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SURA PUBLICATIONS
Chennai

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2022-23 *Edition*

ISBN : 978-93-92559-44-0

Code No : SG 323

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PREFACE

" The woods are lovely, dark and deep. "

But I have promises to keep, and
miles to go before I sleep

\- Robert Frost

Respected Principals, Correspondents, Head Masters / Head Mistresses, Teachers,

From the bottom of our heart, we at SURA Publications sincerely thank you for the support and patronage that you have extended to us for more than a decade.

It is in our sincerest effort we take the pride of releasing **SURA'S Physics Guide (Volume - I & II)** for +2 Standard. This guide has been authored and edited by qualified teachers having teaching experience for over a decade in their respective subject fields. This Guide has been reviewed by reputed Professors who are currently serving as Head of the Department in esteemed Universities and Colleges.

With due respect to Teachers, I would like to mention that this guide will serve as a teaching companion to qualified teachers. Also, this guide will be an excellent learning companion to students with exhaustive exercises and in-text questions in addition to precise answers for textual questions.

In complete cognizance of the dedicated role of Teachers, I completely believe that our students will learn the subject effectively with this guide and prove their excellence in Board Examinations.

I once again sincerely thank the Teachers, Parents and Students for supporting and valuing our efforts.

God Bless all.

Subash Raj, B.E., M.S.
- Publisher
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All the Best

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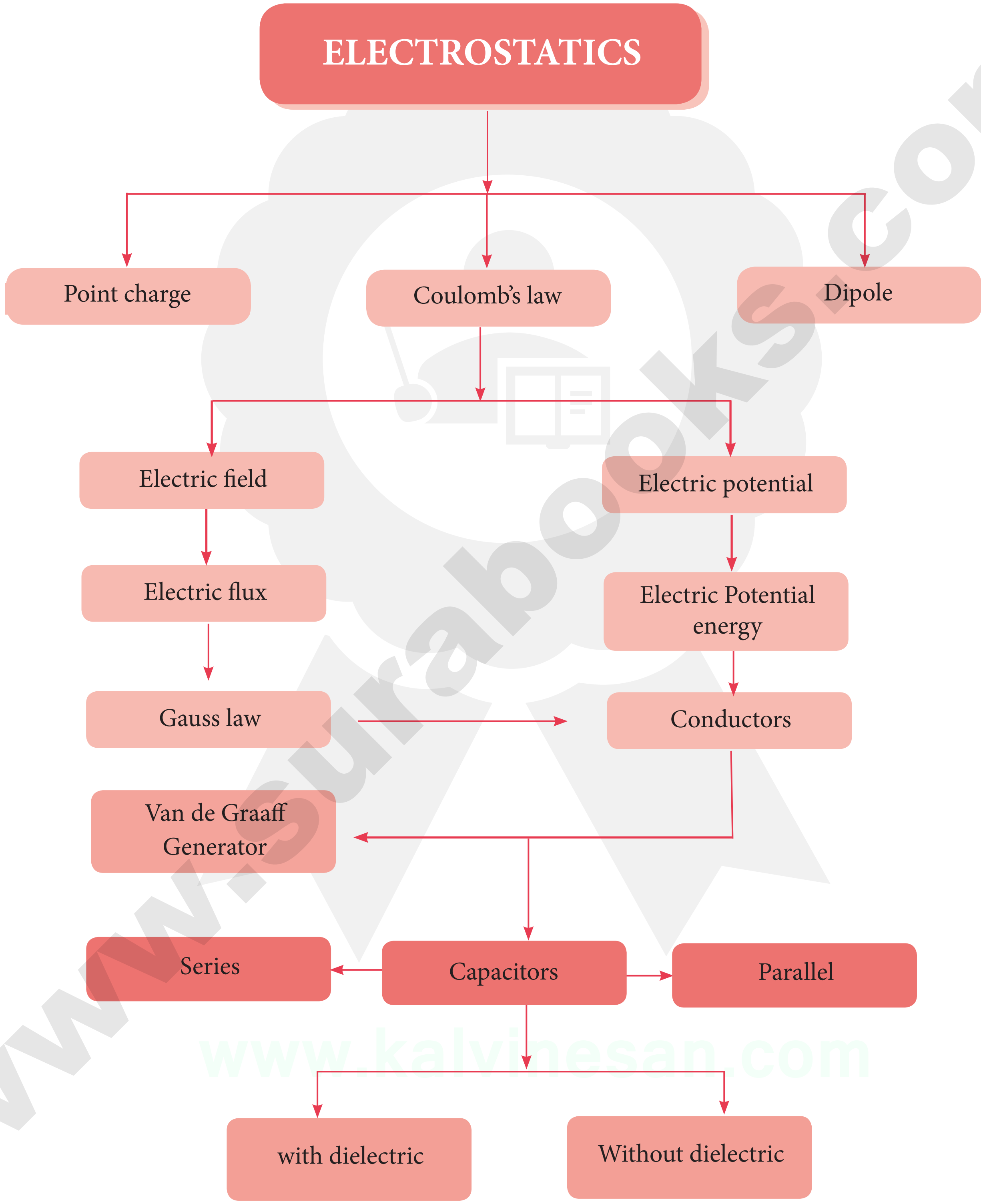
CONCEPT MAP


ELECTROSTATICS
Point charge
Coulomb's law
Dipole
Electric field
Electric potential
Electric flux
Electric Potential energy
Gauss law
Conductors
Van de Graaff Generator
Series
Capacitors
Parallel
with dielectric
Without dielectric

MUST KNOW DEFINITIONS

Electrostatics : Study of electric charges at rest or stationary charged bodies.

Electric charge : A basic property of some substances due to which they can exert a force of electrostatic attraction or repulsion on other charged bodies at a distance.

Frictional electricity :

600 B.C. Thales, a Greek Philosopher - amber with fur - electrification

17th century William Gilbert - glass, ebonite exhibit charging by rubbing.

Elektron (Greek word) - means amber

Positive charge	Negative charge
Glass rod	Silk cloth
Fur cap	Ebonite rod
Woollen cloth	Plastic object

Superposition principle : In an isolated system, the total force on a given charge is the vector sum of the individual forces exerted on it by all other charges, each individual force calculated by Coulomb's law.

$$\vec{F}_1^{tot} = k\left[\frac{q_1q_2}{r_{21}^2}\hat{r}_{21} + \frac{q_1q_3}{r_{31}^2}\hat{r}_{31} + ... + \frac{q_1q_n}{r_{n1}^2}\hat{r}_{nl}\right]$$

Properties of charges :

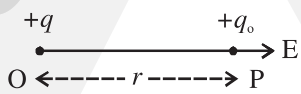
Quantisation of charge $q = ne$ [$n = 0, \pm1, \pm2, \pm3, ...$]

Charges are additive $Q = \Sigma Q_n$

Conservation of charges Q = Constant

A point charge : The dimension of the charged object is very small and neglected in comparison with the distances involved.

Electric field due to a point charge :



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

Direction of E is along line joining OP : Points outward for $+q$ at O
Points inward for $-q$ at O

Definition of Coulomb : It is defined as the quantity of charge which when placed at a distance of 1 metre in air or vacuum from an equal and similar charge experiences a repulsive force of 9×10^9 N.

Test charge : A charge which, on introduction in an existing field, does not alter the field.

Electric field : It is the space or the region around the source charge in which the effect of the charge can be felt.

Electric field intensity : Force experienced by a unit positive charge kept at that point in the field.

Electric lines of force	:	Imaginary straight or curved line along which a unit positive charge tends to move in an electric field. Each unit positive charge gives rise to $\frac{1}{\varepsilon_o}$ lines of force in free space.
Electric dipole	:	Two equal and opposite charges separated by a very small vector distance.
Importance of dipole	:	Any complicated array of a complex arrangement of charges, can be simplified as a number dipoles and analysed.
Potential difference	:	It is defined as the amount of work done in moving a unit positive charge from one point to the other in an electric field.
Volt	:	If 1 joule of work is done in moving 1 coulomb of charge from one point to another in an electric field.
Electric potential	:	It is defined as the amount of work done in moving a unit positive charge from infinity to that point.
Equipotential surface	:	If the potential at all points on a surface is the same, it is said to be an equipotential surface.
Electric flux	:	The total number of electric lines of force crossing a given area. $d\phi = \vec{E}.\vec{ds} = Eds\cos\theta$
Gauss' law	:	It states that the total flux of the electric field E over any closed surface is equal to $\frac{1}{\varepsilon_o}$ times the net charge enclosed by the surface, $\phi = \frac{q}{\varepsilon_o}$.
Gaussian surface	:	The closed imaginary surface over an enclosed net charge.
Electrostatic shielding	:	Process of isolating a certain region of space from external field. It is based on the fact that electric field inside a conductor is zero.
Electrostatic induction	:	It is the method of obtaining charges without any contact with another charge. They are called induced charges and the phenomenon of producing induced charges is called electrostatic induction. It is used in electrostatic machines like Van de Graaff generators and capacitors.
Capacitance	:	It is defined as the ratio of charge given to the conductor to the potential developed in the conductor. Its unit is farad (F). A conductor has a capacitance of one farad if a charge of 1 coulomb given to it raises its potential by 1 volt.
Dielectric	:	A dielectric is an insulating material in which all electrons are tightly bound to the nucleus of the atom. The electrons are not free to move under the influence of an external field. Hence, there are no free electrons to carry current.
Polar molecule	:	It is one in which the centre of gravity (mass) of the positive charges is separated from the centre of gravity of the negative charges by a finite distance. **e.g :** N_2O, H_2O, HC*l*, NH_3. These molecules have a permanent dipole moment.

Non-polar molecules : A non-polar molecule is one in which centers of positive and negative charges coincide. It has no permanent dipole moment, e.g: H_2, O_2, CO_2 etc.

Electric polarisation : The alignment of electric dipole moments of the permanent or induced dipoles in the direction of the external applied field.

Corona discharge : The leakage of electric charges from the sharp points on the charged conductor is called action of points or corona discharge. It is used in machines like Van de Graaff generators and lightning arrestors (conductors).

Force - Displacing vector

Torque - Rotating vectors; it is the moment of force

Hint:

1. In a uniform electric field when equal and opposite forces act at the ends of the dipole, the net force is zero.
2. The forces act at different points. Hence, the moment of the force is non-zero and the torque is non-zero.
3. The non-zero torque, always tends to align the dipole in the direction of the field.
4. The direction of torque vector is along the axis of rotation.
5. Charges outside the Gaussian surface will not contribute to the flux inside.
6. Field outside the charged parallel sheets is zero.

Conduction	Induction
Charges are obtained in contact with other charged body.	Charges are obtained without any contact with other charged body.
Produces similar or one type of charge.	Both positive and negative charges are produced.
Only limited amount of charges are obtained.	Large quantity of charges can be induced.

	Capacitors in series	Capacitors in parallel
Total Charge	q is same for C_1 and C_2 and C_3	$q = q_1 + q_2 + q_3$ $q_1 = C_1V$; $q_2 = C_2V$ $q_3 = C_3V$
Total potential	$V = V_1 + V_2 + V_3$ $V_1 = \frac{q}{C_1}$; $V_2 = \frac{q}{C_2}$; $V_3 = \frac{q}{C_3}$	V is same for C_1, C_2 and C_3
Expression for equivalent capacitance	$\frac{1}{C_s} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$	$C_p = C_1 + C_2 + C_3$

Charge (q)	Mass(m)
Can be zero, +ve or –ve	Can never be zero, only +ve
Force between two charges can be positive or negative	Force between any two masses is always attractive in nature
Value of constant depends upon $\varepsilon, \varepsilon_r, \varepsilon_0$	Value of constant G is always fixed.

FORMULAE

(1) Electrostatic force between charges q_1 and q_2, $F = \vec{F}_{12} = \frac{1}{4\pi\varepsilon_o}\frac{q_1q_2}{r_{21}^2}\hat{r}_{21}$

(2) Value of $k = \frac{1}{4\pi\varepsilon_o} = 9 \times 10^9\ Nm^2C^{-2}$

(3) Value of $\varepsilon = 8.854 \times 10^{-12}\ C^2N^{-1}m^{-2}$

(5) Total charge $q = n \times e$; Number of electrons × Charge of an electron

(6) Components of force F, $F_1 = F\cos\theta$; $F_2 = F\sin\theta$; $|F| = \sqrt{F_1^2 + F_2^2}$

(7) Relative permittivity or Dielectric constant $\varepsilon_r = \frac{\varepsilon}{\varepsilon_o}$

(8) Force between charges in medium $F_m = \frac{F_{air}}{\varepsilon_r}$

(9) Electrostatic field, $E = \frac{force}{charge} = \frac{F}{q} \Rightarrow F = qE$

(10) Electric field due to a point charge $E = \frac{1}{4\pi\varepsilon_o}\frac{q}{r^2}$

(11) Electric dipole moment, $\vec{p} = q \times 2a\hat{i}$

(12) (i) Electric field due to a dipole at a point on the axial line, $\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{2\vec{p}}{r^3}$ $(r >> a)$

(ii) Electric field due to a dipole at a point on the equatorial line $E = \vec{E}_{tot} = \frac{-1}{4\pi\varepsilon_0}\frac{\vec{p}}{r^3}$ $(r >> a)$

(13) Magnitude of torque $\tau = \vec{p} \times \vec{E} = pE\sin\theta$ $(p = q\ 2a)$

(14) Electric potential at a point due to a point charge, $V = \frac{1}{4\pi\varepsilon_o}\frac{q}{r}$

(15) Electric potential energy of dipole $U = -pE\cos\theta = -\vec{p}.\vec{E}$

(16) Electric potential at a point due to an electric dipole $V = \frac{p}{4\pi\varepsilon_o}\frac{\cos\theta}{r^2}$

(17) Electric flux $= \frac{q}{\varepsilon_o} \Rightarrow \phi_E = \vec{E}.\vec{A} = EA\cos\theta$

(18) Electric field due to infinite long straight charged wire, $E = \frac{\lambda}{2\pi\varepsilon_o r}$

(19) Electric field due to plane sheet of charge $E = \frac{\sigma}{2\varepsilon_o} = \frac{q}{A}\frac{1}{2\varepsilon_o}$ Vector form, $\vec{E} = \frac{\sigma}{2\varepsilon_0}\hat{n}$

Unit 1

(20) Electric field at a point between two parallel sheets of charge $E = \frac{\sigma}{\varepsilon_o}$

(21) Electric field due to a uniformly charged sphere -

(i) at a point on the surface of the sphere, $E = \frac{1}{4\pi\varepsilon_o}\frac{Q}{R^2}\hat{r}$ $[\because r = R]$

(ii) at a point outside the sphere $E = \frac{1}{4\pi\varepsilon_o}\frac{Q}{r^2}\hat{r}$

(iii) at a point inside the sphere $E = 0$ $[r < R]$

(22) Capacitance of a conductor $C = \frac{q}{V}$

(23) Work done by a charge $W = qV$

(24) Charge density, $\sigma = \frac{q}{A}$

(25) Capacitance of a parallel plate capacitor $C = \frac{\varepsilon_o A}{d}$

(i) With a dielectric slab, $C = \frac{\varepsilon_o A}{\left[(d-t) + \frac{t}{\varepsilon_r}\right]}$

(ii) With the dielectric completely filled capacitor $C^1 = \frac{\varepsilon_o \varepsilon_r A}{d} = C \times \varepsilon_r$

(26) Energy stored in a capacitor $E = \frac{1}{2}CV^2$

(27) Capacitance of a spherical capacitor, $C = 4\pi\varepsilon_0 A$ or $C = \frac{A}{9\times10^9}$

(28) Equivalent capacitance

(i) C_1 and C_2 in series $C_s = \frac{C_1C_2}{C_1 + C_2}$; $C_s = \frac{1}{C_S} = \frac{1}{C_1} + \frac{1}{C_2}$

(ii) C_1 and C_2 in parallel $C_p = C_1 + C_2$

(29) Polarisation, $\vec{p} = \chi_e \vec{E}_{ext}$ (χ_e - electric susceptibility)

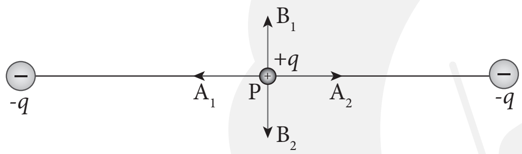
Values And Units

(1)	Permittivity of free space ε_o	=	8.854×10^{-12} $C^2N^{-1}m^{-2}$
(2)	$\frac{1}{4\pi\varepsilon_o}$	=	9×10^9 Nm^2C^{-2}
(3)	Charge of an electron, e	=	1.6×10^{-19} C
(4)	1 micro farad	=	10^{-6} farad
(5)	1 pico farad	=	10^{-12} farad
(6)	Permittivity of medium, ε	=	$C^2N^{-1}m^{-2}$
(7)	Electric charge (q)	=	Coulomb (C)
(8)	Electric field (E)	=	NC^{-1} or $V\ m^{-1}$
(9)	Electric potential (V)	=	JC^{-1} or volt
(10)	Electric dipole moment (p)	=	Coulomb metre
(11)	Electric potential energy (U)	=	Joule
(12)	Capacitance (C)	=	farad
(13)	Electric flux	=	Nm^2C^{-1}
(14)	Torque	=	Nm
(15)	Relative permittivity of air	=	1 (no unit)

EVALUATION

I. MULTIPLE CHOICE QUESTIONS :

1. Two identical point charges of magnitude $-q$ are fixed as shown in the figure below. A third charge $+q$ is placed midway between the two charges at the point P. Suppose this charge $+q$ is displaced a small distance from the point P in the directions indicated by the arrows, in which direction(s) will $+q$ be stable with respect to the displacement?



(a) A_1 and A_2 (b) B_1 and B_2
(c) both directions (d) No stable

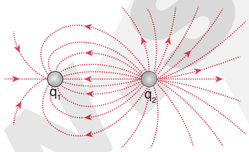
[Ans. (b) B_1 and B_2]

2. Which charge configuration produces a uniform electric field? *[HY-2019; Aug. 2021]*

(a) point Charge
(b) uniformly charged infinite line
(c) uniformly charged infinite plane
(d) uniformly charged spherical shell

[Ans. (c) uniformly charged infinite plane]

3. What is the ratio of the charges $\left|\frac{q_1}{q_2}\right|$ for the following electric field line pattern?



(a) $\frac{1}{5}$ (b) $\frac{25}{11}$ (c) 5 (d) $\frac{11}{25}$

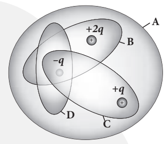
[Ans. (d) $\frac{11}{25}$]

4. An electric dipole is placed at an alignment angle of 30° with an electric field of 2×10^5 N C^{-1}. It experiences a torque equal to 8 N m. The charge on the dipole if the dipole length is 1 cm is *[QY-2019]*

(a) 4 mC (b) 8 mC
(c) 5 mC (d) 7 mC

[Ans. (b) 8 mC]

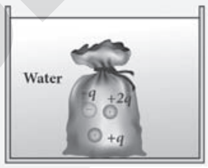
5. Four Gaussian surfaces are given below with charges inside each Gaussian surface. Rank the electric flux through each Gaussian surface in increasing order.



(a) D < C < B < A (b) A < B = C < D
(c) C < A = B < D (d) D > C > B > A

[Ans. (a) D < C < B <A]

6. The total electric flux for the following closed surface which is kept inside water



(a) $\frac{80q}{\varepsilon_o}$ (b) $\frac{q}{40\varepsilon_o}$

(c) $\frac{q}{80\varepsilon_o}$ (d) $\frac{q}{160\varepsilon_o}$

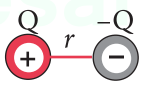
[Ans. (b) $\frac{q}{40\varepsilon_o}$]

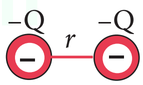
7. Two identical conducting balls having positive charges q_1 and q_2 are separated by a center to center distance r. If they are made to touch each other and then separated to the same distance, the force between them will be *(NSEP 04-05[Sep.-2020]*

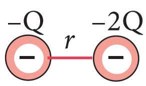
(a) less than before (b) same as before
(c) more than before (d) zero

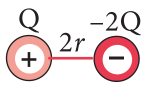
[Ans. (c) more than before]

8. Rank the electrostatic potential energies for the given system of charges in increasing order. *[PTA-4]*

(a) 

(b) 

(c) 

(d) 

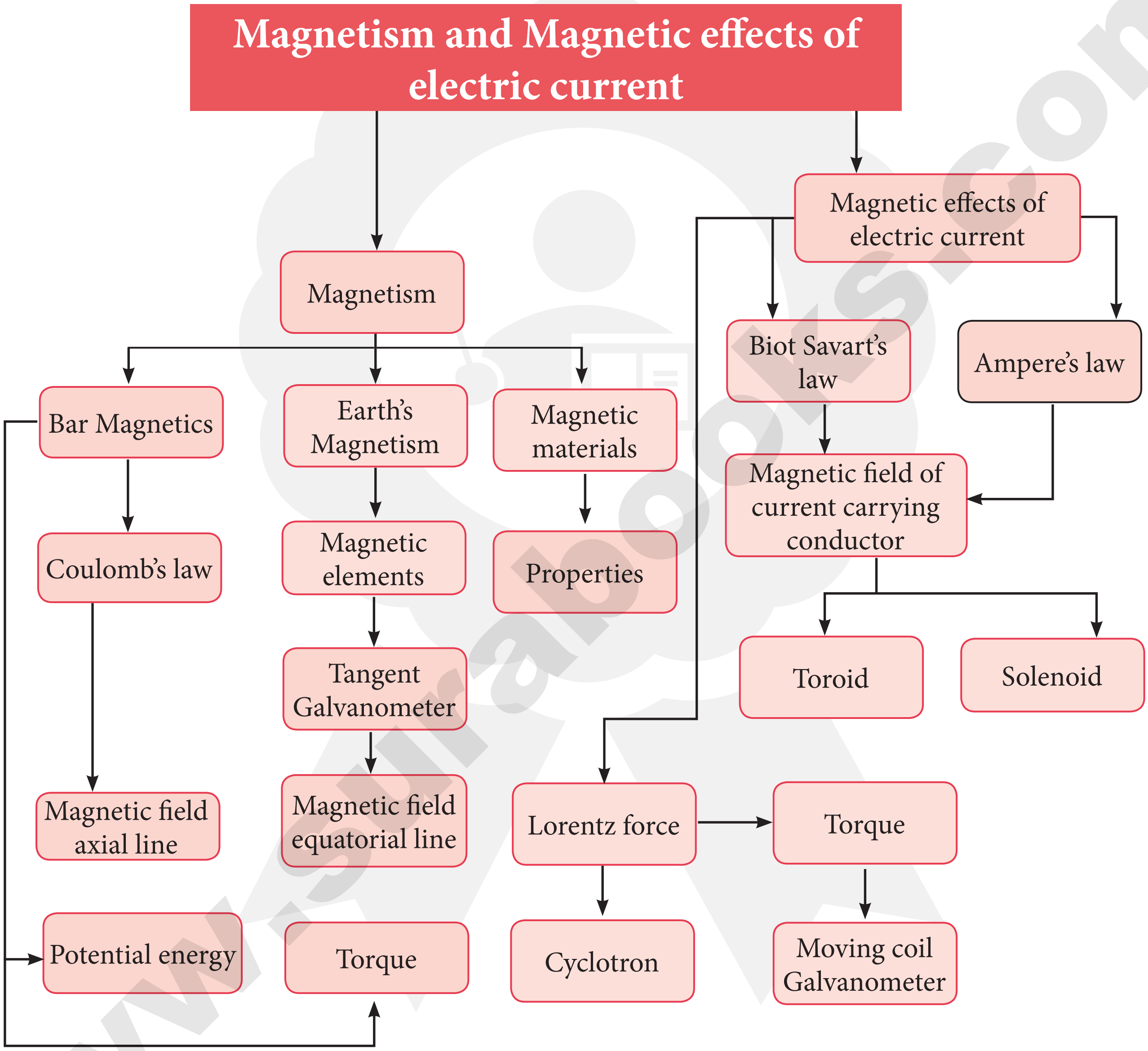
(a) 1 = 4 < 2 < 3 (b) 2 = 4 < 3 < 1
(c) 2 = 3 < 1 < 4 (d) 3 < 1 < 2 < 4

[Ans. (a) 1 = 4 < 2 < 3]

UNIT 3 MAGNETISM AND MAGNETIC EFFECTS OF ELECTRIC CURRENT

CHAPTER SNAPSHOT

CONCEPT MAP


Magnetism and Magnetic effects of electric current
Magnetism
Magnetic effects of electric current
Bar Magnetics
Earth's Magnetism
Magnetic materials
Biot Savart's law
Ampere's law
Coulomb's law
Magnetic elements
Properties
Magnetic field of current carrying conductor
Tangent Galvanometer
Toroid
Solenoid
Magnetic field axial line
Magnetic field equatorial line
Lorentz force
Torque
Potential energy
Torque
Cyclotron
Moving coil Galvanometer

MUST KNOW DEFINITIONS

Maxwells's right hand cork screw rule : If a right handed cork screw is rotated to advance along the direction of the current through a conductor, then the direction of rotation of the screw gives the direction of the magnetic lines of force around the conductor.

Biot - Savart Law : The magnetic induction dB at a point P due to the element of length *dl* is directly proportional to the current (I) and length *dl*.

Directly proportional to the sine of the angle between *dl* and the line joining the element *dl* and the point P (sinθ) inversely proportional to the square of the distance of the point from the element $\left(\frac{1}{r^2}\right)$. $dB = \frac{\mu_0}{4\pi}\frac{Idl\sin\theta}{r^2}$

Tangent galvanometer : It is a device used to measure current. It works on the principle of tangent law.

Tangent law : It states that a magnetic needle suspended at a point where there are two crossed fields at right angles to each other, will come to rest in the direction of the resultant of the two fields. $B = B_h \tan\theta$

Ampere's circuital law : It states that the line integral $\oint \vec{B} \cdot \vec{dl}$ for a closed curve is equal to μ_0 times the net current I_0 through the area bounded by the curve.

Right hand palm rule : The coil is held in the right hand so that the fingers point in the direction of the current in the windings. The extended thumb, points in the direction of magnetic field. This is applied for solenoid to find the direction of 'B'

End rule : When looked from one end, if the current through the solenoid is along clockwise direction, the nearer end corresponds to south pole and the other end is north pole.

When looked from one end, if the current through the solenoid is along anticlockwise direction, the nearer end corresponds to north pole and the other end is south pole.

Magnetic Lorentz force : The force experienced by a charged particle moving inside a magnetic field. $F = q(\vec{v} \times \vec{B}) = Bqv\sin\theta$

Cyclotron : Device used to accelerate charged particles to high energies.

It works on the principle that a charged particle moving normal to a magnetic field experiences a magnetic Lorentz force due to which the particle moves in a circular path.

Fleming's left hand rule : The forefinger, the middle finger and the thumb of the left hand are stretched in mutually perpendicular directions. If the forefinger points in the direction of the magnetic field, the middle finger in the direction of current, then the thumb points in the direction of the force on the conductor.

Ampere : It is defined as that constant current which when flowing through two parallel infinitely long straight conductors of negligible cross section, and placed in air or vacuum at a distance of one metre apart, experience a force of 2×10^{-7} newton per unit length of the conductor.

Moving coil galvanometer : It is a device used for measuring the current in a circuit. It works on the principle that a current carrying coil placed in a magnetic field experiences a torque.

Current sensitivity of a galvanometer : It is defined as the deflection produced when unit current passes through the galvanometer. A galvanometer is said to be sensitive if it produces large deflection for a small current.

Voltage sensitivity of a galvanometer : It is defined as the deflection per unit voltage applied.

Shunt is a low resistance connected in parallel with the galvanometer.

Ideal ammeter has zero resistance.

Ideal voltmeter offers infinite resistance to current.

Ampere's hypothesis : It states that all magnetic phenomena is due to circulating electric current.

Magnetic moment of a current loop : It is defined as the product of the current and the loop area. $P_m = IA$

Its direction is perpendicular to the plane of the loop.

Magnetic moment of electron. It is the vector sum of the orbital magnetic moment and its spin magnetic moment.

Bohr magneton : Minimum value of magnetic moment.

FORMULAE

(1) **Biot Savart law**

In vector form $d\vec{B} = \frac{\mu_o}{4\pi} \frac{I\vec{dl} \times \hat{r}}{r^2}$; In air, $dB = \frac{\mu_o}{4\pi} \frac{I.\, dl \sin\theta}{r^2}$

(2) Magnetic induction due to infinitely long straight conductor carrying current $B = \frac{\mu_o I}{2\pi a}$. In medium, $B = \frac{\mu I}{2\pi a}$ (or) $\vec{B} = \frac{\mu_0 I}{2\pi a}\hat{n}$ (in vector form)

(3) Magnetic induction along the axis of a circular coil carrying current $B = \frac{\mu_0 I R^2}{2\pi (R^2 + z^2)^{\frac{3}{2}}} \times k$ at the centre $B = \frac{\mu_0 I}{2R}$

(4) Tangent galvanometer reduction factor $k = \frac{2kB_H}{\mu_0 N}$

(5) Current I through n turns of Tangent Galvanometer $I = \frac{2RB_h}{\mu_0 N} = K \tan\theta$

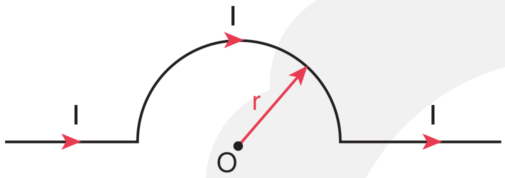
(6) (a) Ampere's circuital law $\oint \vec{B} \,.\, \vec{dl} = \mu_0 I_{enclosed}$.

(b) Magnetic field due to infinitely long current carrying wire using ampere's law $\vec{B} = \frac{\mu_0 I}{2\pi r}\hat{n}$

EVALUATION

I. MULTIPLE CHOICE QUESTIONS

1. The magnetic field at the center O of the following current loop is *[PTA-2]*

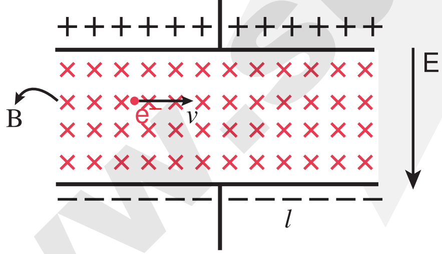


(a) $\frac{\mu_0 I}{4r} \otimes$ (b) $\frac{\mu_0 I}{4r} \odot$
(c) $\frac{\mu_0 I}{2r} \otimes$ (d) $\frac{\mu_0 I}{2r} \odot$

[**Ans.** (a) $\frac{\mu_0 I}{4r} \otimes$]

Hint: $B = \frac{\mu_0 I}{2\pi R}$; Here $R = \frac{2r}{\pi}$

2. An electron moves in a straight line inside a charged parallel plate capacitor of uniform charge density σ. The time taken by the electron to cross the parallel plate capacitor undeflected when the plates of the capacitor are kept under constant magnetic field of induction $\vec{B}$ is



(a) $\varepsilon_0 \frac{elB}{\sigma}$ (b) $\varepsilon_0 \frac{lB}{\sigma l}$
(c) $\varepsilon_0 \frac{lB}{e\sigma}$ (d) $\varepsilon_0 \frac{lB}{\sigma}$

[**Ans.** (d) $\varepsilon_0 \frac{lB}{\sigma}$]

Hint: $F = BIl$

3. A particle having mass m and charge q accelerated through a potential difference V. Find the force experienced when it is kept under perpendicular magnetic field $\vec{B}$. *[Mar-2020; Aug. 2021]*

(a) $\sqrt{\frac{2q^3BV}{m}}$ (b) $\sqrt{\frac{q^3B^2V}{2m}}$
(c) $\sqrt{\frac{2q^3B^2V}{m}}$ (d) $\sqrt{\frac{2q^3BV}{m^3}}$

[**Ans.** (c) $\sqrt{\frac{2q^3B^2V}{m}}$]

Hint: Horentz force $F = q = (\vec{V} \times \vec{B})$

4. A circular coil of radius 5 cm and 50 turns carries a current of 3 ampere. The magnetic dipole moment of the coil is nearly *[PTA-3]*

(a) 1.0 A m^2 (b) 1.2 A m^2
(c) 0.5 A m^2 (d) 0.8 A m^2

[**Ans.** (b) 1.2 A m^2]

Hint: Dipole moment P = IA

5. A thin insulated wire forms a plane spiral of N = 100 tight turns carrying a current I = 8 m A (milli ampere). The radii of inside and outside turns are a = 50 mm and b = 100 mm respectively. The magnetic induction at the centre of the spiral is

(a) 5 μT (b) 7 μT
(c) 8 μT (d) 10 μT

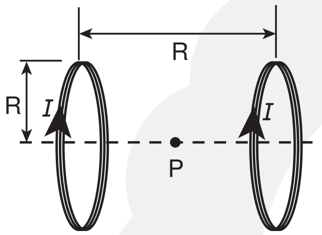
[**Ans.** (b) 7 μT]

6. Three wires of equal lengths are bent in the form of loops. One of the loops is circle, another is a semi-circle and the third one is a square. They are placed in a uniform magnetic field and same electric current is passed through them. Which of the following loop configuration will experience greater torque? *[PTA-1, 3]*

(a) Circle (b) Semi-circle
(c) Square (d) All of them

[**Ans.** (a) Circle]

7. Two identical coils, each with N turns and radius R are placed coaxially at a distance R as shown in the figure. If I is the current passing through the loops in the same direction, then the magnetic field at a point P at a distance of $\frac{R}{2}$ from the centre of each coil is



(a) $\frac{8N\mu_0 I}{\sqrt{5}R}$ (b) $\frac{8N\mu_0 I}{5^{3/2}R}$

(c) $\frac{8N\mu_0 I}{5R}$ (d) $\frac{4N\mu_0 I}{\sqrt{5}R}$

[**Ans.** (b) $\frac{8N\mu_0 I}{5^{3/2}R}$]

Hint: $B = \frac{\mu_0 I_2}{2\pi r}$

8. A wire of length l carrying a current I along the Y direction is kept in a magnetic field given by $\vec{B} = \frac{\beta}{\sqrt{3}}(\hat{i}+\hat{j}+\hat{k})T$. The magnitude of Lorentz force acting on the wire is *[Govt. MQP-2019]*

(a) $\sqrt{\frac{2}{3}}\beta Il$ (b) $\sqrt{\frac{1}{\sqrt{3}}}\beta Il$

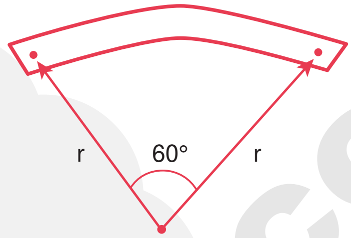
(c) $\sqrt{2}\beta Il$ (d) $\sqrt{\frac{1}{2}}\beta Il$

[**Ans.** (a) $\sqrt{\frac{2}{3}}\beta Il$]

Hint: Lorentz force $F = q = (\vec{V}\times\vec{B})$ and

$\vec{B} = \left[\frac{B}{\sqrt{3}}(i+j+k)\tau\right]$

9. A bar magnet of length l and magnetic moment p_m is bent in the form of an arc as shown in figure. The new magnetic dipole moment will be *(NEET 2013)*



(a) p_m (b) $\frac{3}{\pi}p_m$

(c) $\frac{2}{\pi}p_m$ (d) $\frac{1}{2}p_m$

[**Ans.** (b) $\frac{3}{\pi}p_m$]

Hint: Magnetic moment $M = ml \Rightarrow l = \frac{\pi r}{3}$

$\therefore r = \frac{3l}{\pi}$ New moment $M' = m \times r$

10. A non-conducting charged ring carrying a charge of q, mass m and radius r is rotated about its axis with constant angular speed ω. Find the ratio of its magnetic moment with angular momentum is *[QY-2019]*

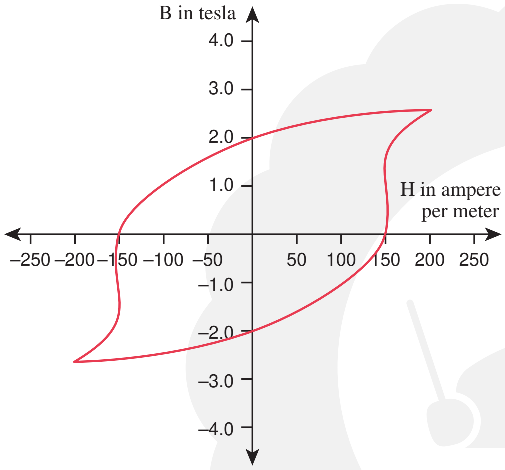
(a) $\frac{q}{m}$ (b) $\frac{2q}{m}$

(c) $\frac{q}{2m}$ (d) $\frac{q}{4m}$

[**Ans.** (c) $\frac{q}{2m}$]

Hint: $\frac{M}{l} = \frac{e}{zm}$

11. **The BH curve for a ferromagnetic material is shown in the figure. The material is placed inside a long solenoid which contains 1000 turns/cm. The current that should be passed in the solenonid to demagnetize the ferromagnet completely is**



(a) 1.00 m A (b) 1.25 mA
(c) 1.50 mA (d) 1.75 mA

[*Ans.* (c) 1.50 mA]

Hint: $H = \frac{nI}{2r}$

12. **Two short bar magnets have magnetic moments 1.20 Am^2 and 1.00 Am^2, respectively. They are kept on a horizontal table parallel to each other with their north poles pointing towards south. They have a common magnetic equator and are separated by a distance of 20.0 cm. The value of the resultant horizontal magnetic induction at the mid-point O of the line joining their centres is (Horizontal components of Earth's magnetic induction is 3.6×10^{-5} Wb m^{-2})**

(NSEP 2000-2001)

(a) 3.60×10^{-5} Wb m^{-2}
(b) 3.5×10^{-5} Wb m^{-2}
(c) 2.56×10^{-4} Wb m^{-2}
(d) 2.2×10^{-4} Wb m^{-2}

[*Ans.* (c) 2.56×10^{-4} Wb m^{-2}]

13. **The vertical component of Earth's magnetic field at a place is equal to the horizontal component. What is the value of angle of dip at this place?**

[HY-2019]

(a) 30° (b) 45° (c) 60° (d) 90°

[*Ans.* (b) 45°]

Hint: B sinθ = B cosθ

14. **A flat dielectric disc of radius R carries an excess charge on its surface. The surface charge density is σ. The disc rotates about an axis perpendicular to its plane passing through the centre with angular velocity ω. Find the magnitude of the torque on the disc if it is placed in a uniform magnetic field whose strength is B which is directed perpendicular to the axis of rotation**

(a) $\frac{1}{4}\sigma\omega\pi BR$ (b) $\frac{1}{4}\sigma\omega\pi BR^2$
(c) $\frac{1}{4}\sigma\omega\pi BR^3$ (d) $\frac{1}{4}\sigma\omega\pi BR^4$

[*Ans.* (d) $\frac{1}{4}\sigma\omega\pi BR^4$]

15. **The potential energy of magnetic dipole whose dipole moment is $\vec{p}_m = (-0.5\hat{i} + 0.4\hat{j})$ Am^2 kept in uniform magnetic field $\vec{B} = 0.2\hat{i}$ T.**

(a) –0.1 J (b) –0.8 J
(c) 0.1 J (d) 0.8 J

[*Ans.* (c) 0.1 J]

Hint: $U = \vec{P}_m \cdot \vec{B}$

II. Short Answer Questions :

1. **What is meant by magnetic induction?**

Ans. The magnetic induction (total magnetic field) inside the specimen $\vec{B}$ is equal to the sum of the magnetic field B produced in vacuum due to the magnetising field and the magnetic field $\vec{B}_m$ due to the induced magnetisation of the substance.

$$\vec{B} = \vec{B}_0 + \vec{B}_m = \mu_0 \vec{H} + \mu_0 \vec{I} = \mu_0 (\vec{H} + \vec{I})$$
$$= (\vec{H} + \vec{I})$$

2. **Define magnetic flux.**

Ans. The number of magnetic field lines crossing per unit area is called magnetic flux Φ_B.

$$\Phi_B = \vec{B}.\vec{A} = BA \cos\theta$$

where θ is the angle between $\vec{B}$ and $\vec{A}$.

3. Define magnetic dipole moment.

Ans. The product of its pole strength and magnetic length. $p_m = 2q_m l$

4. State Coulomb's inverse law.

Ans. The force of attraction or repulsion between two magnetic poles is directly proportional to the product of their pole strengths and inversely proportional to the square of distance between them.

Mathematically, we can write

$$\vec{F} \propto \frac{q_{mA} q_{mB}}{r^2} \hat{r}$$

5. What is magnetic susceptibility?

Ans. It is defined as the ratio of the intensity of magnetisation ($\vec{M}$) induced in the material to the applied magnetising field ($\vec{H}$)

$$\chi_m = \frac{|\vec{M}|}{|\vec{H}|}$$

6. State Biot-Savart's law.

Ans. (i) Magnetic field due to current element is directly proportional to current (I), length of the element (dl), sine of the angle between $\vec{dl}$ and $\hat{r}$.

(ii) Magnetic field due to current element is inversely proportional to square of distance (r).

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

7. What is magnetic permeability?

Ans. The magnetic permeability can be defined as the measure of ability of the material to allow the passage of magnetic field lines through it or measure of the capacity of the substance to take magnetisation or the degree of penetration of magnetic field through the substance.

8. State Ampere's circuital law. *[PTA-4, 6; QY-2019; Sep.-2020; Aug. 2021]*

Ans. **Ampère's law:** The line integral of magnetic field over a closed loop is μ_0 times net current enclosed by loop.

$$\oint_C \vec{B}.\vec{dl} = \mu_0 I_{enclosed}$$

9. Compare dia, para and ferro-magnetism. *[PTA-5 ; Sep.-2020; QY-2019]*

Ans.

	Dia magnetic materials	Para magnetic materials	Ferro magnetic materials
1.	Magnetic susceptibility is negative	Magnetic susceptibility is positive and small	magnetic susceptibility is positive and large
2.	Relativbe permeability is slightly less than unity	Relative permeability is greater than unity	Relative permeability large
3.	The magnetic field lines are repelled or expelled by diamagnetic materials when placed in a magnetic field	The magnetic field lines are attracted in to paramagnetic materials when placed in a magnetic field	The magnetic field line are strongly attracted into the ferromagnetic materials when placed in a magnetic field
4.	Susceptibility is nearly temprature independent Ex : Bismuth, Copper and Water	Susceptibility is inversely preportional to temperature Ex : Aluminium, Platinum and Chromium	Susceptibility is inversely preportioned to temperature Ex : Iron, Nickel and Cobalt

10. What is meant by hysteresis? *[HY-2019]*

Ans. The phenomenon of lagging of magnetic induction behind the magnetising field is called hysteresis. Hysteresis means 'lagging behind'.

11. Define magnetic declination and inclination.

Ans. **Magnetic declination :**

The angle between magnetic meridian at a point and geographical meridian is called magnetic declination (D).

Magnetic Inclination:

The angle subtended by the Earth's total magnetic field $\vec{B}$ with the horizontal direction in the magnetic meridian is called **dip** or magnetic inclination at that point (I).

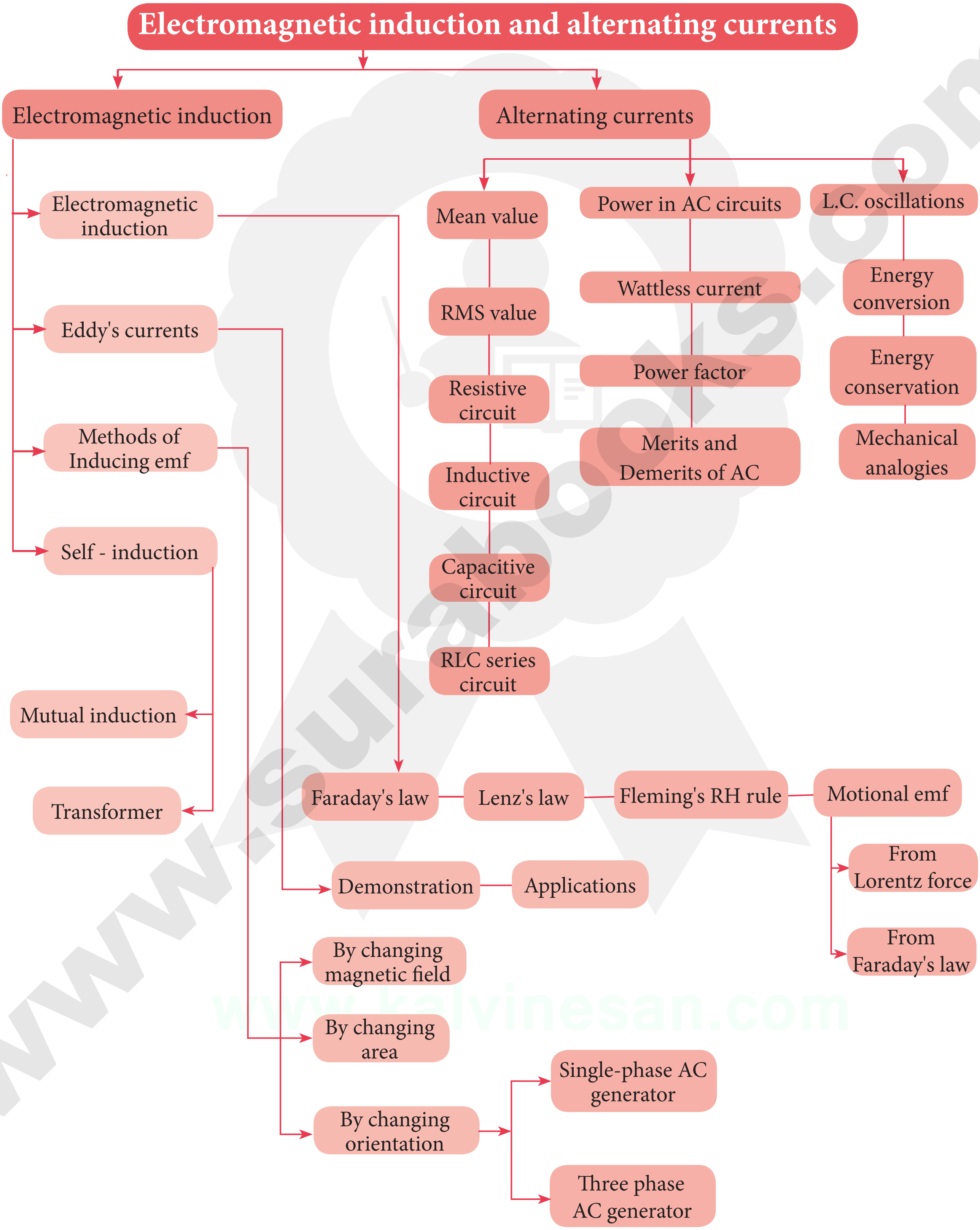
12. What is resonance condition in cyclotron?

Ans. In cyclotron operation, when the frequency 'f' at which the positive ion circulates in the magnetic field becomes equal to the constant frequency of the electrical oscillator force, then this condition is termed as resonance condition.

UNIT 4 ELECTROMAGNETIC INDUCTION AND ALTERNATING CURRENT

CHAPTER SNAPSHOT

CONCEPT MAP


Electromagnetic induction and alternating currents
Electromagnetic induction
Alternating currents
Electromagnetic induction
Eddy's currents
Methods of Inducing emf
Self - induction
Mutual induction
Transformer
Mean value
RMS value
Resistive circuit
Inductive circuit
Capacitive circuit
RLC series circuit
Power in AC circuits
Wattless current
Power factor
Merits and Demerits of AC
L.C. oscillations
Energy conversion
Energy conservation
Mechanical analogies
Faraday's law
Lenz's law
Fleming's RH rule
Motional emf
From Lorentz force
From Faraday's law
Demonstration
Applications
By changing magnetic field
By changing area
By changing orientation
Single-phase AC generator
Three phase AC generator

MUST KNOW DEFINITIONS

Electromagnetic induction	:	When the magnetic flux linked with the conductor changes an emf is induced.
Magnetic flux	:	The magnetic flux (ϕ) linked with a surface held in a magnetic field (B) is defined as the number of magnetic lines of force crossing a closed area (A) $\phi_B = \vec{B}.\vec{A} = B.A \cos \varphi$
Induced emf	:	It is the emf produced wherever there is a change in the magnetic flux linked with a closed circuit.
Electric bulb	:	Resistance of the filament in the bulb is high. ❖ Tungsten with a high melting point 3380°C is used as the filament.
Electromagnetic induction	:	Emf due to the changes in the magnetic flux associated with a closed circuit.
Faraday's laws of electromagnetic induction	:	**First law :** Whenever the amount of magnetic flux linked with a closed circuit changes, an emf is induced in the circuit. The induced emf lasts as long as the change in the magnetic flux continues. **Second law :** The magnitude of emf induced in a closed circuit is directly proportional to the rate of change of magnetic flux linked with the circuit $\varepsilon \propto \frac{d\Phi_B}{dt}$
Lenz's law	:	It states that the induced current produced in a circuit always flows in such a direction that it opposes the change or cause that produces it.
Fleming's right hand rule	:	The forefinger, the middle finger and the thumb of the right hand are held in three mutually perpendicular directions. If the forefinger points along the direction of the magnetic field and the thumb along the direction of motion of the conductor, then the middle finger points in the direction of induced current.
Self induction	:	The property of a coil which enables to produce an opposing induced emf in it, when the current in the coil changes, is called self induction.
Coefficient of self induction	:	It is numerically equal to the magnetic flux linked with a coil when unit current flows through it. It is numerically equal to the opposing emf induced in the coil when the rate of change of current through the coil is unity.
Mutual induction	:	The phenomenon of producing an induced emf in a primary coil due to the change in current in the secondary coil is known as mutual induction.
Coefficient of mutual induction	:	Mutual Inductance of two coils is numerically equal to the magnetic flux linked with one coil when unit current flows through the neighbouring coil. ❖ It is numerically equal to the emf induced in one coil when the rate of change of current through the other coil is unity. SI unit of coefficient of mutual induction is henry.

One henry : It is defined as the coefficient of mutual induction between a pair of coils when a change of current of one ampere per second in one coil produces an induced emf of one volt in the other coil.

The factors on which coefficient of mutual induction depends upon are,

(a) size and shape of the coils, number of turns and permeability of the medium.
(b) proximity of the coils.

Induced emf can be produced by changing

(a) the magnetic induction (B)
(b) area enclosed by the coil (A) and
(c) the orientation of the coil (θ) with respect to the magnetic field.

AC generator (Dynamo) : **Single phase**

(a) It was originally designed by a Yugoslav scientist Nikola Tesla.
(b) It is a device used for converting mechanical energy into electrical energy.
(c) It is based on the principle of electromagnetic induction, by which, an emf is induced in a coil when it is rotated in a uniform magnetic field.

❖ **Polyphase AC generator :** It consists of a number of armature windings which are placed on the same axis but displaced from one another by equal angle which depends upon the number of phases.

❖ **Three phase AC generator :** It consists of three coils, fastened rigidly together and displaced from each other by 120°. Each coil is provided with a separate set of slip rings and brushes and it rotates about a fixed axis in a uniform magnetic field.

Sl.No	Two phase ac generator	Three phase ac generator
1.	2 coils	3 coils
2.	Angle of inclination between coils is 90°	Angle of inclination between coils is 120°
3.	Phase difference between the emf and current of different coils is 90°	Phase difference between emf and current of different coils is 120°
4.	Produces two phase AC.	Produces three phase AC.

Eddy currents :

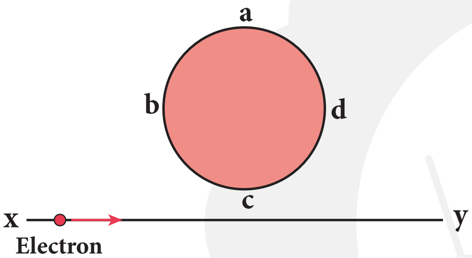
(a) Observed first by Foucault in 1895.
(b) When a mass of a metal of any shape moves in a magnetic field or when the magnetic field through a stationary mass of metal is altered, induced current is produced in the metal.
(c) This induced current flows in the metal in the form of closed loops resembling whirlpool or eddies.
(d) These are known as eddy currents or Foucault current.
(e) Direction of eddy current is given by Lenz's law.

Drawback of Eddy currents : When eddy currents flow in the conductor, large amount of energy is produced in the form of heat and wasted.

Evaluation

I. Multiple Choice Questions

1. An electron moves on a straight line path XY as shown in the figure. The coil *abcd* is adjacent to the path of the electron. What will be the direction of current, if any, induced in the coil? *(NEET – 2015)*

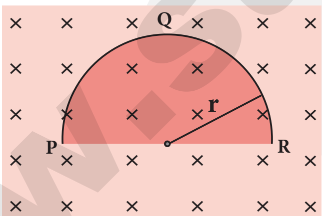


(a) The current will reverse its direction as the electron goes past the coil
(b) No current will be induced
(c) abcd
(d) adcb

[*Ans.* (a) The current will reverse its direction as the electron goes past the coil]

Hint: Direction of current is opposite to the electron flowing direction.

2. A thin semi-circular conducting ring (PQR) of radius r is falling with its plane vertical in a horizontal magnetic field B, as shown in the figure.



The potential difference developed across the ring when its speed *v*, is *(NEET 2014)*

(a) Zero
(b) $\frac{Bv\pi r^2}{2}$ and P is at higher potential
(c) πrBv and R is at higher potential
(d) $2rBv$ and R is at higher potential

[*Ans.* (d) 2rBv and R is at higher potential]

3. The flux linked with a coil at any instant t is given by $\Phi_B = 10t^2 - 50t + 250$. The induced emf at t = 3s is *[HY-2019]*

(a) –190 V
(b) – 10 V
(c) 10 V
(d) 190 V

[*Ans.* (b) – 10 V]

Hint: $e = -\frac{d}{dt}(\phi_B) = \frac{-d}{dt}(10t^2 - 50t + 250) = (20t + 50)$
when t = 3s; e = –60 + 50 = –10 V

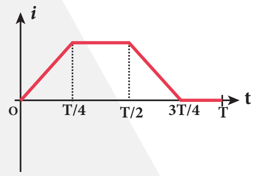
4. When the current changes from +2A to –2A in 0.05 s, an emf of 8 V is induced in a coil. The co-efficient of self-induction of the coil is *[Govt. MQP-2019; Sep.-2020]*

(a) 0.2 H
(b) 0.4 H
(c) 0.8 H
(d) 0.1 H

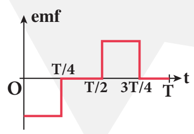
[*Ans.* (d) 0.1 H]

Hint: $L = \frac{-e}{dI/dt} = \frac{-8}{4/0.05} = 0.1$ H

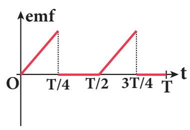
5. The current *i* flowing in a coil varies with time as shown in the figure. The variation of induced emf with time would be *(NEET – 2011)*



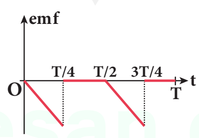
(a)



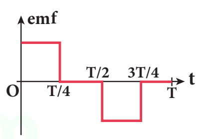
(b)



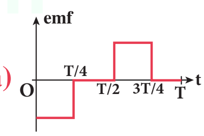
(c)



(d)



[*Ans.* (a)



]

Hint: $e = \frac{LdI}{dt}$

6. A circular coil with a cross-sectional area of 4 cm² has 10 turns. It is placed at the centre of a long solenoid that has 15 turns/cm and a cross-sectional area of 10 cm². The axis of the coil coincides with the axis of the solenoid. What is their mutual inductance?

(a) 7.54 μH (b) 8.54 μH
(c) 9.54 μH (d) 10.54 μH

[*Ans.* (a) 7.54 μH]

Hint: $M = \mu_0\mu_r n_1 n_2 A_2 l$.

7. In a transformer, the number of turns in the primary and the secondary are 410 and 1230 respectively. If the current in primary is 6A, then that in the secondary coil is *[Aug. 2021]*

(a) 2 A (b) 18 A
(c) 12 A (d) 1 A [*Ans.* (a) 2 A]

Hint: $\frac{N_s}{N_p} = \frac{i_p}{i_s}$

8. A step-down transformer reduces the supply voltage from 220 V to 11 V and increase the current from 6 A to 100 A. Then its efficiency is

(a) 1.2 (b) 0.83
(c) 0.12 (d) 0.9

[*Ans.* (b) 0.83]

Hint: $\text{Efficiency} = \frac{V_s i_s}{V_p i_p}$

9. In an electrical circuit, R, L, C and AC voltage source are all connected in series. When L is removed from the circuit, the phase difference between the voltage and current in the circuit is $\frac{\pi}{3}$. Instead, if C is removed from the circuit, the phase difference is again $\frac{\pi}{3}$. The power factor of the circuit is *(NEET 2012)*

(a) $\frac{1}{2}$ (b) $\frac{1}{\sqrt{2}}$
(c) 1 (d) $\frac{\sqrt{3}}{2}$ [*Ans.* (c) 1]

Hint: Power factor $= \cos\phi$ and $\phi = \frac{\pi}{3} - \frac{\pi}{3} = 0$

10. In a series RL circuit, the resistance and inductive reactance are the same. Then the phase difference between the voltage and current in the circuit is *[QY-2019]*

(a) $\frac{\pi}{4}$ (b) $\frac{\pi}{2}$
(c) $\frac{\pi}{6}$ (d) zero

[*Ans.* (a) $\frac{\pi}{4}$]

11. In a series resonant RLC circuit, the voltage across 100 Ω resistor is 40 V. The resonant frequency ω is 250 rad/s. If the value of C is 4 μF, then the voltage across L is

(a) 600 V (b) 4000 V
(c) 400V (d) 1 V

[*Ans.* (c) 400 V]

Hint: $W = \frac{1}{\sqrt{LC}}; I = \frac{V}{R}$ and $V_L = IX_L = IL_W$

12. An inductor 20 mH, a capacitor 50 μF and a resistor 40 Ω are connected in series across a source of emf v = 10 sin 340 t. The power loss in AC circuit is

(a) 0.76 W (b) 0.89 W
(c) 0.46 W (d) 0.67 W

[*Ans.* (c) 0.46 W]

13. The instantaneous values of alternating current and voltage in a circuit are

$i = \frac{1}{\sqrt{2}} \sin(100\pi t)$ A and

$v = \frac{1}{\sqrt{2}} \sin\left(100\pi t + \frac{\pi}{3}\right)$ V.

The average power in watts consumed in the circuit is *(IIT Main 2012)*

(a) $\frac{1}{4}$ (b) $\frac{\sqrt{3}}{4}$
(c) $\frac{1}{2}$ (d) $\frac{1}{8}$ [*Ans.* (d) $\frac{1}{8}$]

(ii) Here, $\theta = 90° - 30° = 60°$

$\phi = 0.3 \times 6 \times 10^{-2} \times \cos 60°$

$\phi = 0.9 \times 10^{-2}$ Wb

(iii) Here, $\theta = 90° - 0° = 90°$

$\phi = 0.3 \times 6 \times 10^{-2} \times \cos 90°$

$\phi = 0°$

18. The magnetic flux through a coil perpendicular to the plane is given by $\varphi = 5t^3 + 4t^2 + 2t$ calculate the induced emf through the coil at $t = 2$s.

Sol.: Given:

We know that $\varepsilon = -\frac{d\phi}{dt}$

$\varepsilon = \frac{d}{dt}(5t^3 + 4t^2 + 2t)$

$\varepsilon = 15t^2 + 8t + 2$

for $t = 2s$, $\varepsilon = 15 \times (2)^2 + 8\,(2) + 2$

$\varepsilon = 78V$

19. A solenoid of length 1 m and 0.05 m diameter has 500 turns. If a current of 2A passes through the coil, calculate (i) the coefficient of self induction of the coil and (ii) the magnetic flux linked with a the coil.

Sol.: Given:

$l = 1$ m ; $d = 0.05$ m ; $r = 0.025$ m ; N = 500 ; I = 2A; (i) L = ? (ii) ϕ = ?

Solution:

(i) $L = \frac{\mu_0 N^2 A}{l} = \frac{\mu_0 N^2 \pi r^2}{l}$

$= \frac{4\pi \times 10^{-7} \times (5 \times 10^2)^2 \times 3.14 (0.025)^2}{1}$

$\therefore$ L = 0.616 mH

(ii) Magnetic flux ϕ = LI

= 0.616 × 10–3 × 2 = 1.232 × 10–3

ϕ = 1.232 milli weber.

20. A circular coil of radius 8.0 cm and 20 turns rotated about its vertical diameter with an angular speed of 50 rad s^{-1} in a uniform horizontal magnetic field of magnitude 3×10^{-2} T. Obtain the maximum and average emf induced in the coil. If the coil forms a closed loop of resistance 10 Ω then calculate the average power loss due to joule heating.

Sol.: Given:

Radius of coil, r = 8.0 cm $= 8 \times 10^{-2}$ m

N = 20 turns, ω = 50 rad s^{-1}

To find : $B = 3 \times 10^{-2}$ T, e_m = ? e = ?

Resistance R = 10 Ω, Power P = ?

We know, $e_m = NAB\omega = N(\pi r^2)B\omega$

$\varepsilon_m = 20 \times \frac{22}{7} \times (8 \times 10^{-2})^2 \times 3 \times 10^{-2} \times 50$

$\varepsilon_m = 0.603V$

Average value of emf induced over a full cycle, $\varepsilon_{av} = 0$

$I_{max} = \frac{e_m}{R} = \frac{0.603}{10} = 0.0603A$

Average power dissipated, $P_{av} = \frac{e_m I_m}{2}$

$= \frac{0.603 \times 0.0603}{2}$; $P_{av} = 0.018$ W

21. What is the self - inductance of a solenoid of length 40cm, area of cross - section 20cm² and total number of turns is 800?

Sol.: Given: l = 40cm = 0.4m

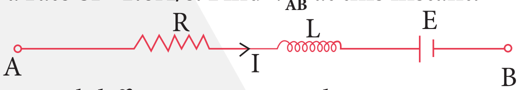
A = 20 cm² $= 20 \times 10^{-4}\ m^2$

N = 800, L = ?

$L = \frac{\mu_0 N^2 A}{l} = \frac{4\pi \times 10^{-7} \times (800)^2 \times 20 \times 10^{-4}}{0.4}$

$L = 4.02 \times 10^{-5}$H

22. In the circuit diagram shown in figure, R = 10Ω, L = 5H, E = 20V, I = 2A. This current is decreasing at a rate of –1.0A/s. Find V_{AB} at this instant.



Sol.: Potential difference across inductor is

$V_L = L.\frac{dI}{dt} = 5 \times (-1.0)$

$V_L = -5.0V$

Using Kirchoff's II law,

$V_A - IR - V_L - E = V_B$

$(V_A - V_B) = IR + V_L + E$

i.e $V_{AB} = (2 \times 10) + (-5.0) + 20 = 35V$

23. A 1m long solenoid with diameter 2cm and 2000 turns has a secondary coil of 1000 turns wound closely near its mid-point. What will be the mutual inductance between the two coils?

Sol.: Given : l = 1m, $r = \frac{2}{2}$ cm = 1 cm $= 10^{-2}$ m

$N_1 = 2000$, $N_2 = 1000$, $A = \pi r^2$

$A = \pi\,(10^{-2})^2$ m²

To find : M= ?

Mutual inductance between the coils is given by

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

$$= \frac{4\pi\times10^{-7}\times2000\times1000\times\pi\times10^{-4}}{1}$$

$M = 78.88 \times 10^{-5}$ H.

24. An AC generator consists of a coil of 1000 turns and cross sectional area of 100 cm², rotating at an angular speed of 100 rpm in a uniform magnetic field of 3.6 × 10⁻² T. Calculate the maximum emf produced in the coil.

Sol.: Given : N = 1000

A = 100 cm² = 10^{-2} m²

v = 100 rpm = $\frac{100}{60}$ rps

B = 3.6×10^{-27}

ε_m = ?

$\varepsilon_m = NBA\omega = NBA\,(2\pi\gamma)$

$= 1000 \times (3.6 \times 10^{-2}) \times (10^{-2}) \times 2 \times \frac{22}{7} \times \frac{100}{60}$

ε = 3.77 V

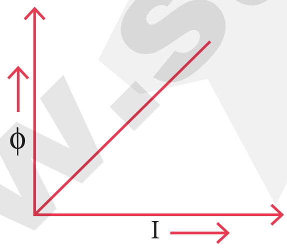
25. The current flowing through an inductor of self inductance L is continuously increasing Plot a graph showing the variation of

a) Magnetic flux versus current.

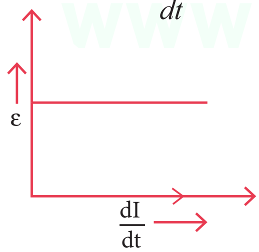
b) induced emf versus $\frac{dI}{dt}$

c) magnetic potential energy stored varsus the current.

Sol.: (a) Given : Magnetic flux versus current :



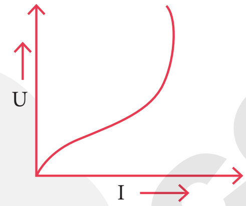
(b) Induced emf versus $\frac{dI}{dt}$ $\qquad \varepsilon = -L\frac{dI}{dt}$



(c) Magnetic potential energy stored versus current :

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

$U \propto I^2$



26. The instantaneous current from an AC source is given by I = 5 sin 314 t. What is the rms value of the current?

Sol.: Given : I = 5 sin 314 *t* ...(1)

We know that I = $I_m \sin \omega t$ ...(2)

Comparing (1) & (2)

I_m = 5A,

ω = 314

$$I_{rms} = \frac{I_m}{\sqrt{2}} = \frac{5}{\sqrt{2}} = 3.536\text{A}$$

27. Calculate the instantaneous voltage for AC supply of 220 V and 50 Hz.

Sol.: Given : E_v = 220 V

γ = 50 Hz

To find : E = ?

We can use $E_v = \frac{E_m}{\sqrt{2}}$

$E_m = \sqrt{2} \times E_v = \sqrt{2} \times 220$

= 311.08 V.

∴ Instantaneous Voltage $E = E_m \sin \omega t$

$E = E_m \sin\ (2\pi\gamma)t$

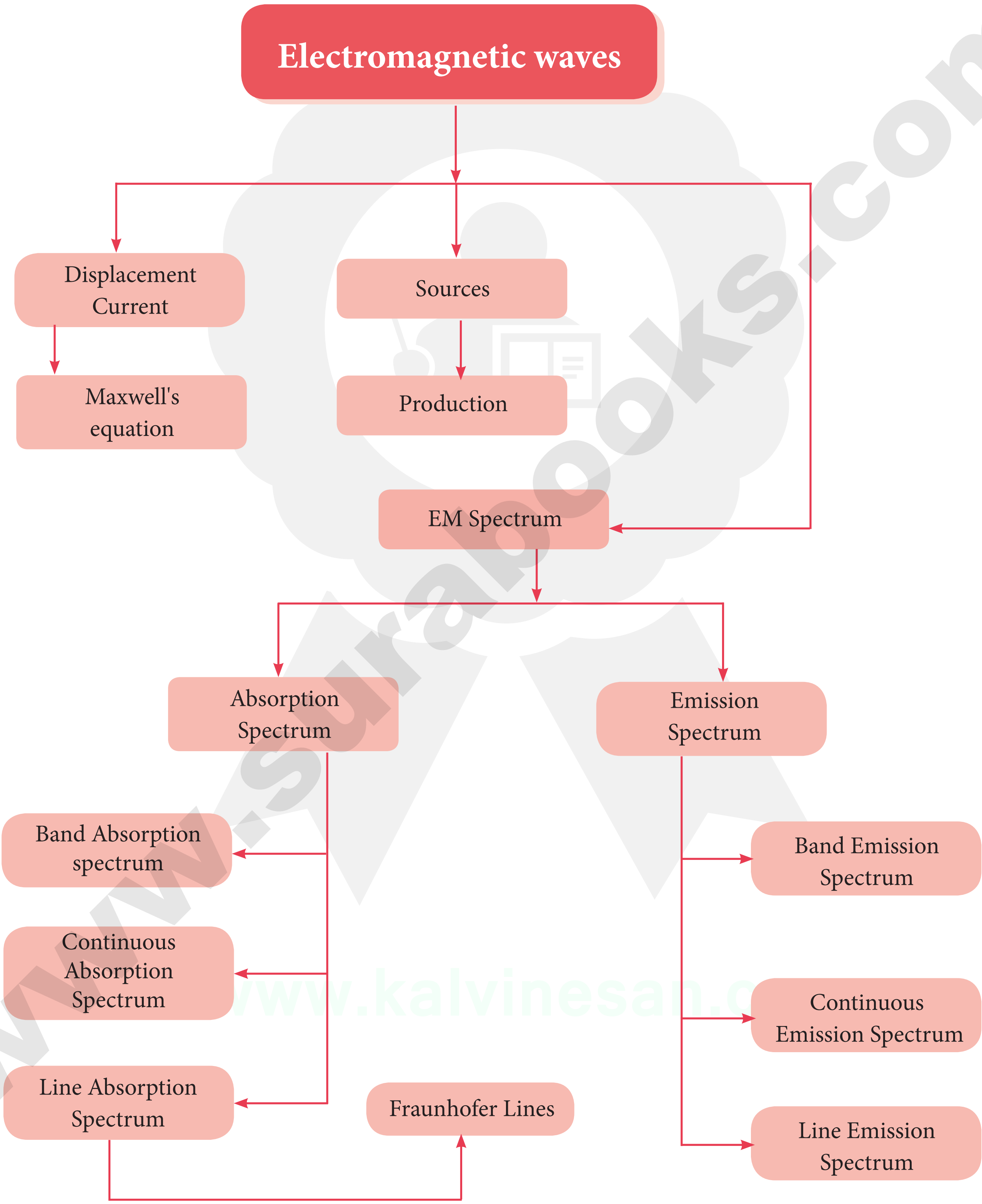
$= 311 \sin\ (2\pi \times 50)t$

= 311 sin 100 π*t*.

UNIT 5 ELECTROMAGNETIC WAVES

CHAPTER SNAPSHOT

CONCEPT MAP



Electromagnetic waves
Displacement Current
Maxwell's equation
Sources
Production
EM Spectrum
Absorption Spectrum
Emission Spectrum
Band Absorption spectrum
Continuous Absorption Spectrum
Line Absorption Spectrum
Fraunhofer Lines
Band Emission Spectrum
Continuous Emission Spectrum
Line Emission Spectrum

7. Ampere - Maxwell's Law : $\oint \vec{B}\cdot\vec{dl} = \mu_0 I_{enclosed} + \mu_0 \varepsilon_0 \frac{d}{dt}\oint_s \vec{E}\cdot d\vec{A}$

8. Faraday's Law : $\oint \vec{E}\cdot\vec{dl} = \frac{d}{dt}\Phi_B$; [Φ_B - Magnetic flux.]

9. Gauss's Law : $\oint \vec{E}\cdot d\vec{A} = \frac{Q_{enclosed}}{\varepsilon_0}$

10. Ampere's circuital Law : $\oint \vec{B}\cdot\vec{dl} = \mu_0 I_c$; [I_c - conduction current]

11. Refractive Index of the medium $\mu = \sqrt{\varepsilon_r \mu_r}$

EVALUATION

I. MULTIPLE CHOICE QUESTIONS:

1. The dimension of $\frac{1}{\mu_0\varepsilon_0}$ is

(a) $[L T^{-1}]$ (b) $[L^2 T^{-2}]$
(c) $[L^{-1} T]$ (d) $[L^{-2} T^2]$

[Ans. (b) $[L^2 T^{-2}]$]

2. If the amplitude of the magnetic field is 3×10^{-6} T, then amplitude of the electric field for a electromagnetic waves is

(a) 100 V m^{-1} (b) 300 V m^{-1}
(c) 600 V m^{-1} (d) 900 V m^{-1}

[Ans. (d) 900 V m^{-1}]

3. Which of the following electromagnetic radiation is used for viewing objects through fog *[QY-2019]*

(a) microwave (b) gamma rays
(c) X- rays (d) infrared

[Ans. (d) infrared]

4. Which of the following is false for electromagnetic waves *[Aug. 2021]*

(a) transverse
(b) non-mechanical waves
(c) longitudinal
(d) produced by accelerating charges

[Ans. (c) longitudinal]

5. Consider an oscillator which has a charged particle oscillating about its mean position with a frequency of 300 MHz. The wavelength of electromagnetic waves produced by this oscillator is

(a) 1 m (b) 10 m
(c) 100 m (d) 1000 m

[Ans. (a) 1 m]

6. The electric and the magnetic fields, associated with an electromagnetic wave, propagating along negative X axis can be represented by

(a) $\vec{E} = E_0 \hat{i}$ and $\vec{B} = B_0 \hat{k}$

(b) $\vec{E} = E_0 \hat{k}$ and $\vec{B} = B_0 \hat{j}$

(c) $\vec{E} = E_0 \hat{i}$ and $\vec{B} = B_0 \hat{j}$

(d) $\vec{E} = E_0 \hat{j}$ and $\vec{B} = B_0 \hat{i}$

[Ans. (b) $\vec{E} = E_0\hat{k}$ and $\vec{B} = B_0\hat{j}$]

7. In an electromagnetic wave travelling in free space the rms value of the electric field is 3 V m^{-1}. The peak value of the magnetic field is

(a) 1.414×10^{-8} T
(b) 1.0×10^{-8} T
(c) 2.828×10^{-8} T
(d) 2.0×10^{-8} T

[Ans. (a) 1.414×10^{-8} T]

8. An e.m. wave is propagating in a medium with a velocity $\vec{\upsilon} = \upsilon\hat{i}$. The instantaneous oscillating electric field of this e.m. wave is along +y-axis, then the direction of oscillating magnetic field of the e.m. wave will be along:

(a) $-y$ direction
(b) $-x$ direction
(c) $+z$ direction
(d) $-z$ direction

[Ans. (c) $+z$ direction]

9. If the magnetic monopole exists, then which of the Maxwell's equation to be modified?

(a) $\oint_s \vec{E}.d\vec{A} = \frac{Q_{enclosed}}{\epsilon_0}$ (b) $\oint_s \vec{B}\cdot d\vec{A} = 0$

(c) $\oint_l \vec{B}.d\vec{l} = \mu_0 i_c + \mu_0 \varepsilon_0 \frac{d}{dt}\oint_s \vec{E}\cdot d\vec{A}$

(d) $\oint_l \vec{E}\cdot d\vec{l} = -\frac{d}{dt}\Phi_B$ **[Ans. (b) $\oint_s \vec{B}\cdot d\vec{A} = 0$]**

10. Fraunhofer lines are an example of_______ spectrum.

(a) line emission (b) line absorption
(c) band emission (d) band absorption

[Ans. (b) line absorption]

11. Which of the following is an electromagnetic wave?

(a) α - rays (b) β - rays
(c) γ - rays (d) all of them

[Ans. (c) γ - rays]

12. Which one of them is used to produce a propagating electromagnetic wave?

(a) an accelerating charge
(b) a charge moving at constant velocity
(c) a stationary charge
(d) an uncharged particle

[Ans. (a) an accelerating charge]

13. If $E = E_0 \sin[10^6 x - \omega t]$ be the electric field of a plane electromagnetic wave, the value of ω is

(a) 0.3×10^{-14} rad s^{-1} (b) 3×10^{-14} rad s^{-1}
(c) 0.3×10^{14} rad s^{-1} (d) 3×10^{14} rad s^{-1}

[Ans. (d) 3×10^{14} rad s^{-1}]

14. Which of the following is NOT true for electromagnetic waves?

(a) it transports energy
(b) it transports momentum
(c) it transports angular momentum
(d) in vacuum, it travels with different speeds which depend on their frequency

[Ans. (d) in vacuum, it travels with different speeds which depend on their frequency]

15. The electric and magnetic fields of an electromagnetic wave are *[QY-2019]*

(a) in phase and perpendicular to each other
(b) out of phase and not perpendicular to each other
(c) in phase and not perpendicular to each other
(d) out of phase and perpendicular to each other

[Ans. (a) in phase and perpendicular to each other]

II. Short Answer Questions :

1. What is displacement current? *[PTA-2,5,6 ; HY-2019]*

Ans. The current that comes into play in the region where the electric field and the electric flux are changing with time.

2. What are electromagnetic waves?

Ans. (i) An electromagnetic wave is radiated by an accelerated charge which propagates through space as coupled electric and magnetic fields, oscillating perpendicular to each other and to the direction of propagation of the wave.

(ii) Electromagnetic wave is a transverse wave. They are non-mechanical wave and do not require any medium for propagation.

3. Write down the integral form of modified Ampere's circuital law.

Ans. Integral form of modified Ampere's law is

$$\oint \vec{B}.\vec{dl} = \mu_0 I_{enclosed} + \mu_0\varepsilon_0 \frac{d}{dt}\int_s \vec{E}.\vec{dA}$$

4. Write notes on Gauss' law in magnetism.

Ans. This law is similar to Gauss's law for electricity. So this law can also be called as Gauss's law for magnetism. The surface integral of magnetic field over a closed surface is zero. Mathematically,

$$\oint_s \vec{B}.d\vec{A} = 0$$

where $\vec{B}$ is the magnetic field.

This equation implies that the magnetic lines of force form a continuous closed path. In other words, it means that no isolated magnetic monopole exists.

ELECTROMAGNETIC WAVES

5. Give two uses each of (i) IR radiation, (ii) Microwaves and (iii) UV radiation.

Ans. **IR radiation :** *[Aug. 2021]*

(i) It provides electrical energy to satellites by means of solar cells.

(ii) It is used in infrared photography.

Microwaves :

(i) It is used in microwave over for cooling.

(ii) It is used in radar system for aircraft navigation.

UV radiation :

(i) It is used to destroy bacteria in sterilizing the surgical instruments.

(ii) It is used in burglar alarm and investigating finger prints.

6. What are Fraunhofer lines? How are they useful in the identification of elements present in the Sun?

Ans. Dark lines seen in the solar spectrum are known as Fraunhofer lines and is used it is used to identify the elements in the sun's atmosphere.

7. Write notes on Ampere-Maxwell law.

Ans. This law relates the magnetic field around any closed path to the conduction current and displacement current through that path.

$$\oint_l \vec{B}.\vec{dl} = \mu_0 i_c + \mu_0 \in_0 \frac{d}{dt}\oint_s \vec{E}.\vec{dA}$$

where $\vec{B}$ is the magnetic field. This equation shows that both conduction current and displacement current produce magnetic field.

8. Why are e.m. waves non-mechanical?

Ans. Electromagnetic waves do not require any medium for propagation. So electromagnetic wave is a non-mechanical wave.

III. Long Answer Questions :

1. Write down Maxwell's equations in integral form. *[PTA-2; Mar.-2020; Aug. 2021]*

Ans. Maxwell's equations explain the behavior of charges, currents and properties of electric and magnetic fields.

(i) **Gauss law :**

$$\oint \vec{E}.\overline{dA} = \frac{Q_{enclosed}}{\varepsilon_0}$$

$\vec{E}$ - electric field ; Q_{encl} - charge enclosed

a. It relates flux and charge.

b. Electric lines start from positive terminate at negative charge.

c. Isolated positive or negative charge exist.

(ii) **Second equation.**

a) $\oint B.dA = 0$ (Gauss law in magnetism)

B - magnetic field

b) Surface integral of magnetic field over a closed surface is zero.

c) No isolated magnetic monopole exists.

(iii) **Third equation :** It relates electric fields with the changing magnetic flux

$$\oint \vec{E}.\overline{dl} = -\frac{d}{dt}(\phi_B) \text{ Faraday's law}$$

E → electric field

The line integral of the electric field around any closed path is equal to the rate of change of magnetic flux.

(iv) **Fourth equation :** It relates magnetic field around closed path to conduction current and displacement current.

$$\oint \vec{B}.\overline{dl} = \mu_0 I_{enclosed} + \mu_0\varepsilon_0 \frac{d}{dt}\int_S \vec{E}.\overline{dA}$$

(Ampere - Marwell's law)

conduction current and displacement current produces magnetic field.

2. Write short notes on (a) microwave (b) X-ray (c) radio waves (d) visible spectrum.

Ans.

Waves	Wavelength	frequency	Production	Uses
a. Microwaves	1×10^{-3} – 3×10^{-1} m	3×10^{11} to 1×10^{9} Hz	E.M. oscillators	i. radar system for air navigation, ii. microwave oven and iii. very long distance wireless communication through satellites.
b. X - ray	10^{-13} – 10^{-8} m	3×10^{21} to 1×10^{16} Hz	i. sudden deceleration of high speed electrons at high-atomic number target. ii. electronic transitions among the innermost orbits of atoms	i. To study crystal and inner atomic electron shells structures. ii. To Detect fractures, diseased organs, formation of bones, stones. iii. healing bones. iv. To detect faults, cracks, flaws and holes in metal product.
c. Radio waves	10^{-1} – 10^{4} m	3×10^{9} to 1×10^{4} Hz	oscillators in electronic circuits	i. Radio and television communication ii. voice communication in cell phone.
d. Visible spectrum	4×10^{-7} – 7×10^{-7} m	7×10^{14} to 4×10^{14} Hz	By incandescent bodies	i. To study structure of molecules, arrangement of electrons in external shells. ii. sensation of our eyes

3. Discuss the Hertz experiment.

Ans. (i) Small spherical metals acts as electrodes.

(ii) They are connected to a large spheres and induction coil with large number of turns.

(iii) Because of high potential air between the spheres gets ionized and spark is produced.

(iv) The gap between electrode at a distance gets the spark.

Hertz apparatus

(v) This implies energy is transmitted to the receiver as electro magnetic wave.

Receiver is rotated by 90°, no spark is obtained.

Conclusion :

(i) They are transverse waves.

(ii) They travel with the velocity of light.

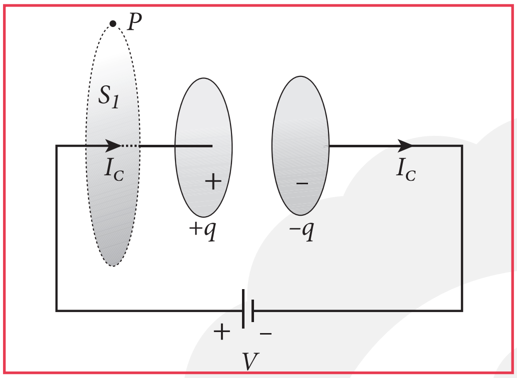
4. Explain the Maxwell's modification of Ampere's circuital law. *[PTA-3]*

Ans. (i) The electric current passing through the wire is the conduction current I_C. This current generates magnetic field around the wire connected across the capacitor.

(ii) Therefore, when a magnetic needle is kept near the wire, deflection is observed. In order to compute the strength of magnetic field at a point, we use Ampere's circuital law is used which states that 'the line integral of the magnetic field $\vec{B}$ around any closed loop is equal to μo times the net current I threading through the area enclosed by the loop'. Ampere's law in equation form is

$$\oint_s \vec{B} \cdot d\vec{l} = \mu_0 I(t) \quad ...(1)$$

(iii) where μ_0 is the permeability of free space.



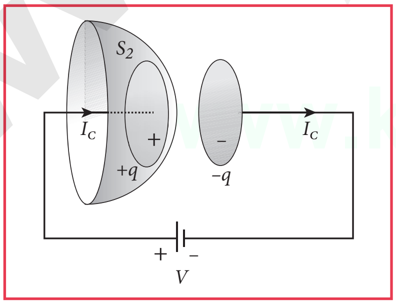
Applying Ampere's circuital law - loop enclosing surface

To calculate the magnetic field at a point P near the wire an amperian loop (circular loop) which encloses the surface S_1 (circular surface), using (equation (1)),

$$\oint_{S_1} \vec{B}.d\vec{l} = \mu_0 I_C \quad ...(2)$$

(iv) Suppose the same loop is enclosed by balloon shaped surface S_2. This means that the boundaries of two surfaces S_1 and S_2 are same but shape of the enclosing surfaces are different (first surface (S_1) is circular in shape and second one is balloon shaped surface (S_2)). As the Ampere's law does not depend on shape of the enclosing surface, the integrals will give the same answer. But by applying (equation (1)),

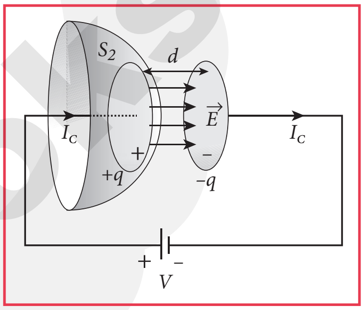
$$\oint_{\text{enclosing } S_2} \vec{B}\cdot d\vec{l} = 0 \quad ...(3)$$



Applying Ampere's circuital law - loop enclosing surface S_2

(v) The right hand side of equation is zero because the surface S_2 no where touches the wire carrying conduction current and further, **there is no current in between the plates of the capacitor** (there is a discontinuity). **So the magnetic field at a point P is zero.**

(vi) Due to external source (battery or cell), the capacitor gets charged up because of current flowing through the capacitor. This produces an increasing electric field between the capacitor plates. The time varying electric flux between the plates of the capacitor produces a current known as displacement current.



Applying Gauss's law between the plates of the capacitor

(vii) From Gauss's law

$$\Phi_E = \oiint \vec{E}.d\vec{A} = EA = \frac{q}{\varepsilon_0}$$

where A is the area of the plates of capacitor. The change in electric flux is

$$\frac{d\Phi_E}{dt} = \frac{1}{\varepsilon_0}\frac{dq}{dt} \Rightarrow \frac{dq}{dt} = I_d = \varepsilon_0 \frac{d\Phi_E}{dt}$$

where I_d is known as displacement current.

(viii) The displacement current can be defined as the current in the region in which the electric field and the electric flux are changing with time. i.e whenever the change in electric field, displacement current is produced. Maxwell modified Ampere's law as

$$\oint \vec{B}\cdot d\vec{S} = \mu_0(I_c + I_d) \quad ...(4)$$

where $I = I_c + I_d$ which means the total current enclosed by the surface is sum of conduction current and displacement current.

(ix) When a constant current is applied, displacement current $I_d = 0$ and hence $I_c = I$. Between the plates, the conduction current $I_c = 0$ and hence $I_d = I$.

UNIT 6 RAY OPTICS

CHAPTER SNAPSHOT

MUST KNOW DEFINITIONS

Reflection of light	:	The bouncing back of light into the same medium when it encounters a reflecting surface is called **reflection of light**.
Angle of deviation	:	The angle between the incident ray and deviated ray of light is called **angle of deviation due to reflection**.
Virtual image	:	Type of image which cannot be formed on the screen but can only be seen with the eyes is called **virtual image**.
Real image	:	Type of image which can be formed on a screen and can also be seen with the eyes is called **real image**.
Convex mirror	:	A spherical mirror whose reflecting surface is curved outwards, is called a convex mirror (or) If the polished surface of the mirror is convex, it is called as **convex mirror**.
Concave mirror	:	If the reflection takes place at the concave surface, it is called a **concave mirror**.
Centre of curvature	:	The centre of the sphere of which the mirror is a part is called the **centre of curvature** (C) **of the mirror**.
Radius of curvature	:	The radius of the sphere of which the spherical mirror is a part is called the **radius of curvature** (R) **of the mirror**.
Pole	:	The middle point on the spherical surface of the mirror (or) the geometrical centre of the mirror is called **pole** (P) **of the mirror** (or) **optic centre**.
Principal axis	:	The line joining the pole (P) and the centre of curvature (C) is called the **principal axis of the mirror**.
Focus or focal point	:	Light rays travelling parallel and close to the principal axis when incident on a spherical mirror, converge at a point for concave mirror or appear to diverge from a point for convex mirror on the principal axis. This point is called the **focus** or **focal point** (F) **of the mirror**.
Focal length	:	The distance between the pole (P) and the focus (F) is called the **focal length (f) of the mirror**.
Focal plane	:	The plane through the focus and perpendicular to the principal axis is called the **focal plane of the mirror**.
Paraxial rays	:	The rays which travel very close to the principal axis and make small angles with it, are called **paraxial rays**.
Marginal rays	:	The rays which travel far away from the principal axis and make small angles with it and fall on the mirror far away from the pole, are called as **marginal rays**.
Refractive index	:	Refractive index of a transparent medium is defined as the ratio of speed of light in vacuum (c) to the speed of light in that medium (υ).
Optical path	:	Optical path of a medium is defined as the distance d' light travels in vacuum in the same time it travels a distance d in the medium.
Snell's law	:	The incident ray, refracted ray and normal to the refracting surface are all coplanar (ie. lie in the same plane).

Evaluation

Multiple choice questions:

1. The speed of light in an isotropic medium depends on,
(a) its intensity (b) its wavelength
(c) the nature of propagation
(d) the motion of the source w.r.t medium

[*Ans.* (b) its wavelength]

Hint: $v = n\lambda$

2. A rod of length 10 cm lies along the principal axis of a concave mirror of focal length 10 cm in such a way that its end closer to the pole is 20 cm away from the mirror. The length of the image is, *(AIPMT Main 2012)*
(a) 2.5 cm (b) 5 cm
(c) 10 cm (d) 15 cm

[*Ans.* (b) 5cm]

Hint: $\frac{1}{f} = \frac{1}{\mu_A} + \frac{1}{v_A}$

3. An object is placed in front of a convex mirror of focal length of f and the maximum and minimum distance of an object from the mirror such that the image formed is real and magnified. *(IEE Main 2009)*
(a) $2f$ and c (b) c and ∞
(c) f and O (d) None of these

[*Ans.* (d) None of these]

Hint: Divergence of convex mirror

4. For light incident from air on a slab of refractive index 2, the maximum possible angle of refraction is,
(a) 30° (b) 45°
(c) 60° (d) 90° [*Ans.*(a) 30°]

Hint: $\mu = \frac{\sin i}{\sin r}$

5. If the velocity and wavelength of light in air is V_a and λ_a and that in water is V_w and λ_w, then the refractive index of water is, *[HY - 2019; Aug. 2021]*
(a) $\frac{V_w}{V_a}$ (b) $\frac{V_a}{V_w}$
(c) $\frac{\lambda_w}{\lambda_a}$ (d) $\frac{V_a\lambda_a}{V_w\lambda_w}$

[*Ans.* (b) $\frac{V_a}{V_w}$]

Hint: $\mu = \frac{V_a}{V_w}$

6. Stars twinkle due to, *[PTA-2, 5]*
(a) reflection
(b) total internal reflection
(c) refraction (d) polarisation

[*Ans.* (c) refraction]

7. When a biconvex lens of glass having refractive index 1.47 is dipped in a liquid, it acts as a plane sheet of glass. This implies that the liquid must have refractive index,
(a) less than one
(b) less than that of glass
(c) greater than that of glass
(d) equal to that of glass

[*Ans.* (d) equal to that of glass]

Hint: $\frac{1}{f} = \left(\frac{\mu_g}{\mu_L} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

8. The radius of curvature of curved surface at a thin planoconvex lens is 10 cm and the refractive index is 1.5. If the plane surface is silvered, then the focal length will be, *[Mar.-2020]*
(a) 5 cm (b) 10 cm
(c) 15 cm (d) 20 cm

[*Ans.* (b) 10 cm]

Hint: $\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

9. An air bubble in glass slab of refractive index 1.5 (near normal incidence) is 5 cm deep when viewed from one surface and 3 cm deep when viewed from the opposite face. The thickness of the slab is,
(a) 8 cm (b) 10 cm
(c) 12 cm (d) 16 cm

[*Ans.* (c) 12 cm]

Hint: $n = \frac{\text{Real depth}}{\text{Apparent depth}}$
$\Rightarrow$ real depth thickness of glass slab 't'

Unit 6

10. A ray of light travelling in a transparent medium of refractive index n falls, on a surface separating the medium from air at an angle of incidents of 45°. The ray can undergo total internal reflection for the following *n*,

(a) $n = 1.25$ (b) $n = 1.33$

(c) $n = 1.4$ (d) $n = 1.5$

[Ans. (d) *n* = 1.5]

Hint: $n = \dfrac{1}{\sin i}$

Short Answer Questions :

1. What is angle of deviation due to reflection?

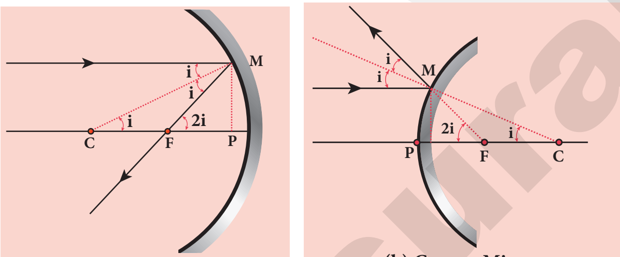
Ans. The angle between the incident ray and deviated ray of light is called **angle of deviation**.

2. Derive the relation between *f* and R for a spherical mirror. *[HY - 2019]*

Ans. (i) C - centre of curvature of the mirror.

F - principal focus

(ii) A parallel ray of light is incident at M and after reflection passes through F angle an incidence *i* will be same to the angle of reflection.



(a) Concave mirror (b) Convex Mirror

(iii) MP perpendicular from M

(vi) $\angle MCP = i$ and $\angle MFP = 2i$

(v) From ΔMCP and ΔMFP,

$$\tan i = \frac{PM}{PC} \text{ and } \tan 2i = \frac{PM}{PF}$$

(vi) Angles are small, $\therefore \tan i \approx i$,

$$i = \frac{PM}{PC} \text{ and } 2i = \frac{PM}{PF}$$

(vii) $2\dfrac{PM}{PC} = \dfrac{PM}{PF}$; 2PF = PC.

PF - focal length '*f*'

PC - Radius of curvature R.

$\therefore \boxed{2f = R}$

3. What are the Cartesian sign conventions for spherical mirrors?

Ans. (i) Incident light is taken from left to right.

(ii) All distances are measured from pole of the mirror.

(iii) Distance measured to the right of the pole is positive and to the left is negative.

(iv) Heights measured in the upward perpendicular direction is positive and downward is negative.

4. What is optical path? Obtain the equation for optical path.

Ans. **Optical path** of a medium is defined as the distance *d*' light travels in vacuum in the same time it travels a distance *d* in the medium.

(i) Refractive index of a medium = *n*

Thickness index of a medium = *d*.

Speed of light through the medium in time $(t) = v$.

$$= \frac{d}{t} \Rightarrow t = \frac{d}{v}$$

(ii) In vacuum, light travels with greater speed and greater distance (d') in same time *t*.

$$c = \frac{d'}{t} \Rightarrow t = \frac{d'}{c}$$

(iii) '*t*' is same in both the cases,

$$\frac{d'}{c} = \frac{d}{v}$$

$\therefore$ Optical path $d' = \dfrac{c}{v}.d$

$\left(\dfrac{c}{v} = n\right.$ - refractive index)

$$d' = n.d$$

$n > 1$ then $d' > $ d.

5. State Snell's law/law of refraction.

Ans. Law of refraction is called Snell's law.

Snell's law states that,

(i) The incident ray, refracted ray and normal to the refracting surface are all coplanar (ie. lie in the same plane).

(ii) The ratio of sine of angle of incident *i* in the first medium to the angle of reflection *r* in the second medium is equal to the ratio of refractive index n_2 of the second medium to the refractive index n_1 of the first medium.

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

6. What is angle of deviation due to refraction?

Ans. When light travels from rarer to denser medium, it deviates towards normal. The angle of deviation in this case is,

$$d = i - r$$

If light travels from denser to rarer medium, it deviates away from normal. The angle of deviation in this case is,

$$d = r - i$$

7. What is principle of reversibility? *[PTA-4]*

Ans. The principle of reversibility states that light will follow exactly the same path if its direction of travel is reversed.

8. What is relative refractive index?

Ans. From Snell's law, $\frac{\sin i}{\sin r} = \frac{n_1}{n_2}$, the term $\left(\frac{n_2}{n_1}\right)$ is called **relative refractive index** of second medium with respect to the first medium which is denoted as n_{21}.

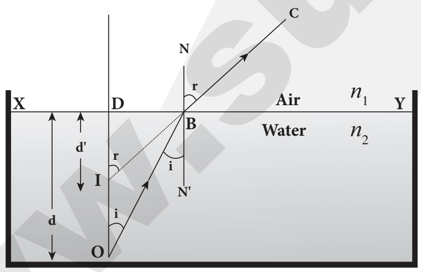
$$n_{21} = \frac{n_2}{n_1}$$

9. Obtain the equation for apparent depth.

Ans. (i) Light from the object O at the bottom of the tank passes from denser medium (water) to rarer medium (air) to reach our eyes.

(ii) It deviates away from the normal in the rarer medium at the point of incidence B.

(iii) The refractive index of the denser medium is n_1 and rarer medium is n_2.



Apparent depth

(iv) Here, $n_1 > n_2$.

(v) The angle of incidence in the denser medium is i and the angle of refraction in the rarer medium is r.

(vi) The lines NN' and OD are parallel. Thus angle $\angle DIB = r$.

(vii) The angles i and r are very small as the diverging light from O entering the eye is very narrow. From the Snell's law,

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

(viii) As the angles i and r are small, $\sin i \approx \tan i$;

$$n_1 \tan i = n_2 \tan i$$

In triangles ΔDOB and ΔDIB,

$$\tan(i) = \frac{DB}{DO} \text{ and } \tan(r) = \frac{DB}{DI}$$

$$n_1 = \frac{DB}{DO} = n_2 \frac{DB}{DI}$$

(ix) DB is cancelled on both sides, DO is the actual depth d and DI is the apparent depth d'.

$$n_1 = \frac{1}{d} = n_2 \frac{1}{d'}$$

$$\frac{d'}{d} = \frac{n_2}{n_1}$$

(x) The apparent depth d',

$$d' = \frac{n_2}{n_1} d$$

(xi) If the rarer medium is air refractive index n_2 (n_2=1). And the refractive index n_1 of denser medium (n_1= n).

(xii) In that case, the equation for apparent depth becomes,

$$d' = \frac{d}{n}$$

(xiii) The bottom appears to be elevated by $d - d'$,

$$d - d' = d - \frac{d}{n} \text{ or } d - d' = d\left(1 - \frac{1}{n}\right)$$

10. Why do stars twinkle?

Ans. (i) The stars actually do not twinkle.

(ii) Due to refraction of light through different layers of atmosphere which vary in refractive index, the path of light deviates continuously when it passes through atmosphere.

11. What are critical angle and total internal reflection? *[Aug. 2021]*

Ans. (i) The angle of incidence in the denser medium for which the angle of refraction is 90° (or) the refracted ray graces the boundary between the two media is called **critical angle** i_c.

(ii) For any angle of incidence greater than the critical angle, the entire light is reflected back into the denser medium itself. This phenomenon is called **total internal reflection**.

ADDITIONAL QUESTIONS AND ANSWERS

CHOOSE THE CORRECT ANSWER 1 MARK

1. A light bulb is placed between two mirrors (plane) inclined at an angle of 60°. Number of images formed are
(a) 2 (b) 4 (c) 5 (d) 6
[*Ans.* (c) 5]

2. Two plane mirror are inclined at an angle of 72°.The number of images of a point object placed between them will be
(a) 2 (b) 3 (c) 4 (d) 5
[*Ans.* (c) 4]

3. To get three images of a single object, one should have two plane mirror at an angle of
(a) 30° (b) 60°
(c) 90° (d) 120° [*Ans.*(c) 90°]

4. A man of length h requires a mirror of length at least equal to, to see his own complete image
(a) $\frac{h}{4}$ (b) $\frac{h}{3}$
(c) $\frac{h}{2}$ (d) h [*Ans.* (c) $\frac{h}{2}$]

5. Two plane mirrors are at 45° to each other. If an object is placed between them than the number of images will be
(a) 5 (b) 9
(c) 7 (d) 8 [*Ans.* (c) 7]

6. An object is at a distance of 0.5 in front of a plane mirror. Distance between the object and image is
(a) 0.5 m (b) 1 m
(c) 7 (d) 8
[*Ans.* (b) 1 m]

7. A man runs towards a mirror at a speed 15 m/s. The speed of the image relative to the man is
(a) 15 ms^{-1} (b) 30 ms^{-1}
(c) 35 ms^{-1} (d) 20 ms^{-1}
[*Ans.* (b) 30 ms^{-1}]

8. The light reflected by plane mirror may form a real images.
(a) If the rays incident on the mirror are diverging
(b) If the rays incident on the mirror are converging
(c) If the object is placed very close to mirror
(d) Under no circumstance
[*Ans.* (b) If the rays incident on the mirror are converging]

9. A man is 180 cm tall and his eyes are 10 cm below the top of his head. In order to see his entire height right from toe to head, he uses a plane mirror kept at a distance of 1 m from him. The minimum length of the plane mirror required is
(a) 180 cm (b) 90 cm
(c) 85 cm (d) 170 cm
[*Ans.* (b) 90 cm]

10. A small object is placed 10 cm infront of a plane mirror. If you stand behind the object 30 cm from the object and look at its image, the distance focused for your eye will be
(a) 60 cm (b) 20 cm
(c) 40 cm (d) 80 cm
[*Ans.* (c) 40 cm]

11. Two plane mirror are at right angles to each other. A man stands between them and combs hair with his right hand. In how many of the images will he be seen using his right hand.
(a) None (b) 1
(c) 2 (d) 3 [*Ans.* (d) 3]

12. A ray of light is incidenting normally on a plane mirror. The angle of reflection will be
(a) 0° (b) 90°
(c) will not be reflected (d) None of these
[*Ans.* (a) 0°]

13. A plane mirror produces a magnification of
(a) –1 (b) + 1
(c) Zero
(d) Between 0 and + ∞ [*Ans.* (b) + 1]

14. When a plane mirror is rotated through an angle θ, then the reflected ray turns through the angle 2θ, then the size of the image.
(a) Is doubled infinite
(b) Is halved
(c) Remains the same
(d) Becomes infinite
[*Ans.* (c) Remains the same]

15. What should be the angle between two plane mirror so that whatever be the angle of incidence, the incident ray and the reflected ray from the two mirrors be parallel to each other
(a) 60° (b) 90°
(c) 120° (d) 175°
[*Ans.* (b) 90°]

RAY OPTICS

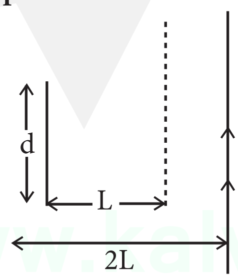
16. **Ray optics is valid, when characteristic dimensions are**
(a) of the same order as the wave length of light
(b) much smaller then the wavelength of light
(c) of the order of one millimeter
(d) much larger than the wavelength of light
[*Ans.* (d) much larger than the wavelength of light]

17. **It is desired to photograph the image of an object placed at a distance of 3m from the plane mirror. The camera which is at a distance of 4.5 m from the mirror should be focused for a distance of**
(a) 3 m (b) 4.5 m
(c) 6 m (d) 7.5 m
[*Ans.* (d) 7.5 m]

18. **Two plane mirrors are parallel to each other and spaced 20cm apart. An object is kept in between them at 15cm from A out of the following at which point on image is not formed in mirror A (distance measured from mirror A)**
(a) 15 cm (b) 25 cm
(c) 45 cm (d) 55 cm
[*Ans.* (c) 45 cm]

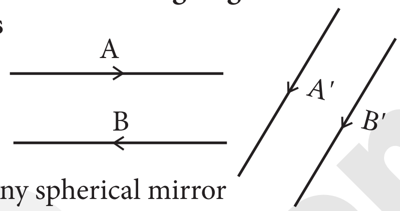
19. **Two plane mirrors A and B are alligned parallel to each other, as shown in the figure. A light ray is incident at an angle of 30º at a point just inside one end of A. The plane of incidence coincides with the plane of the figure. The maximum number of times the ray undergoes reflections (including the first one) before it emerges out is)**
(a) 28 (b) 30
(c) 32 (d) 34 **[*Ans.* (b) 30]**

20. **A point source of light B is placed at a distance L in front of the centre of a mirror of width d hung vertically on a wall. A man walks in front of the mirror along a line parallel to the mirror at a distance of 2 L infront of it as shown. The greatest distance over which he can see the image of the light source in the mirror is**



(a) d/2 (b) d
(c) 2d (d) 3d **[*Ans.* (d) 3d]**

21. **The figure shows two rays A and B being reflected by a mirror and going as 'A' and 'B' the mirror is**
(a) plane
(b) concave
(c) convex
(d) may be any spherical mirror

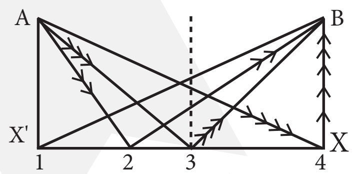


[*Ans.* (a) plane]

22. **An object is initially at a distance of 100 cm from plane mirror. If the mirror approaches the object at a speed of 5 cm/s, then after 6 s the distance between the object and its images will be**
(a) 60 cm (b) 140 cm
(c) 170 cm (d) 150 cm
[*Ans.* (b) 140 cm]

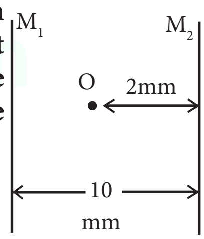
23. **An object placed infront of a plane mirror is displaced by 0.4 m along a straight line at angle of 30º to mirror plane, the change in the distance between the object and its image is**
(a) 0.2 m (b) 0.4 m
(c) 0.25 m (d) 0.80 m
[*Ans.* (b) 0.4 m]

24. **A ray of light travels from A to B with uniform speed. On its way it is reflected by the surface XX'. The path followed by the ray to take least number of times is**



(a) 1 (b) 2
(c) 3 (d) 4 **[*Ans.* (c) 3]**

25. **A point object O is placed between two plane mirror M_1 and M_2 10mm apart. The distance of object O from M_2 is 2mm. Find the distance of the first three images formed by mirror M_2.**



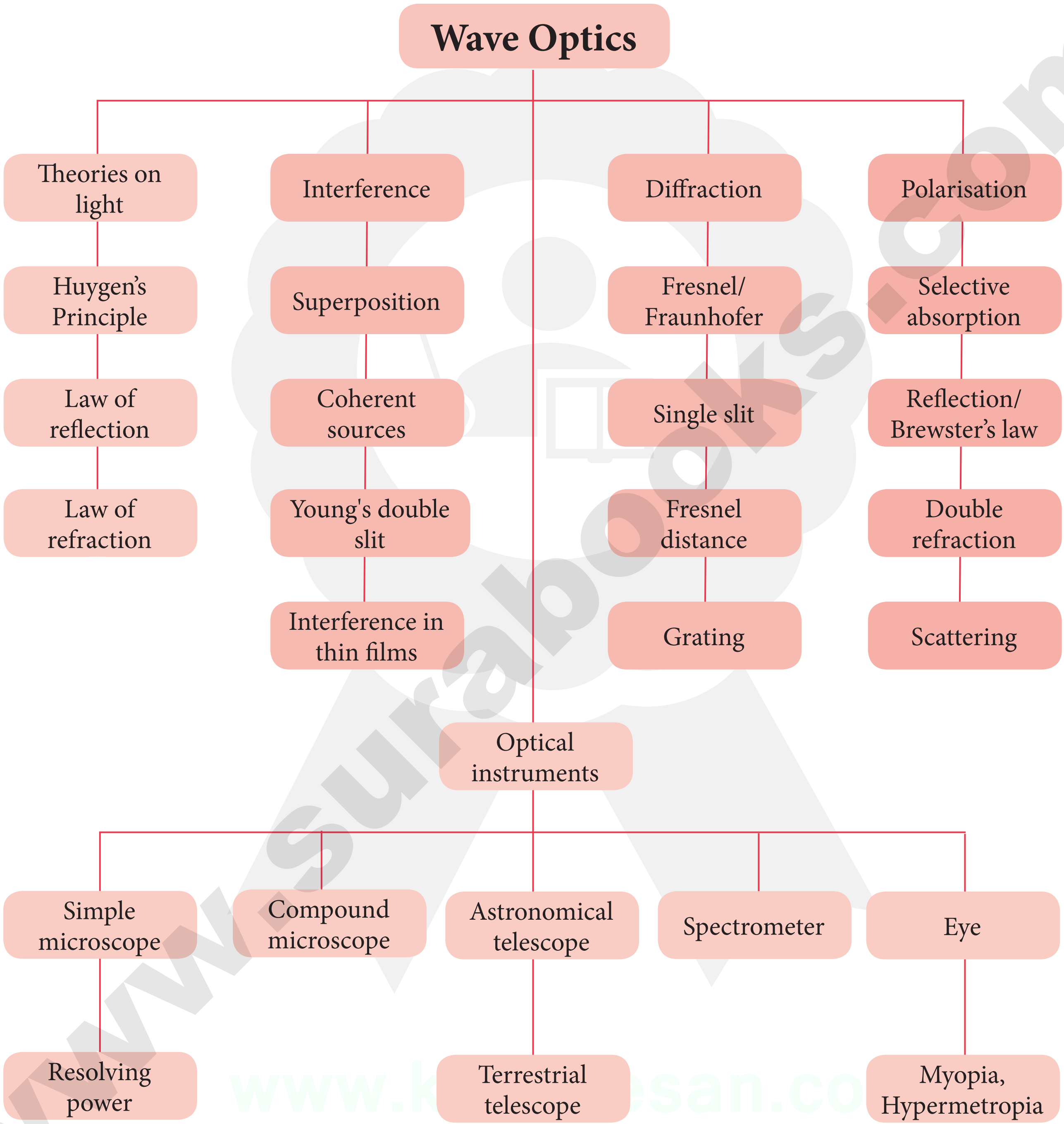
(a) 2 mm, 8 mm, 18 mm
(b) 2 mm, 18 mm, 28 mm
(c) 2 mm, 18 mm, 22 mm
(d) 2 mm, 18 mm, 58 mm
[*Ans.* (c) 2 mm, 18 mm, 22 mm]

Unit 6

UNIT 7 WAVE OPTICS

CHAPTER SNAPSHOT

CONCEPT MAP


Wave Optics
Theories on light
Huygen's Principle
Law of reflection
Law of refraction
Interference
Superposition
Coherent sources
Young's double slit
Interference in thin films
Diffraction
Fresnel/ Fraunhofer
Single slit
Fresnel distance
Grating
Polarisation
Selective absorption
Reflection/ Brewster's law
Double refraction
Scattering
Optical instruments
Simple microscope
Resolving power
Compound microscope
Astronomical telescope
Terrestrial telescope
Spectrometer
Eye
Myopia, Hypermetropia

Evaluation

Multiple choice questions:

1. A plane glass is placed over a various coloured letters (violet, green, yellow, red) The letter which appears to be raised more is,

(a) red (b) yellow
(c) green (d) violet

[*Ans.* (d) violet]

Hint: $\mu_v \rightarrow$ more ; $\lambda_v \rightarrow$ less

2. Two point white dots are 1 mm apart on a black paper. They are viewed by eye of pupil diameter 3 mm approximately. The maximum distance at which these dots can be resolved by the eye is, [take wavelength of light, λ = 500 nm]

(a) 1 m (b) 5 m
(c) 3 m (d) 6 m

[*Ans.* (b) 5 m]

Hint: $d = \frac{xa}{1.22\lambda}$

3. In a Young's double-slit experiment, the slit separation is doubled. To maintain the same fringe spacing on the screen, the screen-to-slit distance D must be changed to, *[PTA-4; Aug. 2021]*

(a) 2D (b) $\frac{D}{2}$
(c) $\sqrt{2}D$ (d) $\frac{D}{\sqrt{2}}$

[*Ans.* (a) 2D]

Hint: $\beta = \frac{\lambda D}{d}$

4. Two coherent monochromatic light beams of intensities I and 4I are superposed. The maximum and minimum possible intensities in the resulting beam are *[IIT-JEE 1988]*

(a) 5I and I (b) 5I and 3I
(c) 9I and I (d) 9I and 3I

[*Ans.* (c) 9I and I]

Hint: $I = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\theta$

5. When light is incident on a soap film of thickness 5×10^{-5} cm, the wavelength of light reflected maximum in the visible region is 5320 Å. Refractive index of the film will be,

(a) 1.22 (b) 1.33
(c) 1.51 (d) 1.83

[*Ans.* (b) 1.33]

Hint: $n = \frac{(2m+1)^{\frac{\lambda}{2}}}{2t}$

6. First diffraction minimum due to a single slit of width 1.0×10^{-5} cm is at 30°. Then wavelength of light used is,

(a) 400 Å (b) 500 Å
(c) 600 Å (d) 700 Å

[*Ans.* (b) 500 Å]

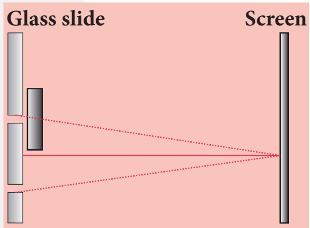
Hint: $a\sin\theta = m\lambda$

7. A ray of light strikes a glass plate at an angle 60°. If the reflected and refracted rays are perpendicular to each other, the refractive index of the glass is, *[Govt. MQP-2018]*

(a) $\sqrt{3}$ (b) $\frac{3}{2}$
(c) $\sqrt{\frac{3}{2}}$ (d) 2 [*Ans.* (a) $\sqrt{3}$]

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

8. One of the of Young's double slits is covered with a glass plate as shown in figure. The position of central maximum will,



(a) get shifted downwards
(b) get shifted upwards
(c) will remain the same
(d) data insufficient to conclude

[*Ans.* (b) get shifted upwards]

9. Light transmitted by Nicol prism is, *[PTA-3]*

(a) partially polarised (b) unpolarised
(c) plane polarised
(d) elliptically polarised

[*Ans.* (c) plane polarised]

10. The transverse nature of light is shown in, *[PTA-6]*

(a) interference (b) diffraction
(c) scattering (d) polarisation

[*Ans.* (d) polarisation]

Short Answer Questions :

1. What are the salient features of corpuscular theory of light?

Ans. (i) Light is emitted as tiny, massless and perfectly elastic particles called **corpuscles**.

(ii) The energy of the light is the kinetic energy of the corpuscles.

(iii) When these corpuscles impinge on the retina of the eye, the vision is produced.

(iv) The different size of the corpuscles is the reason for different colours of light.

(v) When the corpuscles approach a surface between two media, they are either attracted or repelled.

(vi) The reflection is due to the repulsion of the corpuscles by the medium and refraction of light is due to the attraction.

Limitation or Drawback :

This theory could not explain the reason why speed of the light is lesser in denser medium than in rarer medium, and could not explain the phenomena like interference, diffraction and polarisation.

2. What are the important points of wave theory of light?

Ans. (i) Light is a disturbance from a source that travels as longitudinal mechanical waves, and it needs a propagating medium which is ether that pervade all spaces.

(ii) It explains the phenomenon of reflection, refraction, interference and diffraction of light.

Limitation or Drawback :

(i) The wave theory could not explain the propagation of light through vacuum, as the existence of ether was proved wrong.

(ii) The phenomenon of polarisation could not be explained by this theory as it is the property of only transverse waves.

3. What is the significance of electromagnetic wave theory of light?

Ans. (i) The light is an electromagnetic wave which is transverse in nature.

(ii) No medium is necessary for the propagation.

(iii) All the phenomena of light is explained.

Limitation or Drawback :

Photoelectric effect, Compton effect could not be explained.

4. Write a short note on quantum theory of light.

Ans. (i) According to Plank, a photon is discrete packet of energy.

(ii) Each photon has energy $E = hv$

(iii) Here h is Plank's constant 6.625×10^{-34} Js.

5. Define wavefront.

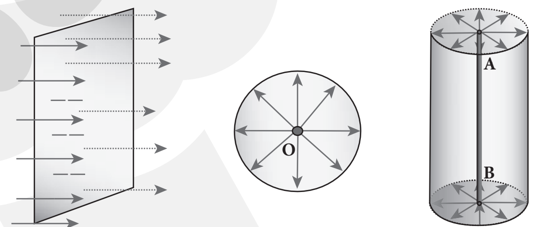
Ans. A wavefront is the locus of points which are in the same state or phase of vibration.

6. What are the shapes of wavefront for (a) source at infinite, (b) point source and (c) line source?

Ans. (a) Source is located at infinity gives plane wavefront.

(b) A point source located at a finite distance gives spherical wavefronts.

(c) An extended (or) line source at finite distance gives cylindrical wavefronts.



Source at infinity Point source Line source

7. State Huygens' principle.

Ans. According to Huygen's principle, each point of the wavefront is the source of secondary wavelets. These wavelets are spreading out in all directions with the speed of the wave. These are called as **secondary wavelets**.

8. What is interference of light?

Ans. The phenomenon of addition or superposition of two light waves which produces increase in intensity at some points and decrease in intensity at some other points is called **interference of light.**

9. What is phase of a wave?

Ans. Phase is the angular position of a vibration.

NEET BASED QUESTIONS

1. The moment of inertia of a collapsing star changes to one-third of its initial value. The ratio of the new rotational kinetic energy to the initial rotational kinetic energy is____
(A) 3 : 1 (B) 1 : 3 (C) 9 : 1 (D) 1 : 9

2. A body of 10 kg is dropped from infinite height towards earth's surface. What will be its velocity just before touching the earth's surface. (Gravitational potential energy of the body at earth's surface is $6{\cdot}25 \times 10^8$ Joule).
(A) 22·4 km/sec (B) 11·2 km/sec
(C) 6·4 km/sec (D) Infinite

3. The vertical escape velocity of a body from earth's surface is 11·2 km/sec. If the body is projected at an angle of 45° from the vertical, its escape velocity will be ______.
(A) $11{\cdot}2 \times \sqrt{2}$ km/s (B) $\frac{11{\cdot}2}{\sqrt{2}}$ km/s
(C) 11·2 × 2 km/s (D) 11·2 km/s

4. Which of the following equations represents a simple harmonic wave ?
(A) $y = a \sin \omega t$ (B) $y = a \sin \omega t \cos kt$
(C) $y = a \sin (\omega t - kx)$ (D) $y = a \cos kx$

5. The focal length of a convex lens is f. When it is divided in two parts by a plane parallel to the principal axis, focal length of each part will be ________
(A) f (B) $\frac{f}{2}$ (C) $2f$ (D) Zero

6. During negative β-decay ________.
(A) Atom electron is ejected
(B) Electron, already present in the nucleus is ejected
(C) Neutron of the nucleus decays ejecting the electron
(D) A part of binding energy is converted into an electron

7. The maximum intensity in the interference pattern of two equal and parallel slits is I. if one of the slits is closed, the intensity at the same point is l_0. Then ________.
(A) $l = l_0$ (B) $l = 2l_0$
(C) $l = 4l_0$
(D) There is no relation between l and l_0

8. X-rays coming out of an X-ray tube ________.
(A) Are monochromatic
(B) Have all wavelengths below a certain minimum wavelength
(C) Have all wavelengths above a certain minimum wavelength
(D) Have all wavelengths between a certain minimum and maximum wavelength

9. The current amplification of common base N–P–N transistor is 0·96. What will be the current gain if it is used as common emitter amplifier ?
(A) 16 (B) 24 (C) 20 (D) 32

10. Who discovered neutron and positron respectively ?
(A) Thomson and Rutherford
(B) Rutherford and Thomson
(C) Anderson and Chadwick
(D) Chadwick and Anderson

11. Amplification factor of a triode is 20 and its plate resistance is 20 kΩ. Its mutual conductance will be ________.
(A) 2×10^5 mho (B) 2×10^4 mho
(C) 500 mho (D) 2×10^{-3} mho

12. The co-ordinates of a moving particle at time t are given by $x = at^2$, $y = bt^2$ The speed of the particle is ________.
(A) $2(a + b)\,t$ (B) $(a^2 + b^2)^{1/2} \times t$
(C) $2(a^2 + b^2)^{1/2} \times t$ (D) $(a + b)\,t$

NEET BASED QUESTIONS

13. If p is the pressure of a gas and ρ is its density, then dimension[2] of velocity is given by ________.

(A) $p^{1/2} \rho^{-1/2}$ (B) $p^{1/2} \rho^{1/2}$
(C) $p^{-1/2} \rho^{1/2}$ (D) $p^{-1/2} \rho^{-1/2}$

14. If R, X and Z represent respectively the resistance, reactance and impedance of an electric circuit carrying alternating current, then the power factor is given by ________

(A) $\frac{R}{Z}$ (B) $\frac{Z}{R}$ (C) $\frac{R}{X}$ (D) $\frac{X}{R}$

15. If the horizontal range of a projectile is equal to the maximum height reached, then the corresponding angle of projection is ________.

(A) $\tan^{-1} 1$ (B) $\tan^{-1} \sqrt{3}$
(C) $\tan^{-1} 4$ (D) $\tan^{-1} 12$

16. Two electrons move parallel to each other with equal speeds v. The ratio of magnetic and electrical forces between them is ________.

(A) $\frac{v}{c}$ (B) $\frac{c}{v}$ (C) $\frac{v^2}{c^2}$ (D) $\frac{c^2}{v^2}$

17. The acceleration of a particle performing S.H.M. is 12 cm/s^2 at a displacement of 3 cm from the mean position. Its time period is ________.

(A) 6·28 s (B) 3·14 s (C) 10·0 s (D) 5·0 s

18. The displacement of a particle is given by $x = 6 \cos \omega t + 8 \sin \omega t$ metre This equation respresents a S.H.M. having amplitude ________.

(A) 14 m (B) 12 m (C) 10 m (D) 5 m

19. An electron of mass 9×10^{-31} kg revolves in a circle of radius 0·53 Å around the nucleus of hydrogen atom with a velocity of $2{\cdot}2 \times 10^6$ ms^{-1}. What is the angular momentum of the electron ?

(A) $\frac{h}{2\pi}$ (B) $\frac{3h}{3\pi}$ (C) $\frac{h}{\pi}$ (D) $\frac{h}{3\pi}$

20. To maintian a rotor at uniform angular speed of 200 rad. s^{-1}, an engine needs to transmit a torque of 180 Nm. The required power of the engine is ________.

(A) 36 W (B) 63 W
(C) 36 KW (D) 63 KW

21. According to Rutherford model of atom the atom consists of ________

(A) Positively charged nucleus surrounded by a cloud of negative charge
(B) Electrons orbiting a positively charged nucleus in definite orbits
(C) Same as (B) with electrons spinning
(D) A rigid sphere only

22. The magnetic moment of a circular orbit of radius r carrying a charge q and rotating with velocity v is given by ______.

(A) $\frac{qvr}{2\pi}$ (B) $\frac{qvr}{2}$ (C) $qv\pi r$ (D) $qv\pi r^2$

23. Along with β-particle emission from a radioactive nucleus one more particle with zero charge is emitted to conserve the energy and momentum. This particle is called ________

(A) Meson (B) Positron
(C) Antineutrino (D) Neutron

24. In a cyclotron the time required to move a charged particle of charge q and mass m in a plane perpendicular to the magnetic field B in a semicircular path is ________.

(A) $t = \frac{m\pi}{Bq}$ (B) $t = \frac{Bqv}{\pi m}$
(C) $t = \frac{B}{\pi mq}$ (D) $t = \pi m Bq$

25. A doubly ionised lithium atom is hydrogen like with atomic number Z = 3. The wavelength of radiation required to excite the electron in Li^{2+} from first to third Bohr orbit will be ________. (Ionisation energy of hydrogen atom is 13·6 eV)

(A) 72·53 Å (B) 113·74 Å
(C) 212·52 Å (D) 17·72 Å

26. A parallel monochromatic beam of light is incident normally on a formed on a screen placed perpendicular to the direction the incident beam. At the first minimum of diffraction pattern the phase difference between the rays coming from the two edges of the slit is ________.

(A) 0 (B) $\frac{\pi}{2}$ (C) π (D) 2π

27. A current carrying coil is freely suspended in a uniform magnetic field. The coil tends to set its plane ________.

(A) Parallel to the magnetic field
(B) Perpendicular to the magnetic field
(C) Inclined to the magnetic field
(D) Continuously rotating

12th STD.

GOVT. SUPPLEMENTARY EXAM AUG. - 2021

Part III - PHYSICS

(With Answers)

Time : 3.00 Hours — Maximum Marks : 70

Introductions :

(1) Check the question paper for fairness of printing. If there is any lack of fairness, inform the Hall Supervisor immediately.

(2) Use Blue or Black ink to write and underline and pencil to draw diagrams.

PART - I

Note : (i) Answer all the questions.

(ii) Choose the most appropriate answer from the given four alternatives and write the option code and the corresponding answer. **(15 × 1 = 15)**

1. In an oscillating LC circuit, the maximum charge on the capacitor is Q. The charge on the capacitor when the energy is stored equally between the electric and magnetic fields is:
   (a) $\frac{Q}{\sqrt{2}}$ (b) $\frac{Q}{2}$
   (c) Q (d) $\frac{Q}{\sqrt{3}}$

2. In a Young's double slit experiment, the slit separation is doubled. To maintain the same fringe spacing on the screen, the screen-to-slit distance D must be changed to:
   (a) $\sqrt{2}$ D (b) 2D
   (c) $\frac{D}{\sqrt{2}}$ (d) $\frac{D}{2}$

3. Which charge configuration produces a uniform electric field?
   (a) Uniformly charged infinite plane
   (b) Point charge
   (c) Uniformly charged spherical shell
   (d) Uniformly charged infinite line

4. The ratio of magnetic length and geometrical length is:
   (a) 0.833 (b) 0.633
   (c) 0.933 (d) 0.733

5. The internal resistance of a 2.1 V cell which gives a current of 0.2 A through a resistance of 10 Ω is:
   (a) 0.8 Ω (b) 0.2 Ω
   (c) 1.0 Ω (d) 0.5 Ω

6. If the nuclear radius of ^{27}Al is 3.6 fermi, the approximate nuclear radius of ^{64}Cu in fermi is :
   (a) 4.8 (b) 2.4
   (c) 3.6 (d) 1.2

7. If the velocity and Wavelength of light in air is V_a and λ_a and that in water is V_W nd λ_W then the refractive index of water is :
   (a) $\frac{\lambda_W}{\lambda_a}$ (b) $\frac{V_W}{V_a}$
   (c) $\frac{V_a\lambda_a}{V_W\lambda_W}$ (d) $\frac{V_a}{V_W}$

8. unit of electric flux is:
   (a) $Nm^{-1}C^2$ (b) $Nm^{-2}C^{-1}$
   (c) Nm^2C^{-1} (d) N^2mC^{-1}

9. For a healthy eye, the distance of the near point is ______.
   (a) 30 cm (b) 20 cm
   (c) 35 cm (d) 25 cm

10. The blue print for making ultra durable synthetic material is mimicked from :
    (a) Parrot fish (b) Lotus leaf
    (c) Peacock feather (d) Morpho butterfly

11. Emission of electrons by the absorption of heat energy is called ______.
    (a) Thermionic (b) Photoelectric
    (c) Secondary (d) Field

12. The Zener diode is primarily used as :
    (a) Oscillator (b) Rectifier
    (c) Voltage regulator (d) Amplifier

13. Which of the following is false for electromagnetic waves?
    (a) longitudinal (b) transverse
    (c) produced by accelerating charges
    (d) non- mechanical waves
14. A particle having mass m and charge q accelerated through a potential difference V. Find the force experienced when it is kept under perpendicular magnetic field $\vec{B}$.
    (a) $\sqrt{\frac{2q^3B^2V}{m}}$ (b) $\sqrt{\frac{2q^3BV}{m}}$
    (c) $\sqrt{\frac{2q^3BV}{m^3}}$ (d) $\sqrt{\frac{q^3B^2V}{2m}}$
15. In a transformer, the number of turns in the primary and the secondary are 410 and 1230 respectively. If the current in primary is 6 A, then that in the secondary coil is :
    (a) 12 A (b) 2 A
    (c) 1 A (d) 18 A

PART - II

Answer any six questions. Question number 24 is Compulsory. **(6 × 2 = 12)**

16. Mention the ways of producing induced emf.
17. Find the Polarizing angle for glass of refractive index 1.5.
18. What is Peltier effect?
19. Define "Electrostatic Potential".
20. How will you define threshold frequency?
21. State Ampere's Circuital Law.
22. Why does sky appear blue?
23. Give two uses of IR radiation.
24. Dielectric strength of air is 4×10^6 Vm^{-1}. Suppose the radius of a hollow sphere in the Van de Graaff generator is R = 0.4m, calculate the maximum potential difference created by this Van de Graaff generator.

PART - III

Answer any six questions. Question number 33 is Compulsory. **(6 × 3 = 18)**

25. State Kirchhoff's current and voltage rule.
26. What are critical angle and total internal reflection?
27. List out the characteristics of Photons.
28. Obtain the expression for energy stored in the parallel plate capacitor.
29. Mention the differences between interference and diffraction.
30. The repulsive force between two magnetic poles in air is 9×10^{-3} N. If the two poles are equal in strength and are separated by a distance of 10 cm, calculate the pole strength of each pole.
31. Draw the circuit diagram of a full wave rectifier and draw its input and output wave forms.
32. Mention the various energy losses in a transformer.
33. $_{92}U^{235}$ nucleus emits 2α particles, 3β particles and 2γ particles. What is the resulting atomic number and mass number?

PART - IV

Answer all questions **(5 × 5 = 25)**

34. (a) Deduce the relation for the magnetic field at a point due to an infinitely long straight conductor carrying current.
    OR
    (b) Obtain the law of radioactivity.
35. (a) Calculate the electric field due to a dipole on its axial line.
    OR
    (b) What is Frequency Modulation? List out the advantages and limitations of frequency modulation.
36. (a) (i) Derive an expression for de Broglie wavelength of electrons.
    (ii) Calculate the momentum of an electron with kinetic energy 2eV.
    OR
    (b) Write down Maxwell equations in integral form.
37. (a) Explain about Astronomical telescope and obtain the equation for the magnification.
    OR
    (b) (i) Explain the equivalent resistance of a series resistor network.
    (ii) A Copper wire of cross-sectional area 0.5 mm^2 carries a current of 0.2A. If the free electron density of copper is 8.4×10^{28} m^{-3} then compute the drift velocity of free electrons.
38. (a) Obtain Lens maker's formula.
    OR
    (b) Derive an expression for phase angle between the applied voltage and current in a series RLC circuit.

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