverted image is thus near (at or within) the focal plane of the eyepiece, at a distance appropriate for final image formation at infinity, or a little closer for image formation at the near point.
- Clearly, the final image is inverted with respect to the original object.
- c) The magnifying power, M of a compound microscope **when final image is formed at least distance of distinct vision-** $M = M_o \times M_e = \dfrac{v_o}{u_o}\left(1 + \dfrac{D}{f_e}\right)$

<u>when image is formed at infinity(NORMAL ADJUSTMENT POSITION)</u>



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- **& when image is formed at infinity-** $M = M_o \times M_e = -\dfrac{L}{f_o} \times \dfrac{D}{f_e}$
  Where M_o and M_e denotes the linear magnification of the objective and eye lens.

Telescope

An instrument used to view distant objects clearly.

It consists of:- (a) Objective lens (b) Eyepiece

<u>Working of Telescope</u>

The telescope is used to provide angular magnification of distant objects.

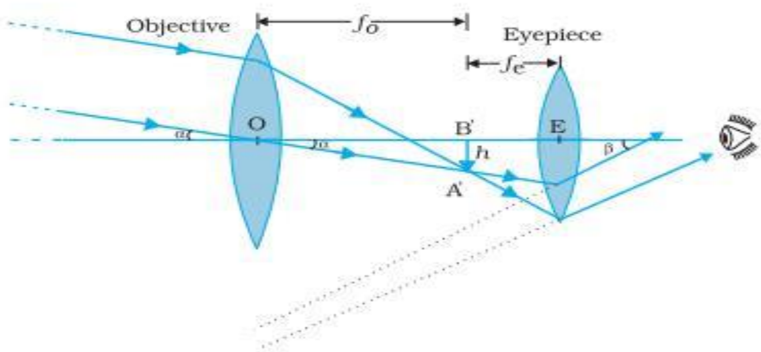
The objective has a large focal length and a much larger aperture than the eyepiece because object is very far away.

Light from a distant object enters the objective and a real and inverted image is formed at its second focal point.

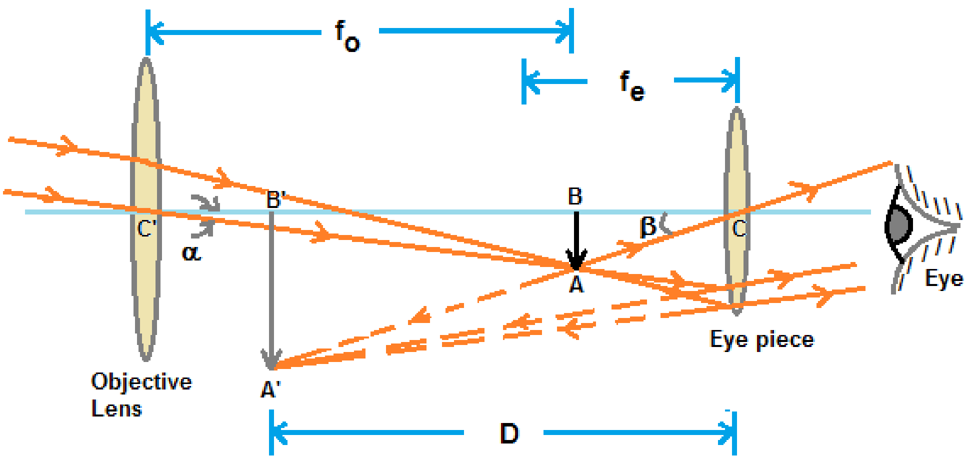
This image acts as an object for the eyepiece; it magnifies this image producing a final inverted image.

When the final image is formed at infinity (NORMAL ADJUSTMENT POSITION)

a) The magnifying power, M of refracting telescope is $M = -\frac{f_0}{f_e}$, $L = (f_0 + f_e)$ Where L is the length of the telescope.



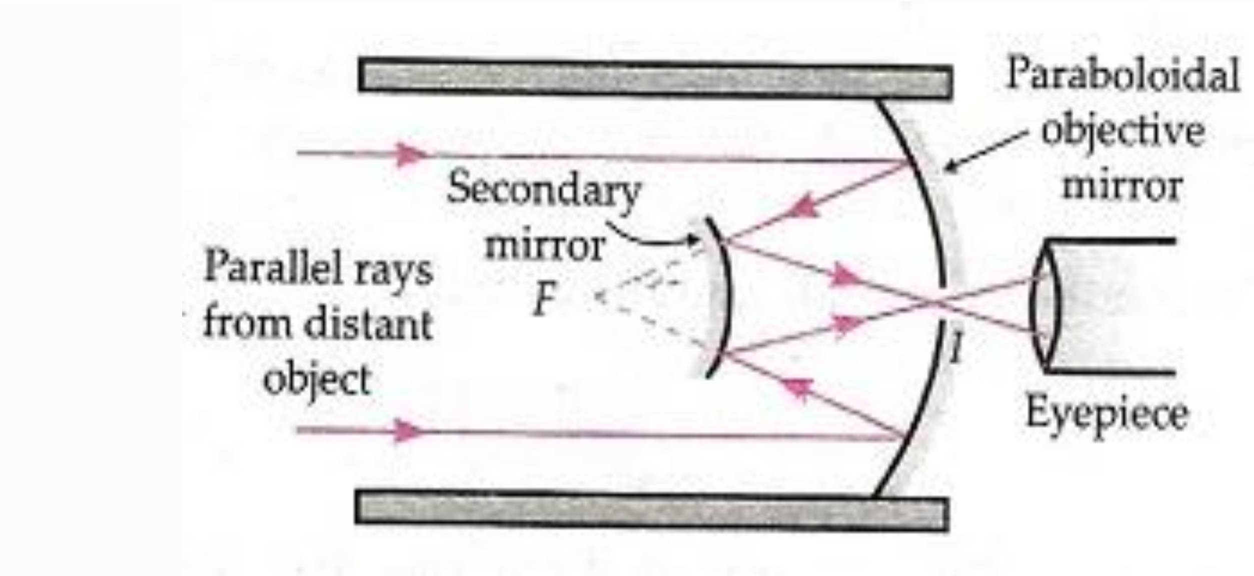
When the final image is formed at D (Least distance of distinct vision)



b) For the final image is formed at the least distance of distant vision, the magnifying power is $M = -\frac{f_0}{f_e}(1 + \frac{f_e}{D})$

REFLECTING TELESCOPES:-

Cassegrain /Newtonian type-



MULTIPLE CHOICE QUESTIONS AND ASSERTION, REASONING QUESTIONS

1. **Which of the following is not a property of light?**
   (a) It can travel through vacuum (b) It has a finite speed
   (c) It requires a material medium for its propagation (d) It involve transportation energy
2. **When light is refracted, which of the following does not change?**
   (a) Wavelength (b) Frequency (c) Velocity (d) Amplitude
3. **A concave mirror is held in water. What should be the change in the focal length of the mirror?**
   (a) Halved (b) Doubled (c) Remains the same (d) Increases exponentially

4. **A convex lens is dipped in a liquid whose refractive index is equal to the refractive index of the lens. Then its focal length will**
   (a) become zero (b) become infinite (c) become small, but non-zero (d) remain unchanged
5. **Short pulse of white light is incident from air to a glass slab at normal incidence. After travelling through the slab, the first colour to emerge is**
   (a) blue. (b) green. (c) violet. (d) red.
6. **Mirage is a phenomenon due to**
   (a) refraction of light (b) reflection of light
   (c) total internal reflection of light (d) diffraction of light.
7. **Critical angle of light passing from glass to water is minimum for**
   (a) red colour (b) green colour (c) yellow colour (d) violet colour
8. **The bottom of the tank filled with water appear to be raised due to**
   a) Reflection b) Dispersion c) Refraction d) Diffraction

9. The angle of incidence corresponding to an angle of refraction 90° is called as

a) Emerging angle b) Deviation angle c) incident angle d) Critical angle

10. **The light traveling through optical fibers is due to**

a) Internal reflection b) Total internal reflection c) Refraction d) Scattering

11. **In case of prism, the angle between emergent ray and the direction of incident ray is called as**

a) Glancing angle b) Refracting angle c) Angle of deviation d) None

12. **The angle of deviation depends on the**

a) Angle of refraction b) Angle of incidence c) Both a and b d) None

13**. For a total internal reflection, which of the following is correct?**

(a) Light travels from rarer to denser medium. (b) Light travels from denser to rarer medium.
(c) Light travels in air only. (d) Light travels in water only.

14. **Which of the following colour of white light deviated most when passes through a prism?**

(a) Red light (b) Violet light (c) Yellow light (d) Both (i) and (ii)

15. Which of the following forms a virtual and erect image for all positions of the object?

(a) Concave lens (b) Concave mirror (c) Convex mirror (d) Both (i) and (iii)

16. Identify the factor on which the angle of deviation of the prism does not depend.

(a) The angle of incidence (b) The material of the prism
(c) The angle of reflection (d) The wavelength of light used

17. **An astronomical refractive telescope has an objective of focal length 20 m and an eyepiece of focal length 2 cm. Then**

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

18. **A double convex air bubble in water behaves as:**

(a) Convergent lens (b) divergent lens (c) plane slab (d) concave mirror

19. **An astronomical telescope has a large aperture to**

(a) reduce spherical aberration (b) have high resolution
(c) increases span of observation (d) have low dispersion

. 20. **What is the angle between the incident ray and the emergent ray in a prism called?**

a) Angle of deviation **b) Angle of refraction**
c) Angle of reflection **d) Angle of dispersion**

21. **Two lenses of focal lengths 5 cm and 50 cm are to be used for making a telescope. Which lens will you use for the objective?**

a) Both **b) Neither** **c) 5 cm** **d) 50 cm**

22. **With an increase in wavelength the refractive index:**

(a) Decreases (b) Increases (c) Remains unaffected (d) None of these

23. The length of an astronomical telescope is 16 cm and its magnifying power is 3. The focal length of the lenses will be :

(a) 4 cm, 12 cm (b) 4 cm, 8 cm (c) 4 cm,2 cm (d) 8 cm, 4 cm

24. **The power of a convex lens (refractive index 1.50) when immersed in water (refractive index 1.33)**

(a) increases (b) decreases (c) remains unchanged (d) None of these

25. **When concave lens of glass is immersed in water, it becomes**

(a) less convergent (b) convergent (c) less divergent (d) more divergent

26. **The image formed by objective lens of a compound Microscope is :**

(a) Virtual and diminished (b) Real and diminished (c) Real and large (d) Virtual and Large

Answers : 1-c,2-b,3-b,4-b,5-d,6-c,7-d,8-c,9-d,10-b,11-c,12-b,13-b,14-b ,15-d,16-c,17-d,18-b,19-b,20 a,21-d,22-a,23-a, 24-b, 25-c 26-c.

Directions: These questions consist of two statements, each printed as Assertion and Reason. While answering these questions, you are required to choose any one of the following four responses.
(a) If both Assertion and Reason are true and the Reason is a correct explanation of the Assertion.
(b) If both Assertion and Reason are true but Reason is not a correct explanation of the Assertion.
(c) If the Assertion is true but Reason is false.
(d) If both the Assertion and Reason are incorrect.

1. **Assertion (A) :** Microscope magnifies the image.
Reason (R) : Angular magnification for image is more than object in microscope.

2. **Assertion :** The resolving power of a telescope is more if the diameter of the objective lens is more.
Reason : Objective lens of large diameter collects more light.

3. **Assertion :** If the rays are diverging after emerging from a lens; the lens must be concave.
Reason : The convex lens can give diverging rays.

4. **Assertion:** The focal length of an equiconvex lens of radius of curvature R made of material of refractive index $\mu = 1.5$, is R.
Reason : The focal length of the lens will be R/2.

5. **Assertion :** The air bubble shines in water.
Reason : Air bubble in water shines due to refraction of light

6. **Assertion :** The focal length of lens does not change when red light is replaced by blue light.
Reason : The focal length of lens does not depends on colour of light used.

7. **Assertion :** Although the surfaces of a goggle lens are curved, it does not have any power.
Reason : In case of goggles, both the curved surfaces have equal radii of curvature.

8. **Assertion :** If objective and eye lenses of a microscope are interchanged then it can work as telescope.
Reason : The objective of telescope has small focal length.

9. **Assertion :** If the angles of the base of the prism are equal, then in the position of minimum deviation, the refracted ray will pass parallel to the base of prism.
Reason : In the case of minimum deviation, the angle of incidence is equal to the angle of emergence.

10. **Assertion :** The frequencies of incident, reflected and refracted beam of monochromatic light incident from one medium to another are same
Reason : The incident, reflected and refracted rays are coplanar.
.

11. **Assertion** :: If the angles of the base of the prism are equal, then in the position of minimum deviation, the refracted ray will pass parallel to the base of prism.
Reason :: In the case of minimum deviation, the angle of incidence is equal to the angle of emergence.

12. **Assertion** : : There is no dispersion of light refracted through a rectangular glass slab.
Reason : : Dispersion of light is the phenomenon of splitting of a beam of white light into its constituent colours.

13. **Assertion :** The resolving power of a telescope is more if the diameter of the objective lens is more.
Reason : Objective lens of large diameter collectd more light.

.

14. **Assertion :** A ray passing through the centre of curvature of a concave mirror after reflection, is reflected back along the same path.

Reason : The ray passing through the centre of curvature is incident normally to the mirror.

15. **Assertion;** For an observer in the denser medium the object observed in rarer medium is seen uplifted.

Reason: This is observed due to refraction.

Answers : 1-a,2-a,3-d,4-c,5-c,6-d,7-a,8-d,9-a,10-b,11-a,12-b,13-a,14-a ,15-a

SHORT ANSWER TYPE QUESTIONS (Two marks each)

1) A converging lens of refractive index 1.5 is kept in a liquid medium having same refractive index. What would be the focal length of the lens in this medium?

The lens in the liquid will act like a plane sheet of glass. Its focal length will be infinite (∞)

∴ Its focal length will be infinite (∞)

$$\because \quad \frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \quad \text{[By Lens Maker's formula}$$

$$\frac{1}{f} = \left(\frac{\mu_2}{\mu_1} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\text{Here } \mu_1 = \mu_2 \quad \therefore \frac{1}{f} = 0 \qquad \Rightarrow f = \infty$$

2) How does the angle of minimum deviation of a glass prism vary, if the incident violet light is replaced with red light?

We know that λ red > λ violet, therefore μ red < μ violet and hence δ red < δ violet.
When incident violet light is replaced with red light, the angle of minimum deviation of a glass decreases.

3) You are given following three lenses. Which two lenses will you use as an eyepiece and as an objective to construct an astronomical telescope

Objective – Less power and more aperture. So L_1

Eyepiece – More power and less aperture. So L_3.

Lenses	Power	Aperture
L_1	3D	8 cm
L_2	6D	1 cm
L_3	10D	1 cm

(Reason Astronomical telescope must have objective lens of high focal length and large aperture and eye lens of short focal length and short aperture. **Power is inversely proportional to the focal length)**

4) **How does the power of a convex lens vary, if the incident red light is replaced by violet light?**

According to Lens Maker's formula

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

$$\because \quad \mu_{violet} > \mu_{red}$$

∴ power of the lens will be increased.

5) **Two thin lenses of power + 4D and – 2D are in contact. What is the focal length of the combination?**

$$P = P_1 + P_2 = 4 + (-2) = +2D$$

$$\text{Since focal length } f = \frac{1}{P}$$

$$\therefore \quad f = \frac{1}{2} = 0.5 \text{ m} = 50 \text{ cm}$$

6) **State the conditions for the phenomenon of total internal reflection to occur**.

Two essential conditions for total internal reflection are :

Light should travel from an optically denser medium to an optically rarer medium.

The angle of incidence in the denser medium must be greater than the critical angle for the two media.

7) Calculate the speed of light in a medium whose critical angle is 30°.

$\because \quad n = \dfrac{1}{\sin C} = \dfrac{1}{\sin 30^\circ} \qquad \therefore\ n = 2$

$\Rightarrow \quad n = \dfrac{c}{v} = 2 \qquad \Rightarrow \dfrac{3\times10^8}{v} = 2$

∴ Speed of light, $v = 1.5 \times 10^8\ ms^{-1}$

8) **For the same value of angle of incidence, the angles of refraction in three media A, B and C are 15°, 25° and 35° respectively. In which medium would the velocity of light be minimum?**

As $\mu = \dfrac{\sin i}{\sin r} = \dfrac{c}{v}$ or $v = \dfrac{\sin r}{\sin i} \times c$

For a given angle of incidence $v \propto \sin r$,

$v_A \propto \sin 15^\circ,\ v_B \propto \sin 25^\circ,\ v_C \propto \sin 35^\circ$

But $\sin 15^\circ < \sin 25^\circ < \sin 35^\circ$

$\therefore \quad v_A < v_B < v_C$

∴ Velocity of light is minimum in medium A.

9) A biconvex lens made of a transparent material of refractive index 1.25 is immersed in water of refractive index 1.33. Will the lens behave as a converging or a diverging lens? Give reason.

The lens will behave as a diverging lens, because

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

$$\frac{1}{f} = \left(\frac{\mu_1}{\mu_2} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\frac{\mu_1}{\mu_2} = \frac{1.25}{1.33} = 0.98$$

The value of (μ – 1) is negative and ‘f’ will be negative.

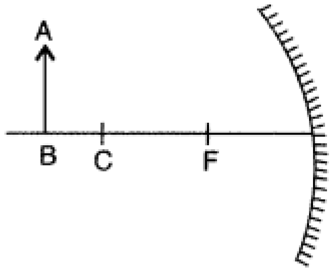
10) **(i) What is the relation between critical angle and refractive index of a material?**
(ii) Does critical angle depend on the colour of light? Explain.

(*i*) $\mu = \dfrac{1}{\sin i_c}$

(*ii*) For a given medium μ depends on the colour,
μ for violet $\mu_v > \mu_r$,

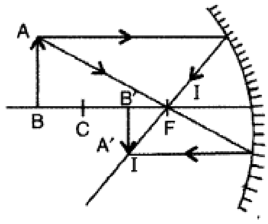
$\therefore$ Critical angle $i_c = \sin^{-1}\left(\dfrac{1}{\mu}\right)$ is greater for red colour.

11) **An object AB is kept in front of a concave mirror as shown in the figure.**



(i) Complete the ray diagram showing the image formation of the object.
(ii) How will the position and intensity of the image be affected if the lower half of the mirror's reflecting surface is painted black?

(*i*)



(ii) When the lower half of the mirror is painted black, the image formed is still of the same size as that with unpainted mirror but the intensity of the image has now reduced.

12) **A small telescope has an objective lens of focal length 144 cm and eyepiece of focal length 6.0 cm. What is the magnifying power of the telescope? What is the separation between the objective and the eyepiece?**
Answer:
1. For normal adjustment.
M.P. of telescope = f0/fe=1446 = 24
2. The length of the telescope in normal adjustment
$L = f_o + f_e$
$= 144 + 6 = 150$ cm.

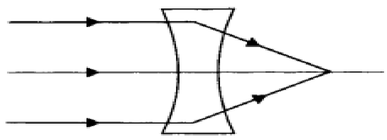
13) **How the focal lengths of a lens change with increase in the wavelength of the light?**

$$\delta = A(\mu - 1) \qquad \delta \propto \mu \ \text{since}\ \mu \propto \frac{1}{\lambda 2}$$

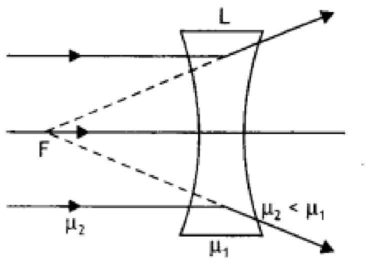
i.e. when wavelength increases $\mu -$ decreases and according to

$\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$ focal length increases.

14) **The refractive index of the material of a concave lens is n_1. It is immersed in a medium of refractive index n_2. A parallel beam of tight is incident on the lens. Trace the path of the emergent rays when $n_2 > n_1$.**
The path of rays is as shown

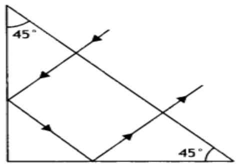


15) **The refractive index of the material of a concave lens is μ_1. It is immersed in a medium of refractive index μ_2. A parallel beam of light is incident on the lens. Trace the path of emergent rays when $\mu_2 < \mu_1$.**
The path of rays is as shown below.



16) **What is the minimum value of the refractive index of the prism shown in the figure below?**

$\mu = 1/\sin i_c = 1/\sin 45^\circ = 1/\sqrt{2}$



17) A biconvex lens made of a transparent material of refractive index 1.5 is immersed in water of refractive index 1.33. Will the lens behave as a converging or a diverging lens? Give reason.

The lens will behave as a converging lens because $\frac{\mu_1}{\mu_2} = \frac{1.5}{1.33} = 1.12 > 1$

Hence value of 'f' will be positive.

18) Write the relationship between angle of incidence 'i', angle of prism 'A' and angle of minimum deviation for a triangular prism.

$$i = \frac{(A + \delta_m)}{2} \text{ or } A + \delta_m = 2i$$

where [δ_m is angle of minimum deviation]

19) The focal length of a biconvex lens is equal to the radius of curvature of either face. What is the refractive index of the material of the lens?

Using $1/f = (n - 1)\left(1/R_1 - 1/R_2\right)$

Given $R_1 = R$

therefore we have, $f = R$, $R_2 = -R$

$$\frac{1}{R} = (n-1)\left(\frac{1}{R} + \frac{1}{R}\right) = \frac{2(n-1)}{R} \text{ or } 2(n-1) = 1$$

or $2n - 2 = 1$ or $n = 3/2 = 1.5$

SHORT ANSWER TYPE QUESTIONS (3 marks each)

1) **Draw a ray diagram of a reflecting type telescope. State two advantages of this telescope over a refracting telescope? Diagram –Refer Minimum Learning Material.**

(ii) Advantages of reflecting telescope over a refracting telescope (Any two can be stated)

a) Due to large aperture of the mirror used, the reflecting telescopes have high resolving power.

b) This type of telescope is free from chromatic aberration (formation of coloured image of a white object).

c) The use of paraboloidal mirror reduces the spherical aberration (formation of non-point, blurred image of a point object).

d) Image formed by reflecting telescope is brighter than refracting telescope.

e) A lens of large aperture tends to be very heavy and therefore difficult to make and support by its edges. On the other hand, a mirror of equivalent optical quality weights less and can be supported over its entire back surface.

2) **(i) How is the working of a telescope different from that of a microscope?**
(ii) The focal lengths of the objective and eyepiece of a microscope are 1.25 cm and 5 cm respectively. Find the position of the object relative to the objective in order to obtain an angular magnification of 30 in normal adjustment

Telescope

1. Resolving power should be higher for certain magni-fication.

2. Focal length of objective should be kept larger while eyepiece focal length should be small for better magni-fication.

3.Objective should be of large aperture.

4.Distance between objective and eyepiece is adjusted to focus the object at infinity.

Microscope

1. Resolving power is not so large but the magnification should be higher.
2. Both objective and eyepiece should have less focal length for better magnification.
3. Eyepiece should be of large aperture.
4. Distance between objective and eyepiece is fixed, for focusing an object the distance of the objective is changed.

Given : $f_0 = 1.25$ cm, $f_e = 5$ cm, $m = 30$

$\therefore$ Distance, $d = 30 - 5 = 25$ cm

Angular magnification = 30, $m = m_e \times m_0$

$$\Rightarrow m_e = \frac{d}{f_e} = \frac{25}{5} = 5 \quad \therefore m_0 = 30 \div 5 = 6$$

$$\text{But } m_0 = \frac{v_0}{u_0} \qquad \Rightarrow -6 = \frac{v_0}{u_0}$$

$\therefore \quad v_0 = -6\ u_0$

Applying *lens equation* to the objective lens,

$$\frac{1}{f_0} = \frac{1}{v_0} - \frac{1}{u_0} \qquad \Rightarrow \frac{1}{f_0} = \frac{1}{-6u_0} - \frac{1}{u_0}$$

2. **Draw a labelled ray diagram of an astronomical telescope in the near point position. Write the expression for its magnifying power.**

Refer Minimum Learning Material

3. **Calculate the distance of an object of height h from a concave mirror of focal length 10 cm, so as to obtain a real image of magnification 2.**

Given : f = -10 cm; Magnification, m = 2

To calculate : u = ?

We have : $\frac{h_1}{h_0} = \frac{-v}{u}$

Mirror formula : $\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$

As image formed is to be real

$$\frac{v}{u} = 2 \qquad \text{or} \quad v = 2u$$

$$\text{or} \quad \frac{-1}{10} = \frac{1}{2u} + \frac{1}{u} \qquad \text{or} \quad \frac{-1}{10} = \frac{3}{2u}$$

or $u = -15$

$\therefore$ **Object distance = 15 cm**

4. **How does the angle of minimum deviation of a glass prism of refractive index 1.5 change, if it is immersed in a liquid of refractive index 1.3?**

Here ${}^{a}\mu_g = 1.5$ and ${}^{a}\mu_w = 1.3$

$\because \quad \delta = (\mu - 1)\,A$

For deviation in air, $\mu = \dfrac{\mu_g}{\mu_a} = \dfrac{1.5}{1} = 1.5$

$\therefore \quad \delta = (1.5 - 1) \times 60^\circ = 30^\circ$

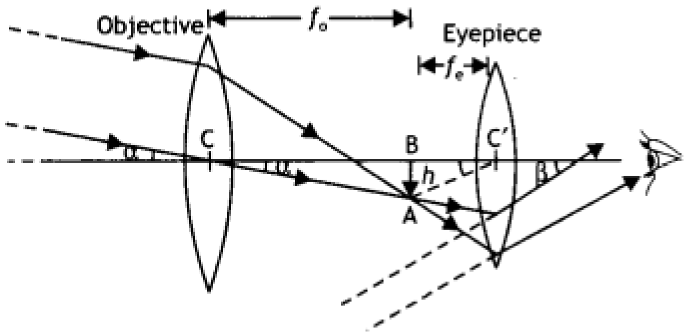
For deviation in water, $\mu = \dfrac{\mu_g}{\mu_w} = \dfrac{1.5}{1.3} = 1.15$

$\therefore \quad \delta = (1.15 - 1) \times 60^\circ = 0.15 \times 60^\circ = 9^\circ$

Hence angle of deviation is decreased.

5. **Draw a labelled ray diagram showing the image formation of a distant object by a refracting telescope. Deduce the expression for its magnifying power when the final image is formed at infinity.**
   (b) The sum of focal lengths of the two lenses of a refracting telescope is 105 cm. The focal length of one lens is 20 times that of the other. Determine the total magnification of the telescope when the final image is formed at infinity.

(a) For the diagram



From right triangles ABC and ABC' as shown in figure, we have

tan α = ABCB=−h/f_0 and

tan β = ABC′A=−h/f_e

From the above we have we have

M = β/α=−h/fe×f_0/(−h)=f_0/fe

(b) L = 105 cm, $f_o = 20f_e$,

Now $L = f_o + f_e = 21f_e$

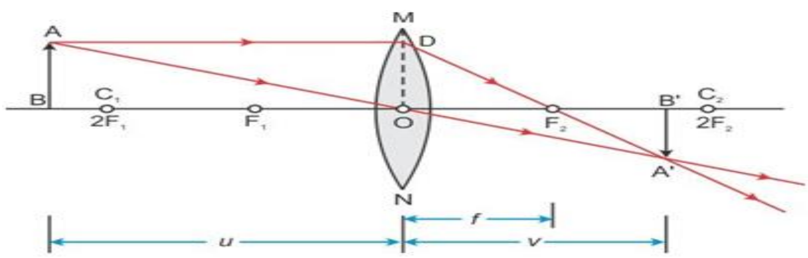
Or

fe = 105/21 = 5 cm

Hence $f_o = 20 \times f_e = 20 \times 5 = 100$ cm

Hence $M = f_o/f_e = 100/5 = 20$

6. **Derive the lens formula for a thin convex lens forming real image?**



The figure above shows that formation of a real, inverted and diminished image A'B' of the object AB placed beyond the centre of curvature at a distance u from the convex lens. Let v be the image distance.
According to Cartesian sign convention,
Object distance (OB) = -u
Image distance (OB') = +v
Focal length ($OF_1 = OF_2$) = +f
From geometry of figure above, right angle ΔABO and ΔA'B'O are similar.

$$\therefore \frac{AB}{A'B'} = \frac{OB}{OB'} = -v................(i)$$

From geometry of figure above, right angle ΔODF_2 and ΔBAF_2 are similar.

$$\therefore \frac{OD}{A'B'} = \frac{OF_2}{F_2B'}$$

$$\therefore \frac{AB}{A'B'} = \frac{OF_2}{F_2B'} \quad (\because OD = AB, \text{ are the opposite sides of } \square ABOD)$$

$$\therefore \frac{AB}{A'B'} = \frac{OF_2}{OB' - OF_2}$$

$$\therefore \frac{AB}{A'B'} = \frac{f}{v - f} \quad ....(ii)$$

From (i) and (ii),

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

$$\Rightarrow -u(v - f) = vf$$

$$\Rightarrow -uv + uf = vf$$

Dividing each term by uvf,

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

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

This equation is called the 'Lens formula'.

7. High precision optical instruments uses prisms instead of mirror to reflect light.

(i) Name the phenomena used for reflecting light using prism.

(ii)What is the advantage of using prism instead of mirror for reflecting light?

(iii)The critical angle of water is 52°. Calculate the refractive index of water.

(i). Total internal reflection

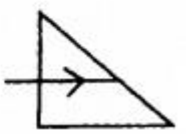
(ii). Prism can be used for total internal reflection. Mirrors can't be used for total internal reflection.

(iii). $n = \frac{1}{\sin c} = \frac{1}{\sin 52^0} = \frac{1}{0.7880}$ n = 1.26.

10. **(i) An air bubble inside an ice block shine brilliant by……… (Refraction, Reflection, total internal reflection)**

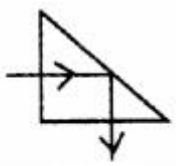
(ii)Explain the above phenomenon.

(iii)The light ray incident at one face of the prism is shown in figure. Copy this figure complete the path of the ray. (Take critical angle of prism C = 42°)



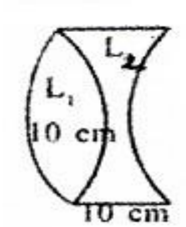
(i). Total internal reflection.

(ii). When a ray of light passes from a denser to rarer medium, after refraction the ray bends away from the normal. If we increase the angle of incidence beyond the critical angle, the ray is totally reflected back to the denser medium itself. This phenomenon is called total internal reflection.

(iii) 

11. Two lenses L_1 and L_2 are placed in contact as shown in figures. The focal length of each lens is 10cm. (i) What is power of L_1, (ii) What is power of L_2 & (iii)What is effective focal length of combination

(iv) "The power of convex is greater than that of concave and combination can act as a diverging lens" Is this statement true in any situation? Explain?



$$P = \frac{1}{f} = \frac{1}{0.1} = +10D$$

$$P = \frac{1}{-0.1} = -10D$$

$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} = \frac{1}{0.10} + \frac{-1}{0.1}$$

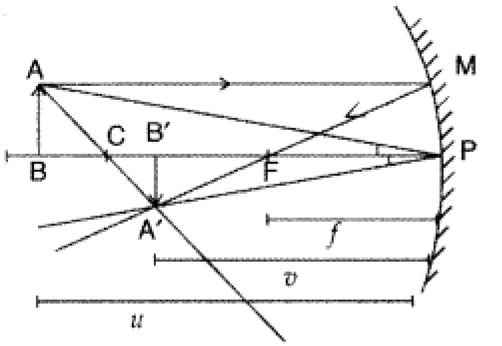
$$\frac{1}{f} = 0, \quad f = \infty$$

The combination will act as plane glass.

4. This is true statement. If we place the above combination in a medium of refractive index greater than this condition.

LONG ANSWER TYPE QUESTIONS (Five marks each)

1. **With the help of a suitable ray diagram, derive the mirror formula for a concave mirror.**
   Answer:
   Consider a concave mirror of focal length/, radius of curvature R receiving light from an object AB placed between F and C as shown in the figure. The image will be formed as shown in the ray diagram.



Using Cartesian sign convention, we find
Object distance, BP = – u
Image distance B’P = – v
Focal length, FP = – l
Radius of curvature, CP = -R = -2f

Now $\Delta A'B'C \sim \Delta ABC$

$$\therefore \quad \frac{A'B'}{AB} = \frac{CB'}{BC} = \frac{CP - B'P}{BP - CP} = \frac{-R + v}{-u + R} \qquad \ldots(i)$$

As $\angle A'PB' = \angle APB \quad \therefore \ \Delta A'B'P \sim \Delta ABP$

Consequently, $\dfrac{A'B'}{AB} = \dfrac{B'P}{BP} = \dfrac{-v}{-u} = \dfrac{v}{u} \qquad \ldots(ii)$

From equations (*i*) and (*ii*), we have

$$\frac{-R + v}{-u + R} = \frac{v}{u} \qquad \Rightarrow -uR + uv = -uv + vR$$

$$\Rightarrow \quad vR + uR = 2uv$$

Dividing both sides by uvR, we have $\dfrac{1}{u} + \dfrac{1}{v} = \dfrac{2}{R}$

But $R = 2f \qquad \therefore \ \dfrac{1}{u} + \dfrac{1}{v} = \dfrac{1}{f}$

This proves the mirror formula for a concave mirror.

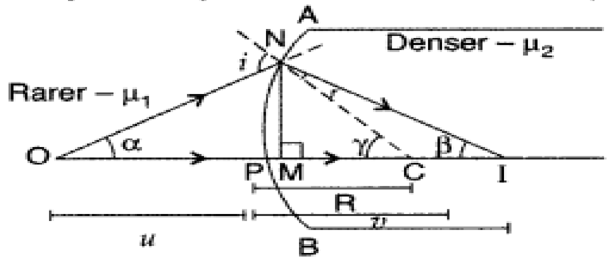
1. **Draw a ray diagram to show the formation of the image of an object placed on the axis of a convex refracting surface, of radius of curvature ‘R’, separating the two media of refractive indices “n_1 and ‘n_2‘ ($n_2 > n_1$). Use this diagram to deduce the relation $n_2/v-n_1/u=n_2-n_1/R$, where u and v represent respectively the distance of the object and the image formed.**

In ΔNOC, i is an exterior angle,

$\therefore \quad i = \alpha + \gamma$

Similarly, from ΔNIC, we have

$\gamma = r + \beta \qquad \Rightarrow r = \gamma - \beta$



Suppose all the rays are paraxial
Then the angles i, r, a, P and y will be small

$$\therefore \quad \gamma = \tan\gamma = \frac{NM}{OM} = \frac{NM}{OP} \quad \ldots[\because \text{ P is close to M}$$

$$\beta = \tan\beta = \frac{NM}{MI} = \frac{NM}{PI} \quad \text{and}$$

$$\gamma = \tan\gamma = \frac{MP}{MC} = \frac{NM}{PC}$$

From *Snell's law of refraction*, $\frac{\sin i}{\sin r} = \frac{\mu_2}{\mu_1}$

As i and r are small

$$\therefore \quad \frac{i}{r} = \frac{\mu_2}{\mu_1} \qquad \Rightarrow \mu_1 i = \mu_2 r$$

$$\Rightarrow \quad \mu_1 (\alpha + \gamma) = \mu_2 (\gamma - \beta)$$

$$\Rightarrow \quad \mu_1 \left[\frac{NM}{OP} + \frac{NM}{PC}\right] = \mu_2 \left[\frac{NM}{PC} - \frac{NM}{PI}\right]$$

$$\Rightarrow \quad \mu_1 \left[\frac{1}{OP} + \frac{1}{PC}\right] = \mu_2 \left[\frac{1}{PC} - \frac{1}{PI}\right]$$

$$\Rightarrow \quad \frac{\mu_1}{OP} + \frac{\mu_1}{PC} = \frac{\mu_2}{PC} - \frac{\mu_2}{PI} \Rightarrow \frac{\mu_1}{OP} + \frac{\mu_2}{PI} = \frac{\mu_2 - \mu_1}{PC}$$

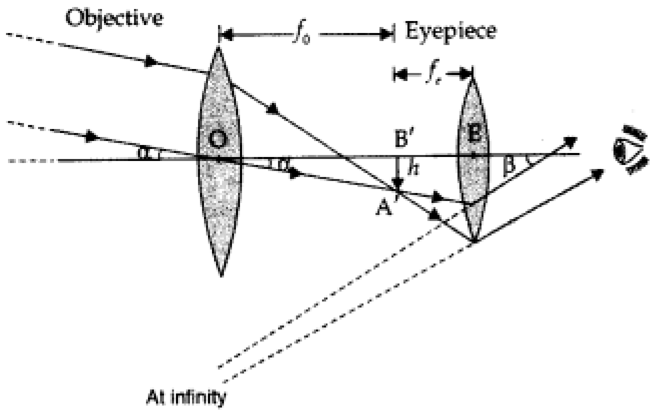
Using new Cartesian sign convention, we find
Object distance, OP = – u,
Image distance, PI = tv
Radius of curvature, PC = + R

$$\therefore \quad \frac{\mu_1}{-u} + \frac{\mu_2}{v} = \frac{\mu_2 - \mu_1}{R} \Rightarrow \frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R} \quad \ldots(i)$$

Here given $\mu_1 = n_1$ and $\mu_2 = n_2$

So equation becomes $\boxed{\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}}$

2. (i) Draw a neat labelled ray diagram of an astronomical telescope in normal adjustment. Mention any two drawbacks of this telescope.
(ii) An astronomical telescope uses two lenses of powers 10 D and 1 D. What is its magnifying power in normal adjustment?
(i) Magnifying power m = $-f_0/fe$. It does not change with increase of aperture of objective lens, because focal length of a lens has no concern with the aperture of lens.



Astronomical telescope in normal adjustment

(ii) Drawbacks :

Images formed by these telescopes have chromatic aberrations.

Lesser resolving power.

The image formed is inverted and faint.

(*ii*) Magnifying power, $m = \frac{f_0}{f_e}$

Given : Power of eyepiece, $P_e = 10$ D,

i.e., $f_e = 10$ cm

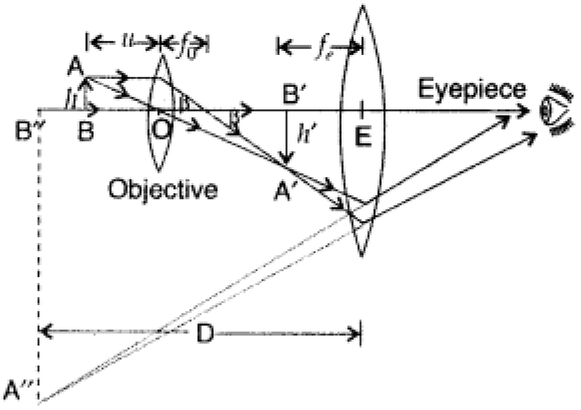
Power of objective, $P_0 = 1$ D, *i.e.*, $f_0 = 100$ cm

$\therefore$ **Power in normal adj.,** $m = \frac{100}{10} = \mathbf{10}$

4. **(i) Draw a neat labelled ray diagram of a compound microscope. Explain briefly its working. (ii) Why must both the objective and the eye-piece of a compound microscope have short focal lengths?**

(a) Ray diagram of a compound microscope : A schematic diagram of a compound microscope is shown in the figure. The lens nearest the object, called the objective, forms a real, inverted, magnified image of the object. This serves as the object for the second lens, the eyepiece, which functions essentially like a simple microscope or magnifier, produces the final image, which is enlarged and virtual.

The first inverted image is thus near (at or within) the focal plane of the eyepiece, at a distance appropriate for final image formation at infinity, or a little closer for image formation at the near point. Clearly, the final image is inverted with respect to the original object.



Magnification due to a compound microscope.

The ray diagram shows that the (linear) magnification due to the objective, namely h'/h, equals

$$m_0 = \frac{h'}{h} = \frac{L}{f_0} \qquad \ldots(i)$$

$$\because \quad \tan\beta = \left(\frac{h}{f_0}\right) = \left(\frac{h'}{L}\right)$$

Here h' is the size of the first image, the object size being h and f_0 being the focal length of the objective. The first image is formed near the focal point of the eyepiece. The distance L, i.e., the distance between the second focal point of the objective and the first focal point of the eyepiece (focal length f_e) is called the tube length of the compound microscope.

As the first inverted image is near the focal point of the eyepiece, we use for the simple microscope to obtain the (angular) magnification me due to it when the final image is formed at the near point, is

$$m_e = 1 + \frac{D}{f_e} \qquad \ldots(ii)$$

When the final image is formed at infinity, the angular magnification due to the eyepiece, me = (D//e)

$$m_e = (D/f_e) \qquad \ldots(iii)$$

Thus, the total magnification from equation (i) and (iii), when the image is formed at infinity, is

$$m = m_0 m_e = \left(\frac{L}{f_0} \times \frac{D}{f_e}\right)$$

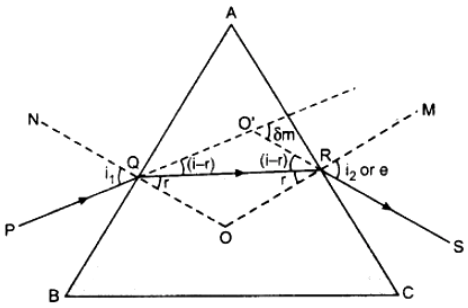
(ii) The magnifying power of a compound microscope is given by,

$$m = m_0 \times m_e = \frac{v_0}{u_0} \times \left(1 + \frac{D}{f_e}\right)$$

$$= \frac{f_0}{u_0 - f_0} \times \left(1 + \frac{D}{f_e}\right)$$

In order to have large angular magnification the objective and eye piece must have short focal length.

5. **Draw a ray diagram to show refraction of a ray of monochromatic light passing through a glass prism.**
Deduce the expression for the refractive index of glass in terms of angle of prism and angle of minimum deviation.
Ray diagram : The minimum deviation Dm, the refracted ray inside the prism becomes parallel to its base, we have



According to Snell's law, the refractive index of the substance of the prism.

$$n = \frac{\sin i}{\sin r} \qquad \ldots(1)$$

In ΔQOR, $\angle r + \angle r + \angle O = 180°$

or $\qquad 2r + \angle O = 180° \qquad \ldots(2)$

In $\square$ $AQOR$, $\quad \angle AQO = \angle ARO = 90°$

$\therefore \qquad \angle A + \angle O = 180° \qquad \ldots(3)$

(Because the sum of all four interior angles of a quadrilateral is equal to four right angles.)

On comparing equations (2) and (3),

$$2r + \angle O = A + \angle O$$

or $\qquad 2r = A \qquad \ldots(4)$

$\therefore \qquad r = \dfrac{A}{2}$

Now in $\Delta O'QR$, the exterior angle,

$$\delta_m = (i - r) + (i - r) = 2i - 2r$$

or $\qquad \delta_m = 2i - A \qquad$ [from equation (4)]

or $\qquad 2i = A + \delta_m$

$$\therefore \quad i = \frac{A+\delta_m}{2} \quad ...(5)$$

Now substituting the values of i and r in equation (1)

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

This formula is also known as **"Prism Formula"**.

6. **State any three assumptions and New cartesian sign conventions and hence derive the Lens maker's formula?**

Basic assumptions in derivation of Lens-maker's formula:

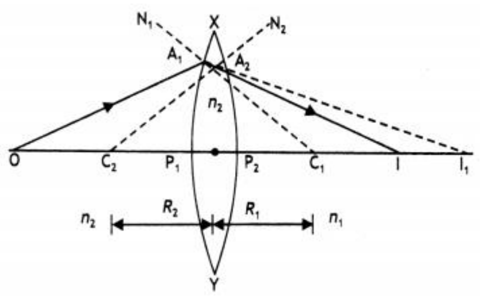
(ii) Aperture of lens should be small
(iii)Lenses should be thin
(iv)Object should be point sized and placed on principal axis.

New Cartesian sign conventions

(i) All the distances are measured from the optical centre of the lens.

(ii) Distances measured in the direction of the propagation of incident light are taken as positive while the distances measured in the direction opposite to the direction of propagation of incident light are taken as negative.

(iii) The heights above the principal axis is taken as positive and below it is taken as negative.



(a) Lens maker's formula : Consider a thin double convex lens of refractive index n_2 placed in a medium of refractive index n_1. Here, $n_1 < n_2$. Let B and D be the poles, C_1 and C_2 be the centres of curvature and R_1 and R_2 be the radii of curvature of the two lens surfaces XP_1Y and XP_2Y respectively. For refraction at surface XP_1Y, we can write the relation between the object distance u, image distance v_1 and radius of curvature R_1 as

$$\frac{n_2}{v_1} - \frac{n_1}{u} = \frac{n_2 - n_1}{R_1} \qquad ...(i)$$

For refraction at surface XP_2Y, we can write the relation between the object distance v_1, image distance v and radius of curvature R_2, as

$$\frac{n_1}{v} - \frac{n_2}{v_1} = \frac{n_1 - n_2}{R_2} \quad \ldots(ii)$$

Adding equations (*i*) and (*ii*), we get

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

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

If the object is placed at infinity ($u = \infty$), the image will be formed at the focus *i.e.* $v = f$,

$$\therefore \quad \frac{1}{f} = \left[\frac{n_2}{n_1} - 1\right]\left[\frac{1}{R_1} - \frac{1}{R_2}\right] \quad \ldots(iv)$$

$$\boxed{\frac{1}{f} = [n_{2i} - 1]\left[\frac{1}{R_1} - \frac{1}{R_2}\right]}$$

This is lens maker's formula.

CASE STUDY QUESTIONS

READ THE FOLLOWING PASSAGE AND ANSWER ANY FOUR QUESTIONS ONLY

1. A prism is a portion of a transparent medium bounded by two plane faces inclined to each other at a suitable angle. A ray of light suffers two refractions on passing through a prism and hence deviates through a certain angle from its original path. The angle of deviation of a prism is,

$\delta = (\mu - 1)$ A, through which a ray deviates on passing through a thin prism of small refracting angle A. If μ is refractive index of the material of the prism, then prism formula is, $\mu=(\sin(A+\delta_m)/2)/(\sin A/2)$.

(i) For which colour, angle of deviation is minimum?

(ii) Name any two factors on which angel of deviation depends on?

(iii) What is the angle of incidence for the maximum deviation?

(iv) What is the deviation produced by a prism of angle 6°? (Refractive index of the material of the prism is 1.644).

(v) A ray of light falling at an angle of 50° is refracted through a prism and suffers minimum deviation. If the angle of prism is 60°, then find the angle of minimum deviation?

ANSWERS

(i) Angle of deviation is minimum for the red colour.

(ii) a) the angle of incidence(b) the material of the prism (c) The wavelength of the light used (iv) the angle of prism.

(iii) The deviation is maximum when angle of incidence is 90°.

(iv) (a): $A=6^\circ;\mu=1.644$

$f=(\mu-1)A$

$f=(1.644-1)6=0.644\times6$

$\delta=3.864^\circ$

(v) (d): $i_1=50^\circ;A=60^\circ,\delta_m=?$

$A+\delta_m=i_1+i_2=50^\circ+50^\circ=100^\circ$

CASE STUDY QUESTIONS II

2. A compound microscope is an optical instrument used for observing highly magnified images of tiny objects. Magnifying power of a compound microscope is defined as the ratio of the angle subtended at the eye by the final image to the angle subtended at the eye by the object, when both the final image and the objects are situated at the least distance of distinct vision from the eye. It can be given that: $m=m_e \times m_o$, where m_e is the magnification produced by the eye lens and m_o is the magnification produced by the objective lens..

(i) **Why must the objective and the eye piece of a compound microscope has short focal length?**

Ans: Only if the objective and eye piece of a compound microscope has short focal length then the angular magnification will be larger/

(ii) **You are given two convex lenses of focal lengths 5 cm and 20 cm. Which one will you choose as an objective lens for forming a compound microscope?**

Ans: Convex lens of focal length 5 cm. since objective lens must have a short focal length

(iii) **What can we say about the length of a compound microscope if the final image is formed at infinity?**

Ans: The length of the compound microscope becomes greater than $f_0 + f_e$

(iv) **Define the angular magnification of a compound microscope?**

Ans: It is defined as the ratio of the angle subtended at the eye by the final virtual image to the angle subtended at the eye by the object, when both are at the least distance of distinct vision.

(v) **Why is the focal length of an objective in a compound microscope is little shorter than the focal length of the eyepiece?**

Ans: This is done so that the objective lens forms image within the focal length of the eyepiece.

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FORMULAE IN WAVE OPTICS

S. No	Physical quantity / Law / Principle	Formulae
1	Refractive index of a medium with respect to vacuum	μ=$\frac{speed\ of\ light\ in\ vacuum}{speed\ of\ light\ in\ midum}$=$\frac{c}{v}$ any medium is optically denser than vacuum. μ>1 so c>v.
2	Relation between wave length of light in medium, speed of the wave and refractive index	v1=$\nu\lambda 1$ v2=$\nu\lambda 2$ $\frac{v1}{v2}=\frac{\nu\lambda 1}{\nu\lambda 2}=\frac{\lambda 1}{\lambda 2}$ μ=$\frac{wave\ length\ of\ light\ in\ vacuum}{wave\ length\ of\ light\ in\ midum}$ frequency of light remains unchanged during its reflection or refraction .
3	First law of reflection	$\angle i=\angle r$
4	Snell's law of refraction	$\frac{\sin i}{sinr}={}_1\mu_2$
+5	Relation between refractive index of the medium μ wave length of light in vacuum λ wavelength of light in medium λ'	μ=$\frac{wave\ length\ of\ light\ in\ vacuum\lambda}{wave\ length\ of\ light\ in\ midum\ \lambda'}$
6	Principle of Superposition	(1). $\vec{y}=\vec{y1}+\vec{y2}+\vec{y3}+\ ....\vec{yn}$ $\vec{y1},\vec{y2},\vec{y3}+\ ....\ \vec{yn}$ displacements due to the different waves acting separately $\vec{y}$ the resultant displacement (2) Amplitude of the resultant wave $A^2=a_1^2+a_2^2+2a_1a_2\cos\emptyset$ a_1a_2 amplitudes of two light waves from two coherent sources ∅ the constant phase difference between the two waves (3) Intensity of the wave α $(amplitude)^2$ I $\alpha\ A^2$ $I_1\ \alpha\ {a_1}^2$ $I_2\ \alpha\ {a_2}^2$ (4) Total intensity at a point where the phase difference ∅ is $I=I_1+I_2+2\sqrt{I_1I_2}\cos$
7	Relation between phase difference and path difference	$\emptyset=\frac{2\pi}{\lambda}\ \Delta x$
8	Young's double slit experiment	(1) Fringe width $\beta=\frac{\lambda D}{d}$ (2) Wavelength of the light used $\lambda=\frac{\beta d}{D}$ 3) If the apparatus is immersed in any other medium (other than air)

		$\beta' = \frac{\lambda' D}{d} = \frac{\lambda D}{\mu d}$ $\mu_{medium} > \mu_{air}$ $\beta' < \beta$
9	**Variation in intensity in the interference pattern due to two coherent sources**	**(1) I_{max} = K (a+a) ^{2} =4 a^2** **(2) I_{min} = K (a-a) ^{2} =0 (dark fringes are perfectly dark)** **(3) $I_1 = a_1{}^2$** **$I_2 = a_2{}^2$** $\frac{I_1}{I_2} = \frac{a_1^2}{a_2^2}$ $\frac{I_{max}}{I_{min}} = \frac{(a_1 + a_2)^2}{(a_1 - a_2)^2}$
10	**Diffraction at a single slit**	**Positions of minima** **Path difference dsinθ = nλ** **n-1,2,3…** **Positions of maxima** **Path difference** **dsinθ =((2n+1)$\frac{\lambda}{2}$** **n-1,2,3…** **d width of the slit**
11	**Central maxima**	**Linear width=$\frac{2\lambda D}{D}$** **Angular width=$\frac{2\lambda}{d}$** **D the distance between the screen and the slit**

WAVE OPTICS - MINIMUM LEARNING MATERIAL

Wavefront:

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

These are three types

(i) Spherical wavefront,(ii) Cylindrical wavefront & (iii) Plane wavefront

Light travels in a medium in the form of wavefront.

A wavefront is the locus of all the particles vibrating in same phase.

All particles on a wavefront behaves as a secondary source of light, which emits secondary wavelets.

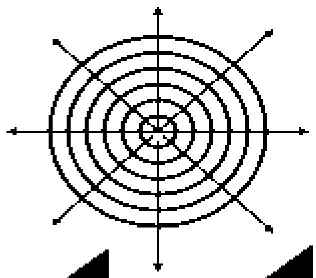
The envelope of secondary wavelets represents the new position of a wavefront.

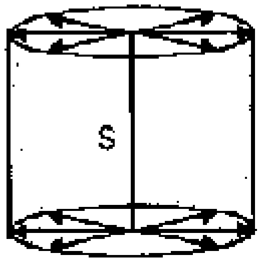
When source of light is a point source,the wavefront is spherical.

Amplitude (A) is inversely proportional to distance (x) A ∝ 1 / x .

∴ Intensity (I) ∝ $(\text{Amplitude})^2$

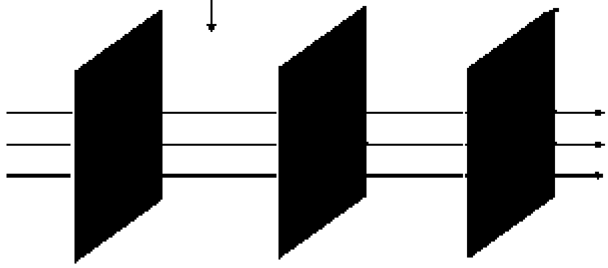
Spherical Wavefront from a

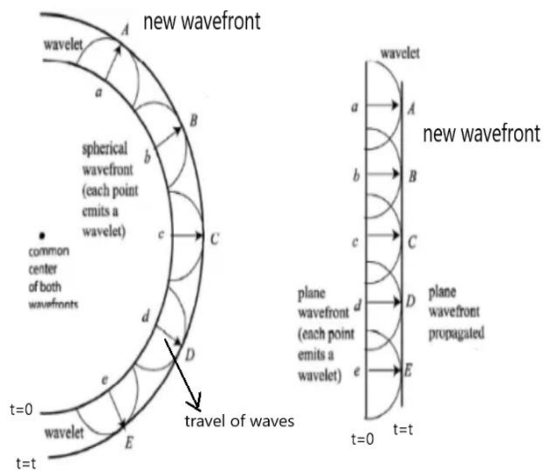




Cylindrical Wavefront from a linear source

Plane Wave front





Huygens's Wave Theory

Huygens's Principle

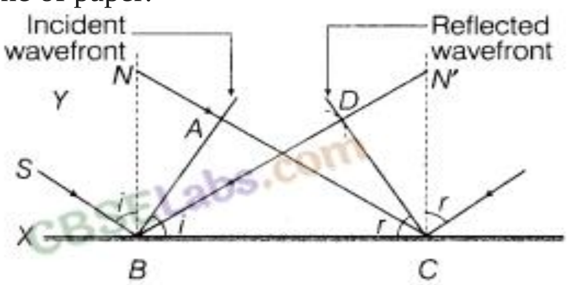
(i) Every point on given wavefront (called primary wavefront) acts as a fresh source of new disturbance called secondary wavelets.

(ii) The secondary wavelets travel in all the directions with the speed of light in the medium.

(iii) A surface touching these secondary wavelets tangentially in the forward direction at any instant gives the new (secondary) wave front of that instant.

Laws of reflection on the basis of Huygens' wave theory

Consider a plane wave front AB incident on the reflecting surface XY, both the wave front and the reflecting surface being perpendicular to the plane of paper.



[wavefronts and corresponding rays for reflecting from a plane surface.]

First the wave front touches the reflecting surface at B and then at the successive points towards C. In accordance with Huygens' principle, from each point on AB, secondary wavelets start growing with the speed c. During the time the disturbance from A reaches the point C the secondary wavelets from B must have spread over a hemisphere of radius BD.

BD = AC = c t,

where t is the time taken by the disturbance to travel from A to C.

The tangent plane CD drawn from the point C over this hemisphere of radius c t will be the new reflected wave front.

Let angles of incidence and reflection be i and r, respectively .

In ΔABC and Δ DCB, we have

$$\angle BAC = \angle CDB \qquad \text{[each is 90°]}$$
$$BC = BC \qquad \text{[common]}$$
$$AC = BD \qquad \text{[each is equal to } ct\text{]}$$
$$\therefore \Delta ABC \cong \Delta DCB$$
Hence $\angle ABC = \angle DCB$

or $\quad i = r$

The angle of incidence is equal to the angle of reflection. The proves the first law of reflection.
Further, since the incident ray SB, the normal BN and the reflected ray BD are all lie.in the same plane. This proves the second law of reflection

Law of refraction on this basis of Huygens' wave theory

Consider a plane wavefront AB incident on a plane surface XY, separating two media 1 and 2, as shown in Figure.

Let v_1 and v_2 be the velocities of light in two media, with $v_1 > v_2$.

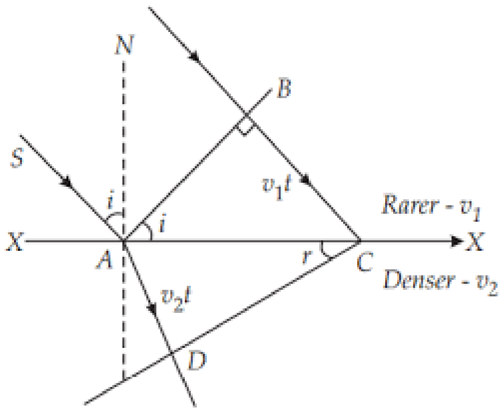
The wave front first strikes at point A and then at the successive points towards C. According to Huygens' principle, from each point on AC, the secondary wavelets starts growing in the second medium with speed v_2.

Let the disturbance take time t to travel from B to C, then BC = v_1t.

During the time the disturbance from B reaches the point C, the secondary wavelets from point A must have spread over a hemisphere of radius AD = v_2t in the second medium. The tangent plane CD drawn from point C over this hemisphere of radius v_2t will be the new refracted wave front.

Let the angles of incidence and refraction be i and r, respectively.

From ΔABC *and* ΔADC we have



$$\sin i = \frac{BC}{AC} = \frac{v_1 t}{AC}$$
$$\sin r = \frac{AE}{AC} = \frac{v_2 t}{AC}$$
$$\frac{\sin i}{\sin r} = \frac{v_1}{v_2} = \mu$$

Thus Snell's law is proved.The incident ray, the normal and the refracted ray are all lie.in the same plane.

Superposition of waves:

When two similar waves propagate in a medium simultaneously, then at any point the resultant displacement is equal to the vector sum of displacement produced by individual waves. $y = y_1 + y_2$

Amplitude of the resultant wave

$A^2 = a_1^2 + a_2^2 + 2a_1a_2 \cos\emptyset$

a_1a_2 amplitudes of two light waves from two coherent sources

$\emptyset$ the constant phase difference between the two waves

(3) Intensity of the wave α (amplitude)^2

I α A^2

$I_1 \; \alpha \; {a_1}^2$

$I_2 \; \alpha \; {a_2}^2$

Total intensity at a point where the phase difference ∅ is

$I = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\emptyset$

Variation in intensity in the interference pattern due to two coherent sources of amplitude a.

$I_{max} = K\,(a+a)^2 = 4\,a^2$
$I_{min} = K\,(a-a)^2 = 0$ (dark fringes are perfectly dark)

$I_1 = {a_1}^2$; $I_2 = {a_2}^2$; $\dfrac{I_1}{I_2} = \dfrac{a_1^2}{a_2^2}$

$\dfrac{I_{max}}{I_{min}} = \dfrac{(a_1 + a_2)^2}{(a_1 - a_2)^2}$

Interference of Light

When two light waves of similar frequency having a zero or constant phase difference propagate in a medium simultaneously in the same direction, then due to their superposition maximum intensity is obtained at few points and minimum intensity at other few points.

This phenomena of redistribution of energy due to superposition of waves is called interference of light waves. To observe interference in light waves we require coherent sources,

Coherent Sources of Light

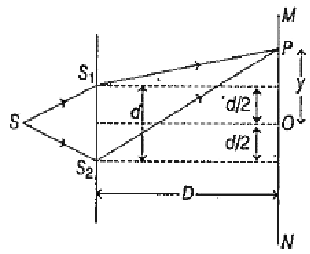
The sources of light emitting light of same wavelength, same frequency having a zero or constant phase difference are called coherent sources of light.
The interference taking place at points of maximum intensity is called **constructive interference**.
The interference taking place at points of minimum intensity is **destructive interference**.

Young's Double Slit Experiment Find Fringe Width

- Two narrow coherent light sources from a monochromatic source S
- produce a pattern of dark and bright bands on a screen placed parallel to the plane of the slits S_1 and S_2..
- The screen is placed at a considerable distance D from the slits. (D> d)
- S_1 and S_2.act as secondary sources. The crests and troughs of the secondary wavelets superpose to produce interference pattern
- The secondary waves reaching the point O travel equal distance and they will meet in phase at O. A central bright fringe is formed at O.
- Consider a point P on the screen at a distance y from O. The two light waves from S_1 and S_2 reach point P along the paths and S_1P and S_2P respectively.
- If the path difference Δx between S_1P and S_2P is an integral multiple of λ the two waves arriving the point P will interfere constructively producing a bright fringe at P. $\Delta x = n\,\lambda$
- If the path difference Δx between S_1P and S_2P is half integral multiple of λ the two waves arriving the point P will produce destructive interference at P. $\Delta x = (2n+1)\frac{\lambda}{2}$

The distance between consecutive bright or dark fringes is called the fringe width or bandwidth.

- Band width $\beta = \frac{\lambda D}{d}$



Constructive Interference:

Phase difference $\Delta\phi = 2\pi n$ where n is an integer
Path difference $\Delta X = n\lambda$ where n is an integer n=01,2..)

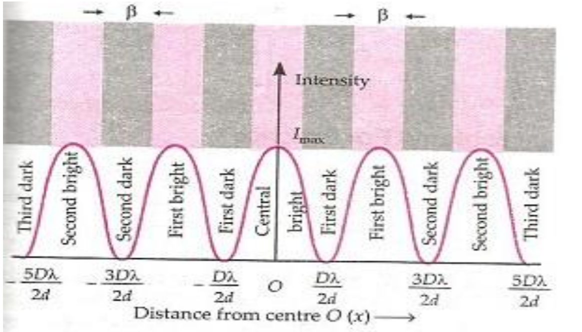
- **Destructive interference:**

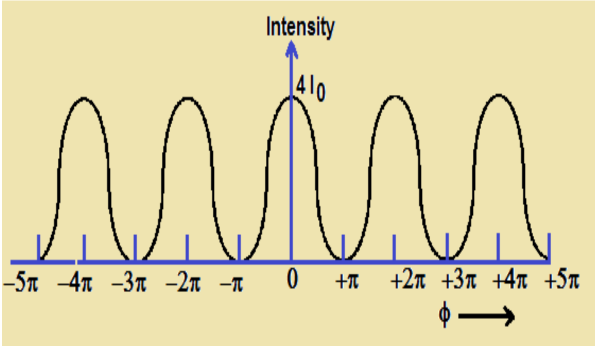
Phase difference $\Delta\phi = (2n-1)\pi$, where n is an integer
Path difference

$$\Delta x = (2n-1)\frac{\lambda}{2}$$

where n is an integer (n=1,2,3..)

- **Intensity distribution curve for interference:**





Interference fringes with white light:- When the slits are illuminated with white light, the interference pattern consist of a central white fringe having on both sides a few coloured fringes and then a general illumination.

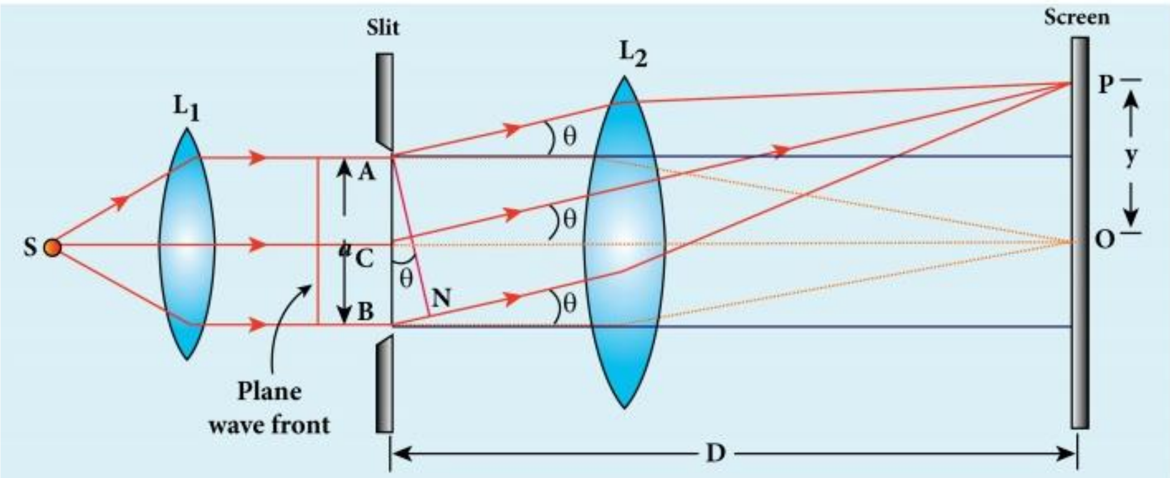
Conditions for sustained interference:-

(i) Two sources of light must be coherent.
(ii) The frequencies (or wavelength) of the two waves should be equal.
(iii) The light must be monochromatic.
(iv) The amplitudes of the interfering waves must be equal or nearly equal.
(v) The two sources must be narrow.

Diffraction:

The phenomenon of bending of light around the corners of an obstacle is called the diffraction of light. Diffraction effect is more pronounced if the size of the aperture or o obstacle is of the order of the wavelength of the wave.

Diffraction due to Single Slit:



Suppose a parallel beam of monochromatic light of wavelength λ falls normally on a slit AB of width d (of the order of the wavelength of light). The diffraction occurs on passing through the slit. The diffraction pattern is focussed on to the screen by a convex lens. The diffraction pattern consists of a central bright fringe, having alternate dark and bright fringes of decreasing intensity on both sides.

Position of central maximum: Let O be the centre of the slit AB. According to Huygens's principle, "when light falls on the slit, it becomes a source of secondary wavelets."

All the wavelets originating from slit AB are in same phase. These secondary waves reinforce each other resulting the central maximum intensity at O.

Consider a point P on the screen at which waves travelling in the direction make an angleθ with CO are brought to focus at P by the lens.
This point P will be of maximum or minimum intensity because the waves reaching P will cover unequal distance.
Draw AN perpendicular to the direction of diffraction rays from A,
BN is the difference between the secondary waves coming from A and B,
From ΔABN

$$\sin\theta = \frac{BN}{AB}$$
$$BN = AB \sin\theta$$
$$= d \sin\theta$$

POSITIONS OF SECONDARY MINIMA

If BN = λ d $\sin\theta = \lambda$ $\theta = \theta 1$ then $\sin\theta 1 = \frac{\lambda}{d}$

Such a point on the screen will be the position of first secondary minimum,

If BN =2 λ d $\sin\theta = 2\lambda$ $\theta = \theta 2$ then $\sin\theta 2 = \frac{2\lambda}{d}$

Such a point on the screen will be the position of second secondary minimum

For nth minimum

Then $\sin\theta n = \frac{n\lambda}{d}$; n = ±1±2±3…

POSITIONS OF SECONDARY MAXIMA

d sin θ =(2n+1)$\frac{\lambda}{2}$

$\theta = \theta 1$’ then d $\sin\theta 1' = \frac{3\lambda}{2}$

then $\sin\theta 1' = \frac{3\lambda}{2d}$

Such a point on the screen will be the position of first secondary maximum.

$\theta = \theta 2'$ d $sin\theta 2' = \frac{5\lambda}{2}$

then $\sin\theta 2' = \frac{5\lambda}{2d}$

Such a point on the screen will be the position of second secondary maximum

For nth maximum

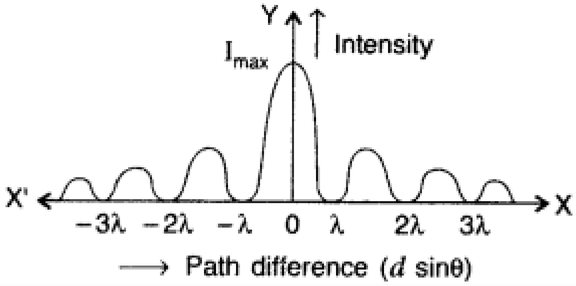
then $\sin\theta n' = \frac{(2n+1)\lambda}{2d}$; n = ±1±2±3…2

Central bright fringe spared between the first dark fringes on either side
Width of central bright fringe is the distance between the centres of first dark fringe on either side.
Width of central bright fringe = $\frac{2\lambda D}{d}$

Angular width of central bright fringe = $\frac{2\lambda}{d}$

D is the distance of the slit from the screen
, d is the slit width.

1. The intensity plot looks as follows, with there being a bright central maximum, followed by smaller intensity secondary maxima, with there being points of zero intensity in between, whenever $d\sin\theta = n\lambda, n \neq 0$
2. Width of central maximum is directly proportional to wavelength of light and inversely proportional to the width of the slit.



Important Points

(a) A soap bubble or oil film on water appears coloured in white light due to interference of light reflected from upper and lower surfaces of soap bubble or oil film.

(b) In interference fringe pattern all bright and dark fringes are of same width,

(c) In diffraction fringe pattern central bright fringe is brightest and widest. and I remaining secondary maximas are of gradually decreasing intensities.

(d) The difference between interference and diffraction is that the interference is the superposition between the wavelets coming from two coherent sources while the diffraction is the superposition between the wavelets coming from the single wavefront

MULTIPLE CHOICE QUESTIONS(1 MARK)

1. Monochromatic yellow light is replaced with red light. The liner width of central bright fringe in diffraction at a single slit

   (a) Increases because $\lambda_{red}<\lambda_{yellow}$ (b) Decreases because $\lambda_{red}>\lambda_{yellow}$

   (c)Increases because $\lambda_{red}>\lambda_{yellow}$ (d) Decreases because $\lambda_{red}<\lambda_{yellow}$

2. To demonstrate the phenomenon of interference we require two sources which emit radiation of
   (a) Nearly same frequency (b) The same frequency
   (c)Different wavelength (d) The same frequency and having definite phase relationship
3. Which of the following cannot be explained on the basics of wave nature of light?
   (a) Polarisation (b) Diffraction
   (c) Photoelectric effect (d) Interference
4. The wave front of distant source of unknown shape is approximately
   (a) Spherical (b) Cylindrical (c)Elliptical (d) plane
5. In young's double slit experiment the slit separation is 0.2cm, the distance between the screen and the slit is 1m, wavelength of light used is 5000A0. The fringe width in mm is
   (a) 0.25 (b)0.26 (c)0.27 (d)0.28
6. If young's double slit experiment of light is performed in water which of the following is correct
   (a) Fringe width will decrease (b)Fringe width will increase
   (c)There will be no fringe (d)Fringe width will remain unchanged

7. A beam of light of wavelength 600nm from a distance source fall on a single slit 1mm wide and the resulting diffraction pattern is observed on a screen 2m away. The distance between the 1st dark fringes on either side of the central bright fringe is
   (a) 1.2cm (b) 1.2mm (c)2.4cm (d)2.4 mm
8. Ratio of intensities of two waves are given by 4:1. Then ration of the amplitude of the two wave is
   (a) 2:1 (b)1:2 (c)4:1 (d) 1:4
9. The locus of all particles in a medium vibrating in the same phase is called
   (a) Fringe (b) Wavelet (c)Wavefront (d) All the above
10. Which of the following factor does the intensity of light depend on?
   (a) Frequency (b) Wavelength (c)Amplitude (d)Velocity

11. What happens to the interference pattern; the two slits S1 and S2 in young's double slit experiment are illuminated by two independent but identical sources?
    (a) The intensity of the bright fringe doubled. (b) The intensity of the bright fringes becomes 4 times.

    (c)Two sets of interference fringes overlap (d) No interference pattern is observed

12. A diffraction pattern is obtained by using a beam of red light. What will happen if the red light is replaced by blue light
    (a) Bands disappear (b)Bands become broader and farther apart

    (c)No change will take place (d) Diffraction bands become narrower and crowded

13. Two coherent sources are used to obtain interference pattern on the screen D m away from the slit separated by distance d. A maximum is obtained when the path difference between the interfering wave is
(a) nλ (b) n$\frac{\lambda}{2}$ (c)(2n+1) $\frac{\lambda}{2}$ (d) (2n-1) $\frac{\lambda}{4}$
14. A minimum is obtained when the phase difference of the superposition waves is
    (a) nπ (b)(n+1/2) π (c)(2n+1) π (d)Zero
15. The fringe width β of a diffraction pattern and the slit width d are related as
    (a) $\beta \propto$ d (b)$\beta \propto$ 1/d $(c)\beta \propto \sqrt{d}$ (d)$\beta \propto 1/d^2$
16. A phase difference of 5π corresponds to a path difference of (in terms of λ)
    (a) 5 λ (b)10 λ (c)5$\frac{\lambda}{2}$ (d)2 λ
17. A monochromatic light is refracted from air to a glass of refractive index μ. The ratio of the wavelength of the incident and the refracted wave is
    (a) $1{:}\,\mu$ $(b) 1{:}\,\mu^2$ $(c) \mu{:}\,1$ $(d) \mu^2{:}\,1$
18. Huygens's principle of secondary wavelet may be used to
    (a) Find the velocity of the light in vacuum (b) Explain the particles behaviour of light
    (c)Find the new position of a waveform (d) Explain photoelectric effect
19. In the phenomenon of interference energy is
    (a) Destroyed at destructive interference (b) Created at constructive interference
    (c)Conserved but it is redistributed (d)Same at all points
20. The reason of interference is

    (a)Phase difference (b)Change of amplitude (c)Change of velocity (d)Intensity

21. From a single slit the first diffraction minima is obtained at 30^0 for a light of 6500A^0 Wavelength. The width of the slit is
    (a) 3250A^0 (b)1.3 μm (c)5.4 X 10^{-4} km (d)1.2X 10^{-2} cm
22. Two disturbances arriving at a point on the screen kept at a distance D from two coherent source have a phase difference of $/2$. The intensity at this point is (assume that intensity of each source id I_o.
    (a) 4 I_o (b)2 I_o (C)1/2 I_o (d)1/4 I_o
23. The ratio of intensities of two points P and Q on a screen in Young's double slit experiment when waves from sources S1 and S2 have phase difference of $\pi/3$ and $\pi/2$ is
    (a) 3:1 (b)2:1 (c)3/2:1 (d)3:2
24. Light waves from two coherent sources arrive at two points P and Q on a screen with path difference of 0 ad $\frac{\lambda}{2}$ the ratio of intensities at the point I_P:I_Q is
(a) 2:1 (b) 4:0 (c)1:2 (d)0:1/2
25. The phase difference between two light waves reaching a point is $\pi/2$. The resultant amplitude if the individual amplitude are 3mm and 4mm is
    (a) 7mm (b)5mm (c)1mm (d)None of the above

Answers :1-c,2-d,3-c,4-d,5-a, 6-a,7-d,8-a,9-c,10-c,11-d, 12-d,13-a,14-c,15-b,16-c,17-c,18-c,19-c, 20-a,21-b,22-b,23-d,24-b, 25-b.

ASSERSION AND REASON TYPE QUESTIONS

Directions: These questions consist of two statements, each printed as Assertion and Reason. While answering these questions, you are required to choose any one of the following four responses.

(a) If both Assertion and Reason are true and the Reason is a correct explanation of the Assertion.

(b) If both Assertion and Reason are true but Reason is not a correct explanation of the Assertion.

(c) If the Assertion is true but Reason is false.

(d) If both the Assertion and Reason are incorrect.

1.Assertion: No interference pattern is detected when two coherent sources are infinitely close to each other
Reason: The fringe width is inversely proportional to the distance between the two sources.

2. Assertion: Interference pattern is made by using yellow light instead of red light, the fringes become narrower.
Reason: In Young's double experiment slit fringe width is given by $\beta = \lambda D/d$

3.Assertion: Coloured spectrum is seen when we look through a muslin cloth.
Reason: It is due the diffraction of white light on passing through fine slits.

4. **Assertion:** Diffraction takes place for all types of waves mechanical or non-mechanical, transverse or longitudinal.
Reason: Diffraction's effect are perceptible only if wavelength of wave is comparable to dimensions of diffracting device.

5.Assertion (A): Interference obeys the law of conservation of energy.
Reason (R): The energy is redistributed in case of interference

6. **Assertion (A):** Diffraction is common in sound but not common in light waves.
Reason (R): Wavelength of light is more than the wavelength of sound

7. **Assertion (A):** We cannot get diffraction pattern from a wide slit illuminated by monochromatic light.
Reason (R): In diffraction pattern, all the bright bands are not of the same intensity.

8. **Assertion (A) :** The maximum intensity in interference pattern is four times the intensity due to each slit.
Reason (R): Intensity is directly proportional to square of amplitude.

9.**Assertion:** In Young's experiment, the fringe width for dark fringes is different from that for white fringes.
Reason: In Young's double slit experiment the fringes are performed with a source of white light then only black and bright fringes are observed.

10. **Assertion (A) :** One of the condition for interference is that the two source should be very narrow.
Reason (R) : One broad source is equal to large number of narrow source.

Answers : 1-a,2-a,3-a,4-b,5-a,6-c,7-b, 8-a, 9-d, 10 –a.

TWO MARKS QUESTIONS

1.How does the fringe width of interference fringes change, when the whole apparatus of Young's experiment is kept in a liquid of refractive index 1.3?

$$\beta_{air} = \frac{\lambda D}{d}$$

In water, $\lambda_\omega = \frac{\lambda_a}{1.3}$ ...where [λ_ω = wavelength in water and λ_a = wavelength in air

$$\beta_{water} = \frac{\lambda_\omega D}{d} = \frac{\lambda_a D}{\mu d} = \frac{\beta_{air}}{1.3}$$

...where [μ = refractive index]

2.How does the angular separation between fringes in single-slit diffraction experiment change when the distance of separation between the slit and screen is doubled?

$$\theta = \frac{\lambda}{d}$$

where [θ is the angular separation.]

When the distance D of separation between the slits and the screen is doubled, the angular separation θ remains unchanged.

3.How does the fringe width, in Young's double-slit experiment, change when the distance of separation between the slits and screen is doubled?

If the distance between slits and screen (D) is doubled, the fringe width in double slit experiment will become double as $x = \frac{D\lambda}{2d}$

$$\Rightarrow \quad x \propto D$$

4.Write the distinguishing features between a diffraction pattern due to a single slit and the interference fringes produced in Young's double slit experiment?

No	Interference of light	Diffraction of light
1	Interference is due to superposition of two distinct waves coming from two coherent sources.	Diffraction is due to superposition of the secondary wavelets coming from different sf parts of the same wavefront.
2	Interference fringes are of the same width.	Diffraction fringes are not to be of the same width.
3	The intensity of minima is zero.	The intensity of minima is never zero.

5.Draw the intensity pattern for single slit diffraction and double slit interference.
Refer -Minimum Learning Material.
6.State the reason, why two independent sources of light cannot be considered as coherent sources.
Two independent sources of light cannot be coherent. This is because light is emitted by individual atoms, when they return to ground state. Even the smallest source of light contains billions of atoms which obviously

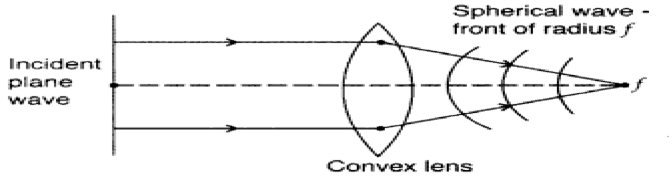
Angular separation, $\theta = \frac{\lambda}{d}$ $\therefore$ $\theta \propto \frac{1}{d}$

cannot emit light waves in the same phase.

7.How does the angular separation of interference fringes change in Young's experiment, if the distance between the slits is increased?

When separation between two slits is increased, angular separation decreases

8. Draw a diagram to show refraction of a plane wave front incident in a convex lens and hence draw the refracted wave front.



9.How does the angular separation between fringes in single-slit diffraction experiment change when the distance of separation between the slit and screen is doubled?

When the distance D of separation between the slits and the screen is doubled, the angular separation θ remains unchanged.

$\theta = \frac{\lambda}{d}$ **where [θ is the angular separation.]**

10. Yellow light (λ = 6000Å) illuminates a single slit of width 1 x 10^{-4} m. Calculate

(i) the distance between the two dark lines on either side of the central maximum, when the diffraction pattern is viewed on a screen kept 1.5 m away from the slit;

(ii) the angular spread of the first diffraction minimum.

(i) Distance between two dark lines, on either

$$\text{side of central maxima} = 2\frac{\lambda D}{a}$$

$$= \frac{2 \times 6000 \times 10^{-10} \times 1.5}{1 \times 10^{-4}} = 18000 \times 10^{-6}$$

$$= 18 \times 10^{-3}\text{m} = \mathbf{18\ mm}$$

11. What is a sustained interference pattern ? State the necessary conditions for obtaining a sustained inference of light .

Interference pattern in which the positions of maxima and minima on observation screen do not change with time . **Conditions are :**

1.The two sources should continuously emit waves of same frequency or wavelength.

2.The two sources should be coherent, 3. The two sources should be narrow &4The two sources should be monochromatic.

SECTION C (3 Mark)

1.In a single slit diffraction experiment, the width of the slit is reduced to half its original width. How would this affect the size and intensity of the central maximum?

$$\beta = \frac{\lambda D}{d}$$

$$\therefore \quad \beta' = \frac{\lambda D}{d} = \frac{2\lambda D}{d} = 2\beta$$

As width reduces to half, *i.e.*, $d' = \dfrac{d}{2}$

Size becomes twice and intensity $I = a^2$

$$\therefore \quad I' = \left(\frac{a}{2}\right)^2 = \frac{1}{4}a^2 = \frac{1}{4}\mathbf{I}$$

2.Yellow light (λ = 6000Å) illuminates a single slit of width 1 x 10-4 m. Calculate

(i) the distance between the two dark lines on either side of the central maximum, when the diffraction pattern is viewed on a screen kept 1.5 m away from the slit;

(ii) the angular spread of the first diffraction minimum.

(i) Distance between two dark lines, on either

side of central maxima $= 2\dfrac{\lambda D}{a}$

$$= \frac{2 \times 6000 \times 10^{-10} \times 1.5}{1 \times 10^{-4}} = 18000 \times 10^{-6}$$

$$= 18 \times 10^{-3}\text{m} = \mathbf{18\ mm}$$

(ii) Angular spread of the first diffraction minimum (on either side)

$$= \theta = \frac{\lambda}{a} = \frac{6 \times 10^{-7}}{1 \times 10^{-4}} = \mathbf{6 \times 10^{-3}\ radians}$$

3.A parallel beam of light of 500 nm falls on a narrow slit and the resulting diffraction pattern is observed on a screen 1 m away. It is observed that the first minimum is at a distance of 2.5 mm from the centre of the screen. Calculate the width of the slit.

Given, $\lambda = 500\ \text{nm} = 500 \times 10^{-9}\ \text{m}$, $\quad D = 1$

$x_n = 2.5\ \text{mm} = 2.5 \times 10^{-3}\ \text{m} \quad n = 1$

$$\frac{x_m d}{D} = n\lambda$$

$$d = \frac{n\lambda D}{x_n}$$

$$d = 1 \times (500 \times 10^{-9}) \times \frac{1}{2.5 \times 10^{-3}} = 2 \times 10^{-4}\ \text{m}$$

4. In a single slit diffraction experiment, a slit of width ‘d’ is illuminated by red light of wavelength 650 nm. For what value of ‘d’ will

(i) the first minimum fall at an angle of diffraction of 30°, and

(ii) the first maximum fall at an angle of diffraction of 30°?

(b) Why does the intensity of the secondary maximum become less as compared to the central maximum? (Al

India 2009)

(a) (i) I minimum at 30° satisfies the condition,

$$d \sin \theta = \lambda$$

$$d = \frac{\lambda}{\sin 30^\circ} = 2 \times \lambda = \mathbf{1300\ nm}$$

(ii) I maxima at 30° satisfies the condition,

$$d \sin \theta = \frac{3\lambda}{2}$$

$$\therefore \quad d = 3 \times \frac{\lambda}{2 \sin 30^\circ} \Rightarrow 3\lambda = 2d \sin 30^\circ$$

$$\Rightarrow \quad 3 \times 650 = 2d \sin 30^\circ$$

$$\Rightarrow \quad 2d \times \frac{1}{2} = 1950$$

$$\therefore \quad d = \mathbf{1950 \times 10^{-9}\ nm}$$

5.In a single slit diffraction experiment, the width of the slit is reduced to half its original width. How would this affect the size and intensity of the central maximum?

$$\beta = \frac{\lambda D}{d}$$

$$\therefore \quad \beta' = \frac{\lambda D}{d} = \frac{2\lambda D}{d} = 2\beta$$

As width reduces to half, *i.e.*, $d' = \frac{d}{2}$

Size becomes twice and intensity $I = a^2$

$$\therefore \quad I' = \left(\frac{a}{2}\right)^2 = \frac{1}{4}a^2 = \frac{1}{4}\mathbf{I}$$

6.In Young’s double slit experiment, mono-chromatic light of wavelength 600 nm illuminates the pair of slits and produces an interference pattern in which two consecutive bright fringes are separated by 10 mm. Another source of monochromatic light produces the interference pattern in which the two consecutive bright fringes are separated by 8 mm. Find the wavelength of light from the second source. What is the effect on the interference fringes if the monochromatic source is replaced by a source of white light?

Answer:

$\lambda_1 = 600$ nm, $\beta_1 = 10$ mm, $\beta_2 = 8$ mm

Since $\beta = \frac{\lambda D}{d} \quad \Rightarrow \frac{\beta_2}{\beta_1} = \frac{\lambda_2}{\lambda_1}$

$$\Rightarrow \quad \lambda_2 = \frac{\beta_2}{\beta_1} \times \lambda_1 \quad \Rightarrow \lambda_2 = \frac{8}{10} \times 600 = \mathbf{480\ nm}$$

Effect: When the monochromatic light is replaced by a white light:

(i) the central bright remains white and

(ii) all the other colours will form individual maximas with the least wavelength violet forming its bright close to the central bright.

7. (a) The ratio of the widths of two slits in Young’s double slit experiment is 4 : 1. Evaluate the ratio of intensities at maxima and minima in the interference pattern.

(b) Does the appearance of bright and dark fringes in the interference pattern violate, in any way, conservation of energy?

(a) Given : $\frac{w_1}{w_2} = \frac{4}{1}$

$$\frac{w_1}{w_2} = \frac{a_1^2}{a_2^2} = \frac{4}{1} \qquad \therefore \frac{a_1}{a_2} = \frac{2}{1} = 2$$

We know, $\frac{I_{max}}{I_{min}} = \frac{(I_1 + I_2)}{(I_1 - I_2)} = \left(\frac{a_1 + a_2}{a_1 - a_2}\right)^2$

Dividing both numerator and denominator by a_2, we get

$$\left(\frac{\frac{a_1}{a_2} + 1}{\frac{a_1}{a_2} - 1}\right)^2 = \left(\frac{2+1}{2-1}\right)^2 = \frac{9}{1} \quad \therefore \frac{\mathbf{I_{max}}}{\mathbf{I_{min}}} = \frac{\mathbf{9}}{\mathbf{1}}$$

(b) The appearance of bright and dark fringes in the interference pattern does not violate the principle of conservation of energy, because the light energy is distributed. If it reduces in one region, producing a dark fringe, it increases in another region, producing a bright fringe. There is no gain or loss of energy.\

SECTION D (5 mark)

1.A plane wavefront is incident at an angle of incidence i on a reflecting surface. Draw a diagram showing incident wavefront, reflected wavefront and verify the laws of reflection.

Refer – Minimum learning Material.

2.(a) State Huygens's principle. Using this principle draw a diagram to show how a plane wave front incident at the interface of the two media gets refracted when it propagates from a rarer to a denser medium. Hence verify Snell's law of refraction.

(b) When monochromatic light travels from a rarer to a denser medium, explain the following, giving reasons:

(i) Is the frequency of reflected and refracted light same as the frequency of incident light?

(ii) Does the decrease in speed imply a reduction in the energy carried by light wave?

(a) Refer – Minimum learning Material

(b) (i) Yes, frequency is the property of source. Hence, frequency does not change when light is reflected or refracted.

(ii) No, decrease in speed does not imply reduction in energy carried by light wave.This is because the frequency does not change and according to the formula E = hv, energy will be independent of speed. Energy carried by a wave depends on the amplitude of the wave, not on the speed of wave propagation.

3.Describe briefly how a diffraction pattern is obtained on a screen due to a single narrow slit illuminated by a monochromatic source of light. Hence obtain the conditions for the angular width of secondary maxima and secondary minima.

Refer – Minimum learning Material

SECTION-E (CASE STUDY)

(1)Diffraction effect is more pronounced if the size of the obstacle or aperture is of the order of the wavelength of the wave. The wavelength of light is much smaller than the size of the objects. But sound wave has large wavelength.If a plane wave front is incident on a narrow rectangular slit of width a, according to Huygens' principle all parts of the incident wave front is the source of secondary wavelets which starts in the same phase

The wavelets spread out in all directions thus passing diffraction of light which can be focused by a convex lens on a screen placed at its focal plane.All the secondary wavelets going straight across the slit AB are focused at the centre point O of the screen. They meet at the same phase. They add constructively to produce a central bright fringe.But the secondary wavelets diffracted at an angle θ reach any point P in different phases.

The directions of 1st minima on either side of central maximum are

$$\theta = \frac{\lambda}{a}$$

1. The secondary waves focused at the central point O of the screen produce central bright fringe. Why?
2. Plot a graph between the intensities of maxima and minima against the diffraction angle θ in the diffraction at a single slit.
3. (i)Define angular width of central maximum.

(ii)How does the angular width of central maximum change when

(a)slit width is increased

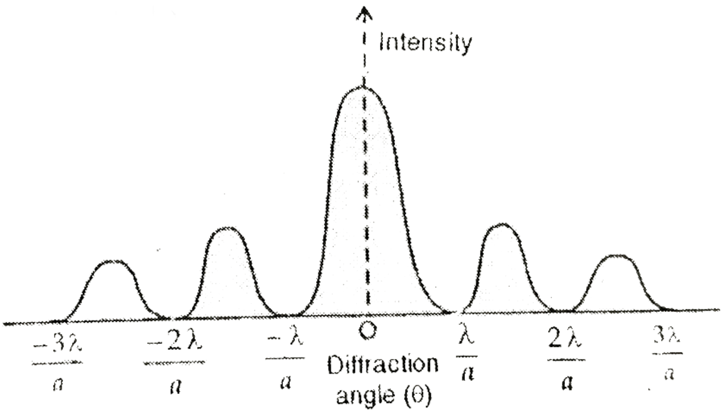
(b)light of smaller visible wavelength is used

(OR)

(i) Define linear width of central maximum

(ii) How is the width of central maxima affected if

(a) the width of the slit is doubled



(b) wavelength of the light used is increased

(c) if the whole apparatus is immersed in water.

Answers:

1) The two waves have zero path difference. They undergo constructive interference producing central bright fringe.
2) (i) Angular width of central maximum = $2\,\theta = 2\,\frac{\lambda}{a}$

(ii)(a) when a increases angular width decreases

(b) if λ decreases angular width (OR)

(i)Linear width of central maximum $=2\frac{\lambda D}{a}$

The distance between first minima on both sides of central maxima.

(ii)(a) if the width of the slit is doubled width of central maximum is halved

(b) if λ increases width of central maximum increases.

(c) wavelength of light in water decreases so width of central maximum also decreases.

2. Young's double slit experiment uses two coherent sources of light placed at a small distance apart. The light from these slits falls on a screen which is at a distance D from the position of slits S1 and S2 d is the separation between the two slits. Interference pattern appears on the screen. The waves from a S1 and S2 travel equal distance to reach the point O the central point which is equidistant from S1 and S2. The path difference for these waves is zero. There will be a central bright fringe at O. but as we move from O upwards or downwards, alternate bright and dark fringe are formed. Fringe width β is the separation between two successive bright or dark fringes. β is independent of the order of fringe (n).

In case of light λ is extremely small. D should be much larger than d so that the fringe width β may be appreciable.

1) State the principle of superposition of waves.
2) Draw the graph showing the variation of intensity in the interference pattern in young's double slit experiment with the distance from the centre O (y).

3) What will be the effect on the interference fringes in young's double slit experiment when
   (a) Separation between the slits is increased.
   (b) Monochromatic source is replaced by source of white light. (OR)

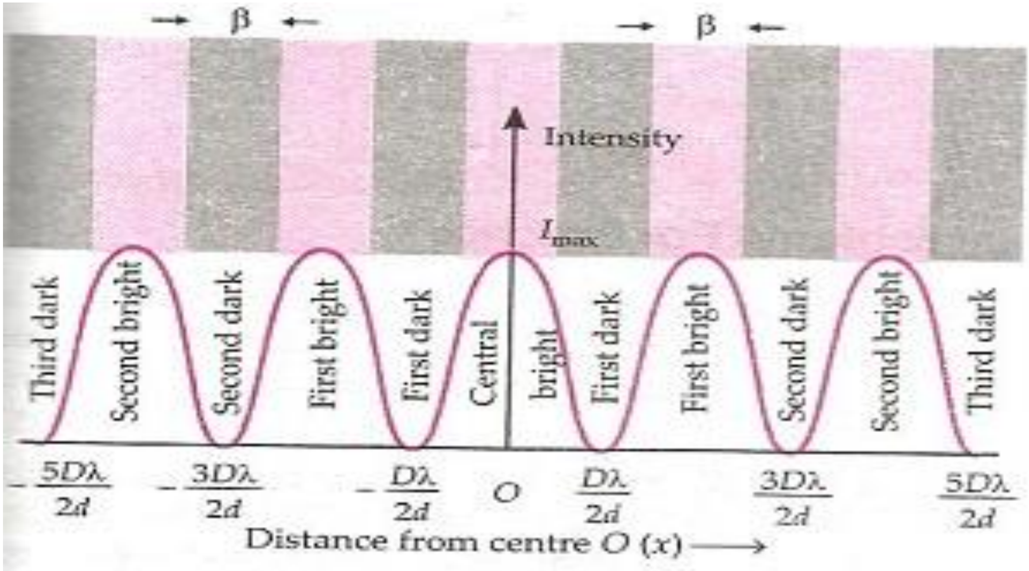
(a) Two waves from S1 and S2 have a phase difference ϕ. If Δx is the path difference between the two waves, write the relation between phase difference and the path difference.

(b) Obtain the ration of the interference fringe width $\beta 1$ and $\beta 2$ obtained with monochromatic red light of $\lambda 1 = 660nm$ and ultraviolet light of $\lambda 2 = 330nm$

Answers:

(1) When a number of waves travelling through a medium superpose on each other the resultant displacement at any point at a given instant is equal to the vector sum of the displacements due to the individual waves at that point.

(2)



(3) (a) Fringe width $\beta = \frac{\lambda D}{d}$

$\beta \; \alpha \; \frac{1}{d}$ $\quad$ β decreases when d increases

(b) central bright fringe is white .The closest fringe on either side of white fringe is violet (smallest wavelength).Farthest fringe is red.

(a) $\emptyset = \frac{2\pi}{\lambda}\ \Delta x$

(b) $\frac{\beta_1}{\beta_2} = \frac{\lambda_1}{\lambda_2} = \frac{660}{330} = \frac{2}{1}$

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Unit VII: Dual Nature of Radiation and Matter
Chapter–11:
Dual Nature of Radiation and Matter

S.NO.	FORMULAE	SYMBOL	APPLICATIONS
1	$E = h\nu = h\frac{c}{\lambda}$	E= energy of photon, h= Plank's constant, ν = frequency	To find the energy of photon
2	$W_0 = h\nu_0 = hc/\lambda_0$	W_0 = work function ν_0 = threshold frequency λ_0= threshold wavelength	Relation between work function and ν_0 , λ_0.
3	$K_{max} = \frac{1}{2} m\, v_{max}{}^2$ $= h\nu - W_0$ $= h(\nu - \nu_0)$	K_{max} = Maximum kinetic energy of emitted electrons V_{max} = maximum velocity	Einstein's photoelectric equation.
4	$K_{max} = \frac{1}{2} m\, v_{max}{}^2 = eV_0$	e = charge of electron V_0 = stopping potential	Relation between maximum kinetic energy and stopping potential.
5	$\lambda = \frac{h}{mv}$ or $\lambda = \frac{h}{p}$	λ = wave length of matter wave h = Plank's constant	De Broglie wavelength for matter wave.
6	$\lambda = \frac{h}{\sqrt{2mE}} = \frac{h}{\sqrt{2mqV}}$	E = kinetic energy V = accelerating potential	Relation between λ and E , V.
7	$\lambda = \frac{h}{\sqrt{2meV}}$, $\lambda = \frac{12.27}{\sqrt{V}}$ A^0	V = accelerating potential	De Broglie wavelength for electron

STUDY MATERIAL

Electron Emission :

It is the phenomenon of emission of electron from the surface of a metal. The electron emission can be obtained from the following process

(i) Thermionic ,(ii)Photoelectric emission & (iii)Field emission

Photon

Photons are the packets of energy emitted by a source of radiation. The energy of each photon is, E = hν

Where h is Planck's constant and ν is frequency of radiation.

The rest mass of a photon is zero & The momentum of a photon p = hν / c = h / λ

Dynamic or kinetic mass of photon m = hν / c^2 = h / cλ where c is speed of light in vacuum and λ is wavelength of radiation. Photons are electrically neutral.

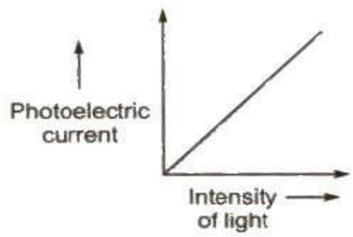
A body can radiate or absorb energy in whose number multiples of a quantum hν, 2hν, 3hν …. nhν, where n is positive integer.

Photoelectric Effect :

The phenomena of emission of electrons from a metal surface, when radiations of suitable frequency is inciden on it, is called photoelectric effect.

Work Function(φ) The minimum amount of energy required to eject one electron from a metal surface, is called its work function.
Threshold Frequency (v_o) The minimum frequency of light which can eject photo electron from a metal surface is called threshold frequency of that metal.
Threshold Wavelength (λ_{max}) The maximum wavelength of light which can eject photo electron from a metal surface is called threshold wavelength of that metal. Relation between work function, threshold frequency and threshold wavelength $\varphi = hvo = hc / \lambda max$

Laws of Photoelectric Effect



1. For a given metal and frequency of incident light, the photo electric current (the rate of emission of photoelectrons) is directly proportional to the intensity of incident light.
2. For a given metal. there is a certain minimum frequency, called **threshold frequency**, below which there is no emission of photo electrons takes place.
3. Above threshold frequency the maximum kinetic energy of photo electrons depends upon the frequency of incident light.
4. The photoelectric emission is an instantaneous process.

Einstein's Photoelectric Equation

The maximum kinetic energy of photoelectrons $\mathbf{(E_k)_{max} = hv - \varphi = h(v - v_o)}$
where v is frequency of incident light and v_o is threshold frequency.

Stopping Potential

The minimum negative potential given to anode plate at which photoelectric current becomes zero is called stopping potential (V_o).
Maximum kinetic energy of photo electrons
$(E_k)_{max} = 1 / 2\, mv^2_{max} = eV_o$

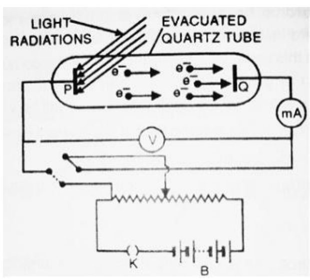
Hertz' Observation

The phenomenon of photo electric emission was discovered in 1887 by Heinrich Hertz during his electromagnetic wave experiment. In his experimental investigation on the production of electromagnetic waves by means of spark across the detector loop were enhanced when the emitter plate was illuminated by ultraviolet light from an arc lamp.

Lenard's Observation

Lenard observed that when ultraviolet radiation were allowed to fall on emitter plate of an evacuated glass tube enclosing two electrodes, current flows. As soon as, the ultraviolet radiations were stopped, the current flows also stopped. These observations indicate that when ultraviolet radiations fall on the emitter plate, electrons are ejected from it which are attracted towards the positive plate by the electric field.

Experimental study of photoelectric effect

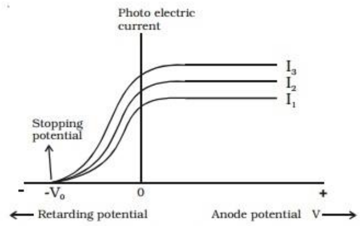


The apparatus consists of an evacuated quartz tube in which two plates P and Q called as cathode and anode are fitted. The plate Q can be given a desired positive or negative potential, using the arrangement as shown.
Voltmeter V, measures the potential difference between the plates P and Q whereas milliammeter (mA) measures the photoelectric current in the circuit.
When light rays of suitable frequency fall on plate P, the photoelectrons are

emitted. If the plate Q is kept at a positive potential, then these electrons get accelerated towards plate Q and hence, photoelectric current flows through the circuit.

- **Effect of Intensity of Light on Photoelectric Current**

The frequency of incident light and the accelerating potential V of the anode are kept constant to evaluate the influence of incident light intensity on photoelectric current. The potential of A is kept positive about that of C, causing the electrons released by C to be drawn to A. The photoelectric current is then measured as the intensity of the incident light is altered. On the x-axis, light intensity is plotted against photocurrent on the y-axis. The number of electrons emitted each second, or photocurrent, is proportional to the intensity of the input light.

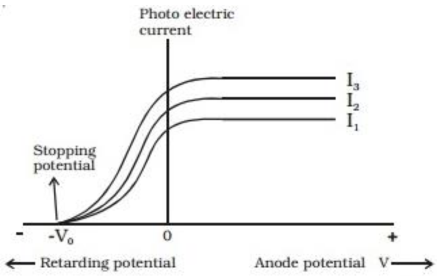


- **Effect of Potential Difference on the Photoelectric Current**

ic Energy of Photoelectron = (1/2) mv'^2_{max} ……….(i)
If e be the charge and V_0 be the stopping potential of the photoelectron, then, work done to stop the photoelectron = eV_0 ……….(ii)
From (i) and (ii),

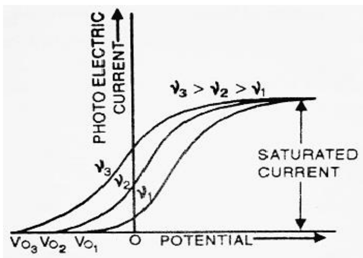
(1/2) $mv'^2_{max} = eV_0$

Thus, we can also conclude that the maximum velocity of emitted photoelectrons does not depend upon the intensity of incident light.

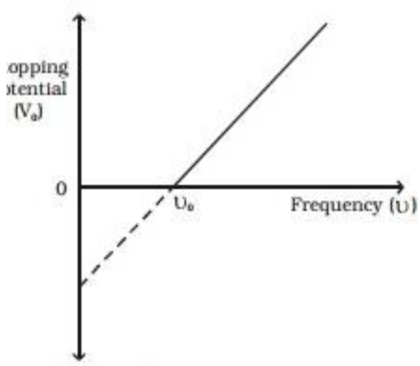


- **Effect of Frequency of Incident Radiation on Stopping Potential**

(a) Allow the light of some fixed intensity and of different frequencies to fall on plate P. Now, draw the graph between photoelectric current and potential of plate Q. We get the graph as shown in the figure.



From the graph, we note that, when we increase the frequency of incident light, the saturation current always remains the same whereas the stopping potential increases. Thus we conclude that the maximum velocity of emitted photoelectrons depends upon the frequency of incident light.
(b) If we plot the graph between stopping potential and frequency, we get a straight line as shown in the figure.
From the graph, it is clear that there is a certain minimum value of frequency (ν_0) below which no photoelectric emission is possible. This minimum value of frequency is called Threshold frequency.
In these experiments, it is found that, if incident light has a frequency greater than the threshold frequency, then photoelectric emission starts instantaneously.



Matter Waves or de-Broglie Waves:

A wave is associated with every moving particle, called matter or de-

Broglie wave.

de-Broglie Wavelength

If a particle of mass m is moving with velocity v, then wavelength of de-Broglie wave associated with it is given by $\lambda = h / p = h / mv$

de-Broglie wavelength of an electron is given by

$\lambda = h / mv = h / \sqrt{2meV} = 12.27 / \sqrt{V}$ A.

where, m = mass of electron, e = electronic charge and V = potential difference with which electron is accelerated.

The two characteristics of the matter wave are:

a. Lower the mass of the body, greater is the wavelength possessed by it.

b. Matter waves are not dependent on the charge present on the material particle.

MULTIPLE CHOICE QUESTIONS and ASSERTION-REASONING QUESTIONS

1. **Protons and alpha particles have the same de-Broglie wavelength. What is same for both of them ?**
   (a) Energy (b) Time period (c) Frequency (d) Momentum
2. **Protons and alpha particles have the same de-Broglie wavelength. What is same for both of them ?**
   (a) Energy (b) Time period (c) Frequency (d) Momentum
3. **The strength of photoelectric current depends upon :**
   (a) angle of incident radiation (b) frequency of incident radiation
   (c) intensity of incident radiation (d) distance between anode and cathode
4. **The momentum of an electron that emits a wavelength of 2 Å. will be:**
   (a) 6.4×10^{-36} $kgms^{-1}$ (b) 3.3×10^{-24} $kgms^{-1}$ (c) 3.3×10^{-34} $kgms^{-1}$ (d) none of these
   Which of the following radiations cannot eject photo electrons?
   (a) ultraviolet (b) infrared (c) visible (d) X-rays
5. **What is the de-Broglie wavelength of an electron accelerated from rest through a potential difference of 100 volts?**
   (a) 12.3 Å (b) 1.23 Å (c) 0.123 Å (d) None of these
6. **What is the de-Broglie wavelength of a proton accelerated from rest through a potential difference of V volts?**
   (a) $12.3/\sqrt{V}$ Å (b) 12.3/V Å (c) $12.2/V^2$ Å (d) None of these
7. **When a yellow light is incident on a surface, no electrons are emitted while green light can emit electrons. If the red light is incident on the surface then:**
   (a) no electrons are emitted (b) photons are emitted
   (c) electrons of higher energy are emitted (d) electrons of lower energy emitted
8. **The de-Broglie wavelength of particle of mass 1 mg moving with a velocity of 1 ms^{-1}, in terms of Planck's constant h, is given by (in metre):**
   (a) 10^5 h (b) 10^6 h (c) 10^{-3} h (d) 10^3 h
9. **Evidence of the wave nature of light cannot be obtained from:**
   (a) diffraction (b) interference (c) doppler effect (d) reflection
10. **The charge of a photo electron is :**
    (a) 9.1×10^{-31} C (b) 9.1×10^{-27} C (c) 9.1×10^{-24} C (d) none of these
11. **The number of photons of frequency n present in energy E, in terms of Planck's constant h:**
    (a) E/nh (b) nhE (c) nh/E (d) nE/h
12. **The different stages of discharge in a discharge tube can be explained on the basis of:**
    (a) the wave nature of light (b) the dual nature of light
    (c) wave nature of electrons
    (d) the collision between the charged particles emitted from the cathode the atoms of the gas in the tube
13. **De-Broglie equation states the:**
    (a) dual nature (b) particle nature (c) wave nature (d) none of these

14. **When an electron jumps across potential difference of 1 V, it gains energy equal to :**
(a) 1.602×10^{-19} J (b) 1.602×10^{19} J (c) 1.602×10^{24} J (d) 1 J

16 **. Light of frequency 1.9 times the threshold frequency is incident on a photosensitive material. If the frequency is halved and intensity is doubled, the photocurrent becomes**

a) doubled (b) quadrupled (c) halved (d) zero

17. For a metal having a work function W_0, the threshold wavelength is λ. What is the threshold wavelength for the metal having work function 2W0?

(a) λ/4 (b) λ/2 (c) 2λ (d) 4λ

18. **Radiation of frequency ν is incident on a photosensitive metal. When the frequency of the incident radiation is doubled, what is the maximum kinetic energy of the photoelectrons?**

a) 4E (b) 2E (c) E + hν (d) E – hν

19.. **Calculate the de Broglie wavelength associated with the electron which has a kinetic energy of 5 eV.**

a.) 5.47 Å (b) 2.7 Å (c) 5.9 Å (d) None of the above

20.De-Broglie equation states the:
(a) dual nature (b) particle nature (c) wave nature (d) none of these

Anwers : 1-d, 2-c, 3 –b, 4-b, 5-a , 6-b, 7-a , 8-b , 9-b, 10-d, 11-d, 12 –a, 13- d, 14-a, 15-a , 16- a ,17 –b, 18 –c, 19 –a , 20 –a ..

Assertion & Reason Questions

The following questions consist of two statements – Assertion (A) and Reason (R). Answer these questions selecting the appropriate option given below:
(a) Both A and R are true and R is the correct explanation of A.
(b) Both A and R are true but R is not the correct explanation of A.
(c) A is true but R is false.
(d) A is false and R is also false.

Q1. **Assertion (A) :** Photoelectric effect demonstrates the wave nature of light.
Reason (R) : number of photoelectrons is proportional to frequency of light

Q2. **Assertion (A) :** The de-Broglie wavelength of particle having kinetic energy K is l. If its kinetic energy becomes 4 K then its new wavelength would be l/2.
Reason (R) : The de-Broglie wavelength l is inversely proportional to square root of the kinetic energy

Q3. **Assertion (A) :** There is a physical significance of matter waves.
Reason (R) : Both interference and diffraction occurs in it.

Q4. **Assertion (A) :** A photon has no rest mass, yet it carries definite momentum.
Reason (R) : Momentum of photon is due to its energy and hence its equivalent mass

Q5. **Assertion (A) :** Photosensitivity of a metal is high if its work function is small.
Reason (R) : Work function = hu0, where u0 is the threshold frequency

Q6. **Assertion :** The kinetic energy of photoelectrons emitted from metal surface does not depend on the intensity of incident photon.
Reason : The ejection of electrons from metallic surface is not possible with frequency of incident photons below the threshold frequency.

Q7. **Assertion :** Two photons of equal wavelength must have equal linear momentum.
Reason : Two photons of equal linear momentum will have equal wavelength.

Q8. **Assertion :**Two sources of equal intensity always emit equal number of photons in any time interval
Reason : Two sources of equal intensity may emit equal number of photons in any time interval.

Q9. **Assertion :** The photon behaves like a particle.
Reason : If E and P are the energy and momentum of the photon, then p = E / c .

Q10. **Assertion :** In an experiment on photoelectric effect, a photon is incident on an electron from one direction and the photoelectron is emitted almost in the opposite direction. It violate the principle of conservation of linear momentum.
Reason : It does not violate the principle of conservation of linear momentum.

Anwers : 1-d, 2-a, 3 –a, 4-a, 5-b , 6-b, 7-d , 8-d , 9-a, 10-d,

SHORT ANSWER TYPE QUESTIONS (Two marks each)

1**. In the wave picture in the wave picture of light, intensity of light is determined by the square of the amplitude of the wave. What determines the intensity in the photon picture of the light?**

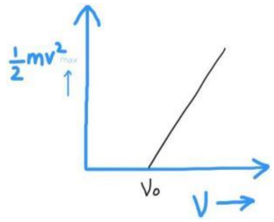
Ans 1.For a given frequency, intensity of light in the photon picture is determined by

I = (energy of photons) / (area×time)

= (n×hν) / (A×t) Where, n is the number of photons incident normally on crossing area A in time t .

2. **Write three basic properties of photons which are used to obtain Einstein's Photoelectric equation. Use this equation to draw a plot of maximum kinetic energy of the electrons emitted versus frequency of incident radiation.**

Ans 2. Three basic properties of photons are given as below:



i) photons are quanta or discrete carriers of energy.
ii) energy off of photon is proportional to the frequency of light.
iii)the photon gives all its energy to the electron with which it interacts.

3. In a Photoelectric effect why should the photoelectric effect current increase as the intensity of monochromate radiation incident on a photosensitive surface is increased? Explain.

Ans3.Photoelectric effect is one-photon-one-electron phenomenon. Therefore when the intensity of radiation incident on the surface increases, the number of photons by unit area increases (since intensity of incident radiation is directly proportional to the number of photons).in**tensity of incident radiation.**Hence, the photoelectron's ejected will be large, which in turn will contribute to the increase in photoelectric current.

4. **Show on a plot the nature of variation of photoelectric current with the intensity of radiation incident on a photosensitive surface.**

Refer Minimum Learning Materiala

5. The stopping potential in an experiment on Photoelectric effect is 1.5 volt. What is the maximum kinetic energy of the photo electrons emitted?

We know that at stopping potential, no electron reaches the plate, i.e. energy of electrons is compensated by energy equivalent to stopping potential.

KE max = eVo , where Vo = cut off potential ; KE max = 1.5 eV.

7. **An Alpha particle and proton are accelerated from rest by the same potential . find the ratio of their de-Broglie wavelengths.**

$\because$ de-Broglie wavelength,

$$\lambda = \frac{h}{\sqrt{2mK}} = \frac{h}{\sqrt{2mqV}} \qquad (\because K = qV)$$

Here, potential is kept constant. **(1)**

$$\Rightarrow \qquad \frac{\lambda_\alpha}{\lambda_p} = \sqrt{\frac{m_p q_p}{m_\alpha q_\alpha}}$$

$$= \sqrt{\left(\frac{m_p}{m_\alpha}\right)\left(\frac{q_p}{q_\alpha}\right)}$$

$$= \sqrt{\left(\frac{1}{4}\right)\left(\frac{1}{2}\right)}$$

$$\frac{\lambda_\alpha}{\lambda_p} = \frac{1}{2\sqrt{2}} \quad \Rightarrow \quad \lambda_\alpha : \lambda_p = 1 : 2\sqrt{2} \qquad \textbf{(1)}$$

8. Photoelectric work function of a metal is 1eV. Light of wavelength $3000A^{o}$ falls on it. What is the velocity of the effected photoelectron?

Ans. $\lambda = \frac{h}{m\upsilon} \; or \; m\upsilon = \frac{h}{\lambda}$

$$\Rightarrow K.E(E') = \frac{h^2}{2m\lambda^2} --- (2)$$

$$K.E = \frac{P^2}{2m}$$

$$\Rightarrow \frac{(K.E.)electron}{(K.E.)alpha} = \frac{m\alpha}{me} \begin{pmatrix} \because \lambda = \frac{h}{P} \\ \text{is same} \end{pmatrix}$$

9.The wavelength λ of a photon and debroglie wavelength of an electron have the same value. Show tha the energy of the photon is $\frac{2\lambda mc}{h}$ times the kinetic energy of electron where m, c, and h have their usual meanings?

Ans. Energy of a photon $E = h\nu = \frac{hc}{\lambda} ------ (1)$

Kinetic energy $E' = \frac{1}{2}m\upsilon^2 = \frac{m^2\upsilon^2}{2m} = \frac{(mv)^2}{2m}$ of an electron

But de-broglie wavelength of an electron is given by

$$\lambda = \frac{h}{m\upsilon} \; or \; m\upsilon = \frac{h}{\lambda}$$

$$\Rightarrow K.E(E') = \frac{h^2}{2m\lambda^2} --- (2)$$

Dividing (1) by (2)

$$\frac{E}{E'} = \frac{hc}{\lambda} \times \frac{2m\lambda^2}{h^2} = \frac{2m\lambda c}{h}$$

$$E = \left(\frac{2m\lambda c}{h} E'\right)$$

SHORT ANSWER TYPE QUESTIONS (3 marks each)

1. **Define the term "cut of frequency" in photoelectric emission. The threshold frequency of a metal is f. Then the light of frequency 2f is incident on the metal plate the maximum velocity of photoelectron**

is v1. When the frequency of the incident radiation is increased to 5f The maximum velocity of photoelectrons is V2. Find the ratio V1:V2 .

Ans 1. The minimum value of the frequency of light below which the photoelectric emissions tops completely, also ever large may be the intensity of light is called the cut of frequency. Given that threshold frequency of metal is f and frequency of light is 2f. Using Einstein's equation for photoelectric effect , We can write

$h(2f-f) = \frac{1}{2}mv1^2$ …(i) ;

Similarly , for light having frequency 5f , we have ; $h(5f-f)=\frac{1}{2}mv2^2$ …(ii)

USING EQUATIONS (i) and (ii) , we find

$f/4f = V1^2/V2^2$; $\Rightarrow V1/V2= 1/2$

2. Write Einstein's Photoelectric equation and point out any two characteristic properties of photons on which this equation is based. Briefly explain three observe features which can be explained by this equation.

Ans 2. **E = W + KE**. **hv = W + KE**. **KE = hv – w**. At the threshold frequency, ν_0 electrons are just ejected and do not have any kinetic energy. Below this frequency, there is no electron emission. The two characteristic properties of photons on which this equation is based are as follows

(I) Energy of photon is directly proportional to the frequency

(Ii) Total energy and momentum of the system of two constituent particles remain constant in photon-electron collision.

3. (i) State three properties of protons which describe the particle picture of electromagnetic radiation.

(ii) use Einstein's Photoelectric equation to define the terms

(a) Threshold frequency

(b) Stopping potential

Refer – Minimum Learning Material

4. The following table gives the values of work functions for a few sensitive metals.

S. No.	Metal	Work function(eV)
1.	Na	1.92
2.	K	2.15
3.	Mo	4.17

If each of these metals is exposed to radiations of wavelength 3300nm, which of these will not exit photoelectrons and why?

Ans. That material will not emit photoelectrons whose work function is greater than the energy of the incident radiation.

$$E = \frac{hc}{\lambda} = \frac{6.6\times10^{-34}\times3\times10^{8}}{33\times10^{-8}}$$

$$E = 6.20\times10^{-19} \text{ Joules}$$

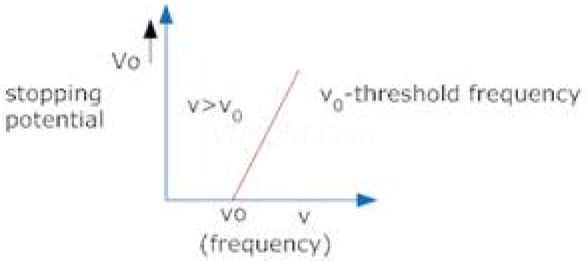
$$\Rightarrow E = \frac{6.20\times10^{-19}}{1.6\times10^{-19}eV}$$

E = 3.76 eV;Hence work function of M_o is (4.17eV) which is greater than the energy of the incident radiation (= 3.76 eV) so M_o will not emit photoelectrons.

5. **(a) Define photoelectric work function? What is its unit?**
(b) In a plot of photoelectric current versus anode potential, how does
(i) Saturation current varies with anode potential for incident radiations of different frequencies but same intensity?
(ii) The stopping potential varies for incident radiations of different intensities but same frequency.
(iii) Photoelectric current vary for different intensities but same frequency of radiations? Justify your answer in each case?

Refer – Minimum Learning Material

6. Draw a graph showing the variation of stopping potential with frequency of the incident radiations. What does the slope of the line with the frequency axis indicate. Hence define threshold frequency?

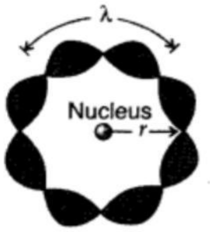


Ans. Slope of the graph $= \frac{\Delta v_o}{\Delta v}$
Einstein photoelectric equation
$eV_o = hv - \phi_o -----(1)$
Differentiating equation (1)
$e\Delta V_o = h\Delta v$
$$\frac{\Delta V_o}{\Delta v} = \frac{h}{e}$$
Thus slope is equal to the ratio of planck's constant to the charge on electron.
<u>Threshold frequency</u> – **Refer – Minimum Learning Material**

LONG ANSWER TYPE QUESTIONS (Five marks each)

1. **(a) Using de-Broglie's hypothesis, explain with the help of a suitable diagram, Bohr's second postulate of quantization of energy levels in a hydrogen atom.**
(b) The ground state energy of hydrogen atom is -13.6 eV. What are the kinetic and potential energies of the state?

(*a*) Consider the motion of an electron in a circular orbit of radius r around the nucleus of the atom. According to de-Broglie hypothesis, this electron is also associated with wave character. Hence a circular orbit can be taken to be a stationary orbit. If it contains an integral number of de-Broglie wavelength *i.e.*, $2\pi r_n = n\lambda$ ...$n = 1, 2, 3$



But de-Broglie wavelength $\lambda = \dfrac{h}{mv}$

$$\therefore \quad 2\pi r = \frac{nh}{mv}$$

The angular momentum C of the electron must be

$$L = mvr = \frac{nh}{2\pi} \qquad \text{...Here } [n = 1, 2, 3 \ldots$$

The electrons are permitted to circulate only in those orbits in which the angular momentum of an electron is an integral multiple of $\dfrac{h}{2\pi}$; h being Planck's constant.

(*b*) Total energy, $E = -13.6$ eV

(*i*) *Kinetic energy* : $T = -E = -(-13.6)$ eV $= \mathbf{13.6\ eV}$

(*ii*) *Potential energy* : $V = -2T = -2 \times 13.6$ eV $= \mathbf{-27.2\ eV}$

2.Write Einstein's photoelectric equation. State clearly how this equation is obtained using the photon picture of electromagnetic radiation. Write the three salient features observed in photoelectric effect which can be explained using this equation.

Refer – Minimum Learning Material

3. Define the terms
(i) 'cut-off voltage' and
(ii) 'threshold frequency' in relation to the phenomenon of photoelectric effect.
Using Einstein's photoelectric equation show how the cut-off voltage and threshold frequency for a given photosensitive material can be determined with the help of a suitable plot/graph.

Refer – Minimum Learning Material

4,(a) Why photoelectric effect can not be explained on the basis of wave nature of light? Give reasons.
(b) Write the basic features of photon picture of electromagnetic radiation on which Einstein's photoelectric equation is based.

Ans4. (a) (i) The maximum kinetic energy of the emitted electron should be directly proportional to the intensity of incident radiations but it is not observed experimentally. Also maximum kinetic energy of the emitted electrons should not depend upon incident frequency according to wave theory, but it is not so.
(ii) According to wave theory, threshold frequency should not exist. Light of all frequencies should emit electrons provided intensity of light is sufficient for electrons to eject.
(iii) According to wave theory, photoelectric effect should not be instantaneous. Energy of wave cannot be transferred to a particular electron but will be distributed to all the electrons present in the illuminated portion. Hence, there has to be a time lag between incidence of radiation and emission of electrons.

(b) Basic features of photon picture of electromagnetic radiation :

(i) Radiation behaves as if it is made of particles like photons. Each photon has energy E = hv and momentum p = h/λ.

(ii) Intensity of radiation can be understood in terms of number of photons falling per second on the surface. Photon energy depends only on frequency and is independent of intensity.

(iii) Photoelectric effect can be understood as the result of one to one collision between an electron and a photon.

(iv) When a photon of frequency

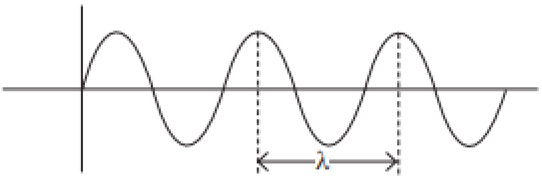
(v) is incident on a metal surface, a part of its energy is used in overcoming the work function and other part is used in imparting kinetic energy, so KE = $h(v - v_0)$.

5. Write Einstein's photoelectric equation and point out any two characteristic properties of photons on which this equation is based. Briefly explain the three observed features which can be explained by this equation.

Refer – Minimum Learning Material

CASE STUDY QUESTIONS

1. According to de-Broglie, a moving material particle sometimes acts as a wave and sometimes as a particle or a wave associated with a moving material particle which controls the particle in every respect. The wave associated with moving particle is called matter-wave or de-Broglie wave where wavelength called de-Broglie wavelength, is given by λ = h/mv.



(i) What does the wave associated with moving particle is called ?

(ii) If a proton and an electron have the same de Broglie wavelength, then what will be the ratio of their momenta?

(iii) Out of electron and alpha particle which particle has the larger de Broglie wavelength if their kinetic energies are same?

(iv) Two particles A_1 and A_2 of masses m_1, m_2 ($m_1 > m_2$) have the same de Broglie wavelength. Then what will be their velocities?

Ans:

(i) matter-wave or de-Broglie wave.

(ii) As de-broglie wavelength is same for both electron and proton, so their momenta (plural of momentum) are also same. By using de-Broglie relation by λ = h / p. momentum of electron = momentum of proton. so, the ratio will be 1:1

(iii) Electron will have larger de-broglie wavelength, because

For a particle , de Broglie wavelength ,

λ=h/p Kinetic energy,

$K = p^2 / 2m$

Then, $\lambda = h / \sqrt{2mK}$

For the same kinetic energy K, the de Broglie wavelength associated with the particle is inversely proportional to the square root of their masses. A proton is 1836 times massive than an electron and an α α-particle four times that of a proton.Hence, α – particle has the shorter de Broglie wavelength.

(iv) the velocity of larger mass will be smaller so as to make the momenta same as their de-broglie wavelengths are same.

2. The photoelectric emission is possible only if the incident light is in the form of packets of energy, each having a definite value, more than the work function of the metal. This shows that light is not of wave nature but of particle nature. It is due to this reason that photoelectric emission was accounted by quantum theory of light.

Q1. What is a Packet of energy called?
Q2. What is One quantum of radiation called?
Q3. What is the expression for Energy associated with each photon?
Q4. Can UV radiations produce photo electric effect?
Ans:

(I) quanta ; (ii) photon ; (iii) hv

(iv) Longer wavelength UV light does not have enough energy to discharge the electrons. Shortwave UV light discharges the electrons, demonstrating the photoelectric effect.

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UNIT 8 . ATOMS & NUCLEI

S.NO.	FORMULAE	SYMBOL	APPLICATIONS
1	$r_0 = \frac{k4Ze^2}{mv^2}$	$k = \frac{1}{4\pi\varepsilon_0}$, Z = Atomic number of element. m = mass of electron, v = velocity of electron.	To find the distance of closest approach r_0. $r_0 = \frac{2Ze^2}{4\pi\epsilon_0 E_k}$
2	$b = \frac{k\,Ze^2\cot\theta/2}{\frac{1}{2}m\,v^2}$	b = impact parameter θ = scattering angle	To find the impact parameter
3	$r_n = \frac{n^2h^2}{4\pi^2mkZe^2}$	r_n = Radius of n^{th} orbit	Bohr's radius (Z =1, n =1) r_0 = 0.53 A^0
4	$v = \frac{2\pi kze^2}{nh}$	v = speed of an electron in n^{th} orbit	$v = \frac{c}{137\,n}$, c = speed of light
5	$E_n = -\frac{2\pi^2mk^2Z^2e^4}{n^2h^2}$	E_n = Total energy of electron in n^{th} orbit.	$E_n = -\frac{13.6}{n^2}$ eV Total energy of electron in n^{th} orbit for hydrogen.
6	$K.E = \frac{kZe^2}{2r}$ $K.E = -E_n$	$k = \frac{1}{4\pi\varepsilon_0}$, Z = Atomic number of element	Kinetic energy of electron Relation between K.E and total energy
7	$P.E = -\frac{kZe^2}{r}$ P.E = 2 E_n = -2K.E		Potential energy of electron Relation between P.E and total energy

8	$\frac{1}{\lambda} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$	λ = Wavelength of emitted radiation. R = Rydberg's constant	$\frac{1}{\lambda}$ = Wave number Lyman series : $n_1 = 1$, $n_2 = 2,3,4$… Balmer series : $n_1 = 2$, $n_2 = 3,4,5$…
9	$R = R_0 A^{1/3}$	$R_0 = 1.2 \times 10^{-15}$ m	Relation between Radius of nucleus and mass number
9	$\rho = \frac{m}{\frac{4}{3}\pi R_0{}^3}$	ρ = Nuclear density , m = average mass of a nucleon.	ρ is independent of mass number.
10	BE = $\triangle m\ c^2$	E_B = Binding Energy $\triangle$ m= mass defect 1 a.m.u.= 931.5 Mev	Relation between binding energy and mass defect.

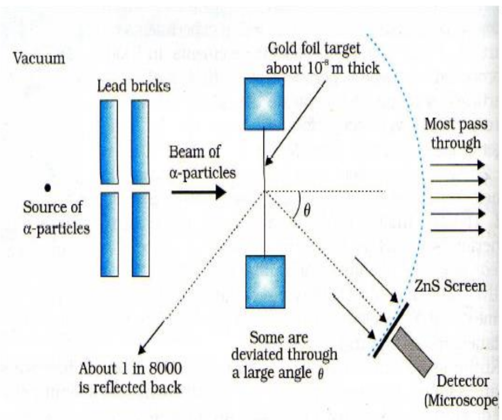
MINIMUM LEARNING MATERIAL

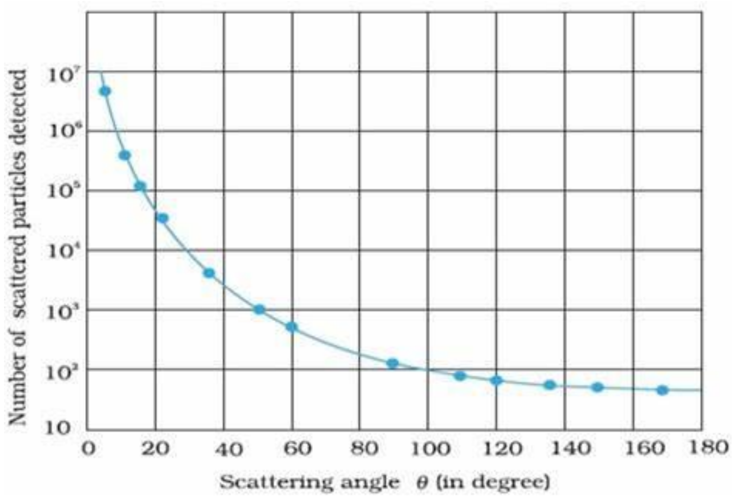
RUTHERFORD'S ATOMIC MODEL:

According to this model, "The entire positive charge and most of the mass of the atom is concentrated in a small volume called the nucleus, with electron revolving around the nucleus just as planets revolve around the sun.

Basic assumption of **Rutherford's atomic model**
(i) Atom consists of small central core, called atomic nucleus in which whole mass and positive charge is assumed to be concentrated.
(ii) The size of nucleus is much smaller than the size of the atom.
(iii) The nucleus is surrounded by electrons and atom is electrically neutral.
(iv) Electrons revolves around the nucleus and centripetal force is of eletrostatic nature.

RUTHERFORD'S A- RAY SCATTERING EXPERIMENTS:





The radioactive source is contained in a lead cavity. The alpha particles emitted by the source are collimated into a narrow beam with the help of lead slit. The collimated beam is allowed ot fall on a thin gold foil of thickness of the order of 2.1×10^{-7}m. The α particles scattered in different direction are observed through a rotatable detector consisting of a zinc sulphite screen and a microscope. The alpha particles produce bright flashes or scintillations on the ZnS screen. These are observed in the microscope and counted at different angels from the direction of incidence of the beam. The angle of θ of deviation of an alpha particle from its original direction is called its scattering angle θ.

A graph is plotted between the scattering angle θ and the number of alpha particles N(θ) .

Coulomb force of repulsion between alpha particle and gold nucleus

SL NO	OBSERVATION	CONCLUSION
1	**Most of the α – particles passed straight through the gold foil.**	**It indicates that most of the space in an atom is empty.**
2	**Some of the α – particles were scattered by only small angles, of the order of a few degrees.**	**It indicates that the positive charges and the most of the mass of the atom are concentrated at the center called "Nucleus".**
3	A few α – particles (1 in 9000) were deflected through large angles (even greater than 90^0). Some of them even retraced their path. i.e. angle of deflection was 180^0.	**α – particles which travel towards the nucleus directly get retarded due to Coulomb's force of repulsion and comes to rest and then move in opposite direction.**

F= $\frac{1}{4\Pi\epsilon_0} \cdot \frac{(Ze)(2e)}{r^2}$ **Where r is distance of alpha particle from the centre of the nucleus.**

Distance of Closest Approach At a certain distance r_0 from the nucleus, whole of the KE of α-particle converts into electrostatic potential energy and α-particle cannot go farther close to nucleus, this distance (r_0) is called distance of closest approach.

Distance of closest approach $r = \dfrac{Ze(2e)}{4\pi\epsilon_0\left(\frac{1}{2}mv^2\right)}$

$$r = \frac{Ze(2e)}{4\pi\epsilon_0\,(kE)}$$

when KE is doubled $r' = \dfrac{Ze(2e)}{4\pi\epsilon_0\,(2kE)} = \dfrac{1}{2}r$

Drawbacks of Rutherford's Model

(i) Could not explained stability of atom clearly.

(ii) Unable to explain line spectrum.

BOHR MODEL OF HYDROGEN ATOM:

According to this model,

(i) Every atom consists of a central core called nucleus, in which entire positive charge and almost entire mass of the atom are concentrated. A suitable number of electrons revolve around the nucleus in a circular orbit. The centripetal force required for revolution is provided by the electrostatic force of attraction between the electron and the nucleus.

(ii) An electron can revolve only in certain discrete non radiating orbits, called stationary orbits, for which total angular momentum of the revolving electron is an integral multiple of $\frac{h}{2\pi}$.

(iii)The emission/absorption of energy occurs only when an electron jumps from one of its specified non radiating orbits to another. The difference in the total energy of electron in the two permitted orbits is absorbed when the electron jumps from an inner to an outer orbit, and emitted when electron jumps from outer to the inner orbit.

Limitations of Bohr's Model

(i) Applicable only for hydrogen like atom.
(ii) Does not explain the fine structure of spectral lines in H-atom.
(iii) Does not explain about shape of orbit.

Nucleus: It is the central core of the atom where the whole mass is concentrated in terms of nucleons (protons and neutrons).

Atomic Number (Z): It is equal to the number of protons contained inside the nucleus.
Mass Number (A): It is a sum of number of protons and neutrons in the nucleus.
$A = Z + N$ or $N = A-Z$

Symbol of element $_ZX^A$
Radius of the nucleus $R= R_oA^{1/3}$

Isobar: They are atoms of the element having same mass number (A) but different atomic number (Z).
E.g.: $_1H^3$, $_2He^3$

Isotope: They are atoms of an element having same atomic number (Z) but different mass number (A).
E.g.: $1H^1$, $_1H^2$, $_1H^3$

Isotones: They are atoms of the elements whose nuclei have the same number of neutrons.
E.g.: $_4Be^9$, $_5B^{10}$

Atomic Mass Unit: It is defined as $1/12^{th}$ of the mass of one $_6C^{12}$ atom. 1 amu = 931 Mev

Mass Defect: It is given by the difference between the sum of mass of nucleons and the mass of the nucleons. $\Delta m = [Zm_p + (A-Z)m_n – M]$

Binding energy: It is defined as the energy required to break up a nucleus into its constituent protons and neutrons.
$B.E = [Zm_p + (A-Z)m_n – M] c^2$; $B.E = \Delta mc^2$

Binding energy per nucleon: It is the average energy required to extract one nucleon from the nucleus. It is given by BE/mass number (A).

Packing Fraction is defined as the mass defect per nucleon of the nucleus Packing Fraction = $\Delta m/A$

NUCLEAR FISSION: The splitting of heavy nucleus in to two or more fragments of comparable masses, with an enormous release of energy is nuclear fission. For example, when slow neutrons are bombarded on $_{92}U^{235}$, the fission takes place according to reaction

$$_{92}U^{235} + {}^{1}_{0}n \longrightarrow {}^{141}_{56}B + {}^{92}_{36}Kr + 3({}^{1}_{0}n) + 200\text{ MeV}$$

(slow neutron)

In nuclear fission the sum of masses before reaction is greater than the sum of masses after reaction, the difference in mass being released in the form of fission energy

NUCLEAR FUSION: The phenomenon of combination of two or more light nuclei to form a heavy nucleus with release of enormous amount of energy is called nuclear fusion. The sum of masses before fusion is greater than the sum of masses after fusion, the difference in mass appearing as fusion energy.

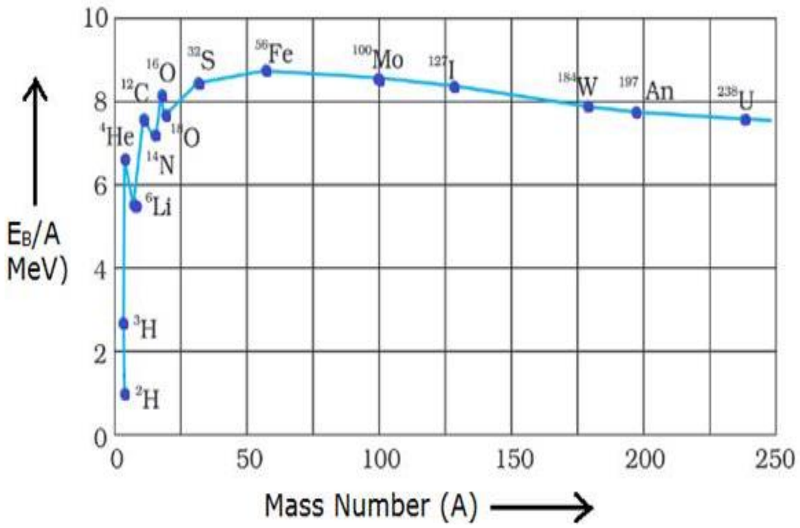
For example, the fusion of two deuterium nuclei in to helium is expressed as

$^{2}_{1}H$ + $^{2}_{1}H$ $\longrightarrow$ $^{4}_{1}He$ + 21.6 MeV

Thus, fusion process occurs at an extremely high temperature and high pressure as in sun where temperature is 10^7 K.

BINDING ENERGY CURVE:

The value of binding energy per nucleon of a nucleus gives a measure of the stability of that nucleus. Greater is the binding energy per nucleon of a nucleus, more stable is the nucleus. Figure shows the graph of binding energy per nucleon drawn against mass number A. The binding energy curve reveals the following important features:



1.Except for some nuclei like $^{4}_{2}He$, $^{12}_{6}C$ and $^{16}_{8}O$, the values of binding energy per nucleon lie on or near a smooth curve.

2.The B.E / nucleon is small for light nuclei like $^{1}_{1}H$, $^{2}_{1}H$ and $^{3}_{1}H$.

In the ma3.ss number range 2 to 20, there are well defined maxima and minima on the curve. The maxima occur for $^{4}_{2}He$, $^{12}_{6}C$ and $^{16}_{8}O$, indicating the higher stability of these nuclei than the neighbouring ones. The maxima, corresponding to low stability, occur for $^{6}_{3}Li$, $^{10}_{5}C$ and $^{14}_{7}N$.

4.The curve has a broad maximum close to the value 8.5 MeV/nucleon in the mass number range from about 40 to 120. It has a peak value of 8.8 MeV/nucleon for $^{56}_{26}Fe$.

5.As the mass number increases further, the B.E/ nucleon shows a gradual decrease and drops to 7.6 MeV/nucleon for $^{238}_{92}U$. This decrease is due to coulomb repulsion between the protons which makes the heavier nuclei less stable.

MULTIPLE CHOICE QUESTIONS

1. Which of the following statements is true about Bohr's atomic model?

a. **The electron can only move in particular orbits only**
b. **An electron radiates energy only when it jumps to another orbit**
c. **An atom consists of a positively charged nucleus.** **d. All of the above**

2.If the radius of Bohr's first orbit is a_0, what is the radius of the nth orbit?

a. **na_0** **b. a_0/n** **c. n^2a_0** **d.a_0/n^2**

3. Of the various series of the hydrogen spectrum, which of the following lies wholly in the ultraviolet region?

a. **Balmer Series** **b.Paschen Series** **c.Brackett series** **d.Lyman Series**

4. In Bohr's model, if the radius of the first orbit is r_0, what is the radius of the third orbit?

a. **$3r_0$** **b.$9r_0$** **c.$r_0/9$** **d.r_0**

5.The ratio of energies of the hydrogen atom in its first to second excited state is

(a) 1/4 (b) 4/1 (c) 9/4 (d) 3/2

6. According to Bohr's theory, the energy of radiation in the transition from the third excited state to the first excited state for a hydrogen atom is

(a) 0.85eV (b)13.6eV (c) 2.55eV (d)3.4eV

7.What is the energy needed to ionize H atom from its second excited state if the energy of the ground state of H atom is 13.6 eV.

(a) 3.4 eV (b) 1.51 eV (c) 12.1 eV (d) 0.85 eV

8.How many number of spectral lines are observed when hydrogen atoms are excited from ground state to the state of principal quantum number 4?

(a) 2 (b) 3 (c) 5 (d) 6

9. The size of the atom is proportional to

(a) A (b) $A^{1/3}$ (c) $A^{2/3}$ (d) $A^{-1/3}$

10. To explain his theory, Bohr used

(a) conservation of linear momentum (b) quantisation of angular momentum

(c) conservation of quantum (d) none of these

11.Which of the following spectral series in hydrogen atom give spectral line of 4860 A^0 ?

(a) Lyman (b) Balmer (c) Paschen (d) Brackett

12. The ratio of the speed of the electrons in the ground state of hydrogen to the speed of light in vacuum is

(a)$1/2$ (b)$2/237$ (c)$1/137$ (d)$1/237$

13. When an electron in an atom goes from a lower to a higher orbits, its

(a) kinetic energy (K E) increases, potential energy (P E) decreases

(b) K E increases, PE increases (c) KE decreases, PE increases

(d) KE decreases, PE decreases

14.The ratio between Bohr radii is

(a) 1:2:3 (b) 2:4:6 c) 1:4:9 (d) 1:3:5

15.Energy of an electron in the second orbit of hydrogen atom is E and the energy of electron in 3rd orbit of He will be

(a)$E_3 = \frac{16E}{3}$ (b) $E_3 = \frac{16E}{9}$ (c) $E_3 = \frac{4E}{9}$ (d) $E_3 = \frac{4E}{3}$

16.In terms of Rydberg constant R, the wave number of the first Balmer line is

(a) R (b) 3R (c) 5R/36 (d) 8R/9

17. The energy of hydrogen atom in the nth orbit is E_n, then the energy in the nth orbit of single ionised helium atom is

(a) E_n /2 (b) $2E_n$ (c) $4E_n$ (d) E_n /4

18.Binding energy per nucleon on a stable nucleus is

8 eV (b) 8 KeV (c) 8 MeV (d) 8 GeV

19. Sun's radiant energy is due to

(a)Nuclear fission (b) nuclear fusion

(c) Photoelectric effect (d) spontaneous radioactive decay

20.Average binding energy per nucleon is maximum for

(a)C^{12} (b) Fe^{56} (c)U^{235} (d)Po^{210}

Answers : 1-d,2-c, 3-d, 4-b, 5-c,6-c,7-b,8-d,9-b,10-b , 11-b, 12 – c

ASSERTION AND REASON BASED MCQs

A) If both assertion and reason are true and the reason is the correct explanation of the assertion.
B) If both assertion and reason are true but reason is not the correct explanation of the assertion.
C) If assertion is true but reason is false.
D) If the assertion and reason both are false.
E) If assertion is false but reason is true.

1. Assertion: It is not possible to use ^{35}Cl as the fuel for fusion energy.
Reason: The binding energy of ^{35}Cl is too small.
2. Assertion : Neutrons penetrate matter more readily as compared to protons.
Reason : Neutrons are slightly more massive than protons.
3. Assertion : Density of all the nuclei is same.
Reason : Radius of nucleus is directly proportional to the cube root of mass number.
4. Assertion : Isobars are the element having same mass number but different atomic number.
Reason : Neutrons and protons are present inside nucleus.
5. Assertion : The force of repulsion between atomic nucleus and α-particle varies with distance according to inverse square law.
Reason : Rutherford did α-particle scattering experiment.
6. Assertion : The positively charged nucleus of an atom has a radius of almost 10^{-15} m.
Reason : In a-particle scattering experiment, the distance of closest approach for a-particles is $\simeq 10^{-15}$ m.
7. Assertion : According to classical theory, the proposed path of an electron in Rutherford atom model will be parabolic.
Reason : According to electromagnetic theory an accelerated particle continuously emits radiation.
8. Assertion : Electrons in the atom are held due to coulomb forces.
Reason : The atom is stable only because the centripetal force due to Coulomb's law is balanced by the centrifugal force.
9. Assertion : The electron in the hydrogen atom passes from energy level n=4 to the n=1 level. The maximum and minimum number of photon that can be emitted are six and one respectively.
Reason : The photons are emitted when electron make a transition from the higher energy state to the lower energy state.
10. Assertion : Hydrogen atom consists of only one electron but its emission spectrum has many lines.
Reason : Only Lyman series is found in the absorption spectrum of hydrogen atom whereas in the emission spectrum, all the series are found.
11. Assertion : It is essential that all the lines available in the emission spectrum will also be available in the absorption spectrum.
Reason : The spectrum of hydrogen atom is only absorption spectrum.

Answers :1-c,2-b, 3-a,4-b,5-b,6-a,7-e,8-c,9-b,10-b , 11-d.

SHORT ANSWER TYPE QUESTIONS

1. **Define ionization energy. How would the ionization energy change when electron in hydrogen atom is replaced by a particle of mass 200 times than that of the electron but having the same charge?**
   Ans: The minimum energy required to free the electron from the ground state of the hydrogen atom is known as ionization energy.
   $$E_0 = \frac{me^4}{8\epsilon^2 h^2} \text{ , ie } E_0 \propto m$$
2. **Calculate the de-Broglie wavelength of the electron orbiting in the n=2 state of hydrogen atom.**
   Hints: **Kinetic Energy of the nth state** $E_n = \frac{13.6eV}{n^2}$
   de Broglie Wavelength $\lambda = \frac{h}{\sqrt{2mE_K}}$
3. **When the electron orbiting in hydrogen atom in its ground state moves to the third excited state, show how the de Broglie wavelength associated with it would be affected.**
   Hints: De Broglie wavelength $\lambda = \frac{h}{p} = \frac{h}{mv}$

$$\lambda \propto \frac{1}{v}$$

Also $v \propto \frac{1}{n}$

$\lambda \propto$ n

4. **When an electron in hydrogen atom jumps from the third excited state to the ground state, how would the de Broglie wavelength associated with the electron change ? Justify your answer**

   Hints: de Broglie Wavelength $\lambda = \frac{h}{\sqrt{2mE_K}}$

   Kinetic energy of the electron in any orbit of hydrogen atom can be given as

   K = - E = - $(-\frac{13.6}{n^2}eV) = \frac{13.6}{n^2}$

   $$\frac{\lambda_1}{\lambda_4} = \sqrt{\frac{k_4}{k_1}} = \sqrt{\frac{n_1^2}{n_2^2}}$$

5. **Write two characteristic features of nuclear force which distinguish it from Coulomb's force.**

   Ans. Characteristic Features of Nuclear Force

   Nuclear forces are short range attractive forces (range 2 to 3 fm) while Coulomb's forces haverange up to infinity and may be attractive or repulsive.

   Nuclear forces are charge independent forces; while Coulomb's force acts only betweencharged particles

6. Why do stable nuclei never have more protons than neutrons?

   Protons are positively charged and repel one another electrically. This repulsion becomes so great in nuclei with more than 10 protons or so, that an excess of neutrons which produce only attractive forces, is required for stability.

7. **Find out the wavelength of the electron orbiting in the ground state of hydrogen atom.**

   Radius of ground state of hydrogen atom, $r = 0.53\ \text{Å} = 0.53 \times 10^{-10}$ m

   According to de Broglie relation, $2\pi r = n\lambda$

   For ground state, $n = 1$

   $$2 \times 3.14 \times 0.53 \times 10^{-10} = 1 \times \lambda$$

   $$\therefore \quad \lambda = 3.32 \times 10^{-10}\ \text{m}$$

   $$= \mathbf{3.32\ Å}$$

8. **The ground state energy of hydrogen atom is −13.6 eV. What are the kinetic and potential energies of the electron in this state?**

   Ground state energy of hydrogen atom, $E = -13.6$ **eV**

   This is the total energy of a hydrogen atom. Kinetic energy is equal to the negative of the total energy.

   Kinetic energy = $-E = -(-13.6) = 13.6$ **eV**

   Potential energy is equal to the negative of two times of kinetic energy.

   Potential energy = $-2 \times (13.6) = -27.2$ **Ev**

9. **State three properties of nuclear forces.**

   (i) **Nuclear forces are the strongest attractive forces.**

   (ii) **Nuclear forces are short ranged up to** 10^{-15}**m**

   (iii)**Nuclear forces are charge independent.**

10. **When four hydrogen nuclei combine to form a helium nucleus, estimate the amount of energy in MeV released in this process of fusion. Given (i) mass of = 1.007825 u (ii) mass of helium**

nucleus = 4.002603, 1u = 931m MeV/c^2

$_1H^1$Energy released = Δm X 931 MeV

Δm = 4m ($_1H^1$) – m (^4_2He)

Energy released Q = [4m($_1H^1$) -m(^4_2He)] X 931 MeV

= [4 X 1.007825 – 4.002603] X 931 MeV

= 26.72 MeV

SHORT ANSWER TYPE QUESTIONS (3 Marks each)

1. Draw the graph showing the variation of binding energy per nucleon with the mass number for a large number of nuclei 2 < A < 240. What are the main inferences from the graph? How do you explain the constancy of binding energy in the range 30 < A < 170 using the property that the nuclear force is short ranged? Explain with the help of this plot the release of energy in the process of nuclear fission and fusion.

BINDING ENERGY CURVE: Refer Minimum Learning Material

Explanation of nuclear fission : When a heavy nucleus (A$\geq$ 235) breaks into two lighter nuclei(Nuclear fission), the binding energy per nucleon increases i.e, nucleon get more tightly bound. This implies that energy would be released in nuclear fission.

Explanation of nuclear fusion: When two very light nuclei(A$\leq$10) join to form a heavy nucleus, the binding energy per nucleon of fused heavier nucleus more than the binding energy per nucleon of lighter nuclei, so again energy would be released in nuclear fusion.

2. Show that the radius of the orbit in hydrogen atom varies as n^2, where n is the principal quantum number of the atom.

Let r be the radius of the orbit of a hydrogen atom. Forces acting on electron are centrifugal force (F_c) and electrostatic attraction (F_e)

At equilibrium, $F_c = F_e$

$$\frac{mv^2}{r} = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r^2} \qquad \text{[for H-atom, } Z = 1]$$

According to Bohr's postulate

$$mvr = \frac{nh}{2\pi} \Rightarrow v = \frac{nh}{2\pi mr}$$

$$m\left(\frac{nh}{2\pi mr}\right)^2 \cdot \frac{1}{r} = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r^2} \Rightarrow \frac{mn^2h^2}{4\pi^2 m^2 r^2 . r} = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r^2}$$

$$r = \frac{n^2h^2\varepsilon_0}{\pi me^2} \Rightarrow \therefore \quad r \propto n^2$$

3. **What is the shortest wavelength present in the Paschen series of spectral lines?**

Rydberg's formula is given as:

$$\frac{hc}{\lambda} = 21.76\times10^{-19}\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

$$\frac{hc}{\lambda} = 21.76\times10^{-19}\left[\frac{1}{(3)^2} - \frac{1}{(\infty)^2}\right]$$

$$\lambda = \frac{6.6\times10^{-34}\times3\times10^{8}\times9}{21.76\times10^{-19}}$$

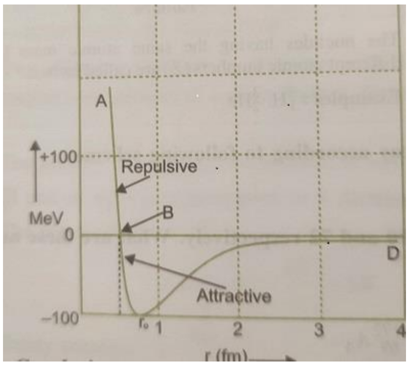
$$= 8.189\times10^{-7}\ \text{m}$$

$$= 818.9\ \text{nm}$$

The shortest wavelength present in the Paschen series of the spectral lines is given forvalues $n_1 = 3$ and $n_2 = \infty$.

3.Draw a graph showing the variation of potential energy between a pair of nucleons as a functionof their separation. Indicate the regions in which the nuclear force is (i) attractive, (ii) repulsive.

Write two important conclusions which you can draw regarding the nature of the nuclear forces.



Conclusions:

(i) The potential energy is minimum at a distance r_0 of about 0.8 fm.

(ii) Nuclear force is attractive for distance larger than r_O.

(iii) Nuclear force is repulsive if two are separated by distanceless than r_O.

(iv) Nuclear force decreases very rapidly at r_0/equilibriumposition.

LONG ANSWER TYPE QUESTIONS

1. Draw a schematic arrangement of Geiger-Marsden experiment for studying α particle scattering by a thin foil of gold. Describe briefly, by drawing trajectories of the scattered α particles. How this study can be used to estimate the size of the nucleus?

Refer – Minimum Learning Material

2.Using the postulates of Bohr's model of hydrogen atom, obtain an expression for the frequency of radiation emitted when atom make a transition from the higher energy state with quantum number n_i to the lower energy state with quantum number n_f($n_f < n_i$)

Suppose m be the mass of an electron and v be its speed in nth orbit of radius r. The centripetal force for revolution is produced by electrostatic attraction between electron and nucleus.

$$\frac{mv^2}{r} = \frac{1}{4\pi\epsilon_0}\frac{(Ze)(e)}{r^2} \qquad \text{…………(i)}$$

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

or $\qquad mv^2 = \frac{1}{4\pi\epsilon_0}\frac{(Ze)(e)}{r^2}$

So, Kinetic energy K = $\frac{1}{2}mv^2$

$$K = \frac{1}{4\pi\epsilon_0}\frac{Ze^2}{2r}$$

Potential Energy = $\frac{1}{4\pi\epsilon_0}\frac{(Ze)(-e)}{2r} = -\frac{1}{4\pi\epsilon_0}\frac{Ze^2}{r}$

Total Energy E = KE + PE

$$= \frac{1}{4\pi\epsilon_0}\frac{Ze^2}{2r} + \left(-\frac{1}{4\pi\epsilon_0}\frac{Ze^2}{r}\right)$$

$$= -\frac{1}{4\pi\epsilon_0}\frac{Ze^2}{2r}$$

Energy of electron in the nth orbit $E_n = -\frac{1}{4\pi\epsilon_0}\frac{Ze^2}{2r_n}$ ……………..(ii)

Negative sign indicates that the electron remain bound with the nucleus

From Bohr's postulate for quantization of angular momentum

$$\mathbf{mvr} = \frac{nh}{2\pi} \Longrightarrow \mathbf{v} = \frac{nh}{2\pi mr}$$

substituting this value of v in (i) , we get

$$\mathbf{r} = \frac{\epsilon_0 h^2 n^2}{\pi m Z e^2}$$

or $$\mathbf{r_n} = \frac{\epsilon_0 h^2 n^2}{\pi m Z e^2}$$

Substituting value of r_n in equation (ii), we get

$$E_n = -\frac{mZ^2e^4}{8\epsilon_0^2 h^2 n^2} \quad \textbf{or} \quad E_n = -\frac{Rhc}{n^2} \quad \textbf{where } R = -\frac{me^4}{8\epsilon_0^2 h^2 n^2}$$

If v is the frequency of emitted radiation, we get

$$\mathbf{v} = \frac{E_i - E_f}{h} = \mathbf{Rc}\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

For Balmer series n_f = 2 and n_i = 3,4,5,……..

CASE STUDY BASED QUESTIONS

1. Neutrons and protons are identical particle in the sense that their masses are nearly the same and the force, called nuclear force, does into distinguish them. Nuclear force is the strongest force. Stability of nucleus is determined by the neutron proton ratio or mass defect or packing fraction. Shape of nucleus is calculated by quadrupole moment and spin of nucleus depends on even and odd mass number. Volume of nucleus depends on the mass number. Whole mass of the atom (nearly 99%) is centred at the nucleus.

1. Write the one feature of nuclear force?

2. What is the range(fm) of nuclear forces?

3. What is the nature of force between the nucleon inside the nucleus (proton ,proton and proton and nutron)

4. How is the radius of a nucleus related to its mass number?

5. Name the fundamental force responsible for binding all the nucleon together

ANSWERS : 1. Charge independent, 2. 10^{-15} m, 3. Attractive force ,4. R= Ro $A^{1/3}$, 5. Nuclear force.

2. The emission spectrum of a chemical element or chemical compound is the spectrum of frequencies of electromagnetic radiation emitted by an atom's electrons when they are returned to a lower energy state. Each element's emission spectrum is unique, and therefore spectroscopy can be used to identify elements present in matter of unknown composition. Similarly, the emission spectra of molecules can be used in chemical analysis of substances. The emission spectrum of atomic hydrogen is divided into a number of spectral series, with wavelengths given by the Rydberg formula.

(i) When an electron jumps in n=1 orbit, name the series of spectral lines obtained ?

(ii) What is wave number ?

(iii) Name the Visible region of electromagnetic spectrum?

(iv) Which series lies in U.V region of electromagnetic spectrum?

Answers : 1. Lyman series, 2 -Number of waves per unit length ,3. 400 nm -700nm VIBGYOR, 4.LymanSeries.

Case Study: III

Apsara is the oldest of India's research reactors. The reactor was designed by the Bhabha Atomic Research Center (BARC) and built with assistance from the United Kingdom. A nuclear reactor, formerly known as an atomic pile, is a device used to initiate and control a self sustained nuclear chain reaction. Nuclear reactors are used at nuclear power plants for electricity generation and in nuclear marine propulsion. Heat from nuclear fission is passed to a working fluid (water or gas), which in turn runs through steam turbines.

(i) What is fission coined in this paragraph?

(ii) Name the moderator used in the nuclear reactor?

(iii) Which isotope of Uranium has the capacity to sustain the chain reaction?

(iv) Write one disadvantage of energy obtained from nuclear reactor ?

Answers :1. Nuclear fission, 2. Heavy water , 3. ${}_{92}U^{235}$ 4. power generation .

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Unit IX: Electronic Devices

Chapter–14

Semiconductor Electronics: Materials, Devices and Simple Circuit

FORMULAE

S.No.	FORMULA	SYMBOL
1	$n_e = n_h$. (Pure Semiconductor)	n_e = free electron density n_h = hole density
2	$n_e < n_h$ (P type Semiconductor)	
3	$n_e > n_h$ (N type Semiconductor)	
4	$n_e . n_h = n_i^2$	n_i = density of Intrinsic carriers
5	$I = I_e + I_h$ $I = n_e e A V_d + n_h e A V_h$	I_e = current through electrons I_h = current through holes V_d = Drift velocity of electrons V_h = Drift velocity of holes
6	$\sigma = \frac{1}{\rho} = e(n_e \mu_e + n_h \mu_h)$	σ - Conductivity
7	$\sigma = \sigma_o \exp\left[-\frac{E_g}{2k_B T}\right]$	σ - Conductivity

9. ELECTRONIC DEVICES

(A) Energy bands in solids:

(i) In solids, the group of closely lying energy levels is known as energy band.

(ii) In solids the atoms are arranged very close to each other. In these atoms there are discrete energy levels of electrons. For the formation of crystal these atoms come close together, then due to nucleus-nucleus, electron-electron and electron-nucleus interactions the discrete energy levels of atom distort and consequently each energy level spits into a large number of closely lying energy levels.

(iii) The number of split energy levels is proportional to the number of atoms interacting with each other. If two atoms interact then each energy level splits into two out of which one will be somewhat above and another will be somewhat below the main energy level. In solids the number of atoms is very large . Hence each energy level splits into large number of closely lying energy levels. Being very close to each other these energy levels assume the shape of a band.

(iv) In an energy band there are 10^{23} energy levels with energy difference of 10^{-23} eV.

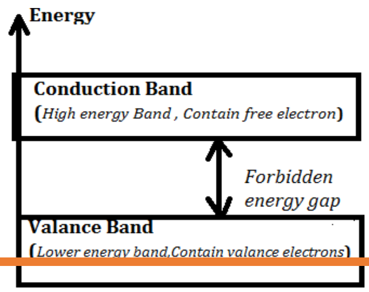
Valence Band [V.B] :

The energy band occupied by valence electrons is called valance band.
This band may be completely filled or partially filled with electrons.
Electrons in this band don't conduct electrical charge because they are not free to move in this band.

Conduction Band [C.B] :

- The energy band which accommodates only those electrons which come out of the valence band is called conduction band.
- These electrons are responsible for current in a conductor.

All the electrons in this band are free electrons.



Forbidden Band / Band Gap :

The energy gap between valence band and conduction band is called band gap.

Semiconductors: The materials in which valence band is completely filled and conduction band s empty. But energy gap is less than 3eV.

At room temperature, semiconductor behaves like a conductor but at absolute zero (0 K) temperature, these behave as perfect insulators.

Fermi Energy It is the maximum possible energy possessed by free electrons of a material at absolute zero temperature (i.e. 0K)

I) THE SEMICONDUCTORS ARE OF TWO TYPES.

(a) Intrinsic or pure semiconductors
(b) Extrinsic or dopes semiconductors

Properties of intrinsic semiconductors:

(a) At absolute zero temperature (0 K) there are no free electrons in them.

(b) At room temperature, the electron-hole pair in sufficient number are produced.

(c) Electric conduction takes place via both electrons and holes.

(d) The drift velocities of electrons and holes are different.

(e) The drift velocity of electrons (Ve) is greater than that of holes (Vh).

(f) The total current is $I = I_n + I_p$

2) **Extrinsic semiconductors:**

(a) **Doping:** The process of mixing impurities of other elements in pure semiconductors is known as doping.

(b) **Extrinsic semiconductors:** the semiconductors, in which trivalent and pentavalent elements are mixed as impurities, are known as extrinsic semiconductors.

(c) The extrinsic semiconductors are of two types

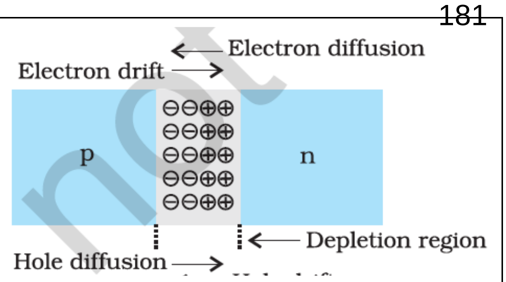
(i) N-type semiconductor (ii) P-type semiconsuctor

In N-type semiconductor, majority charge carriers are electrons and minority charge carriers are holes, i.e. ne> nh .
Here, we dope Si or Ge with a pentavalent element, then four of its electrons bond with the four silicon neighbours, while fifth remains very weakly bound to its parent atom.

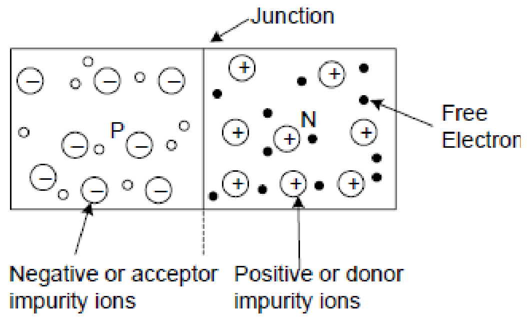
In p-type semiconductor, majority charge carriers are holes and minority charge carriers are eletron i.e. nh > ne .In a p-type semiconductor, doping is done with trivalent impurity atoms, i.e. those atoms which have three valence electrons in their valence shell.

SEMICONDUCTOR DIODE OR P-N JUNCTION, CONDUCTION IN P-N JUNCTION, DEPLETION LAYER AND POTENTIAL BARRIER

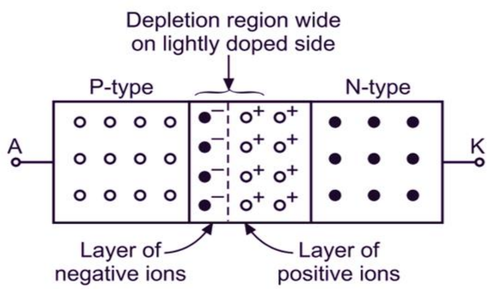
P-N Junction : When a single crystal of semiconductor is doped in such a manner that one half portion of it acts as a p-type semiconductor and other is n-type semiconductor. Then the boundary between the two regions is called p-n junction.



DEPLETION REGION: The small charge region on either side of the junction which gets devoid of free charge carrier and has only immobile ions is called depletion region.



Its thickness is of the order of 1μm (= 10^{-6})
On two sides of it, there are ions of opposite nature. i.e. donor ion (+ve) on N-side and acceptor ions (– ve) on P-side
Diffusion Current : The current induced due to majority charge carrier is called diffusion current. It is directed from P side to N side.
Drift Current : The current induced due to minority charge carrier is called drift current. It is directed from N side to P type



Barrier Potential :

The potential difference between the ends of this layer is defined as the contact potential or potential barrier (VB). The accumulation of –ve charge in the p- region & +ve charge in the n- region sets up a potential difference across the junction. This is called junction potential or barrier potential. It stops the free current carriers to crossover the junction and consequently a potential barrier is formed at the junction. t depends on:-Nature of semiconductor, Temperature & Amount of doping

(The value of VB is from 0.1 to 0.7 volt which depends on the temperature of the junction. It also depends on the nature of semiconductor and the doping concentration. For germanium and silicon its values are 0.3 V and 0.7 V respectively.

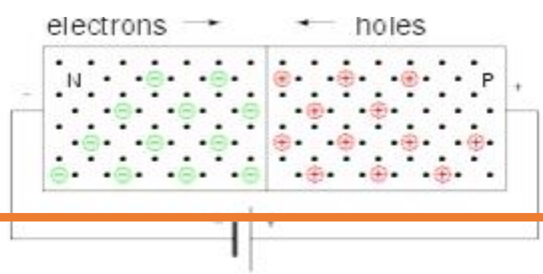
(ii) The direction of current flow is represented by the arrow head.
(iii) In equilibrium state current does not flow in the junction diode.
(iv) In can be presumed to be equivalent to a condenser in which the depletion layer acts as a dielectric

Biasing of diode :The arrangement of applying external potential difference across the p-n junction is called biasing of P-N junction.

It is of two types: Forward Biasing & Reverse Biasing

Forward Biasing :

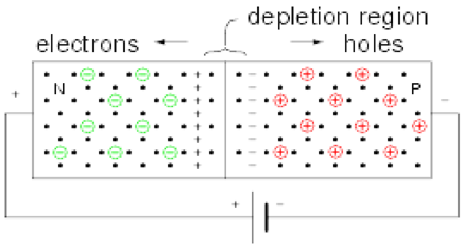
A junction diode is said to be forward biased when its **p-side** is connected to the positive (+) terminal



of the battery and n-side is connected to the negative(-) terminal of the battery.

In forward biasing –Height of the potential barrier is reduced, resistance of diode is low & Charge carrier from each side cross the junction and diode become conductive.

Reverse Biasing: A junction is said to be reverse biased when its p – side is connected to the –ve terminal and n-side is connected to the +ve terminal of the battery.



- In reverse biasing width of potential barrier or height of potential barrier is increased.
- Resistance of diode is high
- Charge carrier from the either side of junction can't cross the junction. Thus in reverse biasing diode doesn't conduct.

CHARACTERISTICS OF JUNCTION DIODE

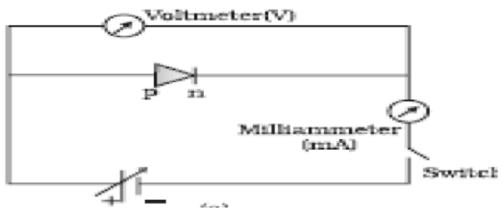
(i) The characteristic curves of junction diode are of two types

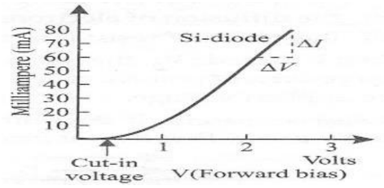
(a) Forward characteristic curve

(b) Reverse characteristic curve

Forward Biasing: If positive terminal of a battery is connected to the p-side and the negative terminal to the n-side, then the junction is said to be forward biased

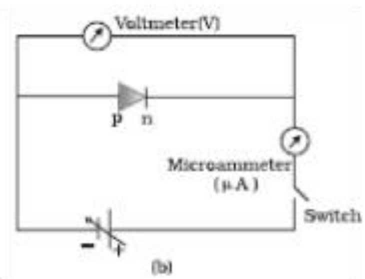
Forward biased characteristics: As shown in the figure a battery is connected across the p-n junction diode to a potential divider. For different values of voltages, the value of current is noted. A graph is plotted between V and I. This V-I graph is called forward characteristic.

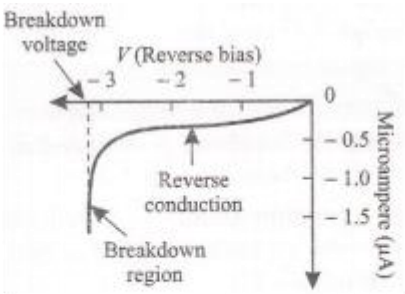




Reverse Biasing: If the positive terminal of the battery is connected to the n-side and negative terminal to the p-side, then the p-n junction is said to be reverse biased.

Reverse Bias characteristics: Figure sows the experimental arrangement for studying characteristic curve of a p-n junction diode when it is reverse biased. Here a microammeter is used to measure the small currents through the reverse biased diode. A V-I graph is drawn, which is called reverse characteristic of junction diode.





SEMICONDUCTOR DIODE AS RECTIFIER

(i) **Rectification:** The process in which an alternating current is converted into direct current, is defined as rectification.

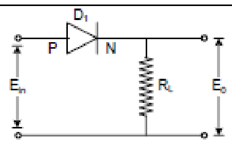
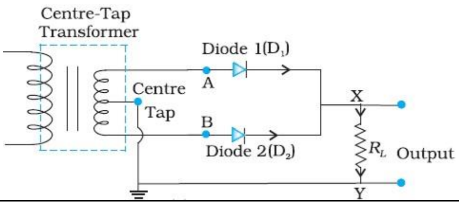
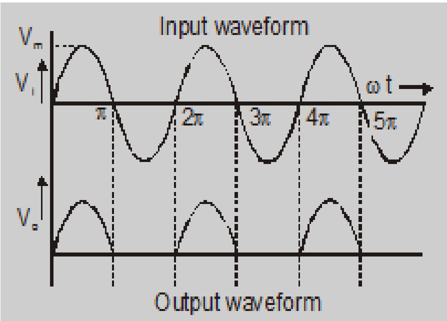
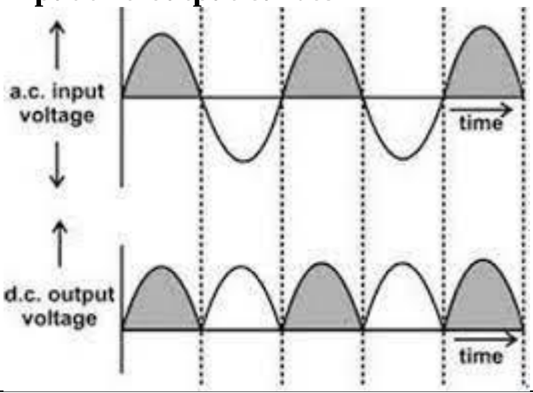
(ii) **Rectifier:** The device employing diode, used to convert an alternating current into direct current, is known as rectifier.

(iii) The rectifiers are of two types:

(a) Half wave rectifier (b) Full wave rectifier

Half wave rectifier: The rectifier, in which only alternate half cycles of applied alternating signal are converted into direct current, is known as half wave rectifier.

Full wave rectifier: The rectifier is which the whole cycle of applied alternating signal is converted into direct current, is known as full wave rectifier.

S.No.	Half-Wave Rectifier	Full Wave Rectifier centre taped
1.		
2.	**In this, one diode or one semiconductor diode is used**	**In this, two diodes or one double diode or two junction diodes are used**
3.	**Ordinary transformer is used**	**Centre tap transformer is used**
4.	**It converts half cycle of applied A.C. signal into D.C. signal**	**It converts the whole cycle of applied A.C. signal into D.C. signal**
5.	**Input and output curves** 	**Input and output curves** 

MULTIPLE CHOICE QUESTIONS

1. If n_h and n_e be the number of holes and conduction electrons in an extrinsic semiconductor. Then
(a) $n_h > n_e$ (b) $n_h = n_e$ (c) $n_h < n_e$ (d) $n_h \neq n_e$.
2. In a semiconductor, the forbidden energy gap between the valence band and the conduction band is of the order is
(a) 1 MeV (b) 0.1 Men (c) 1 eV (d) 5 eV
3. In semiconductors, at room temperature
(a) the conduction band is completely empty
(b) the valence band is partially empty and the conduction band is partially filled
(c) the valence band is completely filled and the conduction band is partially filled
(d) the valence band is completely filled.
4. When p-n junction diode is forward biased then
(a) both the depletion region and barrier height are reduced
(b) the depletion region is widened and barrier height is reduced
(c) the depletion region is reduced and barrier height is increased
(d) Both the depletion region and barrier height are increased.
5. Electric conduction in a semiconductor takes place due to
(a) electrons only (b) holes only
(c) both electrons and holes (d) neither electrons nor holes
6. The impurity atoms with which pure silicon may be to make it a p-type semiconductor are those of
(a) phosphorus (b) boron (c) antimony (d) nitrogen
7. Number of electrons in the valance shell of a pure semiconductor is
(a) 1 (b) 2 (c) 3 (d) 4
8. A semiconductor device is connected in series circuit with a battery and a resistance. A current is found to pass through the circuit. If the polarity of the battery is reversed, the current drops to almost zero. The device may be a/an
(a) Intrinsic semiconductor (b) p-type semiconductor

(c) n-type semiconductor (d) p-n junction diode

9. When an impurity is doped into an intrinsic semiconductor, the conductivity of the semiconductor
(a) increases (b) decreases (c) remains the same (d) becomes zero

10. If a small amount of antimony is added to germanium crystal
(a) it becomes a p–type semiconductor (b) the antimony becomes an acceptor atom
(c) there will be more free electrons than holes in the semiconductor (d) its resistance is increased

11. In Conductor, Semiconductor and Insulator, the forbidden energy gap are E1 ,E2 and E3 respectively. Which one is correct
a) E1 < E3 (b) E1 >E2 = E3 c) E1 = E2 < E3 d) E1 >E2 > E3

12. Silicon is doped with which of the following to obtain P type semiconductor
a) Phosphorus b) Gallium c) Germanium d) Bismuth

13. A semiconductor has an electron concentration of 6×10^{22} per m^3 and hole concentration of 8.5×10^9 per m^3 .Then it is
a) N type semiconductor b) P type semi conductor c) intrinsic semiconductor d) conductor

14.In an unbiased p-n junction, holes diffuse from the p-region to n-region because
(a) free electrons in the n-region attract them. (b) they move across the junction by the potential difference.
(c) hole concentration in p-region is more as compared to n-region. (d) All the above.

15. When a forward bias is applied to a p-n junction, it
(a) raises the potential barrier. (b) reduces the majority carrier current to zero.
(c) lowers the potential barrier. (d) None of the above.

16. In a p-type silicon, which of the following statement is true :
(a) Electrons are majority carriers and trivalent atoms are the dopants.
(b) Electrons are minority carriers and pentavalent atoms are the dopants.
(c) Holes are minority carries and pentavalent atoms are the dopants.
(d) Holes are majority carries and trivalent atoms are the dopants.

17. The intrinsic semiconductor becomes an insulator at
(a) $0\ ^0C$ (b) $<100\ ^0C$ (c) 300 K (d) $0\ ^0K$

18. In the forward bias arrangement of a PN-junction diode
(a) The N-end is connected to the positive terminal of the battery
(b) The P-end is connected to the positive terminal of the battery
(c) The direction of current is from N-end to P-end in the diode
(d) The P-end is connected to the negative terminal of battery

19. In a PN-junction diode
(a) The current in the reverse biased condition is generally very small ~ μA
(b) The current in the reverse biased condition is small but the forward biased current is independent of the bias voltage
(c) The reverse biased current is strongly dependent on the applied bias voltage
(d) The forward biased current is very small in comparison to reverse biased current

Answers : 1-d, 2-c, 3-b,4-a,5-c,6-b,7-d, 8-d,9-a,10-c,11-a,12-b, 13-a,14-c,15-c,16-d,17-d,18-b ,19- a.

ASSERTION REASON QUESTIONS

Directions for (Qs. 1-10) : These questions consist of two statements, each printed as Assertion and Reason. While answering these questions, you are required to choose any one of the following five responses.

(a) If both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.
(b) If both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.
(c) If the Assertion is correct but Reason is incorrect.
(d) If both the Assertion and Reason are incorrect.

01. Assertion : In semi-conductor the resistivity increases with temperature.
Reason : The atoms of semi-conductor vibrate with larger amplitude at higher temperatures thereby increasing its resistivity.

02. Assertion : In a transition the base is made thin.
Reason : A thin base makes the transistor stable.

03. Assertion : The logic gate NOT can be built using diode.

Reason : The output voltage and the input voltage of the diode have 180° phase difference.
04. Assertion : The number of electrons in a p-type silicon semiconductor is less than the number of electrons in a pure silicon semiconductor at room temperature.
Reason : It is due to law of mass action.
5. Assertion : The value of current through p-n junction in the given figure will be 10 mA. + 5V 300 W +2V
Reason : In the above figure, p-side is at higher potential than n-side. [2008]
.6, Assertion : A p-n junction with reverse bias can be used as a photo-diode to measure light intensity.
Reason: In a reverse bias condition the current is small but is more sensitive to changes in incident light intensity.
07. Assertion : If the temperature of a semiconductor is increased then it's resistance decreases.
Reason : The energy gap between conduction band and valence band is very small.
8. Assertion (A): A Pure semiconductor has negative temperature coefficient of resistance.
Reason (R): On raising the temperature, more charge carriers are released, conductance increases and resistance decreases.
09. Assertion (A): At a fix temperature, silicon will have a minimum conductivity when it has a smaller accepter doping.
Reason (R): The conductivity of and intrinsic semiconductor is slightly higher than of a lightly doped p-type.
10. Assertion (A): The electrons in the conduction band have higher energy than those in the valance band of a semi-conductor.
Reason (R): The conduction band lies above the energy gap and valance band lies below the energy gap.
Answers : 1-d, 2-c,3-d,4-a,5-b, 6-a,7-a,8-a ,9-b & 10-a.

2 –MARK QUESTIONS

1. **What type of extrinsic semiconductor is formed when (*i*) germanium is doped with indium? (*ii*) silicon is doped with bismuth?**
(*i*) Indium is trivalent, so germanium doped indium is a *p*-type semiconductor.
(*ii*) Bismuth is pentavalent, so silicon doped bismuth is an *n*-type semiconductor.

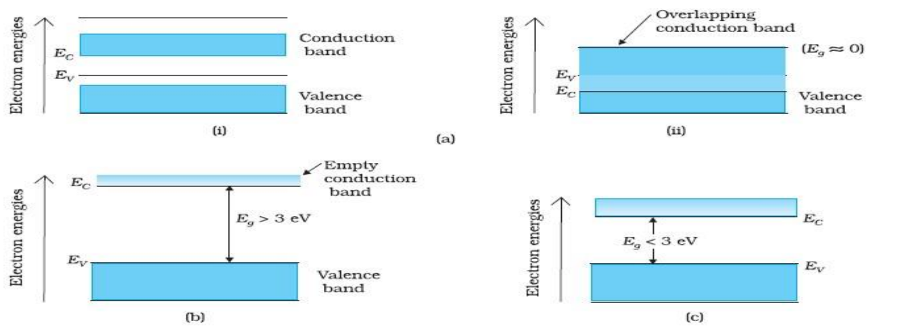
2. **What happens to the width of depletion layer of a *p-n* junction when it is (*i*) forward biased,(*ii*) reverse biased? Ans.** (*i*) When forward biased, the width of depletion layer decreases.(*ii*) When reverse biased, the width of depletion layer increases.

3. **The energy gaps in the energy band diagrams of a conductor, semiconductor and insulator are *E*1, *E*2 and *E*3. Arrange them in increasing order.**
Ans. The energy gap in a conductor is zero, in a semiconductor is ≈ 1 eV and in an insulator is ≥ 3 eV.∴ $E1 = 0$, $E2 = 1$ eV, $E3 \geq 3$ eV ∴ $E1 < E2 < E3$.

4. **How does one understand the temperature dependence of resistivity of a semiconductor?**
Ans. When temperature increases, covalent bonds of neighbouring atoms break and charge carrier become free to cause conduction, so resistivity of semi-conductor decreases with rise of temperature.

5. Distinguishing features between conductors, semiconductors and insulators on the basis of energy band diagrams.

S.No.	**Property**	**Conductors**	**Semi-conductors**	**Insulators**
1.	Electrical conductivity	Very high	Between those of conductors and insulators	Negligible
2.	Resistivity	Very Less	Between those of conductors and insulators	Very high

3.	Band structure			
4.	Energy gap and its value	No energy gap	Energy gap is very small	Energy gap is quite large
5.	Current carriers and current flow	Due to free electrons and very high	Due to free electrons and holes.	No conduction
6	CB & VB	Either the conduction band is partially filled or conduction band is overlapped with the valance band	At absolute zero conduction band is empty and valance band is filled	Conduction band is empty & valence band is completely filled.

6. **Write two characteristic features to distinguish between *n*-type and *p*-type semiconductors.**

n-type semiconductors		p-type semiconductors	
1	It is an extrinsic semiconductors which is obtained by doping the impurity atoms of Vth group of periodic table to the pure germanium or silicon semiconductor.	1	It is an intrinsic semiconductors which is obtained by doping the impurity atoms of III group of periodic table to the pure germanium or silicon semiconductor.
2	The impurity atoms added, provide extra electrons in the structure, and are called donor atoms.	2	The impurity atoms added, create vacancies of electrons (i.e. holes) in the structure and are called acceptor atoms.
3	The electrons are majority carriers and holes are minority carriers.	3	The holes are majority carriers and electrons are minority carriers.
4	The electron density (n_e) is much greater than the hole density (n_h)i.e. n_e>>(n_h)	4	The hole density (n_e) is much greater than the electron density (n_h)i.e. n_h>> n_e
5	The donor energy level is close to the conduction band and far away from valence band.	5	The acceptor energy level is close to valence band and is far away from the conduction band.

7. Can we take one slab of p-type semiconductor and physically join it to another n-type semiconductor to get p-n junction?

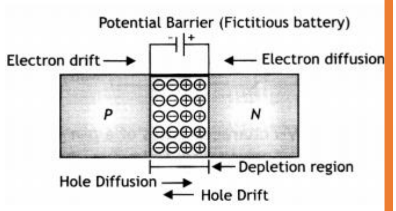
No! Any slab, howsoever flat, will have roughness much larger than the inter-atomic crystal spacing (~2 to 3 Å) and hence continuous contact at the atomic level will not be possible. The junction will behave as a discontinuity for the flowing charge carriers

8 **Give any two differences between 'intrinsic' and 'extrinsic' semiconductors.**

	Intrinsic		**Extrinsic**
1	**It is pure semiconducting material and no impurity atoms are added to it**	**1**	**It is prepared by doping a small quantity of impurity atoms to the pure semiconducting material.**
2	**Examples are crystalline forms of pure silicon and germanium.**	**2**	**Examples are silicon and germanium crystals with impurity atoms of arsenic, antimony, phosphorous etc. or indium, boron, aluminum etc.**
3	**The number of free electron in conduction band and the number of holes in valence band is exactly equal and very small indeed.**	**3**	**The number of free electrons and holes is never equal. There is excess of electrons in n-type semiconductors and excess of holes in p-type semiconductors.**
4	**Its electrical conductivity is low**	**4**	**Its electrical conductivity is high.**
5	**Its electrical conductivity is a function of temperature alone**		**Its electrical conductivity depends upon the temperature as well as on the quantity of impurity atoms doped in the structure**

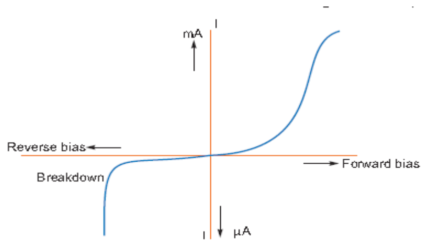
3-MARK QUESTIONS

1. Explain the two processes involved in the formation of a p-n junction diode. Hence define the term 'barrier potential'.
Refer –Minimum Learning material



2. **Draw $V - I$ characteristics of a p–n junction diode. Answer the following questions, giving reasons:**
(*i*) Why is the current under reverse bias almost independent of the applied potential upto a critical voltage?
(*ii*) Why does the reverse current show a sudden increase at the critical voltage?

(*i*) In the reverse biasing, the current of order of μA is due to movement/drifting of minority charge carriers from one region to another through the junction.
A small applied voltage is sufficient to sweep the minority charge carriers through the junction.So, reverse current is almost independent of critical voltage.

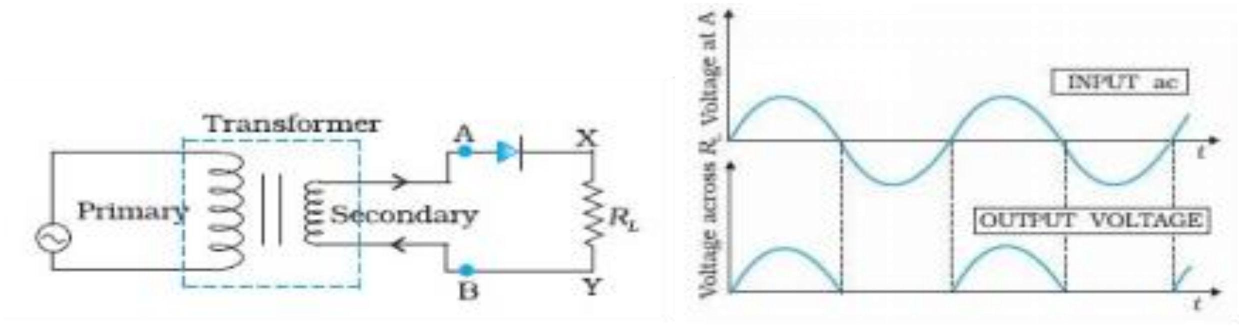


(ii)At critical voltage (or breakdown voltage), a large number of covalent bonds break, resulting in the increase of large number of charge carriers.

3. **State briefly the processes involved in the formation of *p-n* junction explaining clearly how the depletion region is formed.**

Two processes occur during the formation of a *p-n* junction are diffusion and drift. Due to the concentration gradient across *p* and *n*-sides of the junction, holes diffuse from *p*-side to *n*-side ($p \rightarrow n$) and electrons diffuse from *n*-side to *p*-side ($n \rightarrow p$). This movement of charge carriers leaves behind ionised acceptors (negative charge immobile) on the *p*-side and donors (positive charge immobile) on the *n*-side of the junction. This space charge region on either side of the junction together is known as depletion region.

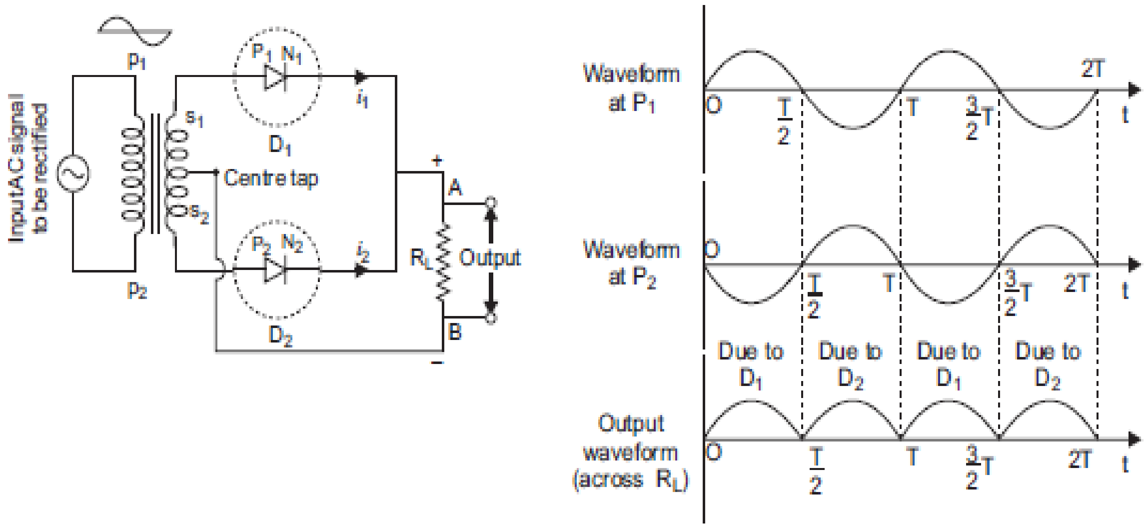
4. **Explain, with the help of a circuit diagram, the working of a *p-n* junction diode as a half-wave rectifier.**
Working



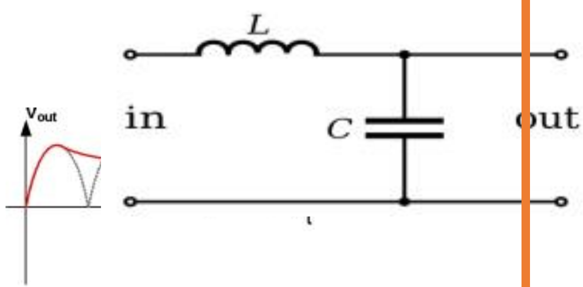
(*i*) During positive half cycle of input alternating voltage, the diode is forward biased and a current flows through the load resistor *RL* and we get an output voltage.
(*ii*) During other negative half cycle of the input alternating voltage, the diode is reverse biased and it does not conduct (under break down region).

LONG ANSWER TYPE QUESTIONS

1.Draw the circuit diagram of a full-wave rectifier and explain its working. Also, give the input and output waveforms.
Principle: Its principle is based on the fact that a diode conduct in forward biased.



Working : let during positive half cycle of input A.C , S_1 is at positive potential and S_2 is at –ve potential w.r.t centre tap. Due to this D_1 is in forward bias and D_2 is in reverse bias and we get output due to the diode D_1. During negative half cycle of input A.C , S_1 is at-ve potential and S_2 is at +ve potential w.r.t centre tap. Due to this D_2 is in forward bias and D_1 is in reverse bias and we get output due to the diode D_2.Thus , we get output for both input half cycle.
Filter Circuit : A circuit which filter the A.C component from the output rectifier. It decreases the ripple factor.



2. Explain briefly with the help of a circuit diagram how V-l characteristics of a p-n junction diode are obtained in (i) forward bias and (ii) reverse bias.

. **Refer –Minimum Learning material.**

CASE STUDY QUESTIONS

Q.NO	CASE STUDY QUESTION/QNS
I	A pure semiconductor germanium or silicon, free of every impurity is called intrinsic semiconductor. At room temperature, a pure semiconductor has very small number of current carriers (electrons and holes) .Hence its conductivity is low. When the impurity atoms of valance five or three are doped in a pure semiconductor, we get respectively n- type or p- type extrinsic semiconductor. In case of doped semiconductor ne nh=ni^2. Where ne and nh are the number density of electron and hole charge carriers in a pure semiconductor. The conductivity ofextrinsic semiconductor is much higher than that of intrinsic semiconductor. Answer the following questions:
Q-1	Which of the majority carrier in N-type semiconductor ? The majority charges in n- type semiconductors are electrons.
Q-2	How to doping with pure semiconsuctor to get P-type semiconductor? The impurity atoms with which pure Si should be doped to make a p- type semiconductor is Boron
Q-3	Holes are majority charge carriers in N-type or P-type Semiconductor? P- type semiconductors
Q-4	At the absolute zero Kelvin temperature , Si acts as which form? Insulator
II CASE	p-n junction is a semiconductor diode. It is obtained by bringing p-type semiconductor in close contact with n- type semiconductor. A thin layer is developed at the p- n junction which is devoid of any charge carrier but has immobile ions. It is called depletion layer. At the junction a potential barrier appears, which does not allow the movement of majority charge carriers across the junction in the absence of any biasing of the junction. p-n junction offers low resistance when forward biased and high resistance when reverse biased.
Q-1	What will be the value of the potential in the middle of depletion layer of reverse biased p- n junction.? Ans: Potential is maximum
Q-2	Name the material in which energy gap is maximum. Ans : Insulators
Q-3	On what factor primarily, the number of majority carriers crossing the junction of diode depends? It is the rate of thermal generation of electron –hole pairs
Q-4	Define Hole It is a vacancy created when an electron leaves covalent bond.