KENDRIYA VIDYALAYA SANGATHAN
RAIPUR REGION

CLASS XII

SESSION 2025-26

STUDY MATERIAL
VOLUME I

PHYSICS (042)

OUR PATRONS

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CONTENT DEVELOPEMENT TEAM FOR CLASS XII

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1.Shri Simanchal Pradhan PGT(Physics) PM Shri KV, Rajnandgaon

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UNIT	CHAPTER	SUB TR	KV
I	1: Electric Charges and Fields	Shri. Sushant Dey	Raipur No-1(S-I)
	2: Electrostatic Potential and Capacitance	Shri. Yogendra Kumar Tiwari	K V No.2 Raipur
II	3.Current Electricity	Shri. Shivendra Singh	Baikunthpur
III	4.Moving Charges and Magnetism	Shri. Suyash Rawat	Bacheli
	5.Magnetism and Matter	Shri. N D Sahu	Raipur No-1(S-2)
IV	6.Electromagnetic Induction	Shri. Vinod Kumar Verma	Korba No.4
	7.Alternating Current	Shri. Amitabh Adhikari	Dongargarh
V	8.Electromagnetic Waves	Ms. Renu	Maharajpur Kawardha
VI	9.Ray Optics and optical instruments	Smt. Runa Chaudhary Sh S.K. Chaturvedi	CISFBhilai Durg
	10.Wave Optics	Shri. Raju Prasad Gupta Shri. Mayadhar Panda	Ambikapur Raigarh
VII	11.Dual Nature of Radiation and Matter	Ms. Monika Yadav	Saraipali
VIII	12.Atoms	Shri. Krishna Kantiwal	Narayanpur
	13.Nuclei	Shri. H.S.Tripathi	Kurud
IX	14.Semiconductor Electronics: Materials, Devices and Simple Circuits	Shri. Ashish Verma	Bijapur
	Materials collection by	Smt. Archana Khare	Korba No-2(NTPC)

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CLASS XII (2025-26)

PHYSICS THEORY)

Time: 3 hrs. **Max Marks: 70**

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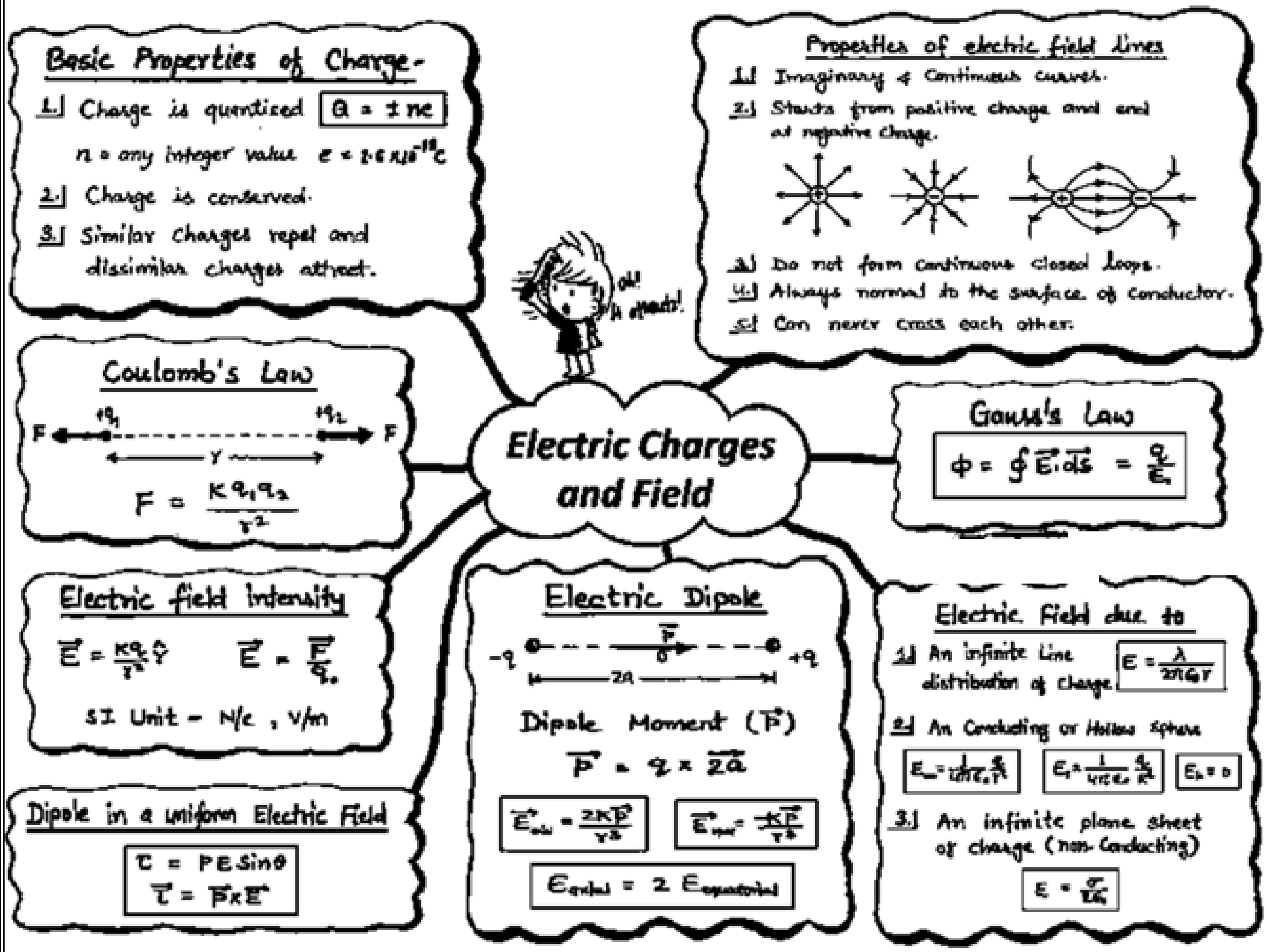
Total		**70**

CHAPTER–1: ELECTRIC CHARGES AND FIELDS

BRAIN MAP



MULTIPLE CHOICE QUESTIONS

1. The electric flux through a closed Gaussian surface depends upon

   (A) Permittivity of the medium (B) Net charge enclosed only

   (C) Net charge enclosed and permittivity of the medium

   (D) Net charge enclosed, shape and size of the Gaussian surface and permittivity of

2. When 2×10^{11} electrons are removed from a neutral metal sphere, the charge on the sphere becomes:

   (A)-16 nC (B) 16 nC (C) -32 nC (D) 32 nC

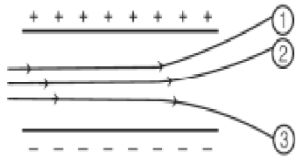
3. A plane square sheet of charge of side 0.5m has uniform surface charge density .An electron at 1cm from the center of the sheet experiences a force of 1.6×10^{-19} N directed away from the sheet. The total charge on the plane square sheet is

   (A) 16.25 µC (B) -22.15 µC (C) -44.27 µC (D) 144.27 µC

4. Three-point charges Q_1, Q_2 and Q_3 are placed equally spaced in order along a straight line. Q_2 and Q_3 are equal in magnitude but opposite in sign . If the net force on Q_3 is zero, the value of Q_1 is

(A) $Q_1 = 4Q_3$ (B) $Q_1 = 2Q_3$ (C) $Q_1= \sqrt{2}\, Q_3$ (D) $Q_1 = |Q_3|$

5. The given figure shows tracks of three charged particles in a uniform electrostatic field. Which of them is probably an α-particle?



(A) 1 (B) 2 (C) 3 (D)None of the above

6. The dimensional representation of ε_0 will be

(A) $[MLT^2A^2]$ (B) $[M^{-1} L^{-3} T^4A^2]$ (C) $[ML^{-2}T^2A^{-2}]$ (D) none of these

7. 10^6 electrons are taken out of a pith ball. The positive charges on the pith ball is

(A) $1.6x10^{-13}$ C (B) $1.6x10^{-19}$ C (C) $1.6x10^{-25}$ C (D) none of these

8. Two parallel large thin metal sheets have equal surface densities $26.4x10^{-12}$ C/m2 of opposite signs. The electric field between these sheets is

(A) 1.5 N/C (B) $1.5x10^{-16}$N/C (C) $3x10^{-10}$N/C (D) 3N/C

9. A cylinder of radius r and length l is placed in a uniform electric field parallel to the axis of the cylinder. The total flux for the surface of the cylinder is given by

(A) zero (B) $3.14\ r^2$ (C) $3.14\ E\ r^2$ (D) $2E(3.14\ r^2)$

10. The ratio of the electrostatic force between two-point charges in air and in a medium of dielectric constant K is:

(A) K :1 (B) 1: K (C) K^2 :1 (D) 1 :1

ANSWER KEY

1	2	3	4	5	6	7	8	9	10
C	D	C	A	C	B	A	D	A	A

ASSERTION REASON QUESTIONS

OPTIONS:

(A) Both Assertion and reason are true and reason is correct explanation of assertion.
(B) Both Assertion and reason both are true but reason is not the correct explanation of assertion.
(C) Assertion is true, reason is false.
(D) Assertion is false, reason is true.

1. **Assertion :** Electric filed lines not form closed loops.

Reason: Electric filed lines are always normal to the surface of a conductor.

2. **Assertion**- If a proton and an electron are placed in the same uniform electric field they experience accelerations of different magnitudes

Reason-Electric force on a charge is independent of its mass

3. **Assertion**: Total flux through a closed surface is zero if no charge is enclosed by the surface.

Reason: Gauss law is true for any closed surface, no matter what its shape or size is.

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

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

5. **Assertion :** Two electric lines of force cannot intersect each other.

Reason (R): The tangent at any point of an electric lines of force gives the direction of electric field intensity at that point.

ANSWER KEY

1	2	3	4	5
A	**B**	**B**	**B**	**B**

2MARKS QUESTIONS

Q1. (a)If a dipole having charge ±2μC is placed inside a sphere of radius 2 m, what is the net flux linked with the sphere? (b) what will be the net flux if charges are +2q and –q?

ANS. (a) Net flux = $\frac{+q-q}{\varepsilon_0}$ = 0 (b) Net flux = $\frac{+2q-q}{\varepsilon_0}$ = $\frac{q}{\varepsilon_0}$

Q2. An electric dipole is held in a uniform electric field.

(a) Show that no translatory force acts on it.

(b) The dipole is aligned parallel to the field. Calculate the work done in rotating it through 180°.

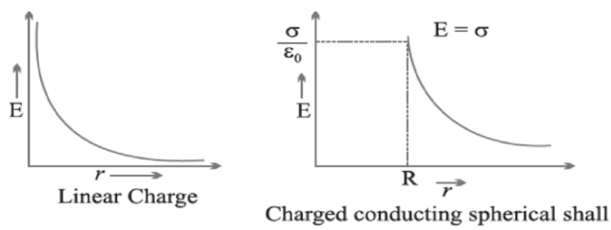
ANS. (a) This is because the forces on the two charges of the dipole are equal in magnitude and opposite in direction, resulting in a net force of zero

(b) $W = U_2 - U_1 = pE - (-pE) = 2pE$.

The work done in rotating an electric dipole aligned parallel to a uniform electric field by 180° is 2pE, where 'p' is the dipole moment and 'E' is the electric field strength.

Q3. Draw the electric field vs distance (from the centre) graph for (i) a long charged rod having linear charge density λ < 0 (ii) spherical shell of radius R and charge Q > 0.

ANS.



Q4. An electric dipole is kept in a uniform electric field. Calculate the work done in rotating the electric dipole from its equilibrium position to an angle θ with the uniform electrostatic field.

ANS. Work done in rotating the dipole from its equilibrium position ($\theta 1 = 0$) to an angle angle θ ($\theta 2 = \theta$) is equal to the change in potential energy: $W = U(\theta) - U(0) = -pE\cos\theta - (-pE) = pE(1 - \cos\theta)$

Q5. What is the force between two small charged spheres having charges of 2×10^{-7}C and 3×10^{-7}C placed 30 cm apart in air?

ANS. Given, $q_1 = 2 \times 10^{-7}$ C, $q_2 = 3 \times 10^{-7}$ C and

$r = 30$ cm $= 0.3$ m, F = ?

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

$$= 9 \times 10^9 \times \frac{2 \times 10^{-7} \times 3 \times 10^{-7}}{(0.3)^2}$$

$= 6 \times 10^{-3}$ N (repulsive in nature, as the two charges are like charges.)

Q6. Show that the electric field intensity at a point can be given as negative of potential gradient. What does the negative sign signify?

ANS. External force required to move a test charge q0 against electric field E is $\mathbf{F} = q_0\mathbf{E}$

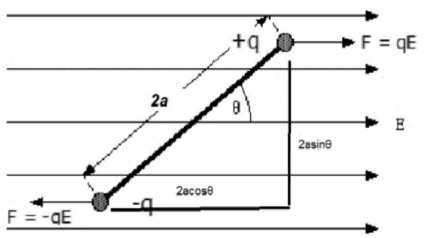
Work done to move charge by dr is, $W = \mathbf{F}.\ dr = -q_0\mathbf{E}.dr$

Again, $W = Q_0 dV$

By equating both equations, $--q_0\mathbf{E}.dr = q_0 dV$, finaly $E = -dV/dr$

7. An electric dipole, which is kept in a uniform electric field. will the dipole experience any net force. Find an expression for the torque acting on an electric dipole, which is held in uniform electric field E.

ANS. If a dipole is kept in an external electric field, it experiences a rotating effect. The rotating effect is also called torque on the dipole.Net force on the dipole



$F_N = qE - qE = 0$, Net force is zero so there is no translatory motion.

Magnitude of torque = $q E \times 2a \sin\theta$,

$\boldsymbol{\tau} = 2 q a E \sin\theta$, **$\boldsymbol{\tau} = p E \sin\theta$** **(Since p = 2 q a)**

The vector form of torque is $\vec{\tau} = \vec{p} \times \vec{E}$

Q8. Two charges – *q* and + *q* are located at points A (0, 0, – *a*) and B (0, 0, + *a*) respectively. How much work is done in moving a test charge from point P (7, 0, 0) to Q (– 3, 0, 0)?

ANS. The charges –q and + located at points A(0,0,-a) and B(0, 0, +a) constitute an electric dipole. Point P(7,0,0) and Q(-3,0,0) both lie at the equatorial line of this dipole. Therefore $V_P = V_Q = 0$. As a result work done in moving a test charge go from point P to Q

$W = q_0(V_Q - V_{P)} = q_0\ (0-0) = 0$

Q10. A point charge Q is kept at the intersection of (i) face diagonals (ii) diagonals of a cube of side a. What is the electric flux linked with the cube in (i) & (ii) ?

ANS.When a point charge Q is placed at the intersection of face diagonals of a cube, the electric flux linked with the cube is $Q/(2\varepsilon_0)$. When the point charge Q is placed at the intersection of the body diagonals of the cube, the electric flux linked with the cube is Q/ε_0.

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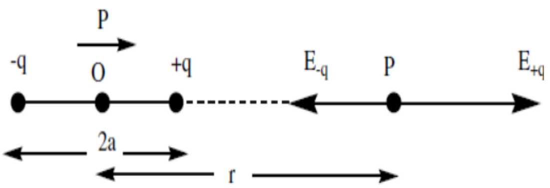
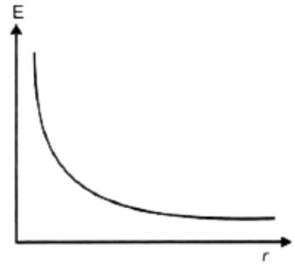
3 MARKS QUESTIONS

Q1. (a) Two charges +q and –q are separated by a distance 2a and kept in a uniform electric field E. Find the electric field E due to the system at a point distant r from the centre of the dipole on the axial line.

(b) Draw a graph of E versus r for r >> a.

ANS. (a) (b)



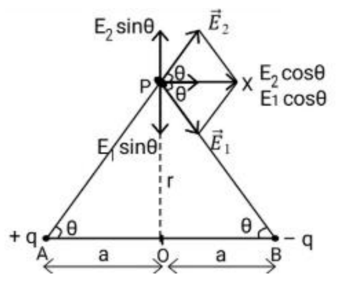


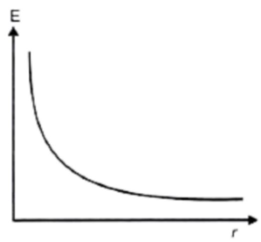
Derivation, $E = \frac{1}{4\pi\varepsilon_0}\frac{2p}{r^3}$

Q2. (a) An electric dipole is kept in an external electric field. Find the electric field E due to a dipole of length '2a' at a point distant r from the centre of the dipole on the equatorial line.

(b) Draw a graph of E versus r for r >> a.

ANS. (a) (b)





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

Q3. (a) A conducting sphere of radius 10 cm has an unknown charge. If the electric field 20 cm from the centre of the sphere is 1.5×10^3 N/C and points radially inward, what is the net charge on the sphere?

(b) Two insulated charged copper spheres A and B of identical size have charges q and -3q respectively. When they are brought in contact with each other and then separated, what are the new charges on them ?

ANS. (a)Here E= 1.5×10^3 N/C and r= 20 cm = 0.2 m and K= 9 X 10^9 Nm^2/C^2

Putting in $E = \frac{Kq}{r^2}$

The net charge on the sphere is, q = - 6.67 x 10^{-9} C

(b) Charge on each sphere = $\frac{q_1+q_2}{2} = \frac{q_A - 3q_A}{2} = -q_A$

Q4. What is linear charge density? An infinite line charge produces a field of 9 × 10^4 N/C at a distance of 2 cm. Calculate the linear charge density.

ANS. Linear charge density is the amount of electric charge per unit length along a line. It describes how densely electric charge is distributed along a wire or any one-dimensional object. The electric field produced by the infinite line charges at a distance 'd'having linear charge densityλ is given by the relation,

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

Putting d = 2 cm = 0.02 m, and E = 9 × 10^4 N/C

$\frac{1}{4\pi\varepsilon_0}$ = 9 X 10^9 Nm^2/C^2 We get, λ = 10 µC/m

Q5. Two electric charges +q and –q are apart by a distance of 2a, kept in a uniform electric field $\vec{E}$. Find the work done in rotating the system of charges through an angle θ in the given electric field. Hence calculate the potential energy of the system.

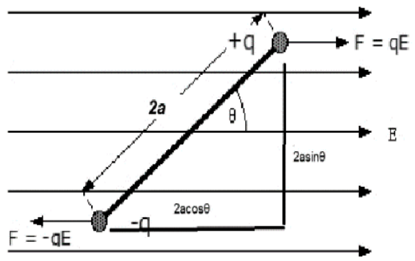
ANS. $\tau = pEsin\theta$

$dW = \tau d\theta = pEsin\theta d\theta$

$W = \int_{\theta_1}^{\theta_2} pEsin\theta d\theta$

Putting the limit from θ_2 =0 to $\theta_1 = \theta$

$U = W = pE(cos0 - cos\theta) = -pEcos\theta$



Q6. What should be the position of charge q = 5µC for it to be in equilibrium on the line joining two Charges q_1 = – 4 µC and q_2 = 16 µC separated by 9 cm. Will the position change for any other value of charge q ? (9 cm from – 4µC)

ANS. For equilibrium, these forces must be equal in magnitude and opposite in direction:

k x (-4µC) x (5µC) / x^2 = k x (16µC) x (5µC)| / $(9-x)^2$

4/ x^2 = 16 / $(9-x)^2$

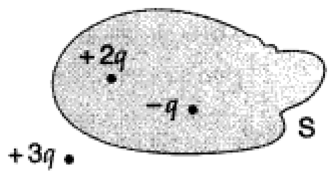
2 / x = 4 / (9-x)

2 x (9 - x) = 4 .x

18 = 6x

x = 3 cm

Q7. (a) Figure shows three point charges, +2q, -q and + 3q. Two charges +2q and -q are enclosed within a surface ‘S’. What is the electric flux due to this configuration through the surface ‘S’



(b)What will be the electric flux if all three charges are kept inside the surface?

ANS.(a). Electric flux $\emptyset = \oint \vec{E}.\overrightarrow{dS}$

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

...where [q_1 is the total charge enclosed by the surface S

$\phi = \frac{2q-q}{\varepsilon_0} = \frac{q}{\varepsilon_0}$ ∴ **Electric flux,** $\phi = \frac{q}{\varepsilon_0}$

(b) $\emptyset = \frac{2q+3q-q}{\varepsilon_0} = \frac{5q}{\varepsilon_0}$

Q8. Given a uniform electric field E= **6 X 10³**$\hat{\imath}$N/C, Find the flux of this field through a square of 10 cm on a side whose plane is parallel to Y-Z plane. What would be the flux through the same square if the plane makes a 30^0 angle with the x- axis ?

ANS.

Given : **E =** $6 X 10^3\ \hat{\imath}$ N/C, $a = 10\ cm = 10X10^{-2}m$, $\phi = ?$

In first case, $\phi = E\ ds\ \cos 0 = 6 X 10^3 X (10 X 10^{-2})^2 = 60\ N\ m^2/C$

In second case, $\phi = E\ ds\ \cos(90-30) = E\ ds\ \cos 60 = 6 X 10^3 X (10 X 10^{-2})^2 X \frac{1}{2} = 30\ N\ m^2/C$

Q9. (a) Why are electric field lines perpendicular at a point on an equipotential surface of a conductor?

(a) Why two electric field lines never intersect each other?

ANS. (a) If the electric field lines were not normal to the equipotential surface, it would have a non-zero component along the surface. To move a unit test charge against the direction of the component of the field, work would have to be done which means this surface cannot be equipotential surface. Hence, electric field lines are perpendicular at a point on an equipotential surface of a conductor.

(b)Two electric field lines never intersect each other because at the point of intersection, the electric field would have two different directions, which is physically impossible. The electric field is a vector quantity, and at any given point, it has a unique direction.

Q10. Define electric flux. Write its S.I. unit.A charge q is enclosed by a spherical surface of radius R. If the radius is reduced to half, how would the electric flux through the surface change?

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

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

Electric flux ϕ by $q_{enclosed}$

Hence the electric flux through the surface of sphere remains same.

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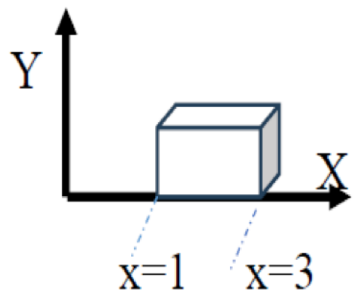
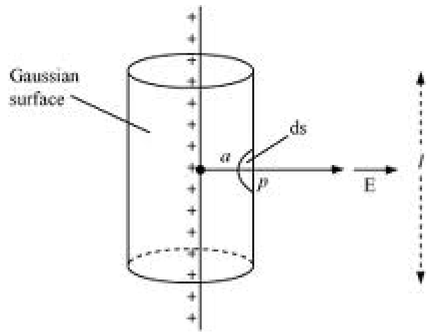
5 MARKS QUESTIONS

Q1. (a) State Gauss's law in electrostatics. Derive an expression for the electric field due to an infinitely long straight uniformly charged wire.

(b)A uniform electric field given by E = (3**i**+ 4**j** +5**k**)N/ C pierces the Gaussian cube as shown. Find the electric flux through the right face and top face in Nm2 /C.



ANS.(a) Gauss's law in electrostatics states that the total electric flux through any closed surface is directly proportional to the enclosed electric charge



The field is radial everywhere and hence the electric flux crosses only through the curved surface of the cylinder.

The field is radial everywhere and hence the electric flux crosses only through the curved surface of the cylinder.

If E is the electric field intensity at P, then the electric flux through the Gaussian surface is

$\emptyset = E \times 2\pi rl$

According to gauss theorem electric flux is

$\emptyset = \frac{q}{\epsilon_0} = \frac{\lambda l}{\epsilon_0}$

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

$\left[\therefore E = \frac{\lambda}{2\pi\epsilon_0 r}\right]$

(b) $\boldsymbol{\Phi}$ = EA Right face $\boldsymbol{\Phi}$ = 3 x 2^2 = 12 , Top face $\boldsymbol{\Phi}$ = 4 x 2^2 = 16

Q2. (a) Using Gauss' law, derive an expression for the electric field intensity at any point outside a uniformly charged thin spherical shell of radius R and charge density a C/m2.

(b) Draw the field lines when the charge density of the sphere is

(i) positive (ii) negative.

(c) A uniformly charged conducting sphere of 2.5 m in diameter has a surface charge density of 100 μC/m^2. Calculate the

(i) charge on the sphere

(ii) total electric flux passing through the sphere

ANS. (a) (i) To find out electric field at a point outside a spherical charged shell we imagine a symmetrical Gaussian surface in such a way that the point lies on it.

Case (i)r>R

At points outside the sphere the electric field is radial

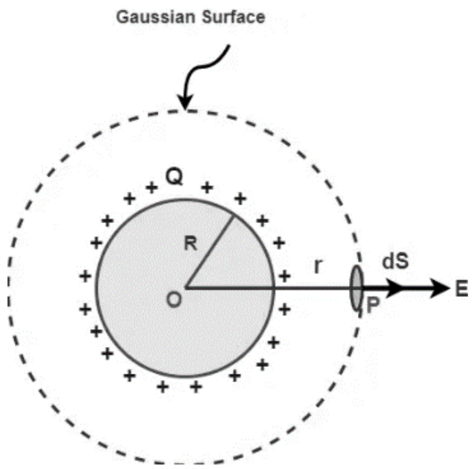
Total electric flux

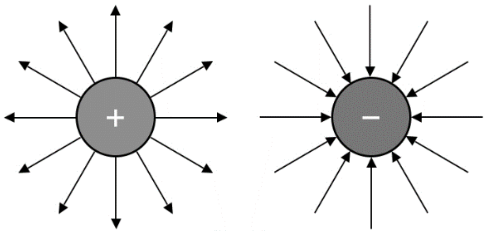
$\emptyset = E \times 4\pi r^2$

According to gauss theorem electric flux is $\emptyset = \frac{q}{\epsilon_0}$

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

$$\left[E = \frac{q}{4\pi \epsilon_0 r^2}\right]$$





(b) (i) **Given** : $r = \frac{2.5}{2}$ m, $\sigma = 100\ \mu C/m^2$

Charge on the sphere, $Q = \sigma . 4\pi r^2$

or $Q = 100 \times 10^{-6} \times 4 \times 3.14 \times \left(\frac{2.5}{2}\right)^2$

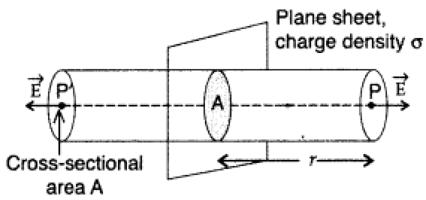
$= 19.6 \times 10^{-4}$ C = $\mathbf{1.96 \times 10^{-3} C}$

Q3. (a) Using Gauss's law, prove that the electric field at a point due to a uniformly charged infinite plane sheet is independent of the distance from it.

(b) How is the field directed if (i) the sheet is positively charged,(ii) negatively charged?

(c) Metal cube of side 5 cm is charged with 6μC. The surface charge density on the cube/

ANS. (a) Consider a thin, infinite plane sheet of charge with uniform surface charge density 0. We wish to calculate its electric field at a point P at distance r from it.



By symmetry, electric field E points outwards normal to the sheet. Also, it must have same magnitude and opposite direction at two points P and P' equidistant from the sheet and on opposite sides. We choose cylindrical Gaussian surface of cross-sectional area A and length 2r with its axis perpendicular to the sheet.

As the lines of force are parallel to the curved surface of the cylinder, the flux through the curved surface is zero. The flux through the plane-end faces of the cylinder is :

$\phi E = EA + EA = 2EA$

Charge enclosed by the *Gaussian surface,*

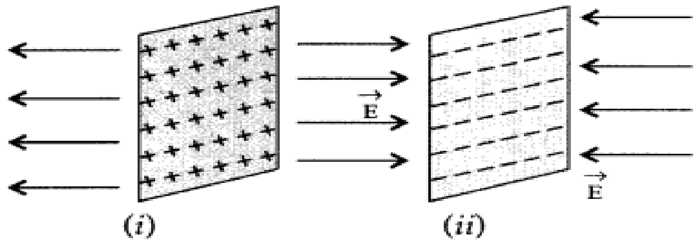
$q = \sigma A$

According to *Gauss's theorem,*

$\phi_E = \frac{q}{\varepsilon_0} \quad \therefore \; 2EA = \frac{\sigma A}{\varepsilon_0}$ or $E = \frac{\sigma}{2\varepsilon_0}$

Clearly, E is independent of *r*, the distance from the plane sheet.

(*c*)



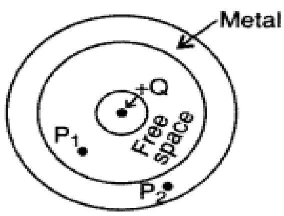
(i) For positively charged sheet → away from the sheet

(ii)For negatively charged sheet →towards the sheet

(b) $\sigma = \frac{6\times10^{-6}\,C}{0.015\,m^2} = 4 \times 10^{-4}\,Cm^{-2}$

Q4. (a) Define electric flux. Write its S.I. unit.

(b)A small metal sphere carrying charge +Q is located at the centre of a spherical cavity inside a large uncharged metallic spherical shell as shown in the figure the expressions for the electric field at points P_1 and P_2.



(b) Draw the pattern of electric field lines in this arrangement.

ANS.(a) Electric flux through a surface represents the total number of electric lines of force crossing the surface. ∴ S.I. unit is $Nm^2\,C^{-1}$.

(b) Calculation of electric field at point Pt:

Net charge enclosed by the Gaussian surface is +Q

$\therefore \; \phi = \oint \vec{E}.d\vec{s} = \frac{Q}{\varepsilon_0}$

As electric field of positive charge is radially outwards, it is parallel to the area vector on the surface chosen.

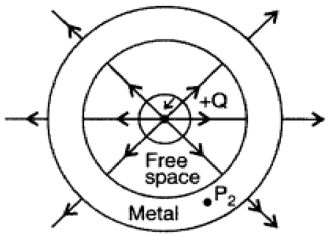
$$\therefore \oint \vec{E}.d\vec{s} = \oint E.\,ds\cos 0° = \frac{Q}{\varepsilon_0}$$

$$E\oint ds = \frac{Q}{\varepsilon_0} \Rightarrow E \times 4\pi r^2 = \frac{Q}{\varepsilon_0}$$

$$\therefore E = \frac{Q}{4\pi\varepsilon_0 r^2}$$

As point P_2 lies inside the metal, therefore electric field at point P_2 is zero

(c)



Electric field lines

Q5. (a) "Gauss's law in electrostatics is true for any closed surface, no matter what its shape or size is". Justify this statement with the help of a suitable example.

(b) Use Gauss's law to prove that the electric field inside a uniformly charged spherical shell is zero.

(c) Two identical conducting spheres P and S with charge Q on each, repel each other with a force 16 N. A third identical uncharged conducting sphere R is successively brought in contact with the two spheres. What will be the new force of repulsion between P and S?

ANS.

Gauss's Law states that the electric flux through a closed surface is given by

Mathematically, $\phi_E = \oint_S \vec{E}\,.\,\Delta\vec{S}$

$$\phi = \frac{q}{\epsilon_0}$$

The law implies that the total electric flux through a closed surface depends on the quantity of total charge enclosed by the surface, and does not depend on its shape and size.

For example, net charge enclosed by the electric dipole (q, -q) is zero, hence the total electric flux enclosed.

The law implies that the total electric flux through a closed surface depends on the quantity of total charge enclosed by the surface, and does not depend on its shape and size.

(b) Electrical field inside a uniformly charged spherical shell. Let us consider a point 'P' inside the shell. The Gaussian surface is a sphere through P centred at O.

The flux through the Gaussian surface is $E \times 4\pi r^2$.

However, in this case, the Gaussian surface encloses no charge. Gauss's law then gives

$E \times 4\pi r^2 = 0$, or $E = 0$ $(r < R)$

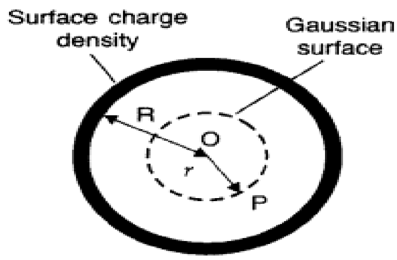
that is, the field due to a uniformly charged thin shell is zero at all points inside the shell.

c)

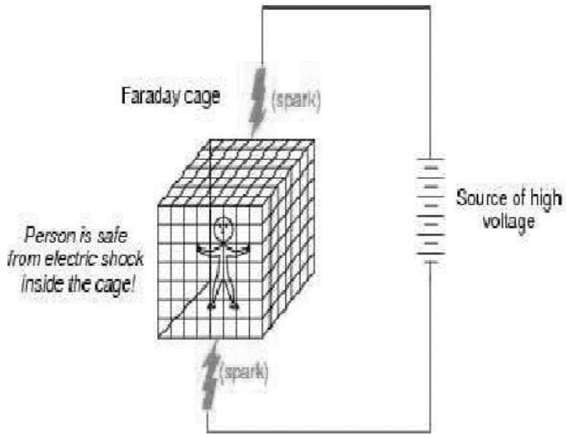
$$F_1 = \frac{KQ^2}{r^2} = 16\,\text{N}$$

$$F_2 = \frac{K\left(\frac{Q}{2}\right)\left(\frac{3}{4}\right)}{r^2} = \frac{3}{8} \times 16 = 6\,\text{N}$$

Final charges on spheres are $\frac{Q}{2}$ and $\frac{3Q}{4}$.



CASE BASED QUESTIONS



Q1. Faraday cages shield their contents from static electric fields. An electric field is a force field surrounding a charged particle, such as an electron or proton. These cages often look distinctly, well, cage like. Some are as simple as chain-link fences or ice pails. Others use a fine metallic mesh. Regardless of their exact appearance, all Faraday cages take electrostatic charges, or even certain types of electromagnetic radiation, and distribute them around the exterior of the cage.

(1)Which of the following material can be used to make a Faraday cage?

(a) Plastic (b) Glass (c) Copper (d) Wood

(2). Example of a real-world Faraday cage is

(a) car (b) plastic box (c) lightning rod (d) metal rod

(3)What is the electrical force inside a Faraday cage when it is struck by lightning?

(a) The same as the lightning (b) Half that of the lightning

(c) Zero (d) A quarter of the lightning

(4) An isolated point charge +q is placed inside the Faraday cage. Its surface must have charge equal to

(a) Zero (b) +q (c) – q (d) +2q

Q2. For electrostatics, the concept of electric field is convenient, but not really necessary. Electric field is an elegant way of characterizing the electrical environment of a system of charges. Electric field at a point in the space around a system of charges tells you the force a unit positive test charge would experience if placed at that point (without disturbing the system). Electric field is a characteristic of the system of charges and is independent of the test charge that you place at a point to determine the field. The term field in physics generally refers to a quantity that is defined at every point in space and may vary from point to point. Electric field is a vector field, since force is a vector quantity.

(1) Which of the following statement is correct? The electric field at a point is

(a) Always continuous.

(b) Continuous if there is a charge at that point.

(c) Discontinuous only if there is a negative charge at that point.

(d) Discontinuous if there is a charge at that point.

(2) The force per unit charge is known as

(a) electric flux (b) electric field (c) electric potential (d) electric current

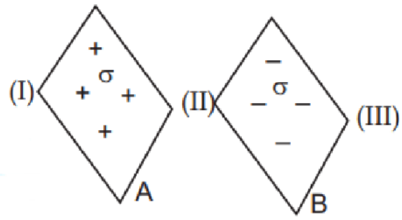
(3) The SI unit of electric field is

(a) N/m (b) N-m (c) N/C (d) N/C2

(4) The magnitude of electric field intensity E is such that, an electron placed in it would experience an electrical force equal to its weight is given by

(a) mge (b) mg/e (c) e/mg (d) e^2g/m^2

Q3. Surface Charge Density. Surface charge density is defined as the charge per unit surface area the surface (Arial) charge symmetric distribution and follow Gauss law of electro statics mathematical term of surface charge density σ=ΔQ/ΔS



Two large thin metal plates are parallel and close to each other. On their inner faces, the plates have surface charge densities of opposite sign (± s). Having magnitude 8.8×10^{-12} cm^{-2} as shown here. The intensity of electrified at a point is E =σ/ε0 and flux is Φ=E.ΔS, where ΔS = 1 m2 (unit arial plate)

(1) E in the outer region (I) of the first (A) plate is

(a) 1.7×10^{-22} N/C (b) 1.1×10^{-12} V/m (c) Zero (d) Insufficient data

(2) E in the outer region (III) of the second plate (B) is

(a) 1 N/C (b) 0.1 V/m (c) 0.5 N/C (d) zero

(3) E between (II) the plate is

(a) 1 N/C (b) 0.1 V/m (c) 0.5 N/C (d) None of these

(4) The ratio of E from left side of plate A at distance 1 cm and 2 m respectively is

(a) 1 : 2 (b) 10 : 2 (c) 1 : 1 (d) 20 : 1

ANSWER KEY

	1	2	3	4
CBQ 1	c	a	c	c
CBQ2	b	b	c	b
CBQ3	a	d	d	c

WORK SHEET

1. Two-point charges + Q and + q is separated by a certain distance. If + Q > + q then in between the charges the electric field is zero at a point

(a) closer to + Q (b) exactly at the mid-point of line segment joining + Q and + q.

(c) closer to + q (d) nowhere on the line segment joining + Q and + q.

2. Electric lines of force about a negative point charge are

(a) circular anticlockwise (b) circular clockwise (c) radial, inwards (d) radial, outwards

3. The electric field at a point on equatorial line of a dipole and direction of dipole moment

(a) will be parallel (b) will be in opposite direction

(c) will be perpendicular (d) are not related

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

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

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

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

(d) None of these

5. **Assertion:** A metallic shield in the form of a hollow shell may be built to block an electric field.

Reason: In a hollow spherical shield, the electric field inside it is zero at every point.

a) Both assertion and reason are correct and the reason is the correct explanation of assertion.

b) Both assertion and reason are correct and reason is not a correct explanation of assertion.

c) Assertion is correct but the reason is incorrect

d) Assertion is incorrect but the reason is correct

6. a) What is the angle between the directions of electric field and dipole moment at any (i) axial point and (ii) Equatorial point due to an electric dipole?

----

b) The force between two-point charges kept at a distance r apart in air is F. If the same charges are kept in water of dielectric constant 81 at the same distance, how does the force between them change

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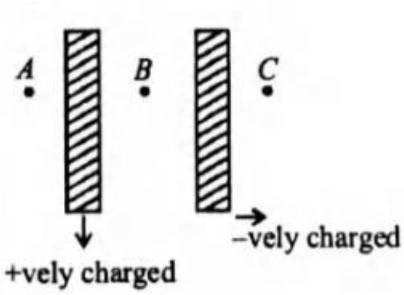
7. i) Define electric dipole moment. Is it scalar or a vector quantity? What is its SI unit?

----

ii) Define electric flux. Write its SI unit. Is it a scalar or vector quantity?

8. Two plane sheet of charge densities $+\sigma$ and $-\sigma$ are kept as shown in figure. What are the electric field intensities at points A, B & C.?

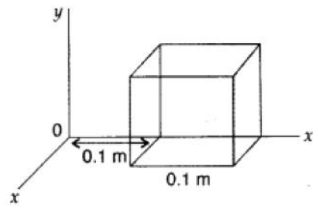


9. An electric dipole of dipole moment p is placed in a uniform electric field E?.
Obtain the expression for the torque τ experienced by the dipole. Identify two pairs of perpendicular vectors in the expression.

10. (a)Define electric flux. Write its SI units.

(b) The electric field components due to a charge inside the cube of side
0.1 m are as shown : Ex = ax, where α = 500 N/C-m
Calculate (i) the flux through the cube, and (ii) the charge inside the cube.

$E_y = 0$, $E_z = 0$.



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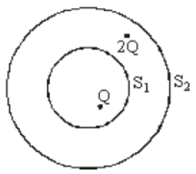
11. $S_1$and S_2 are two parallel concentric spheres enclosing charges Q and 2 Q respectively as shown in Fig.What will be the ratio of the electric flux through $S_1$and S_2 .



-12. An electric dipole with dipole moment $4x10^{-9}$ Cm is aligned at $30^0$with the direction of a uniform electric field of magnitude $5x10^4$N/C. Calculate the magnitude of the torque acting on the dipole.

----

13. The sum of two point charges is 9 μc .They repel each other is force of 2 N. When kept 30 cm apart in free space. Calculate the value of each charge.

----

14. a) Sketch the electric field lines for two-point charges q1 and q2 for q1q2>0 and 0>q1q2 separated by a distance d.

----

b) Plot graph between E & r

----

15. a) A simple pendulum consists of a small sphere of mass m and positive charge q is suspended by the string of length L. The pendulum is placed in the electric field of strength E directed vertically downwards. What will be the time period of simple pendulum?

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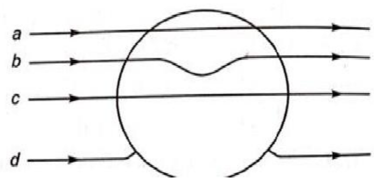
b) A metallic sphere is placed in a uniform electric field. Which one of the path a,b,c and d shown in figure will be followed by the electric field lines and why?



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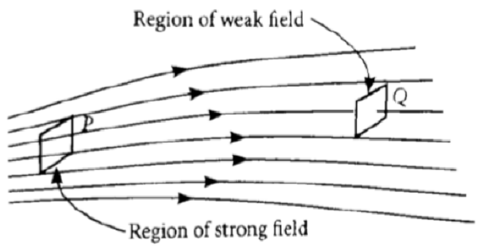
CASE BASED QUESTION

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



(i) Electric lines of force about a positive point charge are 4

(a) radially outwards (b) circular clockwise

(c) radially inwards (d) parallel straight lines

(ii) Which of the following is false for electric lines of force?

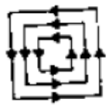
(a) They always start from positive charge and terminate on negative charges.

(b) They are always perpendicular to the surface of a charged conductor.

(c) They always form closed loops.

(d) They are parallel and equally spaced in a region of uniform electric field.

(iii) Which one of the following patterns of electric line of force is not possible in field due to stationary charges?

a.  (b)  (c)  (d) 

(iv) Electric field lines are curved

(a) in the field of a single positive or negative charge

(b) in the field of two equal and opposite charges.

(c) in the field of two like charges.

(d) both (b) and (c)

****

WORKSHEET I ANSWER KEY

1	2	3	4	5
c	C	b	C	a

6. (a) The angle between the directions of electric field and dipole moment at any

(i) axial point is 0^0 and (ii) equatorial point is 180^0

(b) $F_{air} = Kq_1 \times q_2 / r^2$, $F_{water} = Kq_1 \times q_2 / \varepsilon_r r^2$

Therefore, the force between the charges in water will be 1/ 81 times the force in air.

7. (i) It is defined as the product of the magnitude of either charge and the distance between the charges. The electric dipole moment is a vector quantity. SI unit of electric dipole moment is the coulomb-meter (C·m)

(ii) Electric flux is a measure of the electric field passing through a given area. It represents the number of electric field lines that intersect a surface. Electric flux is a scalar quantity. Its SI unit is Newton-meter squared per coulomb (Nm^2/C).

8. The electric field due to a single infinite plane sheet with surface charge density +σ is

$E = \sigma / 2\epsilon_0$

The electric field due to a single infinite plane sheet with surface charge density -σ is

$E = -\sigma / 2\epsilon_0$

So, $E_A = 0$, $E_C = 0$, $E_B = \sigma / \epsilon_0$

9.

If a dipole is kept in an external electric field, it experiences a rotating effect. The rotating effect is also called torque on the dipole.Net force on the dipole

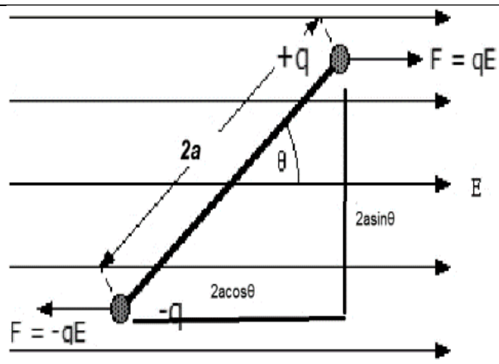
= qE - qE=0,Net force is zero so there is no translatory motion.

Magnitude of torque = q E × 2a sin θ,

τ= 2 q a E sin θ

τ= p E sin θ (Since p = 2 q a)

The vector form of torque is the cross product of dipole moment and electric field**. τ= p X E**



Two pairs of perpendicular vectors in this expression are:
(1) the torque vector (τ) and the electric dipole moment vector (p), and
(2) the torque vector (τ) and the electric field vector (E).

10. (a) Electric flux is a measure of the electric field passing through a given surface. It represents the total number of electric field lines crossing that surface. Its SI unit is newton-meters squared per coulomb ($N{\cdot}m^2/C$) or volt-meters (V·m).

(b) Through the left face $\phi_1 = E \times A \cos 180^0$

$\phi_1 = \ . A \cos 180^0 = 500 \times 0.1 \times 10^{-2} (-1) = -0.5$

Through the right face $\phi_2 = E \times A \cos 0^0$

$\phi_2 = \ . A \cos 0^0 = 500 (0.2) \times 10^{-2} \times 1 = 1.0$

∴ Net flux through the cube $\phi = \phi_1 + \phi_2 = -0.5 + 1 = 0.5 \ N m^2 C^{-1}$

Now,Charge inside the cube, $q = \epsilon_0 \phi = 8.85 \times 10^{-12} \times 0.5 = 4.425 \times 10^{-12} C$

11. The charge enclosed by S_1 is, $q_1 = Q$

The total charge enclosed by S_2 is $q_2 = Q + 2Q = 3Q$

$\therefore\ \Phi_1 = Q / \epsilon_0,\quad \Phi_2 = 3Q / \epsilon_0$

$\therefore\ \Phi_1 / \Phi_2 = 1 / 3$

12. $\tau = pE\sin\theta$

$\tau = (4\times10^{-9})\times(5\times10^{4})\times\sin(30^0)$

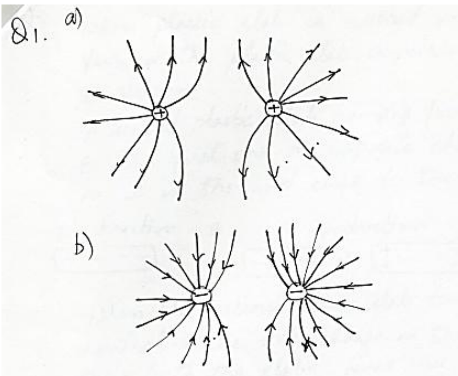
$\tau = 1 \times 10^{-4}$ Nm

13. $q_1 + q_2 = 9\times10^{-6}$ C , $q_2 = 9\times10^{-6}$ C - q_1

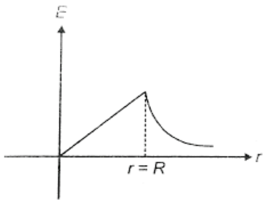
Putting values in $F = K\, q_1 \times q_2 / r^2$

The values of the two charges are 5 μC and 4 μC

14. (a)



(b)



15. (a) The time period of a simple pendulum is $T = 2\pi\sqrt{(L/g)}$.

When a positive charge (q) is placed in a downward electric field (E), it experiences a downward force qE.

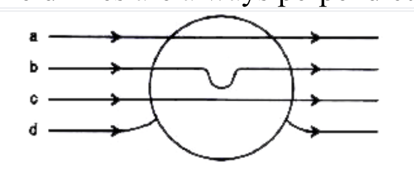
$F_{net} = mg' = mg + qE$

This downward force adds to the gravitational force, effectively increasing the acceleration due to gravity.

So, the new effective acceleration (g') becomes $g' = g + qE/m$.

Substituting g' into the time period formula, we get $T = 2\pi\sqrt{(L / (g + qE/m))}$.

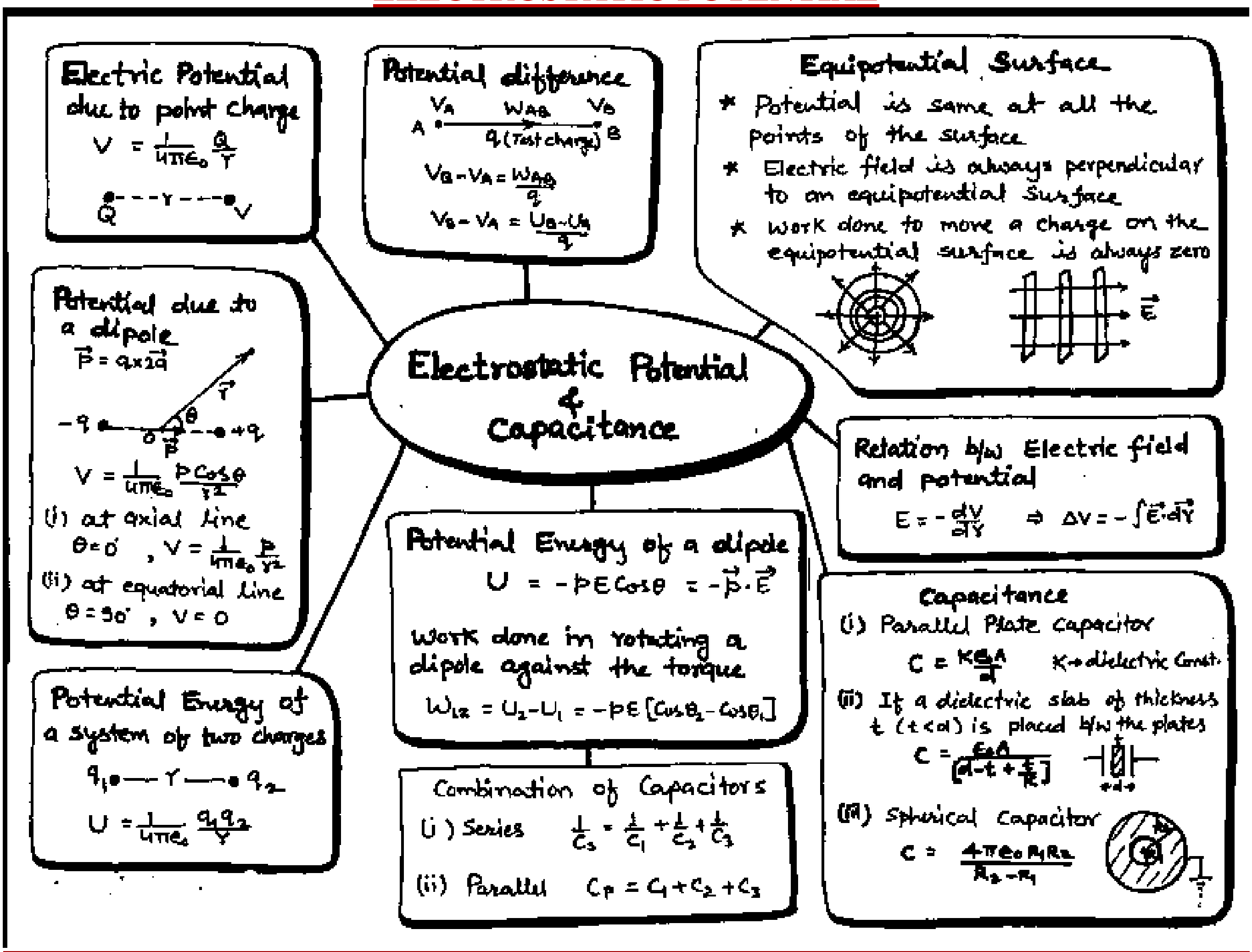
(b) Path d is followed by electric field lines. Electric field intensity inside the metallic sphere will be zero, therefore, electric lines of force exist inside the sphere, also field lines falls normally on the surface. Electric field lines are always perpendicular to the surface of the conductor.



16. (i) a (ii) c (iii) c (iv) d

CHAPTER 2

ELECTROSTATIC POTENTIAL



1. Electrostatic Potential: V=WorkdoneWChargeq
2. Electrostatic Potential due to a Charge at a Point: Vr=14π0Qr
3. Electric potential due to a system of n-point charges: Vr=14π0q1r1+q2r2+q3r3+………..+qnrn
4. The electrostatic potential at a point with position vector **r** due to a point dipole of dipole moment **p** place at the origin is
5. Vr=14π0p.rr3=14π0pcosθr2
6. The electric potential on the perpendicular bisector, i.e. in the equatorial plane due to an electric dipole is zero.
7. Electric potential due to a thin charged spherical shell:

   (a)Inside the shell is Vr=14π0QR for r < R

   (b)On the surface of the shell is Vr=14π0QR for r =R

   (c)Outside the shell is Vr=14π0Qr for r >R

8.Electrostatics Potential Energy Stored in a System of Charges: The work done (by an external agency) in assembling the charges at their locations.

Electrostatic Potential Energy of Two Charges, U=14πϵq1q2r12

Potential Energy of a Charge q in an External Potential: U=qVr

Potential Energy of a Dipole of Dipole Moment p in a Uniform Electric Field: U=-p.E=-pEcosθ

Work done in rotating dipole:

(a) Most stable to most unstable (0° and 180°): +2pE

(b) Most unstable to most stable (180° and 0°): –2pE

(c)Other case: (90° and 0°): –pE, (0° and 90°): +pE

9.Equipotential Surface: An equipotential surface is a surface over which potential has a constant value.

10.Capacitance C of a System of Two Conductors Separated by an Insulator: C=QV

Where Q and – Q are the charges on the two conductors V is the potential difference between them.

Capacitance C of a parallel plate capacitor (with vacuum between the plates): $C = \in_0 A/d$

Capacitors in the series combination $1/C=1/C_1+1/C_2+1/C_3+\ldots$

Capacitors in the parallel combination: $C=C_1+C_2+C_3+\ldots$

The energy stored in a capacitor: $U = \frac{1}{2}CV^2 = \frac{1}{2}QV = \frac{1}{2}\frac{Q^2}{C}$

The electric energy density (energy per unit volume): $u = \frac{1}{2} \in_0 E^2$

MCQ(1)

1.A +3.0 nC charge Q is initially at a distance of r_1 = 10 cm from a + 5.0 nC charge q fixed at the origin. The charge Q is moved away from q to a new position at r_2 = 15 cm. in this process work done by the field is
(a) 1.29×10^{-5} J (b) 3.6×10^{5} J (c) -4.5×10^{-7} J (d) 4.5×10^{-7} J

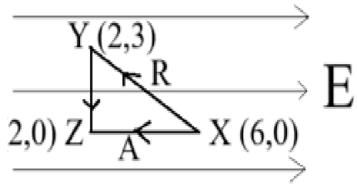
Q2.A variable capacitor is connected to a 200 V battery. If its capacitance is changed from 2 μF to X μF, then the decrease in energy of the capacitor is 0.02 J. the value of X is
(a) F (b) 2 μF (c) 3 μF (d)4 μF

3.Three capacitors of 3 ,3 and 6 micro farad are connected in series to a 10V source. The charge on the 3micro farad capacitor is
(a)5 μC (b)12 μC (c)15μC (d)10 μC

4. If a positively charged particle is released from rest in a uniform electric field, the electric potential energy of the charge:
(A) Remains constant because the electric field is uniform.
(B) Increases because the charge moves along the electric field.
(C) Decreases because the charge moves along the electric field.
(D) Decreases because the charge moves opposite to the electric field.

5. Consider a uniform electric field in the z-direction. The potential is a constant
(a) for any x for a given z (b) for any y for a given z
(c) on the x-y plane for a given z (d) all of these

6. Two charges of same nature and magnitude +q are kept fixed at points X inside a uniform electric field. Now to shift the charges, Rahul used a path X → Y → Z (shown as ‘R’ in the diagram) and Sanjay used a different path of direct X → Z (shown as ‘A’ in the diagram). Find the ratio of their work done to move the charge from X to Y.



(a) 2:1 (b) 1:2 (c) 1:3 (d) 1:1

7.An electric dipole of moment $\vec{p}$ is placed in a uniform electric field $\vec{E}$. Then

(i) the torque on the dipole is **p** ×**E**

(ii) the potential energy of the system is p.E

(iii) the resultant force on the dipole is zero.

Choose the correct option.

(a) (i), (ii) and (iii) are correct (b) (i) and (iii) are correct and (ii) is wrong

(c) only (i) is correct (d) (i) and (ii) are correct and (iii) is wrong

8. What is the angle between electric field and equipotential surface?

(a) 90º always (b)0º always (c)0º to 90 (d)0º to 180º

9.Equipotentials at a great distance from a collection of charges whose total sum is not zero are approximately

(a) spheres. (b) planes. (c) paraboloids (d) ellipsoids.

.

10.An electric dipole of dipole moment p is placed in a uniform electric field of strength E in a direction perpendicular to the field. The work done in rotating the dipole by an angle 90^0 without acceleration in a plane perpendicular to the field is:

a) pE b) –pE c). Zero d). -2Pe

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

ASSERTION – REASON QUESTIONS Directions: These questions consist of two statements, each printed as Assertion and Reason. While answering these questions, you are required to choose any one of the following four responses.

(a) Both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.

(b) Both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.

(c) Assertion is correct, Reason is incorrect

(d) Both Assertion and Reason are correct.

1. .Assertion : If the distance between parallel plates of a capacitor is halved and dielectric constant is three times, then the capacitance becomes 6 times.

Reason : Capacity of the capacitor does not depend upon the nature of the material

1.(c)

2. Assertion: Two equipotential surfaces cannot intersect each other.

Reason: Two equipotential surfaces are parallel to each other.

Ans (c)

3. Assertion (A): The surface of a spherical conductor can be considered an equipotential surface.

Reason (R): In a conductor, charges can easily flow until the potential is the same at the entire surface.

Ans A

4, Assertion: Electron move away from a region of lower potential to a region of higher potential.

Reason: An electron has a negative charge.

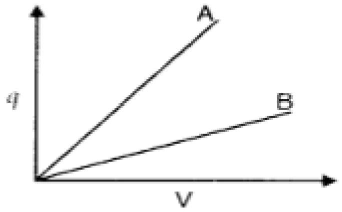
Ans A

.5Assertion: The equatorial plane of a dipole is an equipotential surface.

Reason: The electric potential at any point on equatorial plane is zero.

VERY SHORT ANSWER QUESTIONS 02 MARKS

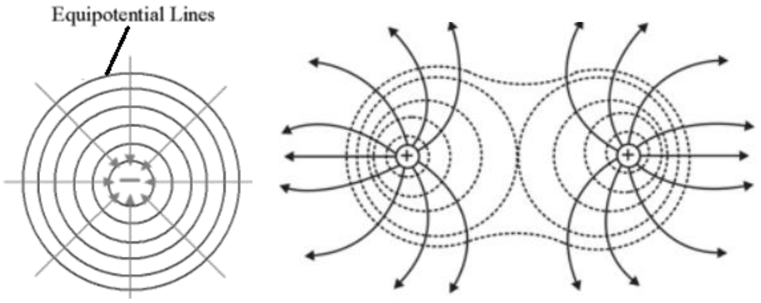
1. The given graph shows variation of charge 'q' versus potential difference 'V' for two capacitors $C_1 > C_2$. Both the capacitors have same plate separation but plate area of C_2 is greater than that of C_1. Which line (A or B) corresponds to C_1 and why?



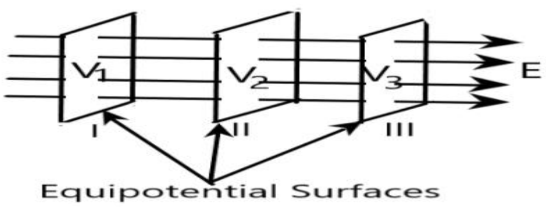
Ans lineA represent C_1 due to high slope

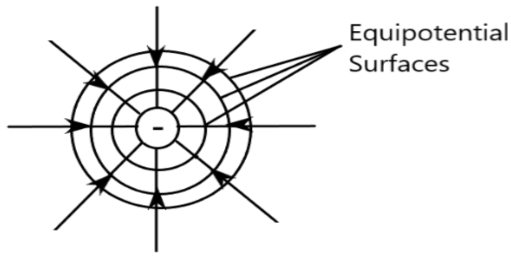
2. If two charged conductors are touched mutually and then separated, prove that the charges on them will be divided in the ratio of their capacitances.
ANS
Explanation: When two charged conductors are touched togetherthey attain a common potential let common potential is V $\frac{q_1}{q_2} = \frac{C_1V}{C_2V}$ therefore $\frac{q_1}{q_2} = \frac{C_1}{C_2}$

3. Sketch equipotential surfaces for (a) A negative point charge
(b) Two equal and positive charges separated by a small distance..
ANS



4.Identify the electric field for given equipotential surface (a) and b



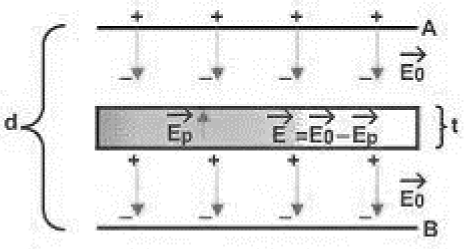


Answer (a) uniform electric field (b) non uniform electric field or field due to negative point charge

5.Two charges 2μC and −2μC are placed at points A and B 6cm apart.
(a) Identify an equipotential surface of the system.
(b) What is the direction of the electric field at every point on this surface?
Answer 5:
(a)An equipotential surface is the plane on which the total potential is zero everywhere. This plane is normal to line joining the charges. The plane is located at the mid-point of line AB because the magnitude of charges is the same.
(b) The direction of the electric field at every point on this surface Is normal to the plane in the direction of joining charges.

6.Find the expression for the capacitance of a parallel plate capacitor of area A and plate separation d if a dielectric slab of thickness t (t<d)

Ans Electric field between the plates is given by



$$\vec{E_O} = \frac{\sigma}{\epsilon_0} \; and \; \vec{E_\iota} = \frac{\sigma}{k\epsilon_0}$$

$$V= \vec{E_O}(d-t) + \vec{E_\iota}t = \frac{\sigma}{\epsilon_0}(d-t) + \frac{\sigma}{k\epsilon_0}t = \frac{\sigma}{\epsilon_0}\left(d-t+\frac{t}{k}\right)$$

Capacity of a capacitor $C = \frac{Q}{V} = \frac{\sigma A}{\frac{\sigma}{\epsilon_0}\left(d-t+\frac{t}{k}\right)} = \frac{\epsilon_0 A}{\left(d-t+\frac{t}{k}\right)}$

$$\left[C = \frac{\epsilon_0 A}{d-t(1-\frac{1}{k})}\right]$$

7. What is the capacitance of arrangement of 4 plates of area A at distance d in air in fig.

Three capacitors are in parallel so

Net Cp=3C =3Aε_O/d

8.Write the expression for the work done on an electric dipole of dipole moment p in turning it from its position of stable equilibrium to a position of unstable equilibrium in a uniform electric field E.

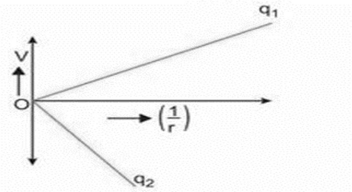
Ans Work done to rotate dipole in uniform electric field is W=PE(Cosθ_1-Cosθ_2)

Foe stable θ_1=0 and for unstable θ_2=180^0 therefore W=pE(1-(-1))=2pE

Q8. The two graphs are drawn below, show the variations of electrostatic potential being the distance of field point from the point charge) for two point charges q_1 and q_2

What are the signs of the two charges?

Which of the two charges has the larger magnitude



Ans: (a)The potential due to positive charge is positive and due to negative charge, it is negative, so, q_1 is positive and q_2 is negative

(b) for charge q_2 slope is more soq_2 is greater thanq_1

Q.9 A point charge Q is placed at point O as shown in the figure. Is the potential difference V_A – V_B positive, negative or zero, if Q is

(i) positive (ii) negative?

Answer:

V_A-V_B=kQ($\frac{1}{OA}$ - $\frac{1}{OB}$) As OA<OB, so the quantity within bracket is negative.

(i)If Q positive charge than V_A-V_B is negative

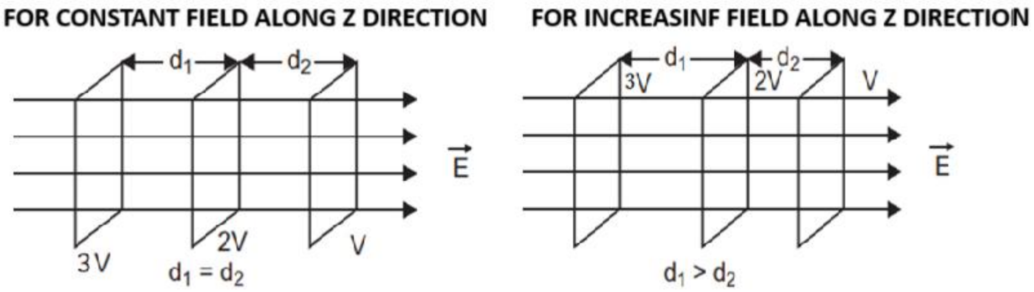
(ii) If q is negative charge, V_A – V_B = positive

Q10. **Describe schematically the equipotential surfaces corresponding to**

(a) a constant electric field in the z-direction,

(b)**a field that uniformly increases in magnitude but remains in a constant (say, z) direction,**

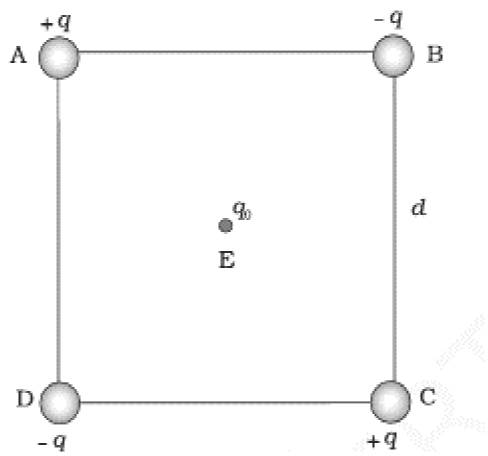
Ans10



Equidistant planes which are parallel to the x-y plane are the equipotential surfaces distance between planes are not equal which are parallel to the x-y plane are the equipotential surfaces.

SHORT ANSWER QUESTION 03 MARKS

1.Four charges are arranged at the corners of a square ABCD of side d, as shown in Fig. Find the work required to put together this arrangement. (b) A charge q0 is brought to the centre E of the square, the four charges being held fixed at its corners. How much extra work is needed to do this?



ANS 1.:Work done to put together this arrangement

$=0+\frac{-q^2}{4\pi\varepsilon_0 d}+\frac{-q^2}{4\pi\varepsilon_0 d}+\frac{q^2}{4\pi\varepsilon_0 d\sqrt{2}}+\frac{-q^2}{4\pi\varepsilon_0 d}+\frac{-q^2}{4\pi\varepsilon_0 d}+\frac{q^2}{4\pi\varepsilon_0 d\sqrt{2}}$

$=\frac{-q^2}{4\pi\varepsilon_0 d}(4-\sqrt{2})$

(B)potential is zero

2.(a) Determine the electrostatic potential energy of a system consisting of two charges 7 C and –2 C (and with no external field) placed at (–9 cm, 0, 0) and (9 cm, 0, 0) respectively.

(b) How much work is required to separate the two charges infinitely away from each other?

(c)Suppose that the same system of charges is now placed in an external electric field $E = A(1/r^2)$; $A = 9 \times 10^5\ NC^{-1}\ m^2$. What would the electrostatic energy of the configuration be?

Ans2:a) $u=\frac{1}{4\pi\varepsilon_0}\left(\frac{Q_1 Q_2}{R_1}\right)=\frac{1}{4\pi\varepsilon_0}\left(\frac{7X2X10^{-6}X10^{-6}}{0.18}\right)$

U =–0.7 J.

(b) W = U2 – U1 = 0 – U = 0 – (–0.7) = 0.7 J.

(c) net energy $=q_1V_1+q_1V_2+U=49.3J$

3.(a) A comb run through one's dry hair attracts small bits of paper. Why? What happens if the hair is wet or if it is a rainy day? (Remember, a paper does not conduct electricity.)

(b) Ordinary rubber is an insulator. But special rubber tyres of aircraft are made slightly conducting. Why is this necessary?

(c) A bird perches on a bare high power line, and nothing happens to the bird. A man standing on the ground touches the same line and gets a fatal shock. Why?

Ans3(a) This is because the comb gets charged by friction. The molecules in the paper gets polarised by the charged comb, resulting in a net force of attraction. If the hair is wet, or if it is rainy day, friction between hair and the comb reduces. The comb does not get charged and thus it will not attract small bits of paper

(b)To enable them to conduct charge (produced by friction) to the ground; as too much of static electricity accumulated may result in spark and result in fire.

(c)Current passes only when there is difference in potential.

4.A slab of material of dielectric constant K has the same area as the plates of a parallel-plate capacitor but has a thickness (3/4)d, where d is the separation of the plates. How is the capacitance changed when the slab is inserted between the plates?

ANS Let E0 = V_0 /d be the electric field between the plates when there is no dielectric and the potential difference is V_0 . If the dielectric is now inserted, the electric field in the dielectric will be E = E_0 /K. The potential difference will then be

$V=\frac{E_0 d}{4}+\frac{3E_0 d}{4K}=\frac{E_0 d}{4}(1+\frac{3}{K}) \ =\frac{V_0}{4}(\frac{K+3}{K})$

The potential difference decreases by the factor $\frac{K+3}{4K}$(while the free charge Q0 on the plates remains unchanged. The capacitancethus increases

$C=\frac{Q_0}{V}=\frac{4KC_0}{k+3}$

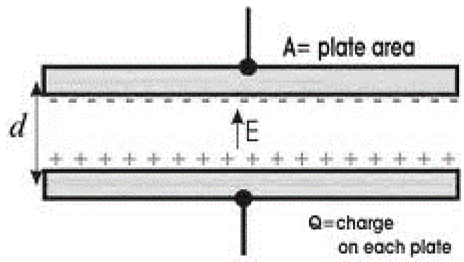
5.A capacitor has some dielectric between its plates and the capacitor is connected to a DC source. The battery is now disconnected and then the dielectric is removed. State whether the capacitance, electric field, charge stored and the voltage will increase, decrease or remain constant.

Ans5. The capacitance of the parallel plate capacitor, filled with dielectric medium of dielectric constant K is given by C=K ϵ0A/d The capacitance of the parallel plate capacitor decreases with the removal of dielectric medium as for air or vacuum K = 1 and for dielectric K > 1.

If we disconnect the battery from capacitor, then the charge stored will remain the same due to conservation of charge. The potential difference across the plates of the capacitor is given by V =q/C Since q is constant and C decreases which in turn increases V and therefore E increases as E = V/d

6.Define the capacitance of a capacitor. Obtain the expression for the capacitance of a parallel plate capacitor in vacuum in terms of plate area A and separation d between the plates

Ans Let the surface charge density on the plates be σ



Such that $\sigma = \frac{Q}{A}$

Electric field between the plates is given by

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

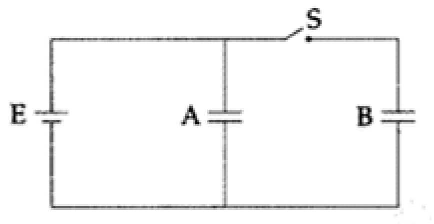
Potential difference between the plates is V=Ed

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

Capacity of a capacitor $C = \frac{Q}{V} = \frac{\sigma A}{\sigma d/\epsilon_0} = \frac{\epsilon_0 A}{d}$

$\left[C = \frac{\epsilon_0 A}{d}\right]$

7.Two identical parallel plate capacitors A and B are connected to a battery of V volts with the switch S closed. The switch is now opened and the free space between the plates of the capacitors is filled with a dielectric of dielectric constant K. Find the ratio of the total electrostatic energy stored in both capacitors before and after the introduction of the dielectric



Ans7:Given : $C_A = C_B = C$, Dielectric costant = K

Energy stored = $\frac{1}{2}Cv^2$

Net capacitance with switch S closed = C+C= 2C E_1= Energy stored = CV^2

After switch S is opened, capacitance of each capacitor = KC

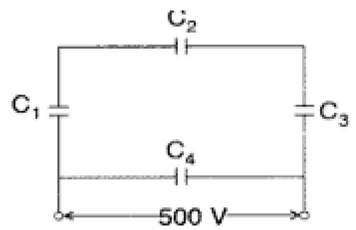
'Energy stored in capacitor A = $\frac{KCV^2}{2}$(iii)

For capacitor B, Energy stored = $\frac{KCV^2}{2} = \frac{CV^2}{2K}$(iv)

From equations (iii) & (iv) E_2 = Total energy stored = $\frac{K^2+1}{2K}cv^2$

Required Ratio = $E_1/E_2 = \frac{2K}{K^2+1}2k$

Q8A Network of four capacitors each of 12μF capacitance is connected to a 500 V supply as shown in the figure. Determine (a) equivalent capacitance of the network and (b) charge on each capacitor.



Ans 8

C123 = 4μF (being in series)

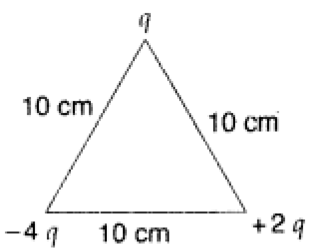
Ceq = C123 + C4 =16μF

(i) Q1 = C4V= 6 X 10^{-3}
(ii) Q2 = C123 V= 2 X 10^{-3} C
(iii) Charge on each of the capacitors C1 ,C2 ,C3 = 2 X 10^{-3} C

Q9. Derive the expression for the electric potential at any point along the axial line of an electric dipole .

Ans Correct derivation

Q10. Calculate the work done to dissociate the system of three charges placed on the vertices of a triangle as shown.



Answer:10
Initial P.E. of the three charges

$U_i = k\left(\frac{q_1\ q_2}{r} + \frac{q_1\ q_3}{r} + \frac{q_2\ q_3}{r}\right)$

By putting value $U_i = -10q^2/r = -2.304 \times 10^{-8}$ J

Final P.E, $u_f = 0$

∴ Work required to dissociate the system of three charges,

$W = u_f - u_i = -2.304 \times 10^{-8}$ J

CASE BASED QUESTION

Dielectric with polar molecules also develops a net dipole moment in an external field, but for a different reason. In the absence of any external field, the different permanent dipoles are oriented randomly due to thermal agitation; so the total dipole moment is zero. When an external field is applied, the individual dipole moments tend to alignwith the field. When summed overall the molecules, there is then a net dipole moment in the direction of the external field, i.e., the dielectric is polarised. The extent of polarisation depends on the relative strength of two factors: the dipole potential energy in the external field tending to align the dipoles mutually opposite with the field and thermal energy tending to disrupt the alignment. There may be, in addition, the 'induced dipole moment' effect as for non-polar molecules, but generally the alignment effect is more important for polar molecules. Thus in either case, whether polar or non-polar, a dielectric develops a net dipole moment in the presence of an external field. The dipole moment per unit volume is called polarization.

(1) The best definition of polarisation is

(a) Orientation of dipoles in random direction (b) Electric dipole moment per unit volume

(c) Orientation of dipole moments (d)Change in polarity of every dipole

Ans**: 1. b**

(2) Calculate the polarisation vector of the material which has 100 dipoles per unit volume in a volume of 2 units.

(a) 200 (b) 50 (c) 0.02 (d) 100

Ans a

(3) The total polarization of a material is the

(a) Product of all types of polarisation (b) Sum of all types of polarisation

(c)Orientation directions of the dipoles (d)Total dipole moments in the material

Ans b

(4). Dipoles are created when dielectric is placed in ___________

(a) Magnetic Field (b) Electric field (c) Vacuum (d) Inert Environment

Ans b

OR

(4) Identify which type of polarisation depends on temperature.

(a)Electronic (b)Ionic (c)Orientational (d) Interfacial

Ans c

2.Consider a system of two point charges +4μC and -4μC and , placed 20 cm apart in a vacuum. The charges are fixed at points A and B respectively along the x-axis, with A at x= -10cm and B at x =+10 cm The electric field and equipotential surfaces generated by these charges are symmetric about the midpoint between the two charges. Equipotential surfaces are surfaces on which the potential at every point is the same. Near the charges, these surfaces are nearly spherical, and at greater distances, the surfaces become elongated along the axis connecting the charges. At the midpoint between the charges, the potential is zero. However, the electric field at this point is not zero, as the electric fields due to the individual charges add up in magnitude but point in opposite directions. A small test charge is moved from a point at infinity to different positions in the vicinity of the charges, including points on equipotential surfaces.

i) At the midpoint between the two charges (the origin), what is the electric potential?

(A) Zero (B) Maximum positive (C) Maximum negative (D) Depends on the path taken
Ans (A)

(ii)Which of the following statements about equipotential surfaces is correct?

(A) Equipotential surfaces are always parallel to the electric field lines.

(B) Equipotential surfaces are perpendicular to electric field lines.

C) The work done by the electric field in moving a test charge between two points on the same equipotential surface is not zero.

(D) Equipotential surfaces do not exist near charges.

Ans . (B)

(iii)If the test charge is moved from a point on an equipotential surface at 10 cm from the origin to another point at 15 cm from the origin, what is the work done by the electric field?

(A) Positive (B) Negative (C) Zero (D) Depends on the charge type

Ans (C)

(iv) In the case of an electric dipole, the equipotential surfaces at points far from the dipole become:

A) Spherical and centered on the dipole axis B) Spherical and centered midway between the charges C) Planar and perpendicular to the dipole axis D) Planar and parallel to the dipole axis

Ans (C)

0R

What can be concluded if the electric potential difference between two points is zero?

A) The points are on the same equipotential surface B) The electric field is zero

C) The electric charge is zero D) The electric current is zero

Ans (A)

3 A physics lab experiment was done by a student on rotating a dipole, consisting of two charges (+q and -q) separated by distance d, in a uniform magnetic field (B). The initial orientation was perpendicular to the magnetic field To rotate the dipole, a torque (τ) was applied. The work done (W) in rotating the dipole was measured for various angles (θ) between the dipole and magnetic field

i) A electric dipole of dipole moment p is placed in an electric field E. If the dipole is rotated through an angle of 90 0 , the work done is:

A) -0 B) −p E C) pE D)−2p E

Ans (b)

ii) work done to turn a dipole from stable equilibrium to unstable equilibrium is

A) pE B)-pE C)+2PE D)ZERO

Ans (C)

iii) Why does the work done become zero at 0° and 180°?

A)Magnetic field is zero B) Dipole moment is zero C) Torque is zero D) Potential energy is minimum

Ans (c)

(iV)What would happen if the magnetic field strength increases?

A) Work done decreases B) Work done increases

C) Angle of rotation decreases D) Dipole moment remains constant

Ans .(B)

Long answer question 05 MARKS

Q1.A parallel plate capacitor of capacitance C is charged to a potential V by a battery. Q is the charge stored on the capacitor. Without disconnecting the battery, the plates of the capacitor are pulled apart to a larger distance of separation. What changes will occur in each of the following quantities? Will they increase, decrease or remain the same? Give an explanation in each case. (a) Capacitance (b) Charge (c) Potential difference (d) Electric field (e) Energy stored in the capacitor

Answer 1.

(a)Capacitance decreases. Capacitance is inversely proportional to the distance of separation.

(b) Charge decreases. From Q=CV, C decreases and V remain s the same, so Q decreases. [0.5 mark for correct change]

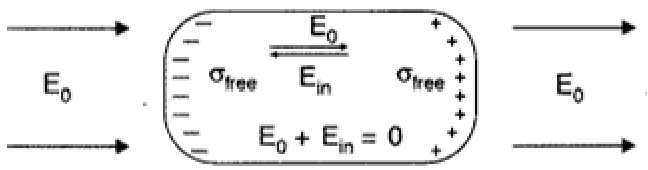
(c) Potential difference remains the same As the capacitor is c onnected to the battery, the potential V of the capacitor will remain the same as that of the battery. [0.5 mark for correct change]

(d) Electric field decrease

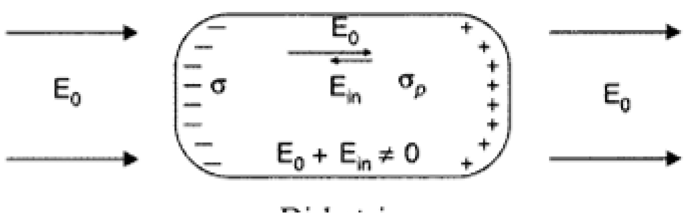
(e) energy store decreases U is proportional to C for constant V

Q2.a) Explain, using suitable diagrams, the difference in the behaivour of a (i) conductor and (ii) dielectric in the presence of external electric field. Define the terms polarization of a dielectric and write its relation with susceptibility.

Ans2(i) Behaviour of conductor in an external electric field :



(ii) Behaviour of a dielectric in an external electrical field :



Explanation: In the presence of electric field, the free charge carriers in a conductor move the charge distribution and the conductor readjusts itself so that the net Electric field within the conductor becomes zero.

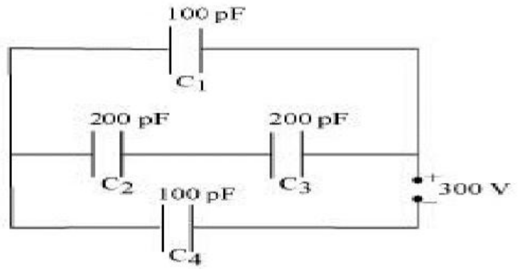
In a dielectric, the external electric field induces a net dipole moment, by stretching / reorienting the molecules. The electric field, due to this induced dipole moment, opposes, but does not exactly cancel the external electric field

Polarisation: Induced Dipole moment, per unit volume, is called the polarisation. For Linear isotropic dielectrics having a susceptibility xc, we have polarisation (p) as: p = XcE

3(a)Derive an expression for the potential energy of an electric dipole of dipole movement p in the electric field E

(b)derive an expression of potential due to diploe at equatorial point.

4(i) Derive the formula for the capacitance of a parallel plate capacitor.
(ii) Obtain the equivalent capacitance of the network in Fig. for a 300 V supply, determine the charge and voltage across each capacitor.

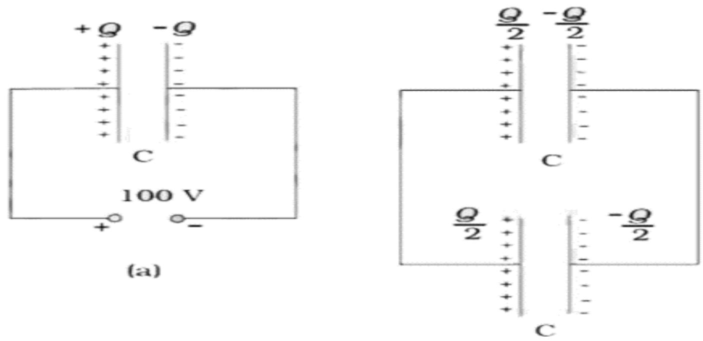


Ans4: (i) Correct derivation of $C = \frac{\epsilon_0 A}{d}$

(ii) Q1 = 10^{-8} V1 = 100 V, Q2 = 10^{-8} CV2 = 50 V,
Q3 = 10^{-8} CV3 = 50 V, Q4 = 2×10^{-8} CV4 = 200 V

Q5(a). Derive an expression for capacitance of parallel plate capacitor

(a) A 900 pF capacitor is charged by 100 V battery [Fig. (a)]. How much electrostatic energy is stored by the capacitor? (b) The capacitor is disconnected from the battery and connected to another 900 pF capacitor [Fig. (b)]. What is the electrostatic energy stored by the system?



(b)

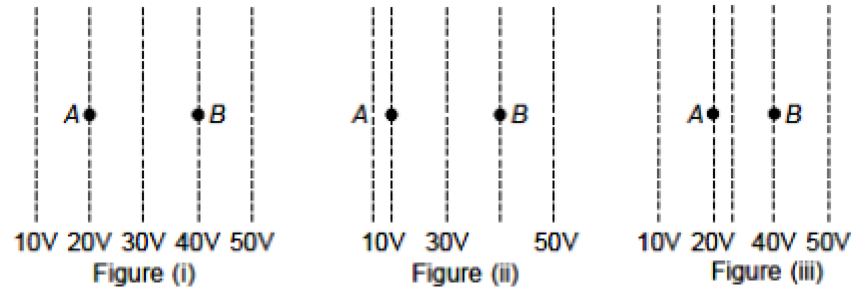
Ans 5(a)The charge on the capacitor is Q = CV = 900 × 10^{-12} F × 100 V = 9 × 10^{-8} C

The energy stored by the capacitor is = (1/2) CV^2 = (1/2) QV = (1/2) × 9 × 10^{-8}C × 100 V = 4.5 × 10^{-6} J

(a) In the steady situation, the two capacitors have their positive plates at the same potential, and their negative plates at the same potential. Let the common potential difference be V'. Thecharge on each capacitor is then Q = CV'. By charge conservation, Q' = Q/2. This implies V = V/2.
(b) The total energy of the system is =2XQ'V'/2= 2.25 10 $^{-6}$jThus in going from (a) to (b), though no charge is lost; the final energy is only half the initial energy.

WORKSHEET -1

1. Figures show some equipotential lines distributed in space. A charged object is moved from point A



to point B.

(a) The work done in Fig. (i) is the greatest.
(b) The work done in Fig. (ii) is least.
(c) The work done is the same in Fig. (i), Fig.(ii) and Fig. (iii).
(d) The work done in Fig. (iii) is greater than Fig. (ii) but equal to that in Fig. (i).

ANS…………………………………….

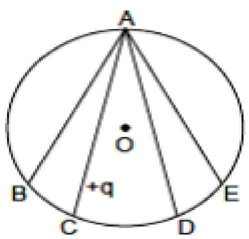
Ans: (c) The work done is the same in Fig. (i), Fig.(ii) and Fig. (iii). The work done by the electric field on the charge will be negative. W electrical = –ΔU = –qΔV = q(V initial – V final) Here initial and final potentials are same in all three cases and the same charge is moved, so work done is same in all three cases

2.A point P lies at a distance x from the mid point of an electric dipole on its axis. The electric potential at point P is proportional to

. $1/x^2$ (b) $1/x^3$ (c) $1/x^4$ (d) $1/x$

ANS……………………………………..

3.In the electric field of a point charge q , a certain charge is carried from point A to B, C, D and E. Then the work done



(a) is least along the path AB. (b) is least along the path AD.

(c) is zero along all the paths AB, AC, AD and AE. (d) is least along AE

ANS …………………………………….

Q4. Draw a plot showing the variation of (i) electric field (E and (ii) electric potential (V) with distance r due to a point charge Q.

ANS………………………………………………………………………………………………

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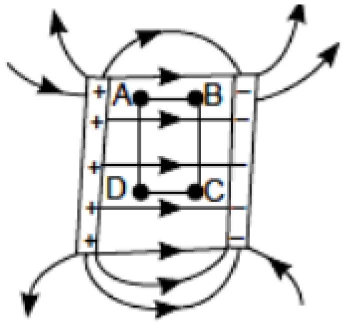
5.Electric field between oppositely charged parallel conducting plates: When two plane parallel conducting plates, having the size and spacing as shown in the figure, are given equal and opposite charges, the field between and around them is approximately as shown, while most of the charge accumulates at the opposite faces of the plates and the field is essentially uniform in the space between them, there is a small quantity of charge on the outer surfaces of the plates and a certain spreading or "fringing of the field at the edges of the plates. As the plates are made larger and the distance between them diminished, the fringing becomes relatively less. This kind of arrangement is called capacitor.



Now if two plates are separated by a distance '3d', and are maintained at a potential difference 'V', then answer the following questions.

(I)Capacitance of a parallel plate capacitor depends on

(a) electric charge stored. (b) electric field between the plates.

(c) potential difference applied. (d) electrical permittivity of the medium between the plates.

ANS……………………………………

(ii) If two protons are placed at points A and B respectively, then which one will experience more force?

. Proton at point A (b) Proton at point B (c) Proton at points A and B both experiences same force. (d) None of the above

ANS……………………………………

(iii) When both the protons are released then which one will gain more K.E. just before striking the negative (–ve) plate?

(a) Proton released from point A (b) Proton released from point B

(c) Proton released from points A and B will gain equal kinetic energy.

(d) No one will gain kinetic energy.

ANS……………………………………….

(iv) If one proton is moved from (I A to B, (II) B to C, and (III) along ABCD, then work done in cases I, II and III respectively are

(a) eED, Zero –eED (b) eED, Zero, Zero (c) –eED, +eED, Zero (d) eED, –eED, Zero

ANS………………………………………………………………………………………………..

WORKSHEET -2

1. A capacitor has some dielectric between its plates, and the capacitor is connected to a dc source. The battery is now disconnected and then the dielectric is removed, then
   (a) capacitance will increase. (b) energy stored will decrease.
   (c) electric field will increase. (d) voltage will decrease

ANS ……………………………..

2 The graph shows the variation of voltage 'V' across the plates of two capacitors A and B versus increase of charge 'Q' stored on them. which of the two capacitors has higher capacitance?

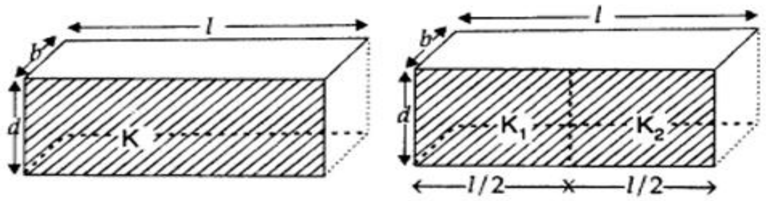
(a) A (b) B (c) both have same (d) none

ANS………………………………….

3. ASSERTION: The surface of a charged conductor is always equipotential.
   REASON: Electric field lines are always perpendicular to the equipotential surface.
   ANS………………………….

4. ASSERTION: A capacitor is a device which stores electric energy in the form of electric field.
   REASON: Net charge on the capacitor is always zero
   ANS…………………………………………..

5. Two identical capacitors of plate dimensions l × b and plate separation d have di electric slabs filled in between the space of the plates as shown in the figure 3



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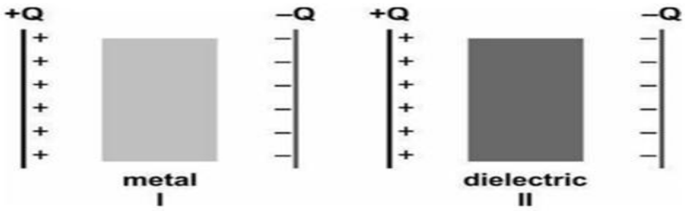
6. Two +ve charges of 0.2 μC and 0.01 μC are placed 10 cm apart. Calculate the work done in reducing the distance to 5 cm.

ANS--

7.Given is a pair of parallel charged metal plates in the arrangement as shown. (a) Sketch the electric field lines between the plates in I and II. (b) Mention whether net electric field intensity is zero or non-zero in each case.



(a) Sketch the electric field lines between the plates in I and II. (b) Mention whether net electric field intensity is zero or non-zero in each case.

Ans……

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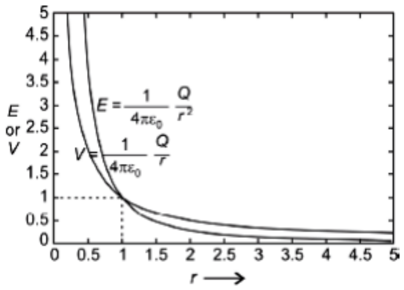
ANSWER OF WORK SHEET 1

Ans1: (c) is zero along all the paths AB, AC, AD and AE. ABCDE is an equipotential surface and on equipotential surface no work is done in shifting a charge from one place to another

ANS 2 Ans: (a) $1/X^2$

ANS 3(c) is zero along all the paths AB, AC, AD and AE.

ANS 4



ANS5

i(d)

i) (c) Both protons will experience same force. Reason: F = qE; E = constant; q = +e (same)

iii. (a) Reason: ∵ VD = VA > VB = VC [In the direction of electric field potential decreases] VA > VB or (P.D)AP2 > (P.D)BP2 ∴ Gain in K.E. = q × P.D. ∴ Gain in K.E. of proton released from point A will be more.

IV (iv)(b) Reason:

ANSWER TO WORKSHEET -2

Ans 1 (c) Ans 2 (A) Ans 3(A)

Ans 4(B)

Ans 5In first case C1=εoKx(lxb)/d……….(i)

In second case, these two apartments are in parallel, their net capacity would be the sum of two individual capacitances C2 = C'2 + C"2

C2= εoK1x(lxb)/2d+ εoK_2x(lxb)/2d

Since capacitor are identical C1=C2

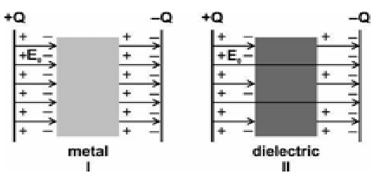
εoKx(lxb)/d= εoK1x(lxb)/2d+ εoK_2x(lxb)/2d

by solving K=K1+K_2/2

ANS6. $3.6X10^{-4}$J

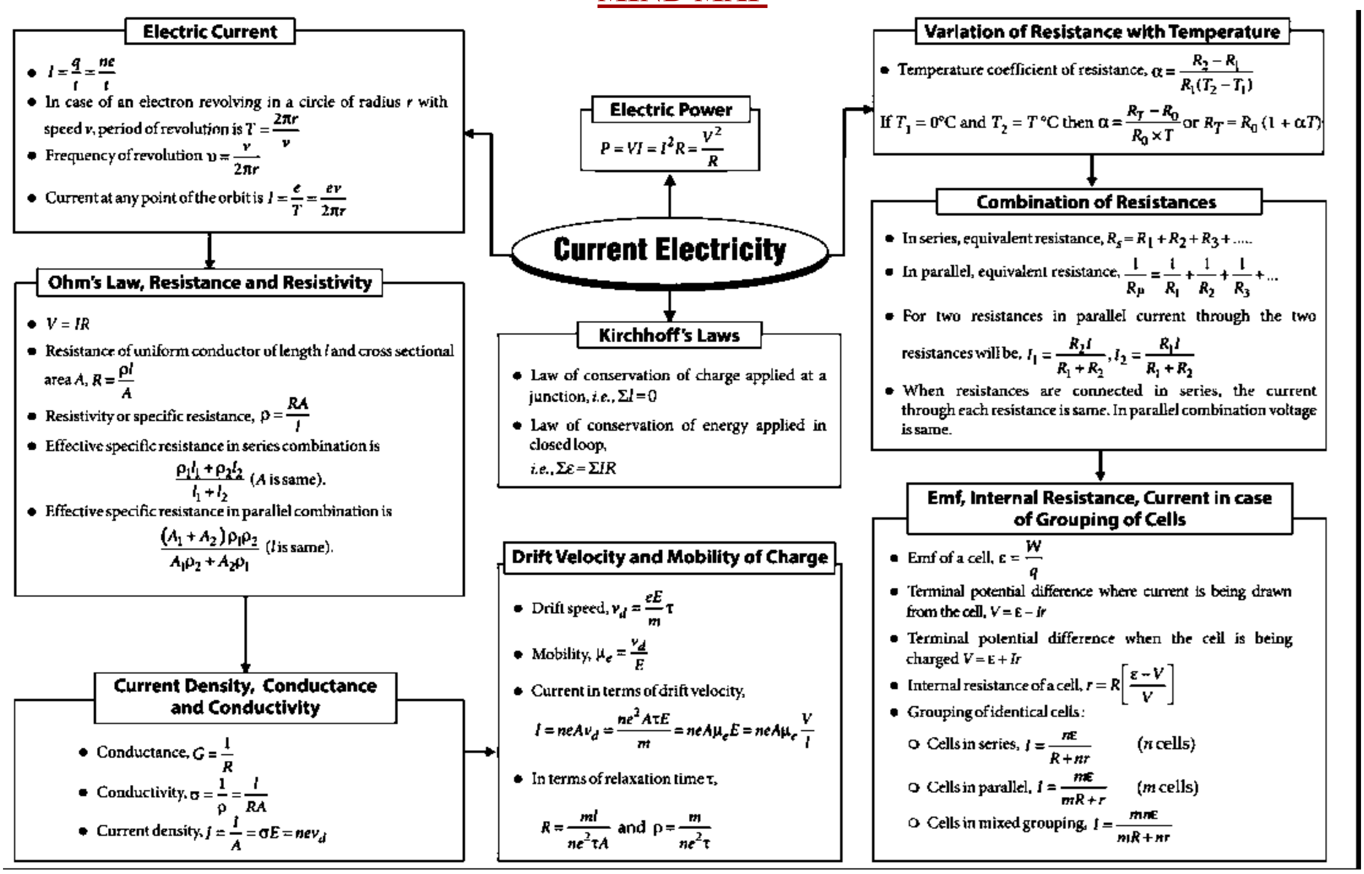
7.Ans

(a) (b) Non Zero



CHAPTER 3
CURRENT ELECTRICITY

MIND MAP



Important Formulae

1. Electric current = $\frac{Charge}{Time}$ or $I = \frac{q}{t} = \frac{ne}{t}$

2. In case of an electron revolving in a circle of radius r with speed v, period of revolution is $T = \frac{2\pi r}{v}$

Frequency of revolution, $v = \frac{1}{T} = \frac{v}{2\pi r}$, Current, $I = ev = \frac{ev}{2\pi r}$

3. Ohm's law, $R = \frac{V}{I}$ or $V = IR$

4. Current in terms of drift velocity (V_d) is $I = enAv_d$

5. Resistance of a uniform conductor, $R = \rho\frac{l}{A} = \frac{ml}{ne^2\tau A}$

6. Resistivity or specific resistance, $\rho = \frac{RA}{l} = \frac{m}{ne^2\tau}$

7. Conductance = $\frac{1}{R}$

8. Conductivity = $\frac{1}{Resistivity}$ or $\sigma = \frac{1}{\rho} = \frac{l}{RA}$

9. Current density = $\frac{Current}{Area}$ or $j = \frac{I}{A} = env_d$

10. Relation between current density and electric field,

$j = \sigma E$ or $E = \rho j$

11. Mobility $\mu = \frac{V_d}{E}$

12. Temperature coefficient of resistance, $\alpha = \frac{R_2 - R_1}{R_1(t_2 - t_1)}$

13. EMF of a cell, $E = \frac{W}{q}$

14. For a cell of internal resistance r, the emf is E = V + Ir = I (R + r)

15. Terminal potential potential of a cell, V = IR = $\frac{E R}{R+r}$

16. Terminal p.d. when a current is being drawn from the cell, V = E – Ir

17. Terminal p.d. when the cell is being charged, V = E + Ir

18. Internal resistance of a cell, r = R $[\frac{E-V}{V}]$

19. For n cell in series, I = $\frac{nE}{R+nr}$

20. For n cells in parallel, I = $\frac{nE}{nR+r}$

21. Heat produced by electric current, H = I^2Rt joule = $\frac{I^2\text{Rt}}{4.18}$ cal

22. Electric power, P = $\frac{W}{t}$ = VI = I^2R = $\frac{V^2}{R}$

23. Electric energy, W = Pt = VIt = I^2Rt

24. For a balanced Wheatstone bridge, $\frac{P}{Q} = \frac{R}{S}$,

If X is the unknown resistance $\frac{P}{Q} = \frac{R}{X}$ or X = $\frac{RQ}{P}$

25. Kirchhoff's law of electrical networks-

(i) Σ I = 0 (Junction Rule)

i.e. Total incoming current = Total outgoing current

(ii) Σ E = Σ IR (Loop Rule)

MULTIPLE CHOICE QUESTIONS-1 MARKS EACH

Q1. How many electrons pass through a lamp in 1 min if the current is 300mA?

(a) 1.125×10^{20} (b) 1.875×10^{-18} (c) 1.875×10^{18} (d) 1.125×10^{-20}

Q2. Drift velocity varies with the intensity of electric field as per the relation

(a) V α E (b) V α 1/E (c) V α E 2 (d) V α E -2

Q3. Kirchhoff's second law for the electric network is based on

(a) Law of conservation of charge (b) Law of conservation of energy

(c) Law of conservation of angular momentum (d) Law of conservation of mass

Q4. In a Whetstone's bridge, all the four arms have equal resistance R. If resistance of the galvanometer arm is also R, then equivalent resistance of the combination is-

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

Q5. EMF of a cell depends:

(a) nature of electrolyte (b) metal of electrode

(c) both (a) and (b) (d) None

Q6. The resistance of an ideal ammeter is

(a) Infinite (b) Very high (c) Small (d) Zero

Q7. Nichrome or Manganin is widely used in wire bound resistors because of their

(a) temperature independent resistivity

(b) very weak temperature dependent resistivity

(c) strong dependence of resistivity with temperature

(d) mechanical strength

Q8. A cell having emf of 1.5V, when connected across a resistance of 14 Ω, produces a voltage of only 1.4V across the resistance. The internal resistance of the cell must be

(a) 1Ω (b)14Ω (c) 15Ω (d) 21Ω

Q9. A steady current flows in a metallic conductor of non-uniform cross-section. Which of these quantities is constant along the conductor-

(a) Current (b) current density (c) drift speed (d) electric field

Q10. The resistance of a metallic conductor increases due to
(a) Change in dimensions of the conductor
(b) Change in carrier density
(c) Increase in the number of collisions between the carriers
(d) Increase in the rate of collisions between the carriers and vibrating atoms of the conductor

ANS.

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

ASSERTION &; REASON EACH 1 MARKS

Q1. ASSERTION: A domestic electrical appliance, working on a three-pin will continue working even if the top pin is removed.

REASON: The third pin is used only as a safety device.

Q2. ASSERTION: A current flows in a conductor only when there is an electric field within the conductor.

REASON: The drift velocity of electron in presence of electric field decreases.

Q3.ASSERTION: Fuse wire must have high resistance and low melting point.

REASON: Fuse is used for small current flow only.

Q4. ASSERTION: Practically a voltmeter will measure the voltage across the battery but not it’s EMF.

REASON: EMF of a cell is measured with the help of a potentiometer.

Q5. ASSERTION: Ohm's law is universally applicable for all conducting elements.

REASON: All conducting elements show straight line graphic variation on (I–V) plot.

ANSWER A& R

1 -A 2 -C 3- C 4- B 5- D

SAQ-I EACH 2 MARKS

Q1. In a Wheatstone bridge circuit P= 5Ω, Q =6Ω, R = 10Ω and S = 5Ω. What is the additional resistance to be used in series with S, so that the bridge is balance.

Ans. 7 ohm

Q2. Out of V – I graph for parallel and series combination of two metallic resistors, which one represents parallel combination of resistors? Justify your answer.

Ans. The resistance for parallel combination in lesser than for series combination for a given set of resistors. Hence B represents parallel combination

Q3. In the figure, what is the potential difference between A and B ?

Ans. VA – VB = – 8 volt.

Q4. A copper wire of resistance R is uniformly stretched till its length is increased to n times its original length. What will be its new resistance?

Ans. $R' = n^2 R$

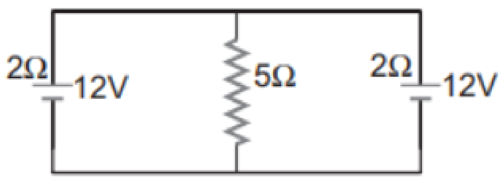
Q5. A car battery is of 12V. Eight dry cells of 1.5 V connected in series also give 12V, but such a combination is not used to start a car. Why?

Ans. Dry cell used in series will have high resistance (= 10Ω) and hence provide low current, while a car battery has low internal resistance (0. 1Ω) and hence gives high current for the same emf, needed to start the car.

Q6. Three identical resistors R1, R2 and R3 are connected to a battery as shown in the figure. What will be the ratio of voltages across R1 and R2. Support your answer with calculations.

Ans. (2 : 1)

Q7. In the arrangement of resistors shown, what fraction of current I will pass through 5Ω resistor?



Ans. 2I/3

Q8. A 100W and a 200 W domestic bulbs joined in series are connected to the mains. Which bulb will glow more brightly? Justify.

Ans. 100W

Q9. Define the term electrical conductivity of a metallic wire. Write its SI unit.

Ans. The conductivity of a material equals the reciprocal of the resistance of its wire of unit length and unit area of cross section. The SI unit is ohm-1m-1.

Q10. A 100W and 200 W domestic bulbs joined in parallel are connected to the mains. Which bulb will glow more brightly? Justify.

Ans. 200W

SAQ-II EACH 3 MARKS

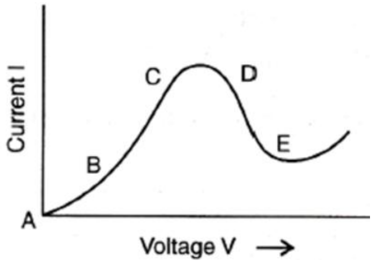
Q1. (i)Why do the ‘free electrons’, in a metal wire, ‘flowing by themselves’, not cause any Current flowing in the wire? (ii)Explain the term ‘drift velocity’ of electrons in a conductor.

Ans. (i) In a metal wire, free electrons move randomly in all directions due to thermal energy, even when no electric field is applied. These random motions are chaotic and uncoordinated, so for every electron moving in one direction, there's likely another moving in the opposite direction. As a result, the net movement of charge is zero, and no electric current is produced. Current only flows when an external electric field (voltage) is applied. This field causes the electrons to drift slightly in a specific direction, superimposed on their random motion — and this directed movement leads to net flow of charge, i.e., electric current.

(ii) Drift velocity is the average velocity with which free electrons move in a conductor under the influence of an applied electric field.

Q3. Graph showing the variation of current versus voltage for a material GaAs is shown in fig.

Identify the region of (i) Negative resistance (ii) Where ohm's law is obeyed.



Ans. i) in the region DE,I decreases with increasing V. Therefore +ve dv/-ve dv = -ve R.

ii) AB/BC is the region where ohm's law is obeyed.

Q4. When 5 V potential difference is applied across a wire of length 0.1 m, the drift speed of electrons is 2.5 x 10^{-4} m/s if the electron density in the wire is 8 x 10^{28} m^{-3} , calculate the resistivity of the material of wire.

Ans. Resistivity + 1.56 x 10^{-5} Ωm

Q5. Two wires A and B of the same material and having same length have their cross sectional area in the ratio 1:4. What would be the ratio of heat produced in these wires when same voltage is applied across each?

Ans. 1 : 4

Q6. Two 120 V light bulbs, of emf 25 W and other of 200 W were connected in series across a 240 V line. One bulb burnt out almost instantaneously, which one was burnt and why ?

Ans. since $R = V^2/P$, so 25 watt bulb has more resistance. In the series circuit same current flows through both the bulbs. The 25 W bulb develops more heat ($H = i^2 Rt$) and hence burns out almost instantaneously.

Q7. A potential difference V is applied across the ends of copper wire of length l and diameter D. What is the effect on drift velocity of electrons if (i) V is halved? (ii) l is doubled? (iii) D is halved?

Ans. (i) halved (ii) halved (iii) unchanged

Q8. A cylindrical metallic wire is stretched to increase its length by 5%. Calculate the percentage change in its resistance.

Ans. 10.25% increase

Q9. Two metallic wires of the same material have the same length but cross sectional area is in the ratio of 1:2. They are connected (i) in series and (ii) in parallel. Compare the drift velocities of electrons in the two wires in both the cases.

Ans. In series 1/2, In parallel 1/1.

Q10. Two wires X, Y have the same resistivity but their cross-sectional areas in the ratio 2:3 and lengths in the ratio 1:2. They are first connected in series and then in parallel to a dc source. Find out the ratio of the drift speeds of the electrons in the two wires for the two cases.

Ans. (i) Series 3/2 (ii) Parallel 2/1.

CBQ EACH 4 MARKS

Q1. Emf of a cell is the maximum potential difference between two electrodes of the cell when no current is drawn from the cell. Internal resistance is the resistance offered by the electrolyte of a cell when the electric current flows through it. The internal resistance of a cell depends upon the following factors;

A. distance between the electrodes B. nature and temperature of the electrolyte

C. nature of electrodes D. area of electrodes.

For a freshly prepared cell, the value of internal resistance is generally low and goes on increasing as the cell is put to more and more use. The potential difference between the two electrodes of a cell in a closed circuit is called terminal potential difference

(a) The terminal potential difference of two electrodes of a cell is equal to emf of the cell when

(i) Current is zero (ii) when current is not equal to zero

(iii) Neither a or b (iv) both a and b

Ans.(i)

(b) A cell of emf E and internal resistance r gives a current of 0.5 A with an external resistance of 12Ω and a current of 0.25 A with an external resistance of 25Ω. What is the value of the internal resistance of the cell?

(i) 5Ω (ii) 1 Ω (iii) 7 Ω (iv) 3 Ω

Ans.(ii)

(c) Choose the wrong statement.

(i) Potential difference across the terminals of a cell in a closed circuit is always less than its emf.

(ii) Internal resistance of a cell decreases with the decrease in temperature of the electrolyte.

(iii) Potential difference versus current graph for a cell is a straight line with a -ve slope

(iv) Terminal potential difference of the cell when it is being charged is given as $V = E + Ir$.

Ans.(ii)

(d) If external resistance connected to a cell has been increased to 5 times, the potential difference across the terminals of the cell increases from 10 V to 30 V. Then, the emf of the cell is

(i) 30 (ii) 60 (iii) 50 (iv) 40

Ans.(ii)

Q2. An electrical appliances (geysers) uses a lot of electric energy when it is operated. The electrical energy consumed is dependent on the time for which a specific appliance of fixed power rating is used. The commercial unit of electric energy is KWh (I unit). Different electric appliances have different power consumption which is mentioned in the device clearly.

(a) A bulb is rated 60W, 220V. It signifies

(i) It consumes 60J in one second (ii) It consumes 220J in one second

(iii) It has 60W energy (iv) None of the above

Ans.(i)

(b) Which of the following does not represent electric power?

(i) VI (ii) $I^2 R$ (iii) V^2 /R (iv) $I^2 V$

Ans. (iv)

(c) The electric bulbs P and Q having resistance ratio 1:2 will consume power in the ratio when V is constant

(i) 1:2 (ii) 2:1 (iii) 1:4 (iv) 4:1

Ans.(ii)

(d) An electric heater consumes 1.5KW power. If it is used every day for 2 hours, then the electric energy used in January is

(i) 90 unit (ii) 92 unit (iii) 93 unit (iv) 95 unit

Ans.(iii)

Q3. An electric cell is a source of energy that maintains a continuous flow of charge in a circuit. It changes chemical energy into electrical energy. It has two electrodes – positive and negative. Electric cell has to do some work in maintaining the current through a circuit. The work done by the cell in moving unit positive charge through the whole circuit is called the emf of the cell.

(a) When two electrodes of a cell are immersed in an electrolytic solution the charges are exchanged between

(i) Positive electrode and electrolyte only (ii) Negative electrode and electrolyte only

(iii) Both electrodes and electrolyte (iv) Directly between two electrodes

Ans.(iii)

(b) The current flowing in the sell is

(i) I = E /(R+r) (ii) I = E/R (iii) I=E/r (iv) I = (R+r)/E

Ans.(i)

(c) The maximum current that can be drawn from a cell is for

(i) R = infinity (ii) R = finite non-zero resistance (iii) R = 0 (iv) R =r

Ans.(iii)

(d) When R is infinite, then potential difference V between P and N is

(i) E (ii) 2E (iii) E/2 (iv) E/4

Ans.(i)

LAQ EACH 5 MARKS

Q1. (a) On the basis of electron drift, derive an expression for resistivity of a conductor in terms of number density of free electrons and relaxation time. On what factors does resistance and resistivity of a conductor depend?

(b) Why alloys like constantan and manganin are used for making standard resistors?

(c) The electron drift arises due to the force experienced by electrons in the electric field in side the conductor. But force should cause acceleration. Why then do the electrons acquire a steady average drift speed?

(d) If the electron drift speed is so small, and the electron's charge is small, how can we still obtain large amounts of current in a conductor?

(e) When electrons drift in a metal from lower to higher potential, does it mean that all the'free' electrons of the metal are moving in the same direction?

Ans.1 (a) Each 'free' electron does accelerate, increasing its drift speed until it collides with a positive ion of the metal. It loses its drift speed after collision but starts to accelerate and increases its drift speed again only to suffer a collision again and so on. On the average, therefore, electrons acquire only a drift speed.

(b) Simple, because the electron number density is enormous, ~1029 m^{-3}.

(c) By no means. The drift velocity is superposed over thelarge random velocities of electrons.

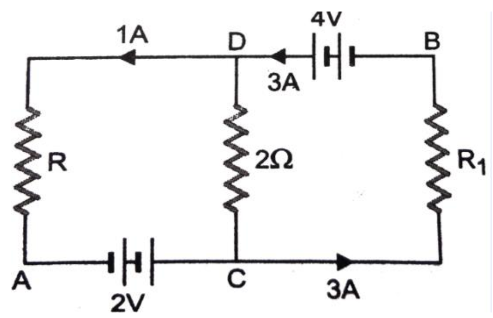
(d) In the absence of an electric field, the paths are straight lines; in the presence of an electric field, the paths are, in general, curved

(e) Not all electrons move in the same direction. Most of their motion is still random, but there's a tiny average shift (drift) in the direction from lower to higher potential.

Q2.(a)State the principle of Wheatstone bridge. Deduce the condition for balance in a Wheatstone bridge.

(b) In the given circuit, assuming point A to be at zero potential, use Kirchhoff's rules to determine the potential at point B.

(3+2)



Ans.2 (a) Let the current flowing in the circuit in the balanced condition be I. This current on reaching point A is divided into two parts I1 and I2. As there is no current in galvanometer in balanced condition, current in resistances P and Q is I1 and in resistances R and S it is I2.

Applying Kirchhoff's I law at point

Condition of Balance of Wheatstone Bridge

$I - I_1 - I_2 = 0$ or $I = I_1 + I_2$ ...(i)

Applying Kirchhoff's II law to closed mesh ABDA

$-I_1 P + I_2 R = 0$ or $I_1 P = I_2 R$ ...(ii)

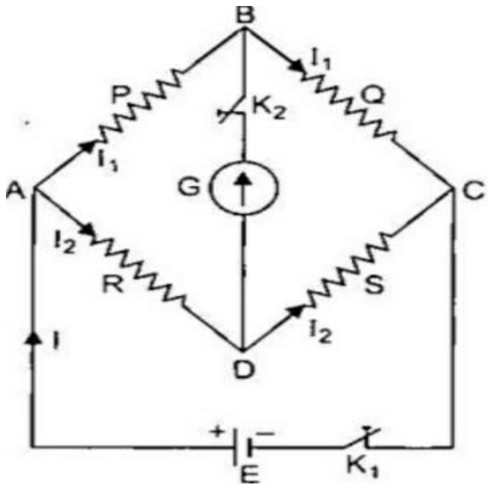
Applying Kirchhoff's II law to mesh BCDB

$-I_1 Q + I_2 S = 0$ or $I_1 Q = I_2 S$ ...(iii)

Dividing equation (ii) by (iii), we get

$I_1 P / I_1 Q = I_2 R / I_2 S$ or $P / Q = R / S$ ...(iv)

This is the condition of balance of Wheatstone bridge.



(b) According to Kirchhoff's Junction Law, when applied at junction D:

Incoming current = outgoing current

So, 3A = 1A + current through 2Ω.

Hence, current through 2Ω is 2A from D to C. Applying Kirchhoff's law to the loop containing R_1, 2Ω and 4V. 3A is the current through R_1 as the current coming out from the 4V battery is 3A.

$4 = 3 \times R_1 + 2 \times 2$

$\Rightarrow R_1 = 0\ \Omega$

So, no potential drop between B and C.

Now let's analyse the bigger loop containing 4V, R and 2V (R_1 can be omitted now); here the 4V and 2V are connected in series with B as a point between the two batteries. So we finally have the potential at B to be 2V.

Q3. (a) Define drift velocity. Write its relationship with relaxation time in terms of the electric field E applied to a conductor. A potential difference V is applied to a conductor of length L.How is the drift velocity affected when V is doubled and L is halved? (3)

(b) Define ionic mobility. Write its relationship with relaxation time. How does one understand the temperature dependence of resistivity of a semiconductor?

Ans.3 (a) Drift Velocity and Its Relation with Relaxation Time

• Drift Velocity:

Drift velocity is the average velocity acquired by free electrons in a conductor under the influence of an external electric field.

• Relationship with Relaxation Time (τ) and Electric Field (E):

$v_d = eE\tau / m$

where:

• Effect of Doubling V and Halving L:

Electric field, $E = V / L$

So, if V is doubled and L is halved, then:

New $E = (2V) / (L/2) = 4 \times (V/L)$ → Electric field becomes 4 times

Therefore, v_d becomes 4 times since $v_d \propto E$

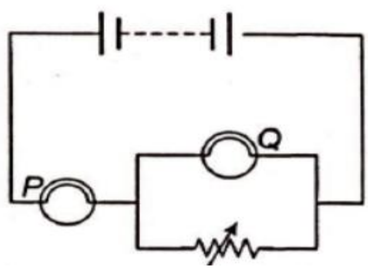
(b) Ionic Mobility and Temperature Dependence of Semiconductor Resistivity

• Ionic Mobility:
It is the drift velocity acquired per unit electric field by an ion. It is defined as:
$\mu = v_d / E$
Using $v_d = eE\tau / m$, we get: $\mu = e\tau / m$
• Temperature Dependence of Resistivity of a Semiconductor:
In a semiconductor, as temperature increases, more charge carriers (electrons and holes) are generated.

This increase in carrier concentration causes the resistivity to decrease with rising temperature.

Hence, semiconductors have **negative temperature coefficient** of resistivity.

Q4.(a) A p.d. of V volts is applied to a conductor of length L and diameter D. How will the drift velocity of e's and the resistance of the conductor change when (i) V is doubled (ii) L is halved and (iii) D is halved , where is each case , the other two factors remain same. Giver reason in each case.



(b) The circuit shown in figure, contains a battery, a rheostat and two identical lamps. What will happen to the brightness of the lamps if the resistance of the rheostat is increased?

Ans.4 (a). Drift velocity: $v_d \propto V / L$

2. Resistance: $R \propto L / D^2$

(i) When V is doubled (L and D constant)

• Drift velocity: Doubles

Reason: $v_d \propto V$. Increasing voltage increases the electric field and hence the drift velocity.

• Resistance: No change

Reason: Resistance depends only on L and D, not on the applied voltage.

(ii) When L is halved (V and D constant)

• Drift velocity: Doubles

Reason: $v_d \propto 1 / L$. Halving the length increases the electric field and thus the drift velocity.

• Resistance: Halved

Reason: $R \propto L$. Reducing the length of the conductor reduces resistance proportionally.

(iii) When D is halved (V and L constant)

• Drift velocity: Decreases

Reason: Smaller diameter reduces cross-sectional area, reducing current and drift velocity.

• Resistance: Increases 4 times

Reason: $R \propto 1 / D^2$. Halving the diameter reduces the area by a factor of 4, increasing resistance by 4 times.

(b) Rh is connected in parallel with lamp Q. As the resistance through Rh is increased, the resistance of the parallel combination increases and so, the total resistance of the circuit increases. This results in a decrease in the current in the whole circuit and also, potential drop across it will decrease. This will decrease the brightness of lamp P. On the other hand, brightness of lamp Q increases because its resistance remains same but due to decrease in potential difference across P, potential across it increases

Q5. Using the concept of free electrons in a conductor, derive the expression for the conductivity of a wire in terms of number density and relaxation time. Hence obtain the relation between current density and the applied electric field E.

Ans.5

Let:

n = number of free electrons per unit volume (number density)

e = charge of an electron. m = mass of an electron, τ = relaxation time

E = electric field applied drift velocity of electrons

When an electric field E is applied, the force on each electron is given by:

$F = -eE$

Acceleration, $a = F/m = -eE/m$

Drift velocity, $v_d = a\tau = (-eE/m) \times \tau = -eE\tau/m$

The negative sign indicates the direction of drift velocity is opposite to the electric field.

Current Density (J)

Current density J is given by:

$J = n\ e\ v_d$

Substituting v_d:

$J = n\ e\ (-eE\tau/m) = -ne^2\tau E/m$

Taking magnitude:

$J = (ne^2\tau/m) \times E$

Conductivity and Ohm's Law

Comparing with Ohm’s law in vector form: $J = \sigma E$,

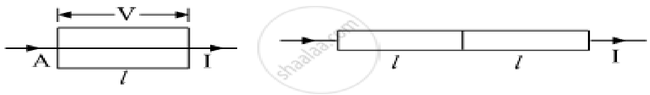
we get:

$\sigma = ne^2\tau/m$

Thus, the conductivity (σ) of a conductor is directly proportional to the number density of electrons (n), the square of the electron charge (e^2), and the relaxation time (τ), and inversely proportional to the mass of the electron (m).

WORKSHEET-I

1. A metal rod of square cross - sectional area having length l and current I flowing through it when a potential difference of V voltage applied across its ends (figure I) and now the rod is cut parallel to its length into two identical pieces and joined as shown in the figure II. What potential difference must be maintained across the length 2l so that the current in the rod is still I?



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2. A copper wire of resistance R is uniformly stretched till its length is increased to n times its original length. What will be its new resistance?

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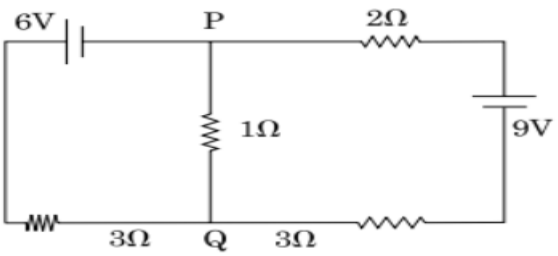
3. Find the magnitude and direction of current in 1Ω resistor in the given circuit.



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4. Two 120 V light bulbs, of emf 25 W and other of 200 W were connected in series across a 240 V line. One bulb burnt out almost instantaneously; which one was burnt and why?

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5. A potential difference V is applied across the ends of copper wire of length l and diameter D. What is the effect on drift velocity of electrons if (i) V is halved? (ii) l is doubled? (iii) D is halved?

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6. Emf of a cell is the maximum potential difference between two electrodes of the cell when no current is drawn from the cell. Internal resistance is the resistance offered by the electrolyte of a cell when the electric current flows through it. The internal resistance of a cell depends upon the following factors;

A. distance between the electrodes B. nature and temperature of the electrolyte

C. nature of electrodes D. area of electrodes.

For a freshly prepared cell, the value of internal resistance is generally low and goes on increasing as the cell is put to more and more use. The potential difference between the two electrodes of a cell in a closed circuit is called terminal potential difference

(a) The terminal potential difference of two electrodes of a cell is equal to emf of the cell when

(i) Current is zero (ii) when current is not equal to zero

(iii) Neither a or b (iv) both a and b

(b) A cell of emf E and internal resistance r gives a current of 0.5 A with an external resistance of 12Ω and a current of 0.25 A with an external resistance of 25Ω. What is the value of the internal resistance of the cell?

(i) 5Ω (ii) 1 Ω (iii) 7 Ω (iv) 3 Ω

(c) Choose the wrong statement.

(i) Potential difference across the terminals of a cell in a closed circuit is always less than its emf.

(ii) Internal resistance of a cell decreases with the decrease in temperature of the electrolyte.

(iii) Potential difference versus current graph for a cell is a straight line with a -ve slope

(iv) Terminal potential difference of the cell when it is being charged is given as $V = E + Ir$.

(d) If external resistance connected to a cell has been increased to 5 times, the potential difference across the terminals of the cell increases from 10 V to 30 V. Then, the emf of the cell is

(i) 30 (ii) 60 (iii) 50 (iv) 40

7. (a) Define drift velocity. Write its relationship with relaxation time in terms of the electric field E applied to a conductor. A potential difference V is applied to a conductor of length L. How is the drift velocity affected when V is doubled and L is halved? (3)

(b) Define ionic mobility. Write its relationship with relaxation time. How does one understand the temperature dependence of resistivity of a semiconductor?

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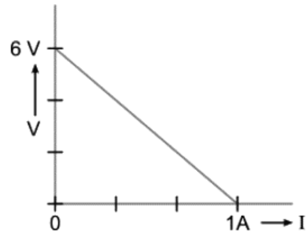
8. The plot of variation of potential difference across a combination of three identical cells in series versus current is shown in the figure. What is the emf and internal resistance of each cell.



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WORKSHEET-II

1. Two wires A and B of the same material and having same length have their cross sectional area in the ratio 1:4. What would be the ratio of heat produced in these wires when same voltage is applied across each?

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2. When 5 V potential difference is applied across a wire of length 0.1 m, the drift speed of electrons is 2.5 x 10^{-4} m/s if the electron density in the wire is 8 x 10^{28} m^{-3} , calculate the resistivity of the material of wire.

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3. A cylindrical metallic wire is stretched to increase its length by 5%. Calculate the percentage change in its resistance.

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4. Two wires X, Y have the same resistivity but their cross-sectional areas are in the ratio 2:3 and lengths in the ratio 1:2. They are first connected in series and then in parallel to a dc source. Find out the ratio of the drift speeds of the electrons in the two wires for the two cases.

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5. (a) On the basis of electron drift, derive an expression for resistivity of a conductor in terms of number density of free electrons and relaxation time. On what factors does resistance and resistivity of a conductor depend?

(b) Why alloys like constantan and manganin are used for making standard resistors?

(c) The electron drift arises due to the force experienced by electrons in the electric field inside the conductor. But force should cause acceleration. Why then do the electrons acquire a steady average drift speed?
(d) If the electron drift speed is so small, and the electron's charge is small, how can we still obtain large amounts of current in a conductor?
(e) When electrons drift in a metal from lower to higher potential, does it mean that all the 'free' electrons of the metal are moving in the same direction?

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6. (a)State the principle of wheatstone bridge. Deduce the condition for balance in a Wheatstone bridge. (3)
(b) In the given circuit, assuming point A to be at zero potential, use Kirchhoff's rules to determine the potential at point B. (2)

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7. Wheatstone bridge, also known as the resistance bridge, is the setup that is used for easuring the unknown resistance. It was invented by Samuel Hunter Christie in 1833 andwas later popularised by Sir Charles Wheatstone in 1843. A Wheatstone bridge comprises four arms which are termed as resistors, and among which the ratio of two resistors is kept at a fixed value and the two arms left, that is, the remaining arms are balanced, one of them can be varied while the other arm is an unknown resistor Then through the method of balancing or null condition, the unknown resistance is calculated. The circuit of the Wheatstone bridge provides the exact measurement of the resistance. There are many variations of the Wheatstone bridge that are utilised for the AC circuits.
(a) Why the Wheatstone bridge is more accurate than the other methods of measuring resistance
(i) It has four resistor arms (ii) It is based on Kirchhoff's laws

(iii) It does not involve ohm's law (iv) It is null method

(b) In a balanced Wheatstone's bridge network, the resistance in arms Q and S are interchanged. As a result of this

(i) galvanometer and cell must be interchanged to balance

(ii) galvanometer shows null deflection

(iii) Network is not balance

(iv) network is still balanced

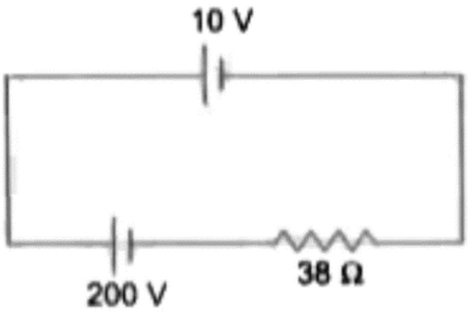
(c) In a Wheatstone bridge circuit P= 5Ω, Q =6Ω, R = 10Ω and S = 5Ω. What is the additional resistance to be used in series with S, so that the bridge is balance

(i) 5Ω (ii) 7 Ω (iii) 10 Ω (iv) 9 Ω

(d) Five equal resistors each of R are connected in a network as shown in the figure. The equivalent resistance between the points A and B is

(i) R (ii) 2R (iii) R/2 (iv) 4R.

8. A 10V cell of negligible internal resistance is connected in parallel across a battery of emf 200 V and internal resistance 38 ohm as shown in the figure. Find the value of current in the circuit.



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ANSWER OF WORKSHEET-I

Ans.1 4 times. Ans.2 $R' = n^2 R$ Ans.3 3/23 A (Q to P)

Ans.4 since $R = V^2/P$, so 25 watt bulb has more resistance. In the series circuit same current flows through both the bulbs. The 25 W bulb develops more heat ($H = i^2 Rt$) and hence burns out almost instantaneously.

Ans.5 (i) halved (ii) halved (iii) unchanged Ans.6 a(i) b(ii) c(ii) d(ii)

Ans.7 (a) Define drift velocity. Write its relationship with relaxation time in terms of the electric field E applied to a conductor. A potential difference V is applied to a conductor of length L. How is the drift velocity affected when V is doubled and L is halved? (3)

(b) Define ionic mobility. Write its relationship with relaxation time. How does one understand the temperature dependence of resistivity of a semiconductor?

Ans.8 As three cells are in series, so emf = 3E and internal resistance = 3r

V= 3E -3Ri

When I=0 , V=6V , so , 6 = 3E - 0 or E=2V

When V=0 , I=1A , so , 0=6-1x3r , 3r=6 , r=2Ω

ANSWER OF WORKSHEET-II

Ans.1 1:4 Ans.2 Resistivity + 1.56 x 10-5 Ωm

Ans.3 10.25% increase Ans.4 Series 3/2, Parallel 2

Ans.5 Refer to long answer question 1 Ans.6 Refer to long answer question 2

Ans7 a(iv) b(iv) c(ii) d(i)

Ans8 5A

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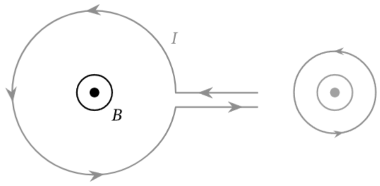
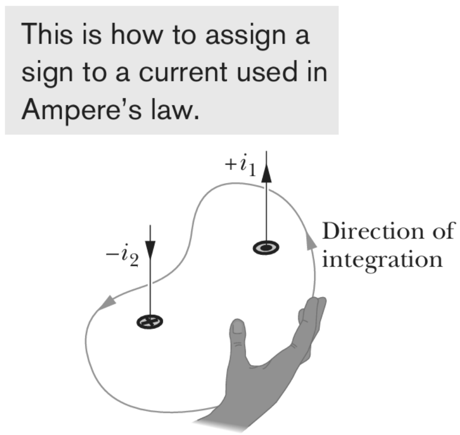
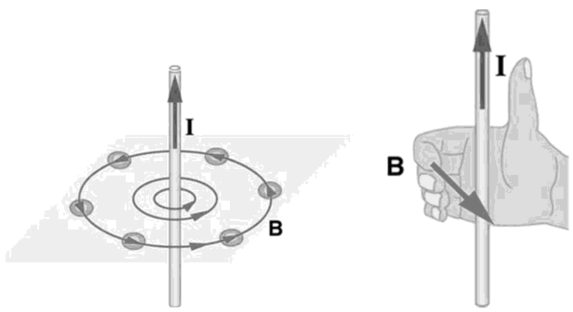
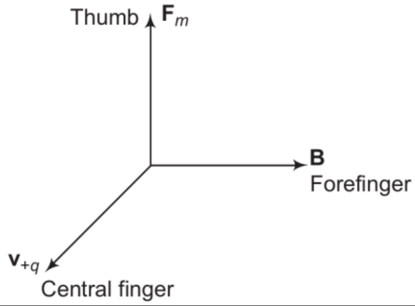
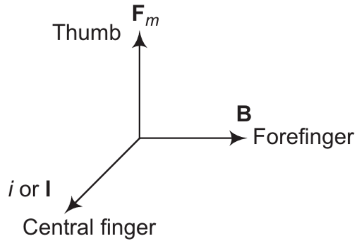
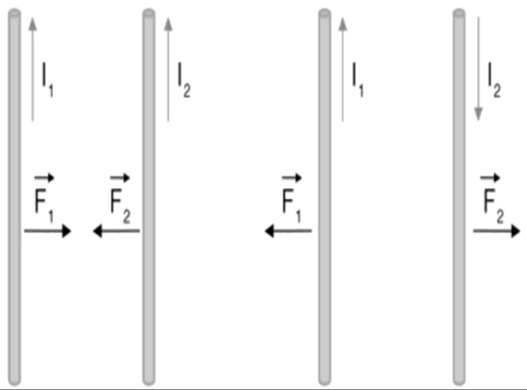
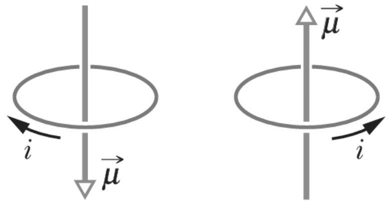
CHAPTER 4

MOVING CHARGES AND MAGNETISM

IMPORTANT FORMULAE

Description	Formula
Biot-Savart Law	$dB = \frac{\mu_0}{4\pi}\frac{Idl\sin\theta}{r^2}$ or $d\vec{B} = \frac{\mu_0}{4\pi}\frac{I\left(d\vec{l}\times\vec{r}\right)}{r^3}$
The magnetic field at a point on the axis of the circular current carrying coil at distance x	$B = \frac{\mu_0}{2}\frac{NIR^2}{\left(x^2+R^2\right)}$
The magnetic field at a point on the center of the circular current carrying coil.	$B = \frac{\mu_0 I}{2R}$ 
Ampere's Circuit law	$\oint \vec{B}\cdot d\vec{l} = \mu_0 I_{enclosed}$ 
Magnetic field due to an infinitely long straight wire at distance r	$B = \frac{\mu_0 I}{2\pi r}$ 

Force on a charged particle in a uniform magnetic field	$\vec{F} = q\left(\vec{v} \times \vec{B}\right)$ or $F = qvB\sin\theta$ **Direction: Left hand rule** 
Force on a current carrying conductor in a uniform magnetic field	$\vec{F} = I\left(\vec{l} \times \vec{B}\right)$ or $F = IlB\sin\theta$ **Direction: Left hand rule** 
Motion of a charged particle in a uniform magnetic field:	Radius of circular path: $r = \frac{mv}{qB} = \frac{p}{qB} = \frac{\sqrt{2mK}}{qB}$ Time period of revolution: $T = \frac{2\pi m}{qB}$ Frequency: $f = \frac{1}{T} = \frac{qB}{2\pi m}$ Angular frequency: $\omega = 2\pi f = \frac{qB}{m}$
When two parallel conductors separated by a distance r carry currents I_1 and I_2, the magnetic field of one will exert a force on the other. The force per unit length on either conductor is $\frac{F}{l} = \frac{\mu_0 I_1 I_2}{2\pi d}$	

Magnetic moment of a current carrying loop with N turns	$\vec{\mu}$ or $\vec{M} = NI\vec{A}$ 
Torque on a current carrying coil placed in a uniform magnetic field	$\tau = NIAB\sin\theta = MB\sin\theta$ or $\vec{\tau} = \vec{M}\times\vec{B}$
An electron revolving around the central nucleus in an atom has a magnetic moment and it is given by	$\vec{M} = -\frac{e}{2m}\vec{L}$ [L is angular momentum]
Conversion of galvanometer into an ammeter by connecting a small resistance S in parallel with galvanometer. [G is resistance of galvanometer]	$S = \left(\frac{I_g}{I - I_g}\right)G$
Conversion of galvanometer into a voltmeter by connecting a high resistance R in series with galvanometer.	$R = \frac{V}{I_g} - G$
Current sensitivity	$I_s = \frac{\theta}{I} = \frac{NAB}{k}$
Voltage sensitivity	$V_s = \frac{\theta}{V} = \frac{NAB}{kR}$

MULTIPLE CHOICE QUESTIONS:

Q1. If in a circular coil a of radius R, current I is flowing and in another coil b of radius $2R$, current $2I$ is flowing, then the ratio of the magnetic field B_a and B_b produced by them will be

(a) 1 (b) 2 (c) $\frac{1}{2}$ (d) 4

Q2. A charged particle moves through a magnetic field perpendicular to its direction. Then its

(a) Kinetic energy changes but the momentum remains constant

(b) Momentum changes but the kinetic energy remains constant

(c) Both momentum and kinetic energy changes

(d) Both momentum and kinetic energy changes

Q3. An electron, a proton and an alpha particle having the same kinetic energy are moving in circular orbits of radius R_e, R_p, and R_α respectively in a uniform magnetic field B. The relation between R_e, R_p and R_α is

(a) $R_e > R_p = R_\alpha$ (b) $R_e < R_p = R_\alpha$ (c) $R_e < R_p < R_\alpha$ (d) $R_e < R_\alpha < R_p$

Q4. When a charged particle moving with velocity $\vec{v}$ is subjected to a magnetic field of induction $\vec{B}$, the force on it is non-zero. This implies that

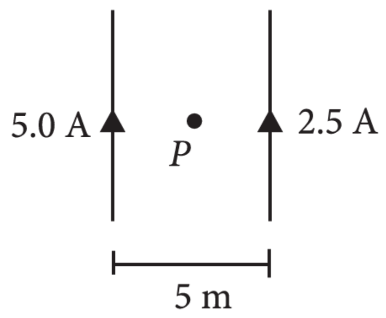
(a) angle between is either zero or 180°

(b) angle between is necessarily 90°

(c) angle between can have any value other than 90°

(d) angle between can have any value other than zero and 180°.

Q5. The magnetic field at centre, *P* will be



(a) $\frac{\mu_0}{4\pi}$ (b) $\frac{\mu_0}{\pi}$ (c) $\frac{\mu_0}{2\pi}$ (d) $4\mu_0\pi$

Q6. Vector form of Biot-savart's law is

(a) $d\vec{B} = \frac{\mu_0}{4\pi} i \left(\frac{d\vec{l} \times \vec{r}}{r} \right)$

(b) $d\vec{B} = \frac{\mu_0}{4\pi} i^2 \left(\frac{d\vec{l} \times \vec{r}}{r} \right)$

(c) $d\vec{B} = \frac{\mu_0}{4\pi} i^2 \left(\frac{d\vec{l} \times \vec{r}}{r^2} \right)$

(d) $d\vec{B} = \frac{\mu_0}{4\pi} i \left(\frac{d\vec{l} \times \vec{r}}{r^3} \right)$

Q7. A straight wire of length 1 m is placed along *x*-axis in a region of magnetic field $\vec{B} = 3\hat{i} + 2\hat{j}$ T. A current of 2 A flows in the wire along the positive *x* direction. The magnetic force acting on the wire is:

(a) 2.0 N, along + *z*-axis (b) 2.0 N, along -*z* axis

(c) 4.0 N, along + *z*-axis (d) 4.0 N, along -*z*-axis

Q8. A current-carrying loop is placed in a uniform magnetic field. The torque acting on it does not depend upon

(a) area of loop (b) shape of loop (c) no. of turns in loop (d) strength of current and magnetic field

Q9. A circular loop of area 0.01 m^2 carrying a current of 10 A, is held perpendicular to a magnetic field of intensity 0.1 T. The torque acting on the loop is

(a) zero (b) 0.01 N-m (c) 0.1 N-m (d) 0.8 N-m

Q10. Beams of electrons and protons move parallel to each other in the same direction. They
(a) attract each other. (b) repel each other.
(c) neither attract nor repel. (d) force of attraction or repulsion depends upon speed of beams.

Answers/Hints:

1. (a) : Use formula $B = \frac{\mu_0 Ni}{2R}$ and take the ratio.

2. (b) : Kinetic does not change because work done by magnetic force is zero. Momentum changes because direction of velocity of particle continuously changes.

3. (b) : Use formula $r = \frac{\sqrt{2mK}}{qB}$ and compare for each particle. Mass of particle is four times the mass of proton, while mass of proton is 1860 times the mass electron. Charge of alpha particle is twice of proton. Proton has same charge as electron.

4. (d) : Use $F = qvB\sin\theta$. Force is zero only when angle is 0 or 180.

5. (c) : Use formula $B = \frac{\mu_0 i}{2\pi r}$ to calculate field at the point due to each wire and then take Vector sum.

6. (d) : Recall Biot-Savart law formula.

7. (c) : Use formula $\vec{F} = I\left(\vec{L} \times \vec{B}\right)$

8. (b) : $\tau = NIAB\sin\theta$

9. (a) : $\tau = NIAB\sin\theta$; The angle between magnetic moment and magnetic field is zero.

10. (b) : Unlike parallel currents repel

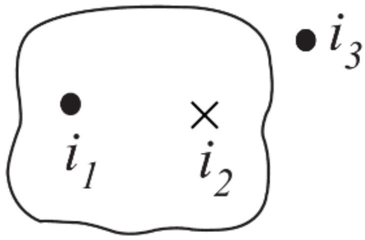
ASSERTION & REASON(1 MARKS)

The questions below are Assertion (A) and Reason (R) type questions. Two statements are given one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer from the codes (a), (b), (c) and (d) as given below.

(a) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).
(b) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A).
(c) Assertion (A) is true, but Reason (R) is false.
(d) Assertion (A) is false and Reason (R) is also false.

Q1. **Assertion (A)**: An electron and a proton enter with the same momentum p in a magnetic field B such that p is perpendicular to B. Then both describe a circular path of the different radius.
Reason (R): The radius of the circular path described by the charged particle (charge q, mass m) moving in the magnetic field B is given by $r = \frac{mv}{qB}$.

Q2. **Assertion (A):** Ampere's law used for the closed loop shown in figure is written as $\oint \vec{B} \cdot d\vec{l} = \mu_0 (i_1 - i_2)$ if the loop is traversed anticlockwise. The right side does not include i_3.



Reason (R): The magnetic field produced by i_3 over the closed loop is zero.

Q3. **Assertion (A):** A current carrying square loop made of a wire of length L is placed in a magnetic field. It experiences a torque which is greater than the torque on a circular loop made of the same wire carrying the same current in the same magnetic field
Reason (R): A square loop occupies more area than a circular loop, both made of wire of the same length.

Q4. **Assertion (A):** The magnetic field produced by a current carrying solenoid is independent of its length and cross-sectional area.

Reason (R): The magnetic field inside the solenoid is uniform.

Q5. **Assertion (A):** Two long straight parallel wires carrying current in the same direction attract each other.

Reason (R): The magnetic field produced by one wire exerts a force on the other wire in the direction of the field

Answers:

1. (a) : Assertion is true because $r = p/qB$. P, q, and B are same for both particle. Reason given is also true and explains the assertion also.

2. (c) : Assertion is true as Ampere's law is correctly applied. i_3 will not come as it does not pass through the surface. Reason is false because the current will produce magnetic field on the points on the loop. The value of its integral over closed loop will be zero.

3. (d) : Assertion is false because torque will be more for circle as its area is more. Reason is also false as the area of circle is maximum for a given length.

4. (b) : Assertion is true because $B = \mu_0 ni$. Reason is also true. But reason is not correct explanation as reason as uniform means magnetic field has same value at all places but not that it doesn't depend on length and area.

5. (c) : Assertion is true, the force acting is $F/l = (\mu_0 I_1 I_2)/2\pi d$. Reason is false because the force does not act in the direction of field.

VERY SHORT ANSWER QUESTIONS (2 Marks)

Q1. Two identical circular coils A and B, each of radius R, carrying currents I and $\sqrt{3}I$ respectively, are placed concentrically in XY and YZ planes respectively. Find the magnitude and direction of the net magnetic field at their common centre.

Ans:

Magnetic field at centre due to first coil: $\frac{\mu_0 I}{2R}$

Magnetic field at centre due to second coil: $\frac{\mu_0 \sqrt{3} I}{2R}$

Since both magnetic fields are perpendicular, net magnetic field at centre:

$$B_{\text{net}} = \sqrt{\left(\frac{\mu_0 I}{2R}\right)^2 + \left(\frac{\mu_0 \sqrt{3} I}{2R}\right)^2} = \frac{\mu_0 I}{R}$$

Q2. (i) How will the magnetic field inside a long solenoid be affected when:

(a) the radius of the turns of the solenoid is increased,

(b) the length of solenoid as well as the total number of its turns are doubled ?

(ii) 'Parallel currents attract, and antiparallel currents repel.' Explain.

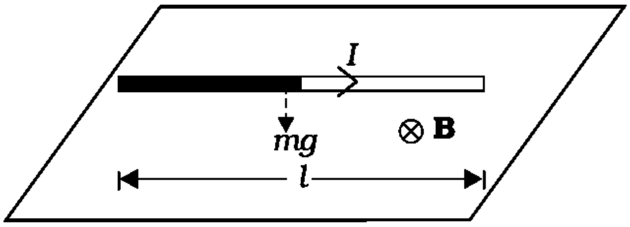
Ans:

(i) (a) Increasing the radius of the turns does not affect the magnetic field inside a long solenoid, as the field depends only on turn density, not radius.

(b) Doubling both the length and total number of turns keeps the number of turns per unit length the same, so the magnetic field remains unchanged.

(ii) Parallel currents attract because the magnetic field produced by one wire exerts a force on the other in the direction of the current, pulling them together. In contrast, antiparallel currents produce opposing magnetic fields, resulting in a repulsive force between the wires.

Q3. A straight wire of mass 200 g and length 1.5 m carries a current of 2 A. It is suspended in mid-air by a uniform horizontal magnetic field ***B***, as shown in figure. What is the magnitude of the magnetic field?



Ans:

There will be an upward force *F*, of magnitude *ILB* on the wire. For mid-air suspension, this must be balanced by the force due to gravity:

$mg = ILB$ $B = mg/IL$ Put values: $B = 0.65$ T

Q4. A tritium (isotope of hydrogen) and alpha particle having the same momentum are in turn allowed to pass through a magnetic field $\vec{B}$, acting normal to the direction of motion of the particles. Calculate the ratio of the radii of the circular paths described by them and the ratio of time angular velocity of revolution.

Ans:

Use formula $r = \frac{mv}{qB} = \frac{p}{qB}$

Charge on tritium is e and charge on alpha particle is $2e$.

Ratio = 2/1

$\omega = \dfrac{qB}{m}$

Q5. (i) A current-carrying circular loop lies on a smooth horizontal plane. Can a uniform magnetic field be set up in such a manner that the loop turns around itself (i.e., turns about the vertical axis)

(ii) A loop of irregular shape carrying current is located in an external magnetic field. If the wire is flexible, why does it change to a circular shape?

Ans:

(i) No, because that would require τ to be in the vertical direction. But $\tau = IA\times B$, and since A of the horizontal loop is in the vertical direction, τ would be in the plane of the loop for any B.

(ii) It assumes circular shape with its plane normal to the field to maximise flux, since for a given perimeter, a circle encloses greater area than any other shape.

Q6. Write the expression for Lorentz magnetic force on a particle of charge q moving with velocity $\vec{v}$ in a magnetic field $\vec{B}$. Show that no work is done by this force on the charged particle.

Ans:

Magnetic force on charge: $\vec{F} = q\left(\vec{v}\times\vec{B}\right) \Rightarrow \vec{F} \perp \vec{v}$ -

Force is perpendicular to displacement made by charged particle.

Hence, $W = Fd\cos 90° = 0$ (since force and displacement are perpendicular to each other)

Q7. In a hydrogen atom, the electron moves in an orbit of radius 2 Å making 8×10^{14} revolutions per second. Find the magnetic moment associated with the orbital motion of the electron.

Ans:

The magnetic moment:

$M = IA = \dfrac{e}{T}\pi r^2 = ef\pi r^2$, where f is frequency, T is time period.

Substitute values:

$M = 1.6\times10^{-23}$ A m^2

Q8. In a certain region of space, electric field $\vec{E}$ and magnetic field $\vec{B}$ are perpendicular to each other.

An electron enters in the region perpendicular to the directions of both $\vec{B}$ and $\vec{E}$, and moves undeflected. Find the velocity of the electron.

Ans:

Net force on electron in the combined electric field and magnetic field is

$\vec{F} = -e\left[\vec{E} + \vec{v}\times\vec{B}\right]$

Since electron moves undeflected, the force on particle is zero.

$$\vec{E} + \vec{v} \times \vec{B} = 0$$

$$\vec{E} = -\vec{v} \times \vec{B}$$

$$|\vec{E}| = |\vec{v}||\vec{B}|$$

$$|\vec{v}| = \frac{|\vec{E}|}{|\vec{B}|}$$

Q9. Two moving coil meters M_1 and M_2 have the following particulars:

$R_1 = 10\ \Omega$, $N_1 = 30$, $A_1 = 4.6\times10^{-3}\ m^2$, $B_1 = 0.5$ T

$R_2 = 14\ \Omega$, $N_2 = 42$, $A_2 = 2.3\times10^{-3}\ m^2$, $B_2 = 1$ T

The spring constants are identical for the two meters. Determine the ratio of (i) Current sensitivity and (ii) Voltage sensitivity of M_2 and M_1.

Ans: (i) Current sensitivity = NBA/k

Ratio of current sensitivity = $\frac{N_2B_2A_2}{N_1B_1A_1} = 1.4$

(ii) Voltage sensitivity = (NBA)/(kR)

Ratio of voltage sensitivity = $\frac{N_2B_2A_2}{N_1B_1A_1} = 1.4$

Q10. How is a moving coil galvanometer converted into a voltmeter? Explain giving the necessary circuit diagram and the required mathematical relation used.

Ans:

A galvanometer can be converted into a voltmeter by connecting a very high resistance ***R*** in series with it.

Let ***R*** is so chosen that current I_G gives full deflection in the galvanometer where I_G is the range of galvanometer. Let galvanometer of resistance ***G***, range I_G, is to be converted into voltmeter of range **V** (volt). Now,

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

$$R + G = \frac{V}{I_G}$$

$$R = \frac{V}{I_G} - G$$

SHORT ANSWER QUESTIONS (3 Marks)

Q1. (i) Write Biot-Savart's law in scalar form. Define each parameter in the expression.

(ii) Write the expression for the magnetic field at the centre of a circular loop of radius *R* and carrying a current *I*.

(iii) Specify the direction of magnetic field at a point on the axis of loop, for both sides.

Ans: (i) $dB = \frac{\mu_0}{4\pi}\frac{Idl\sin\theta}{r^2}$

dB: Magnetic field at a point due to a small element of current

μ_0: Permeability of free space ($4\pi\times10^{-7}$ T m/A

I: Current in the conductor

dl: Length of the small current-carrying element

θ: Angle between ***dl*** vector and position vector ***r***

r: Distance between the element and the point where field is measured

(ii) $B = \dfrac{\mu_0 I}{2R}$

(iii) Direction of Magnetic Field on the Axis of the Loop:

On both sides of the loop (along the axis), the magnetic field points along the axis of the loop.

The direction is given by the right-hand rule: curl your fingers in the direction of current; your thumb gives the direction of the magnetic field on the axis.

Q2. (i) Derive an expression for the force acting on a current carrying straight conductor kept in a magnetic field.

(ii) State the rule which is used to find the direction of this force.

(iii) If a current carrying conductor is placed along the axis of a current carrying solenoid, what is the force experience by the conductor?

Ans:

(i) [**Derivation]:** Prove $F = ILB\sin\theta$, or vectorially $\vec{F} = I\left(\vec{L}\times\vec{B}\right)$]

(ii) Fleming's left-hand rule is used. It says that

"Stretch the thumb, forefinger, and middle finger of your left hand mutually perpendicular, then

- Forefinger → Direction of magnetic field (*B*)
- Middle finger → Direction of current (*I*)
- Thumb → Direction of force (*F*)

(iii) Force experienced is zero because the magnetic field of a solenoid is along the axis which will be then parallel to the direction of current in the conductor.

Q3. (i) State Ampere's circuital law, expressing it in integral form.

(ii) Prove that the magnetic field due to an infinitely long current carrying wire varies inversely with distance from the wire.

Ans:

(i) Ampere's circuital law: The line integral of the magnetic field around any closed loop is equal to μ_0 times the total current enclosed by the loop.

$$\oint \vec{B}\cdot d\vec{l} = \mu_0 I_{\text{enclosed}}$$

(ii) [**Derivation**]: Derive magnetic field due to an infinitely long straight wire: $B = \frac{\mu_0 I}{2\pi r} \propto \frac{1}{r}$

Q4. (i) An alpha particle is projected with velocity $\vec{v} = \left(3\times10^5 \text{ m/s}\right)\hat{i}$ into a region in which magnetic field $\vec{B} = \left[\left(0.4 \text{ T}\right)\hat{i} + \left(0.3 \text{ T}\right)\hat{j}\right]$ exists. Calculate the acceleration $\vec{a}$ of the particle in the region.

Take the charge to mass ratio for alpha particle 5×10^7 C/kg.

(ii) What will be $\vec{a}\times\vec{v}$?

Ans:

(i) Magnetic force:

$$\vec{F} = q\left(\vec{v}\times\vec{B}\right)$$
$$= q\left[\left(3\times10^5\hat{i}\right)\times\left(0.4\hat{i} + 0.3\hat{j}\right)\right]$$
$$= q\left(0.9\times10^5\right)\hat{k}$$

Acceleration:

$$\vec{a} = \frac{\vec{F}}{m}$$
$$= \frac{q}{m}\left(0.9\times10^5\right)\hat{k}$$
$$= 5\times10^7\times0.9\times10^5\hat{k}$$
$$= 4.5\times10^{12} \text{ m/s}^2$$

(ii) Zero (Acceleration is perpendicular to velocity).

Q5. A proton with kinetic energy 3.4×10^{-15} J moving horizontally from north to south, enters a uniform magnetic field B of 2 mT directed eastward. Calculate:
(a) the speed of the proton
(b) the magnitude of acceleration of the proton
(c) the radius of the path traced by the proton
[Take (q/m) for proton = 1×10^{10} C/kg and mass of proton as 1.7×10^{-27} kg]

Ans:

(i) $K = \frac{1}{2}mv^2 \Rightarrow v = \sqrt{\frac{2K}{m}}$. Put values: $v = 2\times10^6$ m/s.

(ii) Magnetic force, $F = qvB$.

Acceleration, $a = F/m = qvB/m$

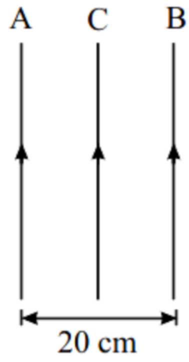
Put values:

$a = 4\times10^{13}$ m/s^2

(iii) Use $r = mv/qB$

$r = 0.1$ m

Q6. Two very long, straight, parallel wires *A* and *B* carry currents of 10 A and 20 A respectively, and are at a distance 20 cm apart, as shown in the figure. If a third wire *C* (length 15 cm) having a current of 10 A is placed between them, how much force will act on *C*? The direction of current in all the three wires is same.



Ans:

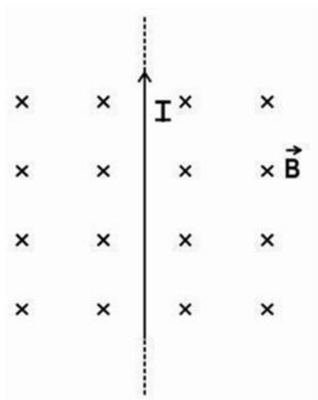
Use formula for force between parallel wires: $\frac{F}{l} = \frac{\mu_0 I_1 I_2}{2\pi d}$

Force on wire *C* due to *A*: $F = 3.0 \times 10^{-5}$ N, towards *A*

Force on wire *C* due to *B*: $F = 6 \times 10^{-5}$ N, towards *B*

Net force on *C*: $F_{\text{net}} = 6 \times 10^{-5} - 3 \times 10^{-5} = 3 \times 10^{-5}$, towards *B*

Q7. A wire carrying a current *I* = 200 A in the upward direction is placed in a magnetic field $B = 2 \times 10^{-3}$ T as shown in the figure.



A null point represents the location of a point with zero net magnetic field.

(i)On which side of the wire will a null point be located?

(ii)On which side of the wire will a null point be located if the direction of applied magnetic field B is reversed? Calculate the perpendicular distance of the null point of the wire.

Ans:

(i) On the left side of the wire.

(ii) On the right side of the wire. Null point is the point where the magnetic field due to the current-carrying wire is equal to the external magnetic field and is opposite in direction.

$$B = \frac{\mu_0}{2\pi}\frac{I}{r} \Rightarrow r = \frac{\mu_0}{2\pi}\frac{I}{B}$$

Put all values. $r = 0.02$ m.

Q8. A rectangular coil of sides 10 cm and 5 cm having 2000 turns and carrying a current of 200 mA is placed in a uniform magnetic field of 0.2 T directed along the positive x-axis.

(i) What is the magnetic moment of the coil?
(ii) What is the maximum torque acting on the coil and in which orientation does it experience it?
(iii) For which orientations, is the coil in stable and unstable equilibrium?

Ans: (i) Magnetic moment = NIA = 2000×0.1×0.05 = 10 A m^2

(ii) Maximum torque acts when angle between area vector and magnetic field is 90.

$$\tau_{\max} = MB\sin\theta = MB\sin 90° = MB = 10 \times 0.2 = 2 \text{ N m}$$

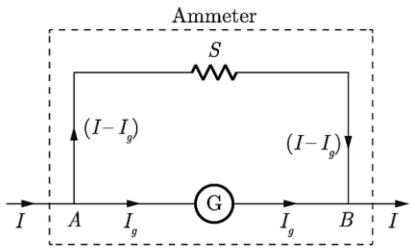
(iii) Stable equilibrium is at $\theta = 0°$ (potential energy is negative) and unstable equilibrium is at $\theta = 180°$ (potential energy is positive). At both angles torque is zero.

Q9. (i) How is a moving coil galvanometer converted into an ammeter? Explain giving the necessary circuit diagram and the required mathematical relation used.

(ii) An ammeter of resistance 0.80 Ω can measure current up to 1.0 A. What must be the value of shunt resistance to enable the ammeter to measure current up to 5.0 A?

Ans:

(i) A galvanometer is converted into an ammeter by connecting a very small resistance in parallel to the galvanometer.



[**Derivation]:** Derive the formula $S = \frac{I_g G}{I - I_g}$

(ii) $S = \frac{(1.0)(0.8)}{5-1} = \frac{0.8}{4} = 0.2\ \Omega$

Q10. (i) What is the importance of a radial magnetic field and how is it produced?

(ii) Why is it necessary to introduce a cylindrical soft iron core inside the coil of a galvanometer?

(iii) A student suggests increasing the number of turns of the coil in a galvanometer to increase its sensitivity. Will this always be effective? Justify your answer

Ans:

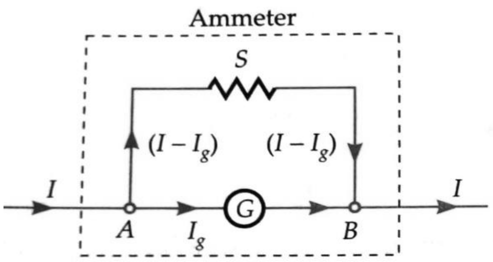
(i) A radial magnetic field ensures that the plane of the coil always remains perpendicular to the magnetic field during rotation, so torque remains proportional to current at all positions. It is produced by shaping the pole pieces of a magnet into concave forms and using a cylindrical iron core.

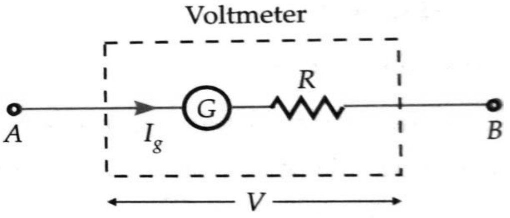
(ii) The soft iron core increases the strength of the magnetic field and makes it radial. This enhances sensitivity and linearity of the galvanometer.

(iii) Not always; increasing turns increases sensitivity but also increases resistance, which may reduce current and affect voltage sensitivity.

CASE BASED QUESTIONS (4 Marks):

Q1. A Galvanometer is a device used to detect current in an electric circuit. It cannot as such be used as an ammeter to measure current in a given circuit. This is because a Galvanometer is a very sensitive device, it gives full scale deflection for a current of the order of μA. Moreover, for measuring current, the Galvanometer has to be connected in series and it has a large resistance, this will change the value of current in the circuit. To overcome these difficulties, we connect a small resistance S called shunt resistance in parallel with the Galvanometer coil so that most of the current passes through the shunt. Now to use Galvanometer as a voltmeter, it has to be connected in parallel with the circuit element across which we need to measure potential difference. Moreover, it must draw a very small current, otherwise it will appreciably change the voltage which we are measuring. To ensure this is large resistance R connected in series with the galvanometer.





(i) A sensitive Galvanometer like a moving coil galvanometer can be converted into an ammeter or a voltmeter by connecting a proper resistance of it. Which of the following statement is true ?

(a) A Voltmeter is connected in parallel and current through its negligible.

(b) An ammeter is connected in parallel and potential difference across it is small.

(c) A voltmeter is connected in series and potential difference across it is small.

(d) An ammeter is connected in series in a circuit and the current passing through it is negligible.

(ii) A Galvanometer coil has resistance of 15 Ω and gives full scale deflection for a current of 4 mA. To convert it to an ammeter of range 0 to 6 A

(a) a 10 mΩ resistance is to be connected in parallel to the Galvanometer.

(b) a 10 mΩ resistance is to be connected in series with the Galvanometer

(c) a 0.1 Ω resistance to be connected in parallel to the Galvanometer.

(d) a 0.1 Ω resistance is to be connected in series with the Galvanometer.

(iii) Two identical galvanometers are taken; one is to be converted into an ammeter and other into a milliammeter. Shunt of milliammeter compared to ammeter is

(a) More (b) Equal (c) Less (d) Zero

(iv) A galvanometer gives full-scale deflection for a current of 5 mA. To convert it into an ammeter of range 5 A, the value of shunt required (assuming galvanometer resistance G = 20 Ω is:
(a) 0.02 Ω (b) 0.05 Ω (c) 0.1 Ω (d) 0.2 Ω

OR

(v) The galvanometer cannot as such be used as an ammeter to measure the value of current in a given circuit. The following reasons are:

1. galvanometer gives full scale deflection for a small current.

2. galvanometer has a large resistance.

3. a galvanometer can give inaccurate values.

(a) 1 and 3 (b) 1 and 2 (c) 2 and 3 (d) 1, 2, and 3

Ans:

(i) (a) : A voltmeter measures potential difference, so it is always connected in parallel across components. To ensure it does not draw current and affect the circuit, it has very high resistance

(ii) (a) : Use formula $S = (I_g R_g)/(I-I_g)$

(iii) (a) : Ammeter measures large current →most of the current must bypass the galvanometer → needs a very small shunt resistance.

Milliammeter measures smaller current → only a small amount bypass needed → shunt resistance will be higher.

So, the shunt resistance of the milliammeter is more than that of the ammeter.

(iv) (a) : Use formula $S = (I_g R_g)/(I-I_g)$. Put $I_g = 0.005$, $G = 20$, $I = 5$.

(v) (b) : A galvanometer gives full-scale deflection with only a small current, so it cannot directly measure large currents. Also, it has high resistance, which would significantly alter the current in the circuit if connected directly. Reason 3 is incorrect; a galvanometer is precise within its range but just not suited for large currents.

Q2. A moving coil galvanometer is an instrument used to detect and measure small electric currents. It works on the principle that a current-carrying coil placed in a magnetic field experiences a torque. The galvanometer consists of a rectangular coil of thin wire wound on a metallic frame, suspended between the poles of a strong permanent magnet. The magnetic field is made radial using a soft iron core, ensuring that the plane of the coil is always parallel to the field lines, resulting in a uniform torque. When current passes through the coil, it deflects, and this deflection is measured by a pointer attached to the coil and suspended by a spring. The deflection is directly proportional to the current.

(i) A galvanometer shows a deflection of θ for a current I. If the number of turns is doubled and the area of the coil is halved, then for the same current the new deflection is:

(a) θ (b) 2θ (c) 0.5θ (d) $\theta/4$

(ii) In a moving coil galvanometer, the deflection is proportional to the current because:

(a) Torque is proportional to square of current (b) Magnetic field is constant

(c) Restoring torque is proportional to angular deflection (d) Magnetic field is variable

(iii) Which of the following changes would not affect the current sensitivity of a galvanometer?

(a) Increasing number of turns of coil (b) Increasing magnetic field strength

(c) Increasing torsional constant (d) Connecting a shunt across it

(iv) If a radial magnetic field is not used in a moving coil galvanometer, which of the following best describes the consequence on its working?

(a) The torque becomes independent of current.

(b) The deflection is no longer linearly proportional to current due to variable torque.

(c) The magnetic field becomes zero at certain angles, so the galvanometer stops working.

(d) The coil experiences a constant torque irrespective of orientation.

OR

(v) The coil of a moving coil galvanometer has an area of 5×10^{-2} m^2. It is suspended in a magnetic field of 2×10^{-2} Wb m^{-2}. If the torsional constant of the suspension fiber is 2×10^{-9} N m deg^{-1}, find its current sensitivity in SI units.

(a) 2×10^5 (b) 5×10^5 (b) 1×10^5 (b) 2.5×10^5

Ans:

(i) (a) : The deflection θ in a galvanometer is directly proportional to the product of the number of turns N and the area of the coil A. If N is doubled and A is halved, θ remains the same.

(ii) (c) : In a moving coil galvanometer, the magnetic torque produced is proportional to the current, and the restoring torque (from the spring) is proportional to the deflection angle. At equilibrium, these torques balance, making deflection directly proportional to current.

(iii) (d) : Current sensitivity refers to deflection per unit current. It depends on factors like number of turns, magnetic field, and torsional constant - all internal to the galvanometer. Connecting a shunt affects its use as an ammeter but does not change its intrinsic current sensitivity.

(iv) (b) : Without a radial magnetic field, θ changes as the coil rotates, making the torque vary non-linearly with current.

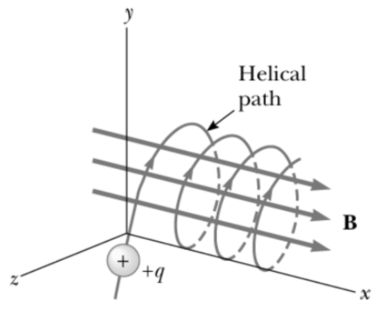
(v) (b) : Current sensitivity = NAB/k. Put given values. Take $N = 1$.

Q3. When a charged particle enters a magnetic field with a velocity perpendicular to the field, it experiences a magnetic force given by Lorentz force: $\vec{F} = q\left(\vec{v} \times \vec{B}\right)$ where q is the charge, v is the velocity, and B is the magnetic field. This force is always perpendicular to the direction of motion, causing the particle to move in a circular path. The magnetic force acts as the centripetal force, and the radius of the circular path is given by:

$r = mv/qB$

where m is the mass of the particle.

The particle undergoes uniform circular motion without any change in speed, only in direction. If the velocity has a component parallel to the magnetic field, the path becomes a helix.



(i) A beam of electrons pass undeflected through crossed E and B fields. When E is switched off, they move:
(a) In an ellipse (b) In a circle (c) In a parabola (d) Along a straight line
(ii) A charged particle enters a magnetic field making an angle α with the field. The resulting trajectory is:
(a) Circular for $\alpha = 0°$ (b) Straight for $\alpha = 90°$
(c) Helical for $0 < \alpha < 90°$ (d) Parabolic for any α
(iii) A proton and an electron have identical velocities and enter a magnetic field at 90°. Which experiences greater acceleration?
(a) Electron (b) Proton (c) Both equal (d) Neither charge experiences any acceleration
(iv) Under a uniform magnetic field, a charged particle describes a circle of radius R at speed v. The time period T of revolution is
(a) Dependent on R and v (b) Independent of R and v
(c) Dependent on R alone (d) Dependent on v alone

OR

(v) The scalar product of force $\vec{F}$ acting on particle in a magnetic field $\vec{B}$, and the magnetic field is

(a) 0 (b) *FB* (c) 2*FB* (d) *FB/2*

Ans: (i) (b) : When the electric field is turned off, only the magnetic field acts, and the magnetic force causes the electrons to move in a circular path, since magnetic force provides the centripetal force.

(ii) (c) : When a charged particle enters a magnetic field at an angle α, its velocity has two components: one parallel and one perpendicular to the field. The perpendicular part causes circular motion, and the parallel part causes linear motion - together forming a helical path

(iii) (a) : Both experience same force. But $a = F/m$, and the mass of electron is less. So, electron experiences more acceleration.

(iv) (b) : $T = 2\pi m/qB$

(v) (a) : Angle between *F* and *B* is 90 degrees. So, scalar product is zero.

LONG ANSWER QUESTIONS (5 Marks)

1. (i) Draw a labelled diagram of a moving coil galvanometer. Describe briefly its principle and working.

(ii)(a) Define current sensitivity and voltage sensitivity of a galvanometer?
(b) Increasing the current sensitivity of a galvanometer may not necessarily increase its voltage sensitivity. Explain, giving reason.

Ans: (i) **[Diagram, principle and working]**
(ii) (a) Current sensitivity: It is the deflection produced per unit current in a galvanometer.

$$\boxed{\text{Current sensitivity} = \frac{\theta}{I}}$$

Voltage sensitivity: It is the deflection produced per unit voltage applied across the galvanometer.

$$\boxed{\text{Voltage sensitivity} = \frac{\theta}{V} = \frac{\text{Current sensitivity}}{R}}$$

(b) Current sensitivity increases with lower spring constant and higher magnetic field, but voltage sensitivity also depends on the coil resistance. If resistance increases to boost current sensitivity, voltage sensitivity may not improve.

Q2. (i) State Biot-Savart's Law.

(ii) Using Biot-Savart law, find an expression for the magnetic field at the axis of a circular coil of *N* turns, radius *R*, carrying current *I*.

(iii) For a coil of radius *R* and carrying current *I*, compare the magnitudes of magnetic field at its center and at an axial distance of $\sqrt{3}R$.

Ans:

(i) Statement & formula. (ii) **[Derivation]:** $B = \dfrac{\mu_0 I R^2}{2\left(x^2 + R^2\right)^{3/2}}$

(iii) At center: $B = \dfrac{\mu_0 I}{2R}$

At axial point: $B = \dfrac{\mu_0 I R^2}{2\left(x^2 + R^2\right)^{3/2}}$. Put $x = \sqrt{3}R$ and solve.

Q3. (i) Discuss the motion of a charged particle of mass *m* and charge *q* in a uniform magnetic field *B* with initial velocity *v*.

(a) Perpendicular to the field direction (θ =90°) (b) Parallel to the field direction (θ = 0°), and

(c) At an angle *θ* with field direction.

(ii) An electron is moving along a circular path of radius 20 cm in a uniform magnetic field 2×10^{-3} T. Calculate:

(a) The speed of the electron, and

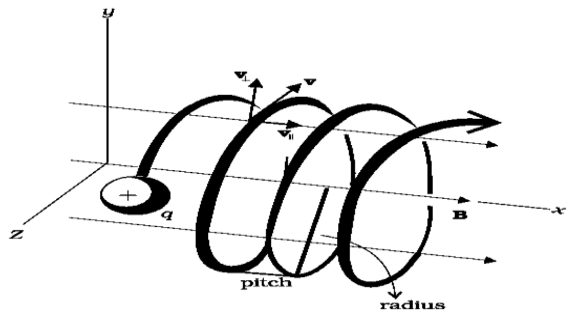
(b) The potential difference through which the electron must be accelerated to acquire this speed.

Ans: (i)(a) The particle undergoes circular motion. Magnetic force provides the centripetal force.

Radius of path = mv/qB

(b) The force acting on particle is zero in this case. So, the particle moves with constant speed along the direction of magnetic field.

(c) In this case, component of velocity perpendicular to field makes the particle undergo circular motion while the parallel component takes it forward in the direction of magnetic field. The net path is a combination of linear and circular = HELIX.



(ii)

(a) Magnetic force = centripetal force

$$evB = \frac{mv^2}{r}$$

$$v = \frac{eBr}{m}$$

Put values.

$v = 7.1 \times 10^7$ m/s

(b) Let *V* be the potential difference required to provide speed v to the electron, then

$$eV = \frac{1}{2}mv^2$$

$$V = \frac{mv^2}{2e}$$

Put values. $V = 14.2 \times 10^3$ V

Q4. (i) Deduce an expression for the torque experienced by a current carrying coil placed in an external uniform magnetic field.

(ii) The maximum torque acting on a current carrying loop of area 0.08 m^2 is 8×10^{-8} N m. The current in the loop is 1.6 μA. Calculate:

(a) The magnetic field in which the loop is kept, and

(b) The magnetic dipole moment of the loop

Ans:

(i) **[Derivation]:** Expression for torque: $\vec{\tau} = \vec{M} \times \vec{B}$ -

(ii) (a) Maximum torque acts when angle between area vector and magnetic field is 90°.

$$\tau_{\max} = NIAB \sin 90° = NIAB$$

$$B = \frac{\tau_{\max}}{NIA}$$

Put values. $B = 0.625$ T

(b) Magnetic moment: $M = NIA = 1.3 \times 10^{-7}$ A m^2.

Q5. Two long straight parallel conductors carry steady current I_1 and I_2 separated by a distance d. If the currents are flowing in the same direction, show how the magnetic field set up in one produces an attractive force on the other. Obtain the expression for this force. What happens when currents are antiparallel?

Ans:

[Derivation]: $\frac{F}{l} = \frac{\mu_0 I_1 I_2}{2\pi d}$

Parallel currents attract because the magnetic field produced by one wire exerts a force on the other in the direction of the current, pulling them together.

Worksheet 1

Q1. A circular loop of area 0.05 m^2 carrying a current of 2 A, is held perpendicular to a magnetic field of intensity 10 T. The torque acting on the loop is

(a) zero (b) 1 N-m (c) 10 N-m (d) 0.1 N-m

Ans---------------

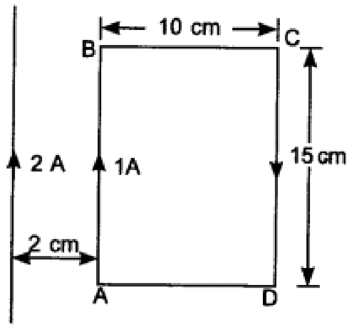
Q2. Assertion (A): The coils of a spring come close to each other, when current is passed through it.

Reason (R): It is because, the coils of a spring carry current in the same direction and hence attract each other.

(a) Both assertion and reason are correct and the reason is the correct explanation of assertion.
(b) Both assertion and reason are correct and reason is not a correct explanation of assertion.
(c) Assertion is correct but the reason is incorrect
(d) Assertion is incorrect but the reason is correct.

Ans: -------------------------

3. What is the net force on the rectangular coil?



(a) 25×10^{-7} N towards wire. (b) 25×10^{-7} N away from wire.
(c) 35×10^{-7} N towards wire. (d) 35×10^{-7} N away from wire

Ans: --------------------------------

Q4. A positive charge enters in a magnetic field and travels parallel to but opposite the field. If experiences
(a) an upward force. (b) a downward force.
(c) an accelerated force. (d) no force.

Ans: ---------------------------------

Q5. An α–particle and a proton are moving in the plane of paper in a region where there is a uniform magnetic field B directed normal to the plane of the paper. If the particles have equal linear momenta, what would be the ratio of the radii of their trajectories in the field? What would the ratio be if they have same speed?

Ans: --

Q6. A wire of length L is bent round in the form of a coil having N turns of same radius. If a steady current I flow through it in a clockwise direction, find the magnitude of the magnetic force exerted on a proton placed at its center, moving along the radius with speed v.

Ans: --

Q7. A proton with kinetic energy 3.4×10^{-15} J moving horizontally from north to south, enters a uniform magnetic field B of 2 mT directed eastward. Calculate:
(a) the speed of the proton
(b) the magnitude of acceleration of the proton
(c) the radius of the path traced by the proton
[Take (q/m) for proton = 1×10^{10} C/kg and mass of proton as 1.7×10^{-27} kg]

Ans: ---

Q8. A moving coil galvanometer is an instrument used to detect and measure small electric currents. It works on the principle that a current-carrying coil placed in a magnetic field experiences a torque. The galvanometer consists of a rectangular coil of thin wire wound on a metallic frame, suspended between the poles of a strong permanent magnet. The magnetic field is made radial using a soft iron core, ensuring that the plane of the coil is always parallel to the field lines, resulting in a uniform torque. When current passes through the coil, it deflects, and this deflection is measured by a pointer attached to the coil and suspended by a spring. The deflection is directly proportional to the current.

(i) A galvanometer shows a deflection of θ for a current I. If the number of turns is quadrupled and the area of the coil is halved, then for the same current the new deflection is:

(a) θ (b) 2θ (c) 0.5θ (d) $\theta/4$

Ans: --

(ii) If a radial magnetic field is not used in a moving coil galvanometer, which of the following best describes the consequence on its working?

(a) The torque becomes independent of current.

(b) The deflection is no longer linearly proportional to current due to variable torque.

(c) The magnetic field becomes zero at certain angles, so the galvanometer stops working.

(d) The coil experiences a constant torque irrespective of orientation.

Ans:---

(iii) The coil of a moving coil galvanometer has an area of 10×10^{-2} m^2. It is suspended in a magnetic field of 2×10^{-2} Wb m^{-2}. If the torsional constant of the suspension fiber is 8×10^{-9} N m deg^{-1}, Number of turns 2, find its current sensitivity in SI units.

(a) 2×10^5 (b) 5×10^5 (b) 1×10^5 (b) 2.5×10^5

Ans: ---

(iv) Which of the following changes would not affect the current sensitivity of a galvanometer?

(a) Increasing number of turns of coil (b) Increasing magnetic field strength

(c) Connecting a resistance across it (d) Increasing torsional constant

Ans: ---

OR

(v) In a moving coil galvanometer, the deflection is proportional to the current because:

(a) Torque is proportional to square of current (b) Magnetic field is constant

(c) Restoring torque is proportional to angular deflection (d) Magnetic field is variable

Ans: --

Q9. (i) Two long straight parallel conductors carry steady current I_1 and I_2 separated by a distance *d*. If the currents are flowing in the same direction, show how the magnetic field set up in one produces an attractive force on the other. Obtain the expression for this force.

(ii) Two identical circular coils *A* and *B*, each of radius *R*, carrying currents $3I$ and $4I$ respectively, are placed concentrically in *XY* and *YZ* planes respectively. Find the magnitude and direction of the net magnetic field at their common centre.

Ans: ---

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Worksheet 2

Q1. Vector form of Biot-savart's law is

a) $d\vec{B} = \frac{\mu_0}{4\pi} i \left(\frac{d\vec{l} \times \vec{r}}{r^3} \right)$

b) $d\vec{B} = \frac{\mu_0}{4\pi} i^2 \left(\frac{d\vec{l} \times \vec{r}}{r} \right)$

c) $d\vec{B} = \frac{\mu_0}{4\pi} i^2 \left(\frac{d\vec{l} \times \vec{r}}{r^2} \right)$

d) $d\vec{B} = \frac{\mu_0}{4\pi} i \left(\frac{d\vec{l} \times \vec{r}}{r} \right)$

Ans: ---------------------------------------

Q2. A current-carrying loop is placed in a uniform magnetic field. The torque acting on it does not depend upon

(a) area of loop
(b) shape of loop
(c) no. of turns in loop
(d) strength of current and magnetic field

Ans --:

Q3. Beams of electrons and protons move parallel to each other in the same direction. They
(a) attract each other.
(b) repel each other.
(c) neither attract nor repel.
(d) force of attraction or repulsion depends upon speed of beams.

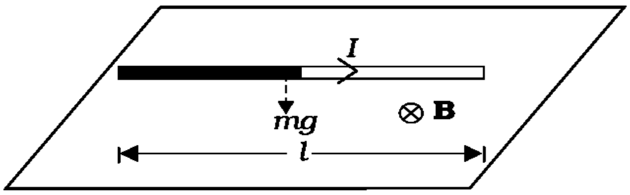
Ans --:

Q4. If in a circular coil *a* of radius *R*, current *I* is flowing and in another coil *b* of radius 4*R*, current 4*I* is flowing, then the ratio of the magnetic field B_a and B_b produced by them will be

(a) 1
(b) 2
(c) $\frac{1}{2}$
(d) 4

Ans: -----------------------------------

Q5. A straight wire of mass 400 g and length 1.5 m carries a current of 2 A. It is suspended in mid-air by a uniform horizontal magnetic field ***B***, as shown in figure. What is the magnitude of the magnetic field?



Ans: --

Q6. Two moving coil meters M_1 and M_2 have the following particulars:

$R_1 = 10\ \Omega$, $N_1 = 30$, $A_1 = 4.6\times10^{-3}\ m^2$, $B_1 = 0.5\ T$

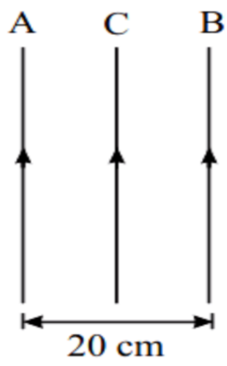
$R_2 = 14\ \Omega$, $N_2 = 42$, $A_2 = 2.3\times10^{-3}\ m^2$, $B_2 = 1$ T

The spring constants are identical for the two meters. Determine the ratio of (i) Current sensitivity and (ii) Voltage sensitivity of M_2 and M_1.

Ans:--

----

7. Two very long, straight, parallel wires *A* and *B* carry currents of 100 A and 200 A respectively, and are at a distance 20 cm apart, as shown in the figure. If a third wire *C* (length 15 cm) having a current of 100 A is placed between them, how much force will act on *C*? The direction of current in all the three wires is same.



Ans:--

Q8. When a charged particle enters a magnetic field with a velocity perpendicular to the field, it experiences a magnetic force given by Lorentz force: $\vec{F} = q\left(\vec{v}\times\vec{B}\right)$ where *q* is the charge, *v* is the velocity, and *B* is the magnetic field. This force is always perpendicular to the direction of motion, causing the particle to move in a circular path. The magnetic force acts as the centripetal force, and the radius of the circular path is given by:

$r = mv/qB$

where *m* is the mass of the particle.

The particle undergoes uniform circular motion without any change in speed, only in direction. If the velocity has a component parallel to the magnetic field, the path becomes a helix.

(i) A charged particle enters a magnetic field making an angle α with the field. The resulting trajectory is:

(a) Circular for $\alpha = 0°$ (b) Straight for $\alpha = 90°$

(c) Helical for $0 < \alpha < 90°$ (d) Parabolic for any α

(ii) A beam of electrons pass undeflected through crossed *E* and *B* fields. When *E* is switched off, they move:

(a) In an ellipse (b) In a circle (c) In a parabola (d) Along a straight line

(iii) Under a uniform magnetic field, a charged particle describes a circle of radius *R* at speed *v*. The time period *T* of revolution is

(a) Dependent on R and v (b) Independent of R and v

(c) Dependent on R alone (d) Dependent on v alone

(iv) A proton and an electron have identical velocities and enter a magnetic field at 90°. Which experiences greater acceleration?

(a) Electron (b) Proton (c) Both equal (d) Neither charge experiences any acceleration

OR

(v) The scalar product of force $\vec{F}$ acting on particle in a magnetic field $\vec{B}$, and the magnetic field is

(a) 0 (b) FB (c) $2FB$ (d) $FB/2$

Q9. (i) State Biot-Savart's Law.

(ii) Using Biot-Savart law, find an expression for the magnetic field at the axis of a circular coil of N turns, radius R, carrying current I.

(iii) For a coil of radius R and carrying current I, compare the magnitudes of magnetic field at its center and at an axial distance of $\sqrt{3}R$.

Ans:--

--……………….

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ANSWERS WORKSHEET I

1. (a) If the coil is held perpendicular to the magnetic field, the angle between area vector and magnetic field will be zero ($\theta = 0$). Torque on coil = $NIAB\sin\theta$. Since, $\sin 0^\circ = 0$, the torque will be zero as well.

2. (a) Assertion is true as well as reason. Parallel currents attract each other, and therefore the wires will come closer.

3. (a) Use formula for force acting between two parallel wires: $\frac{F}{l} = \frac{\mu_0 I_1 I_2}{2\pi d}$

Force on wire AB: 3×10^{-6} N, towards the wire

Force on wire CD: 0.5×10^{-6} N, away from the wire

Net force = 25×10^{-7} N, towards the wire

4. (d) No force because the angle between velocity and magnetic field will be 180°. So, from

$F = qvB\sin\theta$, the force will be zero.

5. In first case:

$r = p/qB$ Since charge on alpha particle is twice that on proton, $r_\alpha/r_p = ½$

In second case:

$r = mv/qB$ Since m/q for alpha particle is 2 times m/q for proton, $r_\alpha/r_p = 2$

6. $L = N * 2\pi r \rightarrow r = L/2\pi N$

Magnetic field at centre:

$B = \frac{N\mu_0 I}{2r}$. Put value of r. $B = \frac{\mu_0 \pi N^2}{L} I$

Force on proton: $F = evB\sin 90^\circ = \frac{ev\mu_0\pi N^2}{L} I$

7. (a) $K = \frac{1}{2}mv^2 \Rightarrow v = \sqrt{\frac{2K}{m}}$.

Put values to get $v = 2\times10^6$ m/s.

(b) Magnetic force, $F = qvB$. Acceleration, $a = F/m = qvB/m$ Put values to get $a = 4\times10^{13}$ m/s^2

(c) Use $r = mv/qB$ Put values to get $r = 0.1$ m

8. **(i) (b)** : The deflection θ in a galvanometer is directly proportional to the product of the number of turns N and the area of the coil A. If N is quadrupled and A is halved, θ becomes two times.

(ii) (b) : Without a radial magnetic field, θ changes as the coil rotates, making the torque vary non-linearly with current.

(iii) (b) : Current sensitivity = NAB/k. Put given values. Answer: 5×10^5

(iv) (c) : In a moving coil galvanometer, the magnetic torque produced is proportional to the current, and the restoring torque (from the spring) is proportional to the deflection angle. At equilibrium, these torques balance, making deflection directly proportional to current.

(v) (c) : Current sensitivity refers to deflection per unit current. It depends on factors like number of turns, magnetic field, and torsional constant - all internal to the galvanometer. Connecting a resistance affects its use as an ammeter but does not change its intrinsic current sensitivity.

9. (i) **[Derivation of force per unit length acting between two parallel current carrying wires]**

(ii) Magnetic field at centre due to first coil: $\frac{\mu_0 3I}{2R}$, Magnetic field at centre due to second coil: $\frac{\mu_0 4I}{2R}$

Since both magnetic fields are perpendicular, net magnetic field at centre:

$$B_{\text{net}} = \sqrt{\left(\frac{\mu_0 3I}{2R}\right)^2 + \left(\frac{\mu_0 4I}{2R}\right)^2} = \frac{\mu_0 5I}{R}$$

ANSWERS WORKSHEET II:

1. (a) 2. (b) 3. (b) 4. (a)

5. There will be an upward force *F*, of magnitude *ILB* on the wire. For mid-air suspension, this must be balanced by the force due to gravity:

$mg = ILB$ $B = mg/IL$ Put values: $B = 1.3$ T

6. (i) Current sensitivity = NBA/k Ratio of current sensitivity = $\frac{N_2B_2A_2}{N_1B_1A_1} = 1.4$

(ii) Voltage sensitivity = (NBA)/(kR) Ratio of voltage sensitivity = $\frac{N_2B_2A_2R_1}{N_1B_1A_1R_2} = 1$

7. Use formula for force between parallel wires: $\frac{F}{l} = \frac{\mu_0 I_1 I_2}{2\pi d}$ Force on wire *C* due to *A*:

$F = 3.0\times10^{-4}$ N, towards *A* Force on wire *C* due to *B*: $F = 6\times10^{-4}$ N, towards *B*

Net force on *C*: $F_{\text{net}} = 6\times10^{-4} - 3\times10^{-4} = 3\times10^{-4}$, towards *B*

8. (i) (c) : When a charged particle enters a magnetic field at an angle α, its velocity has two components: one parallel and one perpendicular to the field. The perpendicular part causes circular motion, and the parallel part causes linear motion - together forming a helical path

(ii) (b) : When the electric field is turned off, only the magnetic field acts, and the magnetic force causes the electrons to move in a circular path, since magnetic force provides the centripetal force.

(iii) (b) : $T = 2\pi m/qB$

(iv) (a) : Both experience same force. But $a = F/m$, and the mass of electron is less. So, electron experiences more acceleration.

(v) (a) : Angle between *F* and *B* is 90 degrees. So, scalar product is zero.

9. (i) Statement & formula.

(ii) **[Derivation]:** $B = \frac{\mu_0 I R^2}{2\left(x^2 + R^2\right)^{3/2}} +$

(iii) At center: $B = \frac{\mu_0 I}{2R}$ At axial point: $B = \frac{\mu_0 I R^2}{2\left(x^2 + R^2\right)^{3/2}}$. Put $x = \sqrt{3}R$ and solve.

CHAPTER 5
Magnetism and Matter
Formula Sheet

1. Magnetic Dipole Moment (M): $M = m \times 2l$

where: m = pole strength, $2l$ = distance between poles

2. Torque on a Magnetic Dipole: $\tau = M \times B = MB \sin\theta$

Where M = magnetic moment, B = magnetic field, θ = angle between M and B

3. Potential Energy of Magnetic Dipole: $U = -M \cdot B = -MB \cos\theta$

4. Magnetic Field due to a Bar Magnet (Axial Line): $B\_axial = (\mu_0 / 4\pi) \times (2M / r^3)$

5. Magnetic Field due to a Bar Magnet (Equatorial Line): $B\_equatorial = (\mu_0 / 4\pi) \times (M / r^3)$

6. Magnetic Moment of a Current Loop: $M = I \times A$

Where I = current, A = Area of the loop

7. Gauss's Law for Magnetism: $\oint B \cdot dA = 0$

MULTIPLE CHOICE QUESTIONS:

Q1. In a permanent magnet at room temperature

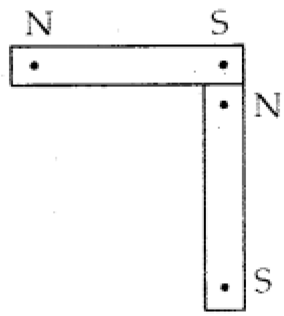
(a) magnetic moment of each molecule is zero.

(b) the individual molecules have non-zero magnetic moment which are all perfectly aligned.

(c) domains are partially aligned.

(d) domains are all perfectly aligned

Q2. Two identical magnets each of dipole moment M and length 2L are perpendicular to each other as shown in figure here. The dipole moment of the combination is



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

Q3. A steel wire of length l has a magnetic moment M. It is the bent into a semicircular arc. The new magnetic moment is:
(a) M/l (b) M (c) $2M/\pi$ (d) Ml

Q4. The magnetic fields strength at a distance d from a short bar magnet in longitudinal and transverse positions are in the ratio.
(a) 2 : 1 (b) 1 : 2 (c) 1 : 1 (d) 3 : 2

Q5. The lines of force due to earth's horizontal magnetic field are:
(a) Curved lines (b) elliptical (c) Parallel and straight (d) concentric circles

Q6. A uniform magnetic field is obtained in a

(a) bar magnet (b) horse shoe magnet
(c) circular coil carrying current (d) None of these.

Q7. At Curie point, ferromagnetic material becomes

(a) Diamagnetic (b) Paramagnetic (c) Strongly ferromagnetic (d) non-magnetic

Q8. Relative permeability (μ_r) of a material has a value lying $1 < \mu_r < 1 + \varepsilon$ (where ε is a small quantity). Nature of the magnetic material is

(a) Diamagnetic (b) Paramagnetic (c) non-magnetic (d) None of these

Q9. A circular coil of *N* turns and radius *R* carries a current *I*. It is unwound and rewound to make another coil of radius *R*/2, current *I* remaining the same. Calculate the ratio of the magnetic moments of the new coil and the original coil.

(a)1/2 (b) 2 (c)1/4 (d) 4

Q10. Intensity of magnetic field at 20 cm from its center on axial line is *B*. Intensity of magnetic field at 10 cm from its center on equatorial line will be

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

Answers:

1. (d) **2.** (a) $M_{net} = \sqrt{(M_1{}^2 + M_2{}^2)} = \sqrt{2}$ M **3.** (c)

When the wire is bent into a semicircular arc, length of wire = $\pi R \Rightarrow R = l / \pi$.

Distance between two poles of semicircle = $2R = 2l/\pi$

New magnetic moment, $M' = m \times 2R = \frac{2}{\pi} ml$

Since original magnetic moment $M = ml$, $M' = \frac{2}{\pi} M$.

4. (a) Magnetic field on axial line (longitudinal position):

$B_1 = (\mu_0/4\pi)\times(2M/d^3)$

Magnetic field on equatorial line (transverse position):

$B_2 = (\mu_0/4\pi)\times(M/d^3)$

$\Rightarrow B_1 / B_2 = 2/1$

5. (a) **6.** (c) **7.** (a) **8.** (b) **9.** (a) **10.** (b)

ASSERTION REASON(1MARKS):

The questions below are Assertion (A) and Reason (R) type questions. Two statements are given one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer from the codes (a), (b), (c) and (d) as given below.

(e) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).
(f) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A).
(g) Assertion (A) is true, but Reason (R) is false.
(h) Assertion (A) is false and Reason (R) is also false.

Q1. Assertion : The poles of a magnet can never be separated.

Reason : Each molecule of a substance is itself a magnet

Q2. Assertion : The flux of magnetic field through any closed surface is always zero.

Reason : Magnetic monopoles do exist.

Q3. Assertion: When the interior of a solenoid is filled with a magnetic filled with a magnetic material, the field inside the solenoid becomes greater than magnetizing field.

Reason: Then total magnetic field inside is the sum of the external magnetizing field and the additional magnetic field produced due to magnetization of the material.

Q4. Assertion (A): When a bar magnet is cut into two equal halves perpendicular to its length, each part behaves like a magnet with a north and south pole.
Reason (R): Magnetic poles always exist in pairs.

Q5. Assertion (A): In ferromagnetic materials, the magnetic susceptibility is large and positive.
Reason (R): The domains in ferromagnetic materials are randomly oriented.

Answers:

1. (a) **2.** (c) **3.** (a) **4.** (a) **5.** (c)

VERY SHORT ANSWER QUESTIONS (2 marks)

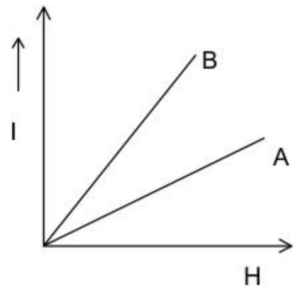
Q1. What should be the orientation of magnetic dipole in uniform magnetic field so that potential energy is (i) minimum (ii) maximum ?

Ans: PE = − MB Cos θ (i) 0^0 (ii) 180^0

Q2. How does the (i) Pole strength and (ii) Magnetic moment of each part of a magnet change if it is cut into two equal pieces transverse to its length?

Ans: (i) Pole strength remain same (ii) Since length will be half, therefore.

$M' = M/2$



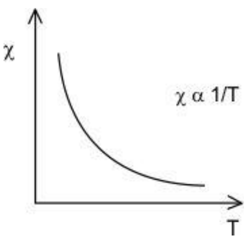
Q3. Figure shows the variation of intensity of magnetization versus the applied magnet field *H* for two magnetic materials *A* & *B*

(i) Identify the materials *A* and *B*.

(ii) Predict the variation of susceptibility with temperature for the material *A*.

Ans: i) A → paramagnetic, B → Ferromagnetic

(ii)



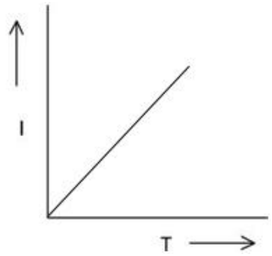
Q4. How does the intensity of magnetization of paramagnetic sample vary with temperature in case of (i) paramagnetic substance (ii) Diamagnetic substance.

Ans: (i) In paramagnetic substance *I* reduces with increase in temperature (ii) In diamagnetic substance, no change.

Q5. Relative permeability (μ_r) of a material has a value lying $1 < \mu_r < 1 + \varepsilon$ (where ε is a small quantity) (i) Identify the nature of the magnetic material. (ii) Draw the graph between Intensity of magnetization and temperature for the material.

Ans: 5 (i) Para magnetic substance

(ii)



Q6. A short bar magnet has a magnetic moment of 0.48 J T^{-1}. Give the direction and magnitude of the magnetic field produced by the magnet at a distance of 10 cm from the centre of the magnet on (a) the axis (b) the equatorial lines (normal bisector) of the magnet.
Ans: (a) On the axial line:

Magnetic field, $B = \frac{\mu_0}{4\pi}\left(\frac{2M}{r^3}\right)$. Put values to get $B = 0.96 \times 10^{-4}$ T.

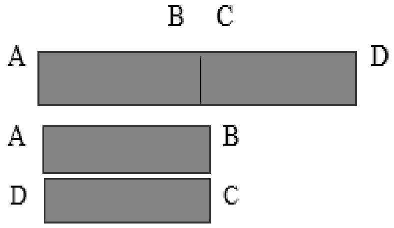
Direction: Along the axis and away from the north pole of the magnet.

(b) On the equatorial line:

Magnetic field, $B = \frac{\mu_0}{4\pi}\left(\frac{M}{r^3}\right)$. Put values to get $B = 0.48 \times 10^{-4}$ T.

Direction: Perpendicular to the magnet axis, from north to south pole.
Q7. The magnetic susceptibility of magnesium at 300 K is 1.2 x 10^5 . At what temperature will its magnetic susceptibility become 1.44 x 10^5 .

Ans: From Curie's Law: $\chi \propto 1/T$. So,
$\chi_1 / \chi_2 = T_2 / T_1$ => $(1.2 \times 10^{-5})/(1.44 \times 10^{-5}) = T_2/300$ => $5/6 = T_2/300$ => $T_2 = 300\times(5 / 6) = 250$ K
∴ Required temperature = 250 K
Q8. Hypothetical bar magnet *AD* is cut into two equal parts . One part is now kept over the other so that the pole C_2 is above C_1. If *M* is magnetic moment of the original magnet what would be the magnetic moment of the combination so formed.



Ans: When a bar magnet is cut into two equal parts, each part has half the magnetic moment. So, magnetic moment of each part = M/2
When they are placed such that C_2 is over C_1, i.e., in the same direction,
Net magnetic moment = $M/2 + M/2 = M$

Q9. A bar magnetic moment M is aligned parallel to the direction of a uniform magnetic field 'B' . What is work done to turn the magnet, so as to align its magnetic moment?

(i) Opposite to the field direction and

(ii) Normal to the field direction.

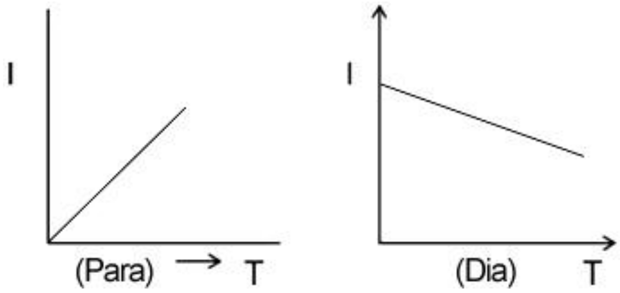
Ans: Given θ = 0 and (i) θ_1=180º , (ii) θ_2 = 90º

(i) $W_{0\to180} = MB(\cos\theta_1 - \cos\theta_2) = MB(\cos 0 - \cos 180) = 2MB$

(ii) Similarly, $W_{0\to90} = MB$

Q10 . Show the graphical variation of intensity of magnetization with applied magnetic field for para and diamagnetic material?

Ans:



SHORT ANSWER QUESTIONS (3 marks)

Q1. Among Bismuth and Aluminium distinguish in following three points: (i) Relative permeability (ii) Susceptibility & (iii) Curie's law

Ans:

Bismuth	Aluminium
1. Relative permeability slightly less than 1 2. $-1 <$ Susceptibility < 0 3. Does not follow Curie law	1. Relative permeability slightly greater than 1 2. $0 <$ Susceptibility < 1 3. It follows Curie law.

Q2. A coil of '*N*' turns and radius '*R'* carries a current '*I*'. It is unwound and rewound to make a square coil of side 'a' having same number of turns (*N*). Keeping the current '*I'* same, find the ratio of the magnetic moments of the square coil and the circular coil.

Ans: Magnetic moment (*M*) of a coil is given by: $M = NIA$

For the circular coil: Area $A_1 = \pi R^2$

Magnetic moment: $M_1 = NI\pi R^2$

For the square coil: Length of the wire = Circumference of the circular coil = $2\pi R$

Each side of the square = a, so perimeter = $4a$

Equating the wire lengths: $2\pi R = 4a \Rightarrow a = \pi R / 2$

Area $A_2 = a^2 = (\pi R / 2)^2 = \pi^2 R^2 / 4$

Magnetic moment: $M_2 = NI(\pi^2 R^2/4)$

Now, the ratio of magnetic moments: $M_2 / M_1 = \pi / 4$

Q3. A short bar magnet which is placed with its axis at 30º experiences a torque of 0.016 N m in an external field of 800G.

(i) Determine the magnetic moment of magnet.
(ii) What is work done by an external force is moving it from its most stable to most unstable position.

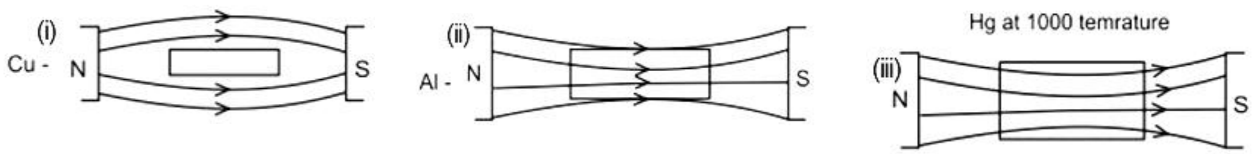
Ans: Given $\theta = 30^o$, $\tau = 0.016$Nm. $B = 800 \times 10^{-4}$ T

(i) $\tau = MB\sin\theta \Rightarrow M = \frac{\tau}{B\sin\theta} = 0.4 \text{ Am}^2$

(ii) $W_{\theta=0\to\theta=180} = MB(\cos\theta_1 - \cos\theta_2) = 2MB = 0.032$ J

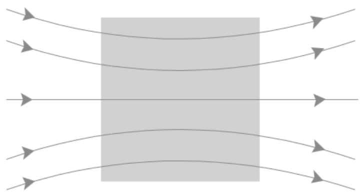
Q4. Draw a diagrams to show the behavior of magnetic field lines near a 'bar' of (i) copper (ii) Aluminum and (iii) mercury cooled to a very low temperature

Ans:



Q5. (i) An iron ring of relative permeability μ_r has windings of insulated copper wire of n turns per metre. When the current in the windings is I, find the expression for the magnetic field in the ring.

(ii) The susceptibility of a magnetic material is 0.9853. Identify the type of magnetic material. Draw the modification of the field pattern on keeping a piece of this material in a uniform magnetic field.



Ans: (i) The magnetic field strength H inside the ring is given by: $H = nI$ ∴

The magnetic field B in the ring is: $B = \mu H = \mu_0\mu_r nI$

Magnetic field in the ring: $B = \mu_0\mu_r nI$

(ii) Since $\chi > 0$ and close to 1, the material is ferromagnetic.

Ferromagnetic materials have high susceptibility and show strong attraction towards magnetic fields.

Q6. (i) State Gauss's law for magnetism. Explain its significance.

(ii) Write the four important properties of the magnetic field lines due to a bar magnet.

Ans: (i) Gauss's law for magnetism states that "The total flux of the magnetic field, through any closed surface, is always zero." This law implies that magnetic monopoles do not exist. Also magnetic field lines form closed loops.
(ii) Four properties of magnetic field lines
(a) Magnetic field lines always form continuous closed loops.
(b) The tangent to the magnetic field line at a given point represents the direction of the net magnetic field at that point.

(c) The larger the number of field lines crossing per unit area, the stronger is the magnitude of the magnetic field.
(d) Magnetic field lines do not intersect.

CASE BASED QUESTION (4 Marks)

Q1. **Ferromagnetism:** In the absence of an external magnetic field, some of the electrons in a ferromagnetic material have their magnetic dipole moments aligned by means of a quantum physical interaction called exchange coupling, producing regions (domains) within the material with strong magnetic dipole moments. An external field $\boldsymbol{B}_{ext}$ can align the magnetic dipole moment of those regions, producing a strong net magnetic dipole moment for the material as a whole, in the direction of $\boldsymbol{B}_{ext}$. This net magnetic dipole moment can partially persist when field $\boldsymbol{B}_{ext}$ is removed. If $\boldsymbol{B}_{ext}$ is non-uniform, the ferromagnetic material is attracted to region of greater magnetic field. These properties are called ferromagnetism. Exchange coupling disappears when a sample's temperature exceeds its Curie temperature, and then the sample has only paramagnetism.

(i) Susceptibility is positive and small for

(a) paramagnetic substances (b) ferromagnetic substances

(c) non-magnetic substances (d) diamagnetic substances

(ii) The primary origin(s) of magnetism lies in

(a) atomic currents (b) Pauli exclusion principle

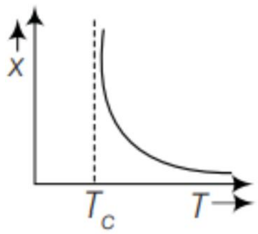
(c) intrinsic spin of electron (d) Both (a) and (c)

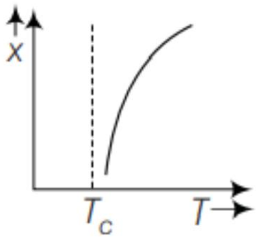
(iii) If the magnetizing field on a ferromagnetic material is increased, its permeability

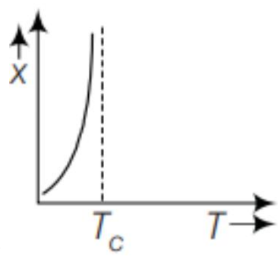
(a) is decreased (b) is increased

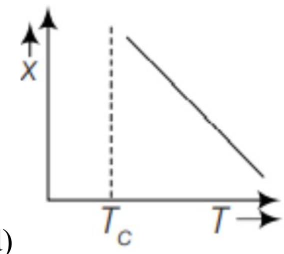
(c) is unaffected (d) may be increased or decreased

(iv) The variation of magnetic susceptibility with the temperature of a ferromagnetic material can be plotted as

(a) 



(b) (c) 

(d) 

OR

(v) If bar magnet of pole strength m and magnetic moment M is cut equally in five parts parallel to its axis and again four equal parts perpendicular to its axis then the pole strength and magnetic moments of each piece are, respectively,

(a) $m/20$, $m/20$ (b) $m/4$, $M/20$ (c) $m/5$, $M/20$ (d) $m/5$, $M/4$

Ans: (i) (a) (ii) (d) (iii) (a) (iv) (b) (v) (c)

WORKSHEET-1

Multiple Choice Questions:

Q1. Magnetism in substances is caused by

(a) orbital motion of electrons only (b)spin motion of electrons only

(c)due to spin and orbital motions of electrons both (d) hidden magnets

Q2. A magnetic needle is kept in a uniform magnetic field. It experiences

(a) a force and a torque (b) a force but not a torque

(c) a torque but not a force (d) neither a torque nor a force

Q3. In a permanent magnet at room temperature

(a) magnetic moment of each molecule is zero.

(b) the individual molecules have non-zero magnetic moment which are all perfectly aligned.

(c) domains are partially aligned.

(d) domains are all perfectly aligned

Q4. Points A and B are situated perpendicular to the axis of a 2 cm long bar magnet at large distances x and $3x$ from its centre on opposite sides. The ratio of the magnetic fields at A and B will be approximately equal to

(*a*) 1: 9 (*b*) 2: 9 (*c*) 27: 1 (*d*) 9: 1

Q5. The meniscus of a liquid contained in one of the limbs of a narrow U-tube is placed between the pole-pieces of an electromagnet with the meniscus in a line with the field. When the electromagnet is switched on, the liquid is seen to rise in the limb. This indicates that the liquid is

(a) ferromagnetic (*b*) paramagnetic (*c*) diamagnetic (*d*) non-magnetic

2 Marks questions:

Q6. The susceptibility of a magnetic material is -2.6×10^{-5}. Identify the type of magnetic material and state its two properties

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Q7. How does the (i) pole strength and (ii) magnetic moment of each part of a bar magnet change if it is cut into two equal pieces transverse to length?

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Q8. A bar magnet has a magnetic moment of 0.3 Am^2. What torque must act to hold it at 30° to a uniform magnetic field of 0.2 T?

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Q9. A magnetic dipole is placed at an angle of 60° to a magnetic field of strength 0.3 T. If it experiences a torque of 0.12 Nm, find its magnetic moment.

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Q10. A solenoid of 1000 turns per metre carries a current of 2 A. Find the magnetizing field H and the magnetic field B inside it (assume vacuum).

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3 Marks Questions

Q11. Two bar magnets have magnetic moments in the ratio 1:2 and axial field strengths in the ratio 1:x. Find the value of x.

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Q12. A magnetic dipole of moment 0.6 Am^2 is placed in a uniform magnetic field of 0.4 T. Find the potential energy of the dipole when the angle between the field and the dipole is (i) 0°, (ii) 90°, (iii) 180°.

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Q13. A paramagnetic material has a magnetic susceptibility of 0.0015 at 300 K. Using Curie's law, find its susceptibility at 500 K.

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Q14. Among Diamagnetic and paramagnetic distinguish in following three points:

(i) Relative permeability (ii) Susceptibility (iii) Curie law

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ANSWERS:

1. (c) 2. (c) 3. (c) 4. (c) 5. (b) paramagnetic

6. The magnetic material having negative susceptibility is diamagnetic in nature.

Properties:

(i) This material has + ve but low relative permeability.

(ii) They have the tendency to move from stronger to weaker part of the external magnetic field.

7. When a bar magnet of magnetic moment $(M = m2l)$ is cut into two equal pieces transverse to its length,

(i) the pole strength remains unchanged (since pole strength depends on number of atoms in cross-sectional area).

(ii) the magnetic moment is reduced to half (since M μ length and here length is halved).

8. 0.03 Nm

9. 0.46 Am^2

10. $H = 2000$ A/m, $B = 2.51 \times 10^{-3}$ T

11. $B \propto M / r^3 \Rightarrow B \propto M$, So ratio of field = 1:2 ⇒ x = 2

12. (i) $U = -MB \cos(0°) = -0.6 \times 0.4 \times 1 = -0.24$ J
(ii) $U = -MB \cos(90°) = 0$
(iii) $U = -MB \cos(180°) = +0.24$ J

13. $\chi \propto 1/T \Rightarrow \chi_2 = \chi_1 \times (T_1 / T_2) = 0.0015 \times (300 / 500) = 0.0009$

14.

Diamagnetic substance	Paramagnetic substance
Relative permeability slightly less than 1 -1 < Susceptibility < 0 Does not follow Curie law	Relative permeability slightly greater than 1 0 < Susceptibility < 1 It follows Curie law.

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CHAPTER 6

ELECTROMAGNETIC INDUCTION

IMPORTANT FORMULAS

S NO	PHYSICAL QUANTITY/ TOPIC	FORMULA
1.	Faraday' law	$e = -N\frac{d\emptyset}{dt}$
2.	Magnetic flux	$\emptyset = \vec{B}.\vec{A}$
3.	Motional emf	$e = Blv$
4.	Inductance	$\emptyset = LI \text{ or } L = \frac{\emptyset}{I}$ $e = -L\frac{dI}{dt} \text{or } L = -\frac{e}{\frac{dI}{dt}}$
5.	Self-Inductance L of a solenoid with air core	$L = \mu_0 N^2 A/l$
6.	Self-Inductance L of a solenoid with medium other than air as core	$L = \mu_r \mu_0 N^2 A/l$ μ_r *is relative vpermeability of medium of core*
7.	Mutual Inductance M of pair of coils with air core	$M = \mu_0 N_1 N_2 A/l$
8.	Mutual Inductance M of pair of coils with medium other than air as core	$M = \mu_r \mu_0 N_1 N_2 A/l$ μ_r *is relative vpermeability of medium of core*
9.	Energy stored in an Inductor	$U = \frac{1}{2}LI^2$
10.	Energy density of solenoid	$u = \frac{1}{2\mu_0}B^2$
11.	A C Generator	Emf induced $e = e_0 sin\omega t$ $e_0 = NAB\omega$

MULTIPLE CHOICE QUESTIONS(Mark1):

Q1. A coil having 500 square loops of side 10 cm is placed normal to magnetic flux which increases at a rate of T/s. The induced emf is

(a) 0.1 V (b) 0.5 V (c) 1 V (d) 5 V

Q2. The current flows from A to B is as shown in the figure. The direction of the induced current in the loop is

(a) clockwise (b) anticlockwise (c) straight line (d) no induced current is produced

Q3. Which of the following statements is not correct?

(a) Whenever the amount of magnetic flux linked with a circuit changes, an emf is induced in circuit.

(b) The induced emf lasts so long as the change in magnetic flux continues.

(c) The direction of induced emf is given by Lenz's law.

(d) Lenz's law is a consequence of the law of conservation of Charge.

Q4. There is a uniform magnetic field directed perpendicular and into the plane of the paper. An irregular shaped conducting loop is slowly changing into a circular loop in the plane of the paper. Then

(a) current is induced in the loop in the anti-clockwise direction.

(b) current is induced in the loop in the clockwise direction.

(c) AC is induced in the loop.

(d) No current is induced in the loop.

Q5. If number of turns in primary and secondary coils is increased to two times each, the mutual inductance

(a) becomes 4 times (b) becomes 2 times

(c) becomes A times (d) remains unchanged 4

Q6. If number of turns per unit length of a coil of a solenoid is doubled its self inductance will

(a) remains constant (b) be doubled (c) be halved (d) be four times

Q7. A solenoid is connected to a battery so that a steady current flows through it. If an iron core is inserted into the solenoid, the current will

(a) increase (b) decrease (c) remain same (d) first increase then decrease

Q8. Energy in a current carrying coil is stored in the form of

(a) Electric field (b) magnetic field (c) dielectric strength (d) heat

Q9. A 100 mH coil carries a current of 1 A energy stored in its magnetic field is

(a) 0.5 J (b) 1 J (c) 0.05 J (d) 0.1 J

Q10. A coil of wire of certain radius has 600 turns and a self inductance of 108 mH. The self inductance of a similar coil of 500 turns will be

(a) 74 mH (b) 75 mH (c) 76 mH (d) 77 mH

Answers:

1. (d) (Emf $\varepsilon = NA\frac{dB}{dt}$)

2. (a) **3.** (d) **4.** (a) **5.** (a) **6.** (d) **7.** (b)

8. (b) **9.** (c) ($U = 0.5LI^2$) **10.** (b) [$L_2/L_1 = (N_2/N_1)^2$]

ASSERTION AND REASON(Marks1):

Each question has 4 choices (a), (b), (c) and (d) out of which ONLY ONE is correct. So select the correct choice. Choices are:

(a) ASSERTION is True, REASON is True; & REASON is a correct explanation for ASSERTION.

(b) ASSERTION is True, REASON is True; & REASON is NOT a correct explanation for ASSERTION.

(c) ASSERTION is True, but REASON is False.

(d) ASSERTION is False, and REASON is also False.

Q1. ASSERTION: The induced current flows so as to oppose the cause producing it.

REASON: Lenz's law is based on energy conservation.

Q2. ASSERTION: When the magnetic flux through a loop is maximum, induced emf is maximum.

REASON: When the magnetic flux through a loop is minimum, induced emf is minimum.

Q3. ASSERTION: An inductor acts as perfect conductor for DC.

REASON: DC remains constant in magnitude and direction.

Q4. ASSERTION: Magnetic flux is given by ϕ = Li = (product of the self-inductance and current).

REASON: When current is increased; self-inductance increases.

Q5. ASSERTION: The induced emf in a conducting loop of wire may not be zero when it rotates in a uniform magnetic field.

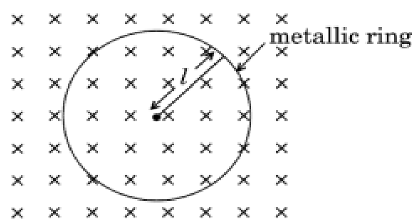
REASON: The emf must be induced due to change in magnetic field.

Answers:

1. (a) 2. (d) 3. (a) 4. (c) 5. (a)

VERY SHORT ANSWER QUESTIONS (2 Marks)

Q1. A metallic rod of length L is rotated with angular frequency of ω with one end hinged at the centre and the other end at the circumference of a circular metallic ring of radius L about an axis passing through the centre and perpendicular to the plane of the ring. A constant and uniform magnetic field B parallel to the axis is presents everywhere. Deduce the expression for the emf between the centre and the metallic ring.

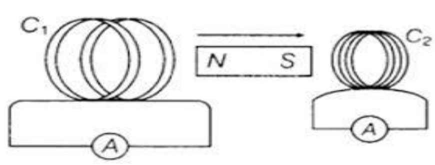


Ans: The motive force (emf) induced is:

$d\varepsilon = (\vec{v} \times \vec{B}) \cdot \vec{dl}$

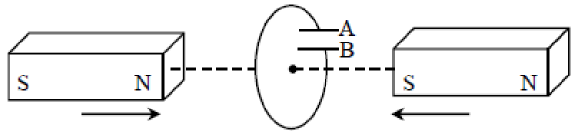
$\varepsilon = \int_0^l B\omega r dr = B\omega \int_0^l r dr = B\omega \left[\frac{r^2}{2}\right]_0^l = \frac{1}{2} B\omega l^2$

Q2. A magnet is quickly moved in the direction indicated by an arrow between two coils C_1 and C_2 as shown in the figure. What will be the direction of induced current in each coil as seen from the magnet? Justify your answer.



Ans: Large deflection obtained when change in magnetic flux is fast. Deflection in Ammeter is clockwise.

Q3. Predict the polarity of the capacitor in the situation described by adjoining figure. Explain the reason too.



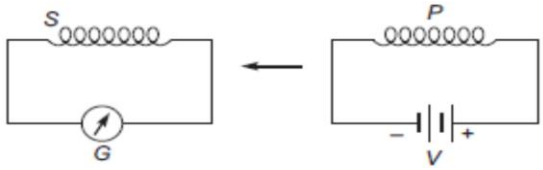
Ans: Induced current is clockwise hence plate *A* acquire positive and *B* is negative**.**

Q4. Two identical loops one of copper and the other of aluminium are rotated with the same angular speed in the same magnetic field. Compare (i) the induced emf and (ii) The current produced in the two coils. Justify your answer.

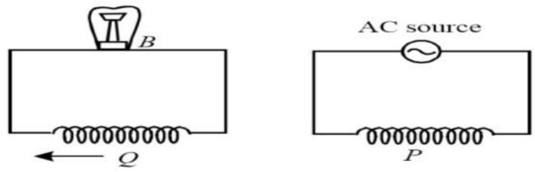
Ans: (i) EMF in the both loops will be same from Faraday's law.

(ii) Induced current in the copper coil is more as its resistance is less, as $I = \varepsilon/R$

Q5. (i) When primary coil P is moved towards secondary coil S (as shown in figure below) the galvanometer shows momentary deflection. What can be done to have larger deflection in the galvanometer with the same battery? (ii) State the related law.



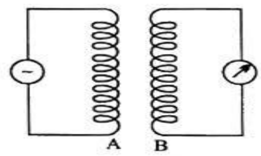
Ans: (i) The coil *P* should be moved quickly towards or away from the coil *S*.
(ii) Statement of Faraday's law.
Q6. A coil *Q* is connected to low voltage bulb *B* and placed near another coil *P* as shown in the figure. Give reasons to explain the following observations (i) The bulb *B* lights (ii) Bulb gets dimmer if the coil *Q* is moved towards left.



Ans: (i) The bulb B lights due to induced current in coil *Q* because of change in magnetic flux linked with it on a consequence of continuous variation of magnitude of alternating current flowing in *P*.

(ii) When coil *Q* moves towards left the rate of change of magnetic flux linked with *Q* decreases and so lesser current is induced in *Q*.

Q7. The circuit arrangement given below shows that when an AC passes through the coil *A*, the current starts flowing in the coil *B*. (i) State the underlying principle involved. (ii) Mention two factors on which the current produced in the coil *B* depends.



Ans: (i) Mutual Induction.
(ii) Coefficient of mutual inductance, current in coil *A* and resistance of coil *B*.

Q8. A rectangular coil of area *A* having number of turns *N* is rotated at *f* revolutions per second in a uniform magnetic field *B,* the field being perpendicular to the coil. Prove that the maximum emf induced in the coil is $2\pi fNBA$.

Ans: Magnetic flux passing through the coil, $\phi = BA\ cos\omega t$

EMF setup in the coil ε = $\frac{-d\phi}{dt} = \frac{-d}{dt}(BAcos\omega t) = BA\omega sin(\omega t)$,

For no. of turns '*N*' and $\omega t = 90^o$, $\varepsilon = NBA2\pi f$

Q9. Current in a circuit falls steadily from 2 A to 0 A in 10 ms. If an average emf of 200 V is induced, calculate the self-inductance of the circuit.

Ans: $E = -L\frac{\Delta I}{\Delta t} \Rightarrow L = \frac{E}{\Delta I/\Delta t}$

Put values to get *L* = 1 H

Q10. (i) The flux linked with a large circular coil of radius *R* is 0.5×10^{-3} Wb. When a current of 0.5 A flows through a small neighboring coil of radius *r*, calculate the coefficient of mutual inductance for the given pair of coils. (ii) If the current through the small coil suddenly falls to zero, what would be its effect in the larger coil?

Ans: (i) $\phi = MI \Rightarrow M = \frac{\phi}{I} = \frac{0.5\times10^{-3}}{0.5} = 10^{-3}$ H.

(ii) Produces large induced emf in it.

SHORT ANSWER QUESTIONS (3 Marks)

Q1. (i) State faraday's law of electromagnetic induction.

(ii) A jet plane is travelling towards west at a speed of 1800 km/h. What is the voltage difference developed between the ends of the wing having a span of 25 m, if the earth's magnetic field at the location has magnitude of 5×10^{-4} T and the dip angle is 30º ?

Ans: (i) Statement of Faraday's law.

(ii) $B_V = B_o \sin\delta = 2.5\times10^{-4}$ T

$\varepsilon = B_V v l$ =3.125 V

Q2. Define self- inductance coefficient. A coil of number of turns *N* area *A* is rotated at a constant speed ω in a uniform magnetic field *B* and connected to a resistor *R*. Deduce expressions for (i) maximum emf induced in the coil (ii) power dissipation in the coil.

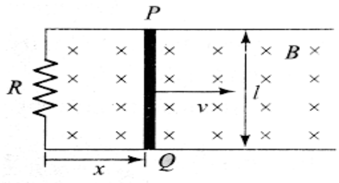
Ans: (i) Magnetic Flux passing through the coil: $\phi = NBA\ cos\omega t$

EMF setup in the coil ε = $\frac{-d\phi}{dt} = \frac{-d}{dt}(NBAcos\omega t) = NBA\omega sin\omega t$

For maximum emf $\omega t = 90^o \Rightarrow \varepsilon_0 = NBA\omega$.

(ii) $P = \frac{\varepsilon_{rms}{}^2}{R} = \frac{\varepsilon_o{}^2}{2R} = (N^2B^2A^2\omega^2)/2R$

Q3. A conducting rod *PQ* of length *l* connected to a resistor *R* is moved at a uniform speed *v* normal to a uniform magnetic field *B* as shown in the figure. (i) Deduce the expression for the emf induced in the conductor. (ii) Find the force required to move the rod in the magnetic field. (iii) Mark the direction of induced current in the conductor.

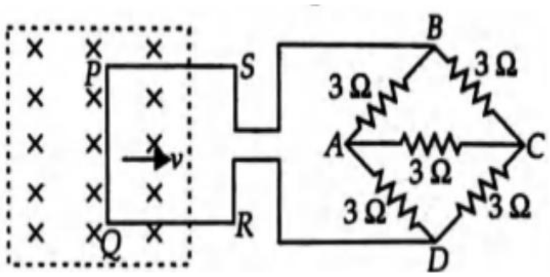


Ans: (i) $\varepsilon = \frac{d\phi}{dt} = Blv$

(ii) $I = \frac{\varepsilon}{R} = \frac{Bvl}{R} \Rightarrow F = BIl = (B^2l^2v)/R$

(iii) From *Q* to *P*

Q4. A metallic square loop PQRS of size 10 cm and resistance 1 Ω is moved at a uniform velocity of *v* m/s in a uniform magnetic field of 2 T the field lines being normal to the plane of paper. The loop is connected to an electrical network of resistors each of resistance 3 Ω. Calculate the speed of the loop for which 1 mA current flows in the loop.



Ans: As network ABCD is a balanced Wheatstone bridge. So, effective resistance of bridge is

$\frac{1}{R'} = \frac{1}{6} + \frac{1}{6} = \frac{1}{3} \Rightarrow R' = 3\ \Omega$

Total resistance, R = 1 + 3 = 4 Ω

Induced emf, $\varepsilon = Blv$

Induced current, $I = \varepsilon/R = Blv/R \Rightarrow v = \frac{IR}{Bl}$

Substitute the values. $v = 2 \times 10^{-2}$ m/s

Q5. (i) Define self- inductance. Write its SI units. (ii) Derive an expression for self –inductance of a long solenoid of length *l* cross-sectional area *A* having *N* number of turns.

Ans: (i) Self-inductance is the property of a coil (or circuit) by virtue of which it opposes any change in the current flowing through it by inducing an emf in itself. SI unit is henry.

(ii) Magnetic field inside a long solenoid $B = \mu_o nI = \mu_o \frac{N}{l} I$

Magnetic flux through one turn $\phi = BA = \mu_o \frac{N}{l} I\, A$

Total flux linkage for all N turns $\Phi = N\phi = \mu_o \frac{N^2}{l}\, A\, I$

So, $L = \frac{\emptyset}{I} = \mu_o A \frac{N^2}{l}$

Q6. Define the coefficient of mutual inductance. A long solenoid of length l and radius r_1 is enclosed coaxially within another long solenoid of length l and radius r_2 ($r_2 > r_1$ and $l \gg r_2$). Deduce the expression for the mutual inductance of this pair of solenoids.

Ans: The coefficient of mutual inductance (or simply mutual inductance) between two coils is defined as the measure of the ability of one coil to induce an emf in another nearby coil due to a change in current in the first coil.

The magnetic field inside a long solenoid is uniform and given by: $B_1 = \mu_0 n_1 I_1$

Flux linkage with the outer solenoid: $\phi = B_1 \pi r_1^2 = \mu_0 n_1 I_1 \cdot \pi r_1^2$

Total flux linkage with outer solenoid: $\Phi = N_2 \phi$

$\Rightarrow M = (\mu_o N_1 N_2 R^2{}_1)/\, 2r_2$

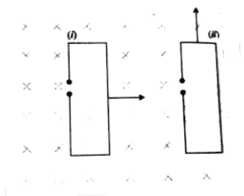
Q7. The magnetic flux through a coil perpendicular to the plane is varying according to the relation $\phi = (5t^3 + 4t^2 + 2t - 5)$ weber. Find the current through the coil at $t = 2$ seconds if the resistance of the coil is 5 Ω.

Ans: $\varepsilon = \frac{d\emptyset}{dt} = 15t^2 + 8t + 2$

At $t = 2$ seconds, $\varepsilon = 15(2)^2 + 8(2) + 2 = 15\times4 + 16 + 2 = 78$ V

$I = \frac{e}{R} = 15.6$ A

8. A rectangular wire loop of sides 8 cm and 2 cm with a small cut is moving out of a region of uniform magnetic field of 0.3 T directed normal to the loop.



(i) What is the emf developed across the cut if the velocity of the loop is 1 cms^{-1} in a direction normal to the (a) Shorter side (b) Longer side of the loop?

(ii) For how long does the induced voltage last in each case.

Ans: (a) Longer side: $\varepsilon = Blv = 2.4 \times 10^{-4}$ V $\quad T = \frac{b}{v} = 2$ seconds

(b) Shorter side: $\varepsilon = 0.6\times 10^{-4}$ V $\quad T = \frac{l}{v} = 8$ seconds

CASE STUDY BASED QUESTION (4 Marks)

Q1. Electromagnetic induction is defined as the production of an electromotive force across an electric conductor in the changing magnetic field. The discovery of induction was done by Michael Faraday in the year 1831. Electromagnetic induction finds many applications such as in electrical components which includes transformers, inductors, and other devices such as electric motors and generators. An inductor is a passive component that is used in most power electronic circuits to store energy in the form of magnetic energy when electricity is applied to it. When a current begins to flow through a coil of wire, it undergoes an opposition to its flow in addition to the resistance of the metal wire. On the other hand, when an electric circuit carrying a steady current and containing a coil is suddenly opened, the collapsing, and hence diminishing, magnetic field causes an induced electromotive force that tends to maintain the current and the magnetic field and may cause a spark between the contacts of the switch.

(i) How to increase the energy stored in an inductor by four times?

(a) By doubling the current (b) This is not possible

(c) By doubling the inductance (d) By making current √2 times

(ii) Consider an inductor whose linear dimensions are tripled and the total number of turns per unit length is kept constant, what happens to the self-inductance?

(a) 9 times (b) 3 times (c) 27 times (d) 13 times

(iii) What will be the acceleration of the falling bar magnet which passes through the ring such that the ring is held horizontally and the bar magnet is dropped along the axis of the ring?

(a) It depends on the diameter of the ring and the length of the magnet

(b) It is equal to acceleration due to gravity

(c) It is less than acceleration due to gravity

(d) It is more than acceleration due to gravity

(iv) Which of the following statements is correct for a current carrying infinitely long wire kept along the diameter of a circular wire loop without touching it.

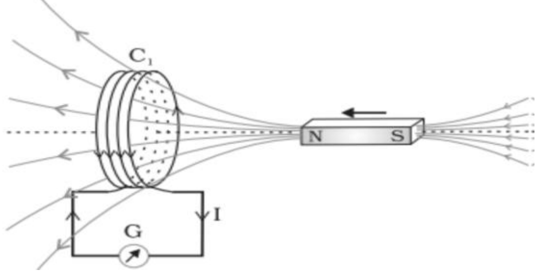
(a) The emf induced in the loop is zero if the current is constant

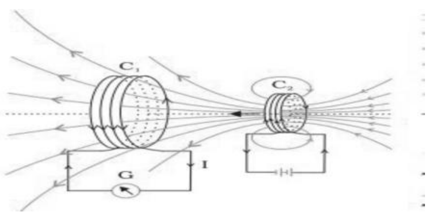
(b) The emf induced in the loop is finite if the current is constant

(c) The emf induced in the loop is finite if the current decreases at a steady rate

(d) The emf induced in the loop is finite if the current increases at a steady rate.

Q2. A coil C_1 connected to a galvanometer G. When the North-pole of a bar magnet is pushed towards the coil, the pointer in the galvanometer deflects, indicating the presence of electric current in the coil. The deflection lasts as long as the bar magnet is in motion. The galvanometer does not show any deflection when the magnet is held stationary. When the magnet is pulled away from the coil, the galvanometer shows deflection in the opposite direction. In second figure, the bar magnet is replaced by a second coil C_2 connected to a battery. The steady current in the coil C_2 produces a steady magnetic field. As coil C_2 is moved towards the coil C_1, the galvanometer shows a deflection. This indicates that electric current is induced in coil C_1. When C_2 is moved away, the galvanometer shows a deflection again, but this time in the opposite direction.





The deflection lasts as long as coil C_2 is in motion. When the coil C_2 is held fixed and C_1 is moved, the same effects are observed.

(i). An iron rod is inserted in coil C_1 .What change is observed in deflection of the galvanometer

(a) Deflection increases due to increase in current

(b) Deflection decreases due to increase of back emf

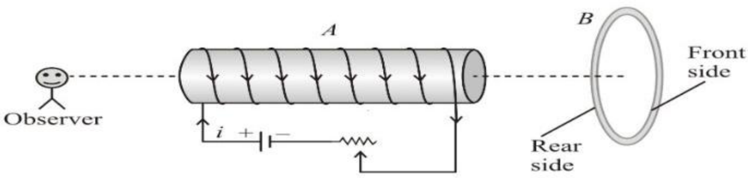
(c) Deflection decreases due to decrease in induced current

(d) Deflection increases due to increase in back emf

(ii). The current induced in the coil is given by I= 3t2 + 2t If the inductance of the coil is 10mH the value of induced emf at t=2 seconds will be

(a) 0.14V (b) 0.12V (c) 0.11V (d) 0.13V

(iii). An aluminum ring B faces an electromagnet. If current through A is altered



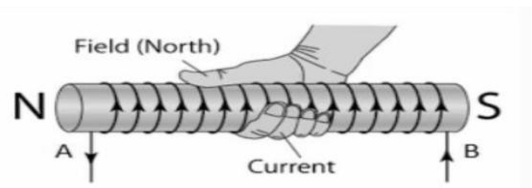
(a) B will not experience any force

(b) If I decreases A will repel B

(c) If I increases A will attract B

(d) If I increases A will repel B

(iv) An insulated copper wire is wound on a soft iron core. Current is passed through the coil such that at end A the current flows anti-clockwise and a magnetic compass needle is placed at other end B of the coil. The magnetic compass will point towards



(a) With its North towards A

(b) With its South towards A

(c) With its North away from A

(d) Data insufficient

Q3. **Bottle Dynamo:** A bottle dynamo is a small generator to generate electricity to power the bicycle light. Is is not a dynamo. Dynamo generates *DC* but a bottle dynamo generates *AC*. Newer models are now available with a rectifier. The available *DC* can power the light and small electronic gadgets. This is also known as sidewall generator since it operates using a roller placed on the sidewall of bicycle tyre. When the bicycle is in motion, the dynamo roller is engaged and electricity is generated as the tyre spins the roller. When engaged, a dynamo requires the bicycle rider to exert more effort to maintain a given speed than would otherwise be necessary when the dynamo is not present or disengaged. Bottle dynamos can be completely disengaged during day time when cycle light is not in use. In wet conditions, the roller on a bottle dynamo can slip against the surface of the tyre, which interrupts the electricity generated. This causes the lights to go out intermittently.

(i). Why bottle dynamo is not a dynamo ?

(a) It generates AC only (b) It generates DC only

(c) It looks like a bottle (d) It requires no fuel to operate

(ii) Can you recharge the battery of your mobile phone with the help of bottle dynamo ?

(a) Yes (b) No

(c) Yes, when a rectifier is used (d) Yes, when a transformer is used

(iii) Bottle generator generates electricity:

(a) when fuel is poured in the bottle. (b) when cycle is in motion.

(c) when it is mounted properly. (d) when wind blows.

(iv) Bulb of bicycle light glows:

(a) with AC supply only. (b) with DC supply only.

(c) with both AC and DC supply. (d) only when AC supply is rectified.

Answers

1.	(i) (a)	(ii) (c)	(iii) (b)	(iv) (c)
2.	(i) (a)	(ii) (b)	(iii) (c)	(iv) (a)
3.	(i) (a)	(ii) (b)	(iii) (d)	(iv) (a)

LONG ANSWER QUESTIONS (5 Marks)

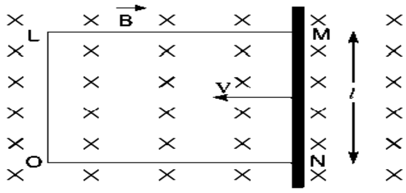
Q1.(i) What is induced emf? Write Faraday's law of electromagnetic induction. Express it mathematically. (ii) A conducting rod of length 'l', with one end pivoted, is rotated with a uniform angular speed 'ω' In a vertical plane, normal to a uniform magnetic field 'B'. Deduce an expression for the emf induced in this rod. If resistance of rod is R, what is the current induced in it?

Ans: (i) Refer to text book

(ii) Small motive force (emf) induced is: $d\varepsilon = (\vec{v}\times\vec{B})\cdot dl$

$$\varepsilon = \int_0^l B\omega r dr \quad = B\omega\int_0^l r dr \quad = B\omega\left[\frac{r^2}{2}\right]_0^l \quad = \tfrac{1}{2} B\omega l^2$$

Q2. (i) State Faraday's law of electromagnetic induction. Explain Lenz's law is based on energy conservation. (ii) Figure shows a rectangular conductor $LMNO$ is placed in a uniform magnetic field of 0.5 T. The field is directed perpendicular to the plane of the conductor. When the arm MN of length of 20 cm is moved towards left with a velocity of 10 m/s. Calculate the emf induced in the arm. Given the resistance of the arm to be 5 Ω (assuming that other arms are of negligible resistance), find the value of the current in the arm.



Ans: (a) Refer to textbook

(b) Induced emf in a moving rod in a magnetic field is given by: $\varepsilon = Blv$

On solving, we get ε = 1 V. Current in the rod $I = \frac{\varepsilon}{R} = \frac{1}{5}$ = 0.2 V

Q3. (i) How is the mutual inductance of a pair of coils affected when (a) separation between the coils is increased? (b) the number of turns in each coil is increased? (c) a thin iron sheet is placed between the two coils, other factors remaining the same? Justify your answer in each case.

(ii) How does the mutual inductance of a pair of coils change when (a) distance between the coils is increased and (b) number of turns in the coils is increased

Ans: (i) (a) When the relative distance between the coil is increased, the leakage of flux increases which reduces the magnetic coupling of the coils. So magnetic flux linked with all the turns decreases. Therefore, mutual inductance will be decreased.

(b)Mutual inductance for a pair of coil is given by $M = K(L_1 L_2)^{1/2}$ where $L = (\mu_0 N^2 A)/l$ and L is called self- inductance. Therefore, when the number of turns in each coil increases, the mutual inductance also increases.

iii)When a thin iron sheet is placed between the two coils, the mutual inductance increases because M∝ permeability. The permeability of the medium between coils increases.

(ii) (a) Mutual inductance decreases because flux linked with the secondary coil decreases.

(b) $M = \mu_0 n_1 n_2 A l$, so when n_1 and n_2 increase, mutual inductance (M) increases.

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Work Sheet 1

Note:

Q. No. 1-4 is of 01 mark each,

Q. 5-6 is of 02 marks each,

Q.No.7 is of 03 marks,

Q. No. 8 is a case study based and is of 04 marks,

Q. No. 9 is of 05 marks.

Q1.Two coils are placed closed to each other. The mutual inductance of the pair of coils depends upon

(a) the rate at which currents are changing in the two coils.

(b) relative position and orientation of two coils.

(c) the material of the wires of the coils.

(d) the currents in the two coils.

Ans:

Q2.The current flows from A to B is as shown in the figure. The direction of the induced current in the loop is

(a) clockwise. (b) anticlockwise.

(c) straight line. (d) no induced e.m.f. produced.

Ans:

Q3.Direction of current induced in a wire moving in a magnetic field is found using

(a) Fleming's left-hand rule (b) Fleming's right-hand rule

(c) Ampere's rule (d) Right hand clasp rule

Ans:

Q4.Assertion (A): Induced emf will always occur whenever there is change in magnetic flux.

Reason (R): Current always induces whenever there is change in magnetic flux.

(a) Both assertion and reason are correct and the reason is the correct explanation of assertion.

(b) Both assertion and reason are correct and reason is not a correct explanation of assertion.

(c) Assertion is correct but the reason is incorrect

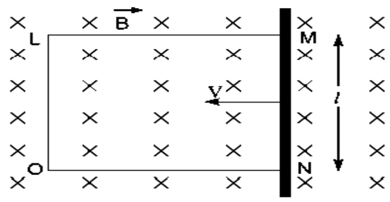
(d) Assertion is incorrect but the reason is correct.

Ans:

Q5.State Lenz's Law. A metallic rod held horizontally along east-west direction, is allowed to fall under gravity. Will there be an emf induced at its ends? Justify your answer.

Ans:

Q6.A rectangular conductor LMNO is placed in a uniform magnetic field of 0.5 T. The field is directed perpendicular to the plane of the conductor. When the arm MN of length of 20 cm is moved towards left with a velocity of 10 m/s. Calculate the emf induced in the arm. Given the resistance of the arm to be 5 Ω (assuming that other arms are of negligible resistance), find the value of the current in the arm.



Ans:

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Q7.Show that Lenz's law is in accordance with the law of conservation of energy.

Ans

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Q8.**Case study-based questions**

Electromagnetic induction is defined as the production of an electromotive force across an electric conductor in the changing magnetic field. The discovery of induction was done by Michael Faraday in the year 1831. Electromagnetic induction finds many applications such as in electrical components which includes transformers, inductors, and other devices such as electric motors and generators. Alternating current is defined as an electric current which reverse in direction periodically. In most of the electric power circuits, the waveform of alternating current is the sine wave.

i). How to increase the energy stored in an inductor by four times?

(a) By doubling the current (b) This is not possible

(c) By doubling the inductance (d) By making current 2 times

Ans:

ii). Consider an inductor whose linear dimensions are tripled and the total number of turns per unit length is kept constant, what happens to the self-inductance?

(a) 9 times (b) 3 times (c) 27 times (d) 13 times

Ans:

iii). Lenz law is based on which of the following conservation

(a) Charge (b) Mass (c) Momentum (d) Energy

Ans:

iv). What will be the acceleration of the falling bar magnet which passes through the ring such that the ring is held horizontally and the bar magnet is dropped along the axis of the ring?

(a) It depends on the diameter of the ring and the length of the magnet

(b) It is equal due to gravity

(c) It is less than due to gravity

(d) It is more than due to gravity

Ans:

Q9.(a) What is induced emf? Write Faraday's law of electromagnetic induction. Express it mathematically.

(b) A conducting rod of length 'l', with one end pivoted, is rotated with a uniform angular speed 'ω' in a vertical plane, normal to a uniform magnetic field 'B'. Deduce an expression for the emf induced in this rod. If resistance of rod is R, what is the current induced in it?

Ans:

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WORK SHEET 2

Note:
Q. No. 1-4 is of 01 mark each,
Q. 5-6 is of 02 marks each,
Q.No.7 is of 03 marks,
Q. No. 8 is a case study based and is of 04 marks,
Q. No. 9 is of 05 marks.

Q1When the current in a coil change from 5 A to 2 A in 0.1 s, an average voltage of 50V is produced. The self-inductance of the coil is

(a)1.67 H (b) 6 H (c) 3 H (d) 0.67 H

Ans:

Q2.A coil having 500 sq. loops of side 10 cm is placed normal to magnetic flux which increases at a rate of 1 T/s. The induced emf is

(a) 0.1 V (b) 0.5 V (c)1 V (d) 5 V

Ans:

Q3 Lenz's law of electromagnetic induction is as per the law of conservation of

(a)energy (b)Angular momentum (c) charge. (d) Mass

Ans:

Q4.ASSERTION: Only a change in magnetic flux will maintain an induced current in the coil.

REASON: The presence of large magnetic flux through a coil maintain a current in the coil if the circuit is continuous.

(a) Both assertion and reason are correct and the reason is the correct explanation of assertion.

(b) Both assertion and reason are correct and reason is not a correct explanation of assertion.

(c) Assertion is correct but the reason is incorrect

(d) Assertion is incorrect but the reason is correct.

Ans:

Q5.How is the mutual inductance of a pair of coils affected when (i) separation between the coils is increased? (ii) the number of turns in each coil is increased? (iii) a thin iron sheet is placed between the two coils, other factors remaining the same? Justify your answer in each case.

Ans:

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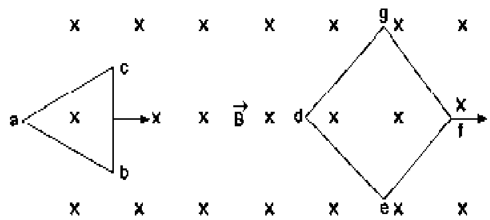
6.Two loops of different shapes are moved in the region of a uniform magnetic field pointing downward. The loops are moved in the directions shown by arrows. What is the direction of the induced current in each loop?



Ans:

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Q7.How does the mutual inductance of a pair of coils change when (i) distance between the coils is increased and (ii) number of turns in the coils is increased

Ans:

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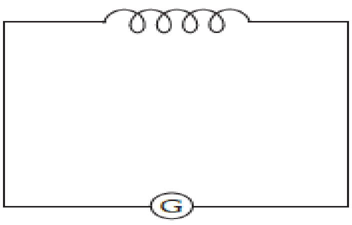
Q8.Case based: When a current I flows through a coil, flux linked with it is φ = LI, where L is a constant known as self- inductance of the coil. Any charge in current sets up an induced emf in the coil. Thus, self-inductance of a coil is the induced emf set up in it when the current passing through it changes at the unit rate. It is a measure of the opposition to the growth or the decay of current flowing through the coil. Also, value of self- inductance depends on the number of turns in the solenoid, its area of cross-section and the permeability of its core material.



(i)The inductance in a coil plays the same role as

(a) inertia in mechanics (b) energy in mechanics (c) momentum in mechanics (d) force in mechanics

Ans:

(ii) A current of 2.5 A flows through a coil of inductance 5 H. The magnetic flux linked with the coil is

(a) 0.5 Wb (b) 12.5 Wb (c) zero (d) 2 Wb

Ans:

(iii)The inductance L of a solenoid depends upon its radius R as

(a) $L \propto R$ (b) $L \propto 1/R$ (c) $L \propto R^2$ (d) $L \propto R^3$

Ans:

(iv)The unit of self-inductance is

(a) Weber ampere (b) $Weber^{-1}$ ampere (c) Ohm second (d) Farad

Ans:

OR

(v)The induced emf in a coil of 10 henry inductance in which current varies from 9 A to 4 A in 0.2sec is

(a) 200 V (b) 250 V (c) 300 V (d) 350 V

Ans:

Q9. (a) Define mutual inductance and write its SI units.

(b) Derive an expression for the mutual inductance of two long co-axial solenoids of the same length wound one over the other.

(c) In an experiment, two coils C_1 and C_2 are placed close to each other. Find out the expression for the emf induced in the coil C_1 due to a change in the current through the coil C_2.

Ans:

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WORKSHEET I ANSWERS :

1. (b) 2. (b) 3. (b) 4. (a)
5. Yes, an emf will be induced between the ends of the rod.
6. Induced emf in a moving rod in a magnetic field is given by: $\varepsilon = Blv$

   On solving, we get ε = 1 V. Current in the rod $I = \frac{\varepsilon}{R} = \frac{1}{5} = 0.2$ A

   (Direction given by Fleming's right-hand rule: current flows from M to N)
7. Lenz's Law ensures that mechanical energy is always spent to produce electrical energy in electromagnetic induction. Thus, it is completely consistent with the law of conservation of energy.
8. (i). (a) (ii). (b) (iii). (d) (iv). (c)
9. (a) Refer to text book (b) $v = \omega r$

   Small motive force (emf) induced is: $d\varepsilon = Bvdr = B\,\omega r dr$

   $$\varepsilon = \int_0^l B\omega r dr = B\omega \int_0^l r dr = B\omega \left[\frac{r^2}{2}\right]_0^l = \tfrac{1}{2} B\omega l^2$$

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WORKSHEET II ANSWERS

1 (a) 2. (d) 3. (a) 4. (c)

5. (i) When the relative distance between the coil is increased, the leakage of flux increases which reduces the magnetic coupling of the coils. So magnetic flux linked with all the turns decreases. Therefore, mutual inductance will be decreased.

ii)Mutual inductance for a pair of coil is given by $M = K(L_1 L_2)^{1/2}$

where $L = \mu_0 N^2 A/l$ = and L is called self- inductance. Therefore, when the number of turns in each coil increases, the mutual inductance also increases.

iii)When a thin iron sheet is placed between the two coils, the mutual inductance increases because of M∝ permeability. The permeability of the medium between coils increases.

6. Loop *abc* is entering the magnetic field, so the magnetic flux linked with it begins to increase. According to Lenz's law, the current induced opposes the increases in magnetic flux, so the current induced will be anticlockwise which tends to decrease the magnetic field

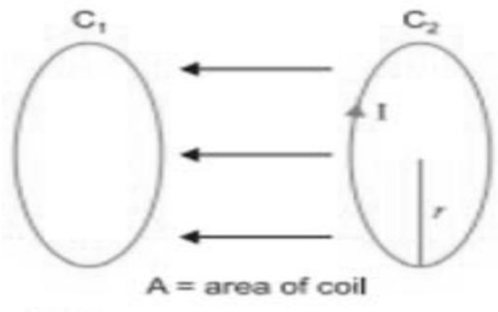
7. (i) Mutual inductance decreases because flux linked with the secondary coil decreases.

   (ii) $M = \mu_0 n_1 n_2 A l$, so when n_1 and n_2 increase, mutual inductance (M) increases.

8. (i) (a) inertia in mechanics (ii) (b) 12.5 Wb (iii)(c) $L \propto R^2$ (iv)(c) ohm second (v) (b) 250 V

9. a) Statement b) Derivation

c)When the current in the coil C_2 changes the flux linked with C_1 changes. This change in flux linked with C_1 induces emf in C_1.



Flux linked with C_1 = Flux linked with C_2

$$\phi_{12} = BA = \frac{\mu_0 I}{2r} A$$

$$\varepsilon = \frac{d\phi_{12}}{dt} = \frac{\mu_0 A}{2r}\frac{dI}{dt}$$

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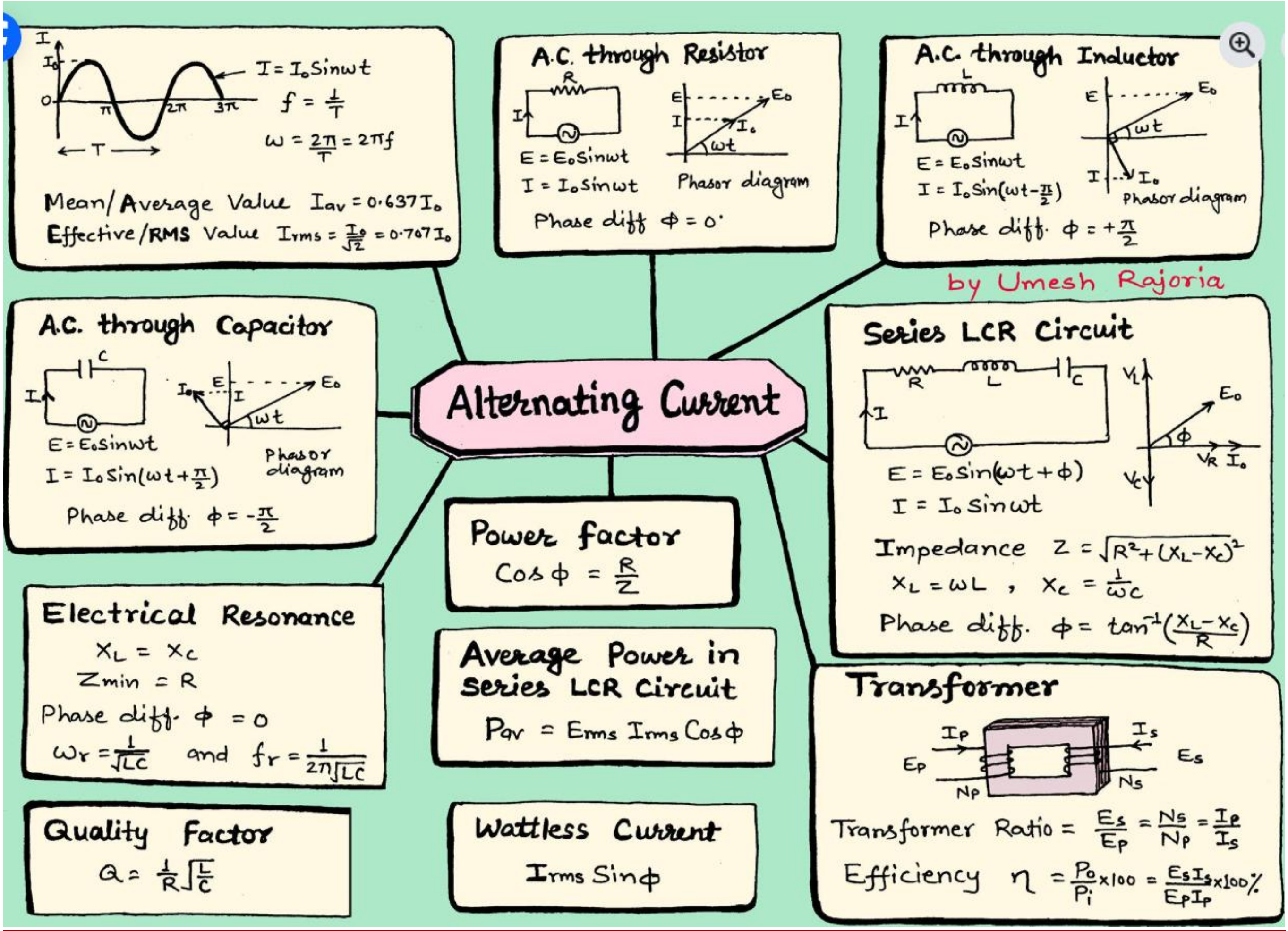
CHAPTER 7

ALTERNATING CURRENT

IMPORTANT FORMULAS



LTIPLE CHOICE QUESTIONS (1 Mark)

Q1. Pick out the correct combination for a step-up transformer.

(a) $k < 1$; $V_s > V_p$, $I_s > I_p$, $N_s > N_p$ (b) $k > 1$; $V_s > V_p$, $I_s < I_p$, $N_s > N_p$

(c) $k > 1$; $V_s > V_p$, $I_s > I_p$, $N_s > N_p$ (d) $k < 1$; $V_s < V_p$, $I_s > I_p$, $N_s > N_p$

Ans: (b)

Q2. In a step-down transformer, the number of turns in the secondary coil is 20 and the number of turns in the primary coil is 100. If the voltage applied to the primary coil is 120 V, then what is the voltage output from the secondary coil?

(a) 24 V (b) 12 V (c) 6 V (d) 18 V

Ans: (a)

Q3. An a.c. generator consists of a coil of 1000 turns and cross-sectional area of $3m^2$, rotating at a constant angular speed of 60 rad s^{-1} in a uniform magnetic field 0.04 T. The resistance of the coil is 500Ω. Calculate the maximum current drawn from the generator.

(a) 2500 A (b) 14.4 A (c) 6.25 A (d) 0.55 A

Ans: (b)

Q4. An a.c. generator consists of a coil of 50 turns and an area 2.5 m^2 rotating at an angular speed of 60 rad s^{-1} in a uniform magnetic field of 0.3 T between two fixed pole pieces. What is the flux through the coil, when the current is zero?

(a) Maximum (b) Minimum (c) Zero (d) Independent of current

Ans: (a)

Q5. What will be the rms value of the voltage, if the sinusoidal value voltage is given as E = 100 sin 314 t applied across a resistor of resistance 15 ohms?

(a) 200 V (b) 70.71 V (c) 100 V (d) 33.87 V

Ans: (b)

Q6. A transformer is a device used for converting :
(a) high ac voltage and large ac current to low ac voltage and small ac current
(b) high ac voltage and small ac current to low ac voltage and small ac current
(c) low ac voltage and large ac current to high ac voltage and small ac current
(d) low ac voltage and small ac current to high ac voltage and large ac current
Ans: (c)
Q7. The frequency of ac is doubled. How does X_L get affected?

(a) X_L gets doubled (b) X_L becomes zero (c) X_L is halved (d) X_L is indefinite .

Ans: (a)

Q8. When are the voltage and current in LCR-series ac circuit in phase?

(a) $X_L = X_C$ (b) $X_L > X_C$ (c) $X_L < X_C$ (d) Indeterminant

Ans: (a)

Q9. If the frequency of the ac source in a series LCR-circuit is increased, how does the current in the circuit change?

(a) Decreases then increase (b) Increases then decrease (c) Becomes zero (d) Remains constant

Ans: (b)

Q10. A capacitor of capacitance 10 μF is connected to an oscillator giving an output voltage, E = 10 sin ωt volt. If ω = 10 rad s^{-1}, find the peak current in the circuit.

(a) 197 mA (b) 1 mA (c) 179 mA (d) 5 Ma

Ans: (b) $I_0 = E_0/(1/\omega C) = 1\times10^{-3}$ = 1 mA.

ASSERTION REASON BASED QUESTIONS (1 Mark)

Directions: Each of these questions contain two statements, Assertion and Reason. Each of these questions also has four alternative choices, only one of which is the correct answer. You have to select one of the codes (a), (b), (c) and (d) given below.

(a) Assertion is correct, reason is correct; reason is a correct explanation for assertion.

(b) Assertion is correct, reason is correct; reason is not a correct explanation for assertion

(c) Assertion is correct, reason is incorrect

(d) Assertion is incorrect, reason is correct.

Q1. **Assertion :** In a purely inductive or capacitive circuit, the current is referred to as wattless current.
Reason: No power is dissipated in a purely inductive or capacitive circuit even though a current is flowing in the circuit.
Ans: (a)

Q2. **Assertion** : When the frequency of the AC source in an LCR circuit equals the resonant frequency, the reactance of the circuit is zero, and so there is no current through the inductor or the capacitor.
Reason : The net current in the inductor and capacitor is zero.
Ans: (d)
Q3. **Assertion** : Average power loss in series LC circuit or in parallel LC circuit is always zero.
Reason : Average values of voltage and current in A.C. is zero.
Ans: (b)
Q4. **Assertion** : The resistance of a coil for direct current is 5 ohm. An alternating current is sent through it. The resistance will remain same.

Reason : The resistance of a coil does not depend upon nature of current.

Ans: (a)

Q5. **Assertion** : If the frequency of alternating current in an A.C. circuit consisting of an inductance coil is increased than current get decreased.

Reason : The current is inversely proportional to frequency of alternating current.

Ans: (a)

VERY SHORT ANSWER TYPE QUESTIONS (2 Marks)

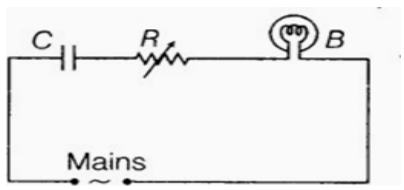
Q1. A coil of inductance L, a capacitor of capacitance C and a resistor of resistance R are all put in series with an alternating source of emf E = (E_o sin wt). Write an expression for the

(a)Total impedance of the circuit

(b)Frequency of the source emf for which the current carrying circuit will show resonance.

Ans: (a) $Z = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}$ (b) $f_0 = \omega_0 / 2\pi = 1/[2\pi\sqrt{(LC)}]$

Q. A capacitor C, a variable resistor R and a bulb B are connected in series to the AC mains in the circuit as shown. The bulb glows with some brightness. How will the glow of the bulb change if (i) a dielectric slab is introduced between the plates of the capacitor keeping resistance R to be the same (ii) the resistance R is increased keeping the same capacitance?



Ans: (i) Dielectric slab increases the capacitance. This decrease Z. This increases current (I = V/Z) which results in a brighter bulb.

(ii) Increasing the resistance (R) increases the total impedance. The bulb will glow with less intensity

Q3. State the principle of working of a transformer. Can a transformer be used to step-up or step-down a DC voltage? Justify your answer.

Ans: Transformer is based on the principle of mutual induction. No, transformer cannot be used to change DC voltage. This happens because DC voltage cannot change flux linked with primary or secondary coils

Q4. A transformer rated at 10 KW is used to connect a 5KV transmission line to a 250 V circuit. What is the ratio of the turns in the primary and secondary windings of the transformer?

Ans: It is a step-down transformer. So, $V_p/V_s = N_p/N_s \Rightarrow N_p/N_s = 5000/250 = 20:1$

Q5. The instantaneous current of an AC is given by I = 5sin(314t) A. What is the (i) peak value (ii) rms value?

Ans: $I_0 = 5$ A; $I_{rms} = I_0/\sqrt{2} = 3.54$ A

Q6. A pure inductor of 25.0 mH is connected to a source of 220 V. Find the inductive reactance and rms current in the circuit if the frequency of the source is 50 Hz.

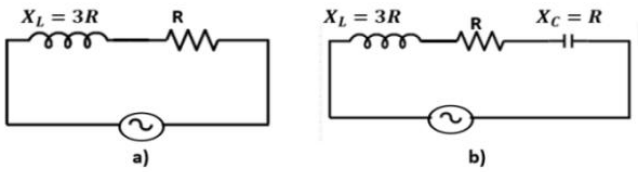
Ans: $\omega = 2\pi f = 2\pi\times 50 \approx 314.16$ rad/s; $X_L = \omega L = 314.16 \times (25.0\times 10^{-3}) \approx 7.85\ \Omega$; $I_{rms} = 220/7.85 \approx 28.0$ A.

Q7. An electric lamp having coil of negligible inductance connected in series with a capacitor and an AC source is glowing with certain brightness. How does the brightness of the lamp change on reducing the (i) capacitance and (ii) the frequency? Justify your answer.

Ans: (i) When capacitance is reduced capacitive reactance $X_C = 1/\omega C$ increases, hence impedance of circuit $Z = \sqrt{R^2 + X_C^2}$ increases and so, current I = V/Z decreases. As a result the brightness of the bulb is reduced.

(ii) When frequency decreases; capacitive reactance $X_C = 1/2\pi fC$ increases and hence impedance of circuit increases, so current decreases. As a result brightness of bulb is reduced.

Q8. Shown in the figure, two electric circuits (a) and (b). Calculate the ratio of power factor of the circuit (b) to the power factor of the circuit (a).



Ans: Circuit (a): Impedance (Z) = $\sqrt{R^2 + (3R)^2} = \sqrt{R^2 + 9R^2} = \sqrt{10R^2} = R\sqrt{10}$

Power factor ($\cos\phi$) = R/Z = $R/(R\sqrt{10}) = 1/\sqrt{10}$

Circuit (b): Impedance (Z') = $\sqrt{R^2 + (3R - R)^2} = \sqrt{R^2 + (2R)^2} = \sqrt{R^2 + 4R^2} = \sqrt{5R^2} = R\sqrt{5}$

Power factor ($\cos\phi'$) = R/Z' = $R/(R\sqrt{5}) = 1/\sqrt{5}$

Ratio = $(1/\sqrt{5}) / (1/\sqrt{10}) = \sqrt{10} / \sqrt{5} = \sqrt{2}:1$

Q9. State the condition under which the phenomenon of resonance occurs in series LCR circuit when ac voltage is applied. In a series LCR circuit, the current is in same phase with voltage. Calculate the value of self-inductance if the capacitor used is 20μF and resistance used is 10 ohm with the ac source of frequency 50 Hz.

Ans: Circuit is in resonance condition $\Rightarrow \omega L = 1/\omega C \Rightarrow L = 1/\omega^2 C = 0.507$ H

Q10. An inductor L of inductance X_L is connected in series with a bulb B and an AC source. How would brightness of the bulb change when (i) number of turns in the inductor is increased (ii) an iron rod is inserted in the inductor and (iii) a capacitor of reactance $X_C = X_L$ is inserted in series.

Ans: (i) $L \propto N^2$. As L increases, X_L also increases, leading to an increase in impedance Z.
Since Z increases, the current I in the circuit decreases. Conclusion: The brightness of the bulb decreases.

(ii) Inserting an iron rod increases its inductance (L). Similar to the first case, as Z increases, the current I decreases. Conclusion: The brightness of the bulb decreases

(iii) Under this condition, the current in the circuit will become maximum.

SHORT ANSWER TYPE QUESTIONS (3 Marks)

Q1. A step-up down transformer operated on a 2.5 kV line. It supplies a load with 20 A. The ratio of the primary winding to the secondary is 10 :1. If the transformer is 90% efficient, calculate
(i) the power output (ii) the voltage and the current in the secondary coil.
Ans: (i)$N_P/N_S = 10/1$; % efficiency = 90/100 =output power/input power
$\Rightarrow$ Output power = $(90/100)\times V_p I_p = 4.5 \times 10^4$ W
(ii)$V_s = 250$ V
(iii) $I_s = 180$ A
Q2. A 60 W load is connected to the secondary of a transformer whose primary draws line voltage. If a current of 0.54 A flows in the load, what is the current in the primary coil? Comment on the type of transformer being used.

Ans: $V_s = 110$V; Ratio factor = 110/220 = 0.5 $\Rightarrow$ step down transformer

Q3. A series LCR circuit with L = 4.0 H, C = 100 μF and R = 60 Ω is connected to a variable frequency 240 V source. Calculate (i) angular frequency of the source which drives the circuit in resonance, (ii) current at the resonating frequency, (iii) rms potential drop across the inductor at resonance.

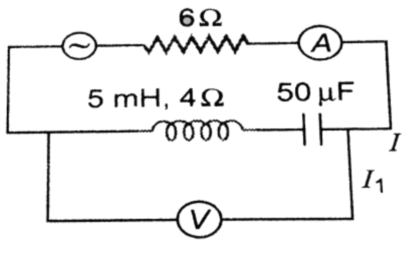
Ans: (i) $\omega = 1/\sqrt{LC} = 50$ rad/s (ii) At Z = R, I = E/R = 4 A (iii) $V_L = IX_L = 4(\omega L) = 800$ V

Q4. Calculate the current drawn by the primary of a transformer which steps down 200 V to 20 V to operate a device of resistance 20 **Ω**. Assume the efficiency of transformer to be 80%.

Ans: Current through the secondary coil is $I_s = V_s/R = 20/20 = 1$ A

Efficiency: $\eta = V_s I_s / V_p I_p \Rightarrow I_p = V_s I_s / V_p \eta = 0.125$ A

5. In the circuit shown in figure, the AC source gives a voltage V = 20cos(2000t). Neglecting source resistance, the voltmeter and ammeter readings will be?



Ans: R = 10 Ω, $X_L = \omega L = 10\Omega$, $X_C = 1/\omega C = 10\ \Omega$

$Z = \sqrt{(R)^2 + (X_L - X_C)^2} = 10\ \Omega$

$I_o = V_o/Z = 20 / 10 = 2$ A
Hence, $I_{rms} = 2/\sqrt{2} = 1.4$ A and $V_{rms} = 4\times1.41 = 5.64$ V

Q6. (a)What do mean by rms value of alternating current?
(b)A light bulb is rated 100 W for 220 V ac supply of 50 Hz. Calculate (i) the resistance of the bulb; (ii) the rms current through the bulb.
Ans: (a) The equivalent DC value that would produce the same amount of heat in a resistor as the given AC current
(b)(i) $P = V^2/R = 484\ \Omega$ (ii) $I_{rms} = V_{rms}/R = 0.45$ A

Q7. Two heating elements of resistances R_1 and R_2 when operated at a constant supply of voltage, V, consume powers P_1 and P_2 respectively. Deduce the expressions for the power of their combination when they are, in turn, connected in (i) series and (ii) parallel across the same voltage supply.

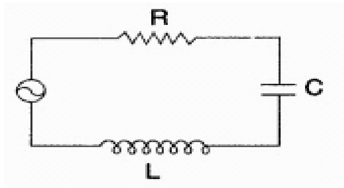
Ans: When they are connected in series, power will be

$$\frac{1}{P}=\frac{1}{P_1}+\frac{1}{P_2}=\frac{R_1}{V^2}+\frac{R_2}{V^2}=\frac{R_1+R_2}{V^2}\Rightarrow P=\frac{V^2}{R_1+R_2}$$

When connected in series,

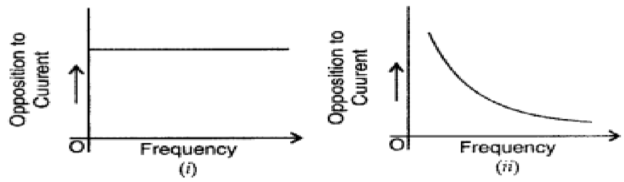
$$P=P_1+P_2=\frac{V^2}{R_2}+\frac{V^2}{R_2}=\frac{\left(R_1+R_2\right)V^2}{R_1R_2}$$

Q8. The figure shows a series LCR circuit with L = 5.0 H, C = 80 μF, R = 40 Ω connected to a variable frequency 240 V source. Calculate (i) The angular frequency of the source which drives the circuit at resonance.(ii) The current at the resonating frequency. (iii) The rms potential drop across the capacitor at resonance.



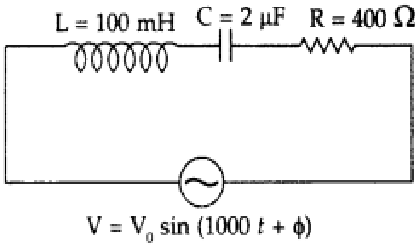
Ans: (i) $\omega = 1/(LC)^{1/2} = 50$ rad/s
(ii) $I_{rms} = V_{rms}/R = 6$ A
(iii) $V_{rms} = 1500$ V

Q9. (a) The graphs (i) and (ii) shown in the figure represent variation of opposition offered by the circuit elements, X and Y, respectively to the flow of alternating current versus the frequency of the applied emf. Identify the elements X and Y.



(b) Write the expression for the impedance offered by the series combination of these two elements connected to an ac source of voltage $V = V_0 \sin \omega t$. Show on a graph the variation of the voltage and the current with time in the circuit.
Ans: (a) X is Resistor ,Y is Capacitor (b) **[Derivation & Graph]**

Q10. (i) Find the value of the phase difference between the current and the voltage in the series LCR circuit shown here. Which one leads in phase: current or voltage?



(ii) Without making any other change, find the value of the additional capacitor C_1 to be connected in parallel with the capacitor C, in order to make the power factor of the circuit unity.

Ans: (i) $X_L = \omega L = 100\ \Omega$; $X_c = 1/\omega C = 500\ \Omega$

$\phi = \tan^{-1}\{(X_L - X_c)/R\} = 45^0$ and current leads voltage.

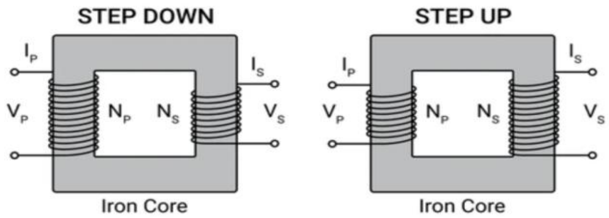
(ii) To make power factor unity, $X_C = 100\ \Omega = 1/\omega C' \Rightarrow C' = 10\ \mu F$

C1 to be connected in parallel = C' – C = 8 μF

CASE BASED QUESTIONS (4 Marks)

Q1. A group of students is preparing for their physics exam, focusing on transformers and their applications in electrical systems. They explore how transformers operate based on electromagnetic induction principles, emphasizing their role in efficiently transferring electrical energy between circuits. They learn that transformers can step up or step-down voltages, which is crucial for long-distance power transmission, reducing energy losses.

During their study session, they discuss various types of transformers, such as step-up and step-down transformers, and how the turns ratio influences their functionality. They also consider real-world applications, like how high-voltage transmission lines minimize current and thus reduce resistive losses in the wires. As they prepare for practical questions, they recognize the importance of understanding the limitations of transformers, such as energy losses due to heat and the necessity for alternating current (AC) for operation.



(i). A power company uses transformers to step up the voltage to 500 kV for transmission over long distances. If a fault occurs, resulting in the voltage dropping to 100 kV at the substation, what could be the immediate consequences for the electrical grid?

(a) Increased power loss due to higher current flow.

(b) Improved efficiency in power transmission.

(c) Immediate shutdown of all connected devices.

(d) Decrease in voltage regulation across the grid.

(ii). An electric vehicle charging station utilizes a transformer to convert 480 V AC from the grid to 240 V AC for charging. If the transformer has an efficiency of 95% and the charging station requires 6 kW of power, what is the minimum input power required from the grid?

(a) 5.7 K W (b) 6.3 kW (c) 6.7 kW (d) 5.9 K W

(iii). In a renewable energy application, a solar power system uses a transformer to convert the generated voltage from the solar panels (typically low voltage) to a higher voltage suitable for feeding into the grid. If the transformer steps up the voltage from 48 V to 240 V, what is a key benefit of this voltage transformation in terms of energy transmission?

(a) It allows for lower current, reducing resistive losses over long distances.
(b) It increases the overall energy produced by the solar panels.
(c) It eliminates the need for batteries in the system.
(d) It increases the efficiency of solar panel operation.
(iv) A transformer operates at an efficiency of 90%. If the input power is 1000 W, what is the maximum output power it can deliver?
(a) 900 W (b) 1000 (c) 1100 W (d) 100 W

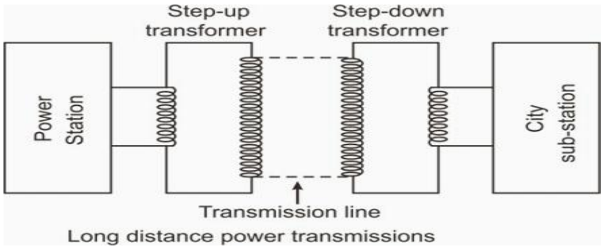
OR

(v) Which of the following factors primarily affects the voltage transformation ratio in a transformer?
(a) The frequency of the alternating current. (b)The material of the wire used for the coils.

(c) The number of turns in the primary and secondary coils. (d)The temperature of the transformer.

Ans: (i) (a) (ii) (b) (iii) (a) (iv) (a) (v) (c)

Q2. The large-scale transmission and distribution of electrical energy over long distances is done with the use of transformers. The voltage output of the generator is stepped-up.



It is then transmitted over long distances to an area sub-station near the consumers. Then the voltage is stepped-down. It is further stepped-down at distributing sub-stations and utility poles before a power supply of 240 V reaches our homes. Read the given passage carefully and give the answer of the following questions:

(i). Which of the following statement is true?

(a) Energy is created when a transformer steps-up the voltage

(b) A transformer is designed to convert an AC voltage to DC voltage

(c) Step-up transformer increases the power for transmission

(d) Step-down transformer decreases the AC voltage

(ii). If the secondary coil has a greater number of turns than the primary:

(a) the voltage is stepped-up ($V_s > V_p$) and arrangement is called a step-up transformer

(b) the voltage is stepped-down ($V_s < V_p$) and arrangement is called a step-down transformer

(c) the current is stepped-up ($I_s > I_p$) and arrangement is called a step-up transformer

(d) the current is stepped-down ($I_s < I_p$) and arrangement is called a step-down transformer.

(iii) We need to step-up the voltage for power transmission, so that:

(a) the current is reduced and consequently, the I^2R loss is cut down

(b) the voltage is increased the power losses are also increased

(c) the power is increased before transmission is done

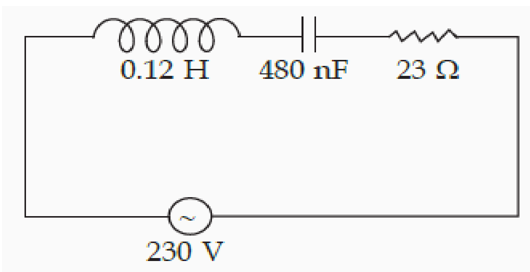
(d) the voltage is decreased so V^2/R losses are reduced

(iv). A power transmission line feeds input power at 2300 V to a step-down transformer with its primary windings having 4000 turns. The number of turns in the secondary in order to get output power at 230 V are:

(a). 4 (b) 40 (c) 400 (d.)4000

Ans: (i) (d) (ii) (a) (iii) (a) (iv) (c)

Q3. Resonant Series LCR Circuit. When the frequency of ac supply is such that the inductive reactance and capacitive reactance become equal, the impedance of the series LCR circuit is equal to the ohmic resistance in the circuit. Such a series LCR circuit is known as resonant series LCR circuit and the frequency of the ac supply is known as resonant frequency. Resonance phenomenon is exhibited by a circuit only if both L and C are



present in the circuit. We cannot have resonance in a RL or RC circuit. A series LCR circuit with L = 0.12 H, C = 480 nF, R = 23 Ω is Connect to a 230 V variable frequency supply.

(i) Find the value of source for which current amplitude is maximum.

(a) 222.32 Hz (b) 550.52 Hz (c) 663.48 Hz (d) 770 Hz

(ii) The value of maximum current is

(a) 14.14 A (b) 22.52 A (c) 50.25 A (d) 47.41 A

(iii) The value of maximum power is

(a) 2200 W (b) 2299.3 W (c) 5500 W (d) 4700 W

(iv) What is the Q-factor of the given circuit?

(a) 25 (b) 42.21 (c) 35.42 (d) 21.74

(OR)

(v) At resonance which of the following physical quantity is maximum?
(a) Impedance (b) Current (c) Both (a) and (b) (d) Neither (a) nor (b).

Ans: (i) (c) (ii) (a) (iii) (b) (iv) (d) (v) (b)

LONG ANSWER TYPE QUESTIONS (5 Marks)

Q1. A series LCR circuit is connected to an AC source having voltage $V = V_m \sin\omega t$. Derive the expression for the instantaneous current I and its phase relationship to the applied voltage. Obtain the condition for resonance to occur. Define 'power factor'. State the conditions under which it is (i) maximum, (ii) minimum.

ANS-According NCERT Book

Q2. (a)Write the principle of working of an ac generator. Draw its labelled diagram and explain its working.

(b) A resistor of 400 **Ω**, an inductor of (5/π) H and a capacitor of (50/π) μF are joined in series across an ac source V = 140 sin(100t) V. Find the rms voltages across these three circuit elements. The algebraic sum of these voltages is more than the rms voltage of source. Explain.

Ans: (a) [AC Generator – Diagram, Principle, Working]

(b) Calculate X_L, X_C.

Calculate Z using X_L, X_C and R.

Find I = Vrms/Z.

$V_R = I_{rms}R = 0.2×400 = 80$ V

$V_L = I_{rms}X_L = 40$ V

$V_C = I_{rms}X_C = 40$ V

Q3. (a) Write the principle of working of a transformer. With the help of a labelled diagram, explain the working of a step-up transformer.

(b) An ideal transformer is designed to convert 50 V into 250 V. It draws 200 W power from an ac source whose instantaneous voltage is given by $V_i = 20 \sin(100\pi t)$ V. Find: (i) RMS value of input current. (ii) Expression for instantaneous output voltage. (iii) Expression for instantaneous output current.

Ans: (b) (i) $I_{rms} = P/V_{rms} = 200/(20/\sqrt{2}) = 10\sqrt{2}$ A

(ii) Transformer turn ratio = 250/50 = 5 ⇒ $V_o = 5 \times V_i$. Hence, the instantaneous output voltage is

$V_o = 100\sin(100\pi t)$ V

(iii) Instantaneous output current is $0.8\sin(100\pi t)$ A.

Q4. (a) Differentiate between peak and rms values of alternating current. How are they related?

(b) When a circuit element X is connected across on ac source of emf $220\sqrt{2}$ volt, current of $\sqrt{2}$ A flows through it in phase with the voltage. When another element Y is connected across the same ac source, the same current flows through the circuit, but it leads the voltage by $\pi/2$ radian. Name the circuit element X and Y. Find the current that flows in the circuit when series combination of X and Y is connected across the same source.

Ans: (a) The peak value of alternating current (AC) is the maximum value of current in one cycle, while the RMS (Root Mean Square) value is the equivalent DC value that would produce the same amount of heat in a resistor. The RMS value is related to the peak value by the formula: $I_{rms} = I_{peak} / \sqrt{2}$

(b) As current is in phase with the voltage, element X must be a resistor.

$R = E_v / I_v = 220$ ohm

Through Y, current leads the voltage by $\pi/2$. ∴ Y must be a capacitor $X_C = E_v/I_v = 220$ ohm

When series combination of R and C is connected, $Z=\sqrt{R_2+X_C^2} = 220\sqrt{2}$ ohm

$I_v = E_v/Z = 1$ A

WORK SHEET-1

Q.1 Define root mean value of an alternating current. Derive an expression for the root mean square value of alternating current.

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Q.2 An alternating voltage given by V = 140 sin314t is connected across a pure resistor of 50 Ω. Find (i) the frequency of the source (ii) the rms current through the resistor.

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Q.3 A 100 Ω resistor is connected to a 220 V, 50 Hz ac supply.

(a)What is the rms value of current in the circuit?

(b)What is the net power consumed over a full cycle?

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Q.4 A power transmission line feeds input power at 2300 V to a step down transformer with its primary windings having 4000 turns. What should be the number of turns in the secondary in order to get output power at 230 V?

ANS……
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Q.5 (1) The selectivity of a series LCR ac current is large, when

(a) L is large and R is large (b) L is small and R is small

(c) L is large and R is small (d) LR

ANS…………………..

(2.) The power factor of a series LCR circuit at resonance will be

(a) 1 (b) 0 (c) ½ (d) $1/\sqrt{2}$

ANS……………

Q6. Answer the following questions.

(a) In any ac circuit, is the applied instantaneous voltage equal to the algebraic sum of the instantaneous voltages across the series elements of the circuit? Is the same true for rms voltage?

ANS. (a)..

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(b) A capacitor is used in the primary circuit of an induction coil.

ANS(b)………………………………………………………………………………………

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(c) An applied voltage signal consists of a superposition of a dc voltage and an ac voltage of high frequency. The circuit consists of an inductor and a capacitor in series. Show that the dc signal will appear across *C* and the ac signal across *L*.

ANS(c)……………………………………………………………………………………………

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Q.7 In a series LCR circuit, $V_L = V_C \neq V_R$. What is the value of power factor for this circuit?

ANS……………………………………………………………………………………………………

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Q.8 A transformer has 300 primary turns and 2400 secondary turns. If the primary supply voltage is 230V, what is the secondary voltage?

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WORKSHEET-2

Q.1 (a) The peak voltage of an ac supply is 300 V. What is the rms voltage?

(b) The rms value of current in an ac circuit is 10 A. What is the peak current?

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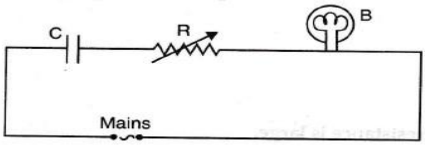
Q.2 A capacitor, 'C', a variable resistor 'R' and a bulb 'B' are connected in series to the ac mains in circuits as shown. The bulb glows with some brightness.



How will the glow of the bulb change if (i) a dielectric slab is introduced between the plates of the capacitor, keeping resistance R to be the same; (ii) the resistance R is increased keeping the same capacitance?

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Q.3 A bulb of resistance 10 Ω connected to an inductor of inductance L, is in series with an ac source marked 100 V, 50 Hz. If the phase angle between the voltage and current is π/4 radian, calculate the value of L.

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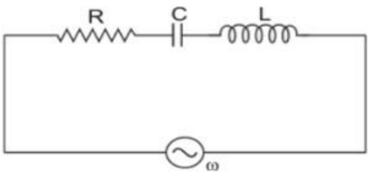
Q.4 In the circuit shown in figure, R represents an electric bulb. If the frequency of the supply is doubled, how should the values of C and L be changed so that the glow in the bulb remains unchanged?



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Q.5 A 100 μF capacitor in series with a 40 Ω resistance is connected to a 110 V, 60 Hz supply.

(a)What is the maximum current in the circuit?

(b)What is the time lag between the current maximum and the voltage maximum?

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Q.6 A circuit containing a 80 mH inductor and a 60 μF capacitor in series is connected to a 230 V, 50 Hz supply. The resistance of the circuit is negligible.(a) Obtain the current amplitude and rms values. (b) Obtain the rms values of potential drops across each element. (c) What is the average power transferred to the inductor?(d) What is the average power transferred to the capacitor. (e) What is the total average power absorbed by the circuit?

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Q.7 A small town with a demand of 800 kW of 1 electric power at 220 V is situated 15 km away from an electric plant generating power at 440V. The resistance of the two wire line carrying power is 0.5 Ω per km. The town gets 1 power from the line through a 4000-220 V step- down transformer at a sub-station in the town.

(a) Estimate the line power loss in the form of heat.
(b) How much power must the plant supply, assuming there is negligible power loss due to leakage?
(c) Characterize the step up transformer at the plant.
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ANSWERS WORKSHEET I:

1. The equivalent DC current that would produce the same amount of heat in a resistance as the AC current does over one complete cycle.

Derivation for $I_{rms} = I_m/\sqrt{2} = 0.707 I_m$.

2. $f = \omega/2\pi \Rightarrow f = 314/6.28 \Rightarrow f \approx 50$ Hz and $I_{RMS} = 2.8/\sqrt{2} = 1.98$

3. (a) $I_v = E_v/R = 220/100 = 2.2$ A
(b) Net power consumed over a full cycle: $P = E_v I_v = 220 \times 2.2 = 484$ W

4. $V_s/V_p = N_s/N_p$ or $230/2300 = N_s/4000$. So, $N_s = 400$.

5. (1) c (2) a

6. (a) Yes, in any AC circuit, the applied instantaneous voltage is indeed equal to the algebraic sum of the instantaneous voltages across the series elements. However, the same does not hold true for RMS voltage.

(b) To prevent sparking when the circuit is broken.

(c) For dc, impedance of L is negligible and of C very high (infinite), so the dc signal appears across C. For high frequency ac, impedance of L is high and that of C is low. So, the ac signal appears across L.

7. When $V_L = V_C$, $X_L = X_C$, $Z = R$, $\cos\phi = R/Z = 1$ i.e., power factor is unity.

8. $V_s = V_p \times (N_s/N_p) \Rightarrow V_s = 230 \times (2400/300) = 8 \Rightarrow V_s = 230 \times 8 = 1840$ V

ANSWERS WORKSHEET II

1. $E_0/\sqrt{2} = E_{rms} = 212$ V, $I_0 = 14.14$ A

2. (i) On introducing a dielectric slab between the plates of capacitor, the reactance of capacitor ($X_C = 1/\omega C$) will decrease resulting in the increase of current in the circuit. Due to it, the bulb will glow brighter

(ii) On increasing resistance R, the effective resistance of circuit increase. Due to it, the current in the circuit decrease. Therefore, the glow of bulb will decrease.

3.

$$\tan\phi = \frac{X_L}{R} = \frac{\omega L}{R} = \frac{2\pi f L}{R}$$

$$\Rightarrow L = \frac{R\tan\phi}{2\pi f}$$

Put values to get $L = 0.032$ H

4. Current in *RLC* circuit is

$$I = \frac{E}{Z} = \frac{E}{\sqrt{R^2 + \left(2\pi f L - \frac{1}{2\pi f C}\right)}}$$

The glow of bulb will remain unchanged when I remains constant. When f is doubled, L should be halved and C should also be halved to keep Z, and hence I constant.

5. $X_C = 1/(2\pi f C) = 26.52\ \Omega$. Now, $Z = \sqrt{(R^2+X^2_C)} = 48 \Rightarrow V_{max} = 141.4$ V, $I_{max} = 2.95$ A

6. (a) Find $Z = X_L - X_C$. Peak value of current $= V_0/Z = 11.63$ A. RMS value = 8.22 A

(b) $V_L = IX_L$, $V_C = IX_C$

(c) Average power consumed by the inductor is zero as the voltage leads current by π/2.

(d) Average power consumed by the capacitor is zero as the voltage lags current by π/2.

(e) The total power absorbed is zero.

7. (a) Total resistance of the wires, R = (15 + 15)×0.5 = 15 Ω

The rms current in the wires is given as $I_{rms} = P/V_1$ = 800000/4000 = 200 A

Line power loss = $I^2R = (200)^2 \times 15$ = 600 kW

(b) Assuming there will be little loss from leakage, total power supply equals town power demand plus line power loss = 800 kW + 600 kW = 1400 kW

(c) Voltage drop on the line is equals = IR = 200×15 = 3000 V.

Consequently, total voltage transmitted from plant V = 4000 + 3000 = 7000 V.

Power generated is 440 V. Hence, the rating of plant's step-up transformer is 440 V to 7000 V.

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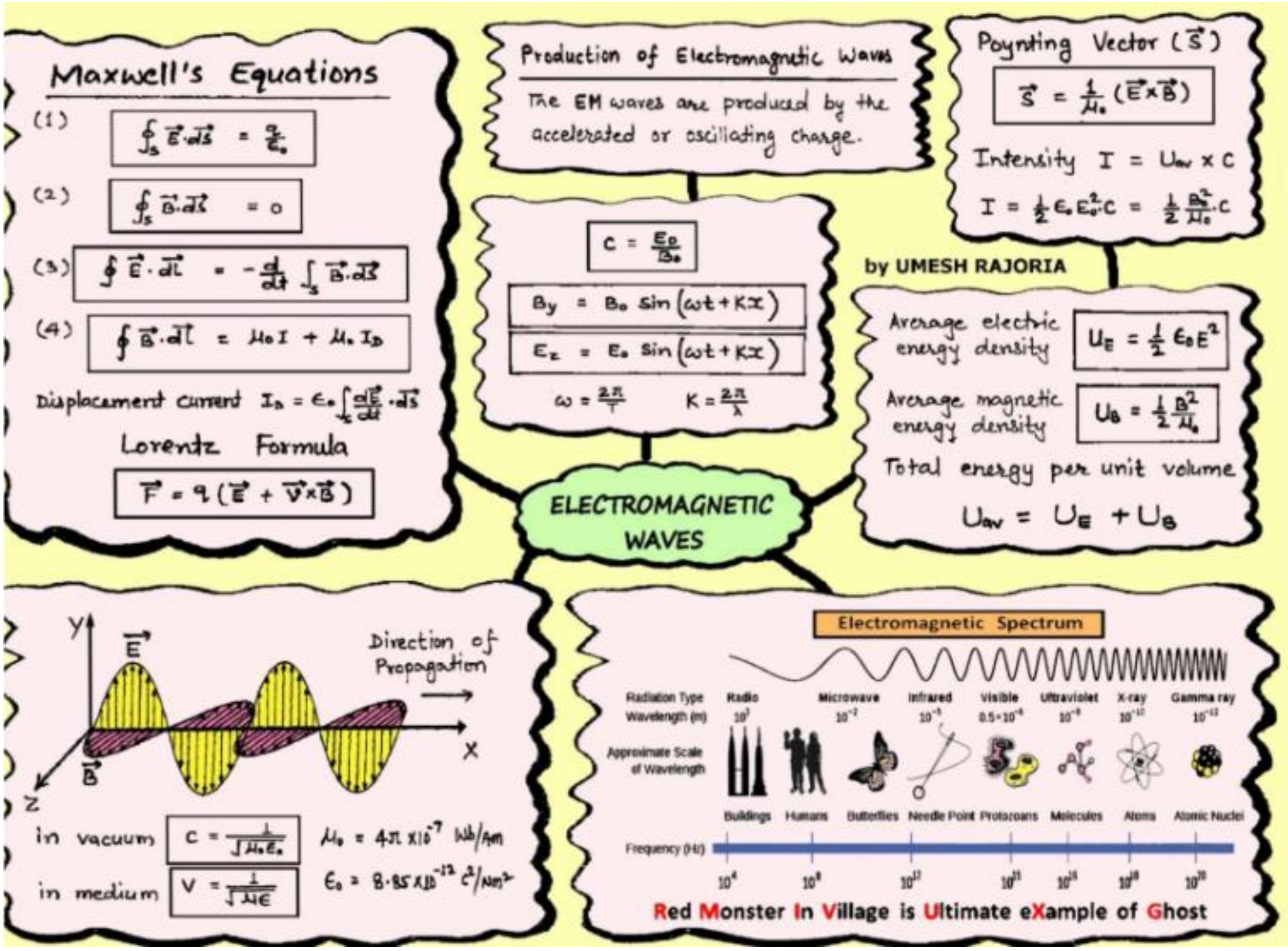
CHAPTER 8

ELECTROMAGNETIC WAVES

MIND MAP



IMPORTANT FORMULAS

1. Wave Equation: Formula: $c = \lambda \times \nu$ Where:

• c = Speed of light (3×10^8 m/s) • λ = Wavelength (in meters) • ν = Frequency (in Hz)

2. Speed of EM Waves in Vacuum: Formula: $c = 1 / \sqrt{(\mu_0 \varepsilon_0)}$

Where:

• $\mu_0 = 4\pi \times 10^{-7}\, H/m$ • $\varepsilon_0 = 8.854 \times 10^{-12}\, F/m$

3. Electromagnetic Wave Equations: $E = E_0 \sin(kx - \omega t), B = B_0 \sin(kx - \omega t)$

Where:

• $k = 2\pi / \lambda$ (wave number) • $\omega = 2\pi\nu$ (angular frequency)

4. Ratio of Fields: Formula: $E / B = c$

• E and B are perpendicular and in phase

5. Energy Density: $u = (1/2)\varepsilon_0 E^2 + (1/2\mu_0) B^2$

Where:

• u = Total energy density

6. Pointing Vector: $S = (1/\mu_0)(E \times B)$
Where:

• Indicates energy flow direction and rate

7. Electromagnetic Spectrum:
Where:
• Radio Waves > Microwaves > Infrared > Visible > UV > X-rays > Gamma Rays

• Frequency ↑, Wavelength ↓

MULTIPLE CHOICE QUESTIONS (1 MARK)

Q1.Which of the following has the **highest frequency**?

a) Radio waves b) X-rays c.)Infrared d)Microwaves

Ans b

Q2.For an EM wave, the magnetic field vector is $B=2\times10^{-7}$ in(kz−ωt)j^**.**What is the

electric field amplitude?

a) 60V/m b) 30V/m c) 75V/m d)100V/m

Ans a

Q3. In the electromagnetic spectrum, the waves with shortest wavelength are:

a)X-rays b)Gamma rays c)UV rays d)Infrared rays

Ans b

Q4. The electric field amplitude of an EM wave is 100V/m. What is the magnetic field amplitude?

a)3.33×10^{-7} T b)1×10^{-6} T c) 3×10^{8}T d) 3.33×10^{8}T

Ans d

Q5. Which field regenerates the other in electromagnetic wave propagation?

a) Static electric b)Static magnetic c)Time-varying E and B d)Particle motion

Ans c

Q6. In electromagnetic waves, electric and magnetic fields are:

a)Parallel b)Perpendicular c) At 45° d) None

Ans b

Q7. An EM wave in vacuum has a frequency of 2×10^{10}Hz. What is its wavelength?

a) 1.5cm b) 2.5cm c) 3cm d) 4.5cm

Ans a

Q8. Electromagnetic waves can travel in:

a)Vacuum only b) Conductors only c)Both vacuum and material medium d) Only insulators

Ans c

Q9. The direction of propagation of EM wave is:

a.) Along E field b)Along B field c)Perpendicular to both E and B d)None

Ans c

Q10. Microwaves are used in:

a) Radiotherapy b)Cooking ovens c)X-ray imaging d)Ozone formation

Ans b

<u>Assertion & Reason Questions:-</u>

Q11. Assertion: Displacement current exists in vacuum.

Reason: It is due to time-varying magnetic field.

a) A and R are true; R explains A b) A is true, R is false

c) A is false, R is true d) Both are false

Ans b

Q12. Assertion: The direction of EM wave propagation is along the electric field.
Reason: Electric field and magnetic field are perpendicular in EM waves.

Ans a

Q13. Assertion: EM waves carry momentum.

Reason: They are made up of oscillating electric and magnetic fields.

Ans a

Q14. Assertion: In EM waves, electric and magnetic fields are in phase.

Reason: Both reach maximum and zero values simultaneously.

Ans a

Q15. Assertion: Radio waves are longitudinal waves.

Reason: They require a medium for propagation.

Ans d

SHORT ANSWER TYPE QUESTIONS (2 MARK)

1. If the total energy density of an EM wave is 3.54×10^{-7}J/m3, calculate the amplitude of the electric field.

Solution:- Electric-field amplitude:

$E_0 = \sqrt{(u / \varepsilon_0} = \sqrt{((3.54 \times 10^{-7}\ J\ m^{-3})/(8.85 \times 10^{-12}\ F\ m^{-1}))}$

$\approx 2.0 \times 10^2\ V\ m^{-1}$.

2. Calculate the speed of EM wave in vacuum using $\varepsilon_0=8.85\times 10^{-12}$F/m and $\mu_0=4\pi\times 10^{-7\ H/m}$

Solution:-2. Speed of light (vacuum):

$c = 1 / \sqrt{(\mu_0\, \varepsilon_0)}$

$= 1 / \sqrt{((4\pi \times 10^{-7}\ \text{H m}^{-1})(8.85 \times 10^{-12}\ \text{F m}^{-1}))}$

$\approx 3.00 \times 10^{8}\ \text{m s}^{-1}$.

3. For the EM wave $E=150\sin(kz-\omega t)$, calculate the **total average energy density** in the wave. Take $\varepsilon_0=8.85\times10^{-12}$F/m

Solution:-5. Total average energy density:

$\langle u \rangle = \varepsilon_0 E_0^2 / 2$

$= (8.85 \times 10^{-12})(150)^2 / 2$

$\approx 1.0 \times 10^{-7}\ \text{J m}^{-3}$.

4.A plane EM wave delivers an average power of 1 W/m^2 to a perfectly absorbing surface. Calculate the radiation pressure.

Solution:- Radiation pressure on a perfectly absorbing surface:

$P = S/c = (1\ \text{W m}^{-2})/(3 \times 10^{8}\ \text{m s}^{-1})$

$\approx 3.3 \times 10^{-9}\ \text{N m}^{-2}$.

5.What are the essential conditions for a wave to be electromagnetic?

Solution:-Conditions: mutually perpendicular, in-phase, time-varying E & B satisfying Maxwell's equations; no material medium required.

6. The magnetic field in a plane electromagnetic wave is given by

$$B_Y = 2 \text{ X } 10^{-7} \sin (0.5 \text{ x } 10^{3} x + 1.5 \text{ X } 10\text{-}^{11} t) \text{ T}$$

(i) What is the wavelength & frequency of the wave ? (ii) write an expression for the electric field.

Solution :- Ans. (i) λ = 1.26m, $\nu = 2.4 \text{ x } 10^{11}$ H_Z (ii) $E_Z = 60 \sin (0.5 \text{ x } 10^{3} x + 1.5 \text{ X } 10^{11} t)$

SHORT ANSWER TYPE QUESTIONS (3 MARK)

Q1. The frequency of an electromagnetic wave is 6×10^{14}Hz. Calculate its wavelength in vacuum. (Take $c=3\times 10^{8}$ m/s)

ANS: Solution:- $\lambda = c/f = (3 \times 10^{8}\ \text{m s}^{-1})/(6 \times 10^{14}\ \text{Hz}) = 5.0 \text{ X } 10^{-7}$ m (500 nm).

Q2. In an EM wave, the peak value of electric field is E_0=120V/m. Find the peak value of magnetic field. (Take $c=3\times 10^{8}$m/s).

ANS:Solution:- $B_0 = E_0/c = 120\ \text{V m}^{-1} / 3 \times 10^{8}\ \text{m s}^{-1} = 4.0 \times 10^{-7}$ T.

Q3. An EM wave has an electric field amplitude of 200V/m. Calculate the energy density of the electric field.
(Take $\varepsilon 0=8.85\times10^{-12}\ C^2/Nm^2$)

ANS:Solution:-3. Electric-field energy density:

$\langle u_E \rangle = \tfrac{1}{2} \varepsilon_0 E_0^2 = 0.5 \times 8.85 \times 10^{-12} \times (200)^2$

$\approx 1.77 \times 10^{-7}\ \text{J m}^{-3}$.

Q4.In an EM wave, the electric field is given by $E=120\sin(kz-\omega t)\hat{i}$ Find the corresponding magnetic field amplitude B0.

ANS:Solution:-. $B_0 = E_0/c = 120\ \text{V m}^{-1} / 3 \times 10^{8}\ \text{m s}^{-1} = 4.0 \times 10^{-7}$ T. Therefore $\vec{B} = 4.0 \times 10^{-7} \sin(kz - \omega t)\,\hat{j}$.

Q5. How are EM waves classified? Name three types with applications.

ANS:Solution:-Spectrum classes & uses:

• Radio – broadcasting • Microwaves – radar, ovens • Infra-red – thermal imaging

• Visible – photography • UV – sterilization • X-ray – medical imaging
• Gamma – cancer therapy.

Q6..The electric field of an EM wave is given by: $\vec{E}=100\sin(2\pi.10^7z-6.28\times10^{15}t)\ i$

Find: (a) Wavelength λ (b) Frequency f (c) Speed of the wave

ANS:Solution:-. Comparing with $E = E_0 \sin(kz - \omega t)$:
$k = 2\pi \times 10^7\ m^{-1} \Rightarrow \lambda = 2\pi/k = 1 \times 10^{-7}$ m;
$\omega = 6.28 \times 10^{15}\ s^{-1} \Rightarrow f = \omega/2\pi = 1 \times 10^{15}$ Hz;
Speed $v = f\lambda = 1 \times 10^8\ m\ s^{-1}$.

7.Show that in an EM wave, energy is equally distributed between E and B fields.
ANS:Solution:-Using $u_E = \frac{1}{2}\varepsilon_0 E^2$ and $u_B = B^2/(2\mu_0)$ with $B = E/c$, one gets $u_E = u_B \Rightarrow$ energy is equally shared.

8.A wave has a frequency of 6×10^{14} Hz. Find its wavelength.

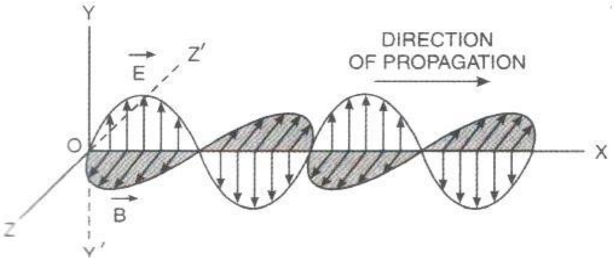
ANS:Solution:-$\lambda = c/f = 3 \times 10^8 / 6 \times 10^{14} = 5.0 \times 10^{-7}$ m.

Q 9. What is the significance of displacement current in charging a capacitor?

ANS:Solution:- Displacement current ($\varepsilon_0\, d\Phi_E/dt$) maintains continuity of $\oint B\cdot dl$ across the capacitor gap, allowing changing electric fields to create magnetic fields even in vacuum.

Q10.What is meant by transverse nature of electromagnetic wave? Draw a diagram showing the propagation of an electromagnetic wave along the x direction, indicating clearly the directions of the oscillating electric and magnetic fields associated with it.

ANS:Solution :-



E.M. waves are transverse in nature i,e, E & B are perpendicular to each other as well as perpendicular to the direction of propagation of the wave. $\vec{E}$ & $\vec{B}$ are related as follows -

$$\frac{E_0}{B_0}=c \quad \text{or} \quad \frac{E}{B}=c$$

WORKSHEET-1

Instructions: Read each question carefully and write the correct answer.

Section A – Fill in the Blanks (1 mark each)

Q1. Electromagnetic waves are produced by __________ charges.

Q2. The speed of electromagnetic waves in vacuum is __________ m/s.

Q3. The electric and magnetic fields in an EM wave are __________ to each other.

Q4. The unit of frequency is __________.

Q5. __________ waves are used in microwave ovens.

Section B – True or False (1 mark each)

Q6. Electromagnetic waves need a medium to propagate. (True / False)

Q7. X-rays have higher frequency than visible light. (True / False)

Q8. Radio waves can be used for communication. (True / False)

Q9. Gamma rays have the lowest energy in the EM spectrum. (True / False)

Q10. The direction of propagation of an EM wave is perpendicular to both electric and magnetic fields. (True / False)

Section C – Match the Following (1 mark each)

A	B
1. Radio waves	a. Sterilization of food
2. Microwaves	b. Night vision
3. Infrared rays	c. Mobile communication
4. Ultraviolet rays	d. Radar and cooking
5. Gamma rays	e. Remote control

Section D – Short Answer Type (2 marks each)

Q11. Write any two uses of ultraviolet rays.

____

____

Q12. What is the relation between speed, frequency, and wavelength of EM waves?

____

Q13. Name any two properties of EM waves.

Q14. Why are X-rays used in medical diagnosis?

Q15. What is the full form of UV and IR. Write the source of these waves?

Answers

Section A – Fill in the Blanks

1. Accelerating 2. 3×10^8 3. Perpendicular 4. Hertz (Hz) 5. Microwaves

Section B – True or False

6. False 7. True 8. True 9. False 10. True

Section C – Match the Following

11 → c 12 → d 13 → e 14 → a 15 → b

Section D – Short Answers

16. Used to kill germs; in water purification.

17. $c = \lambda\nu$, where c is speed, λ is wavelength, and ν is frequency.

18. Transverse in nature; do not require medium.

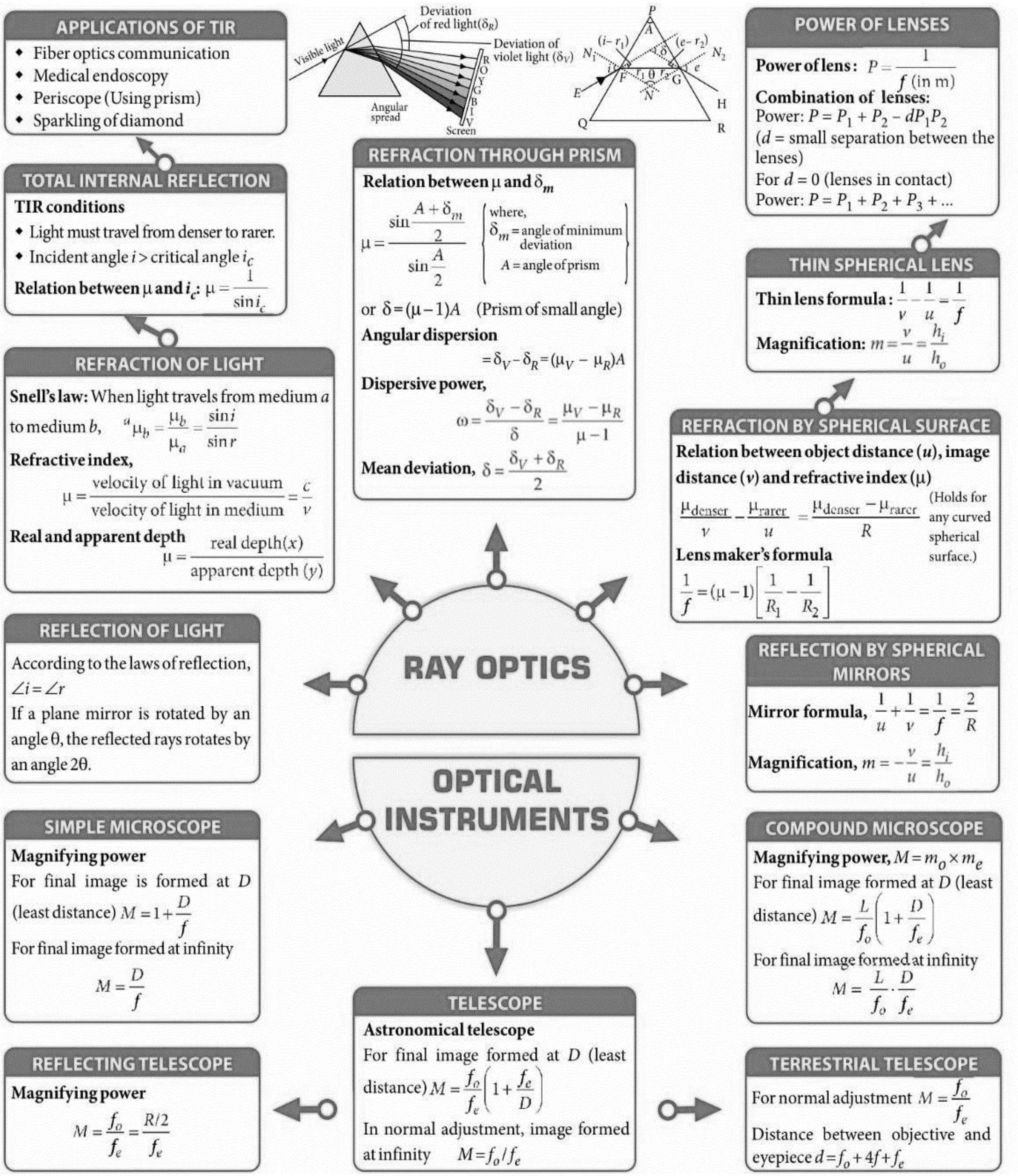
19. They can penetrate tissues and are absorbed by bones, showing clear images.

20. Ultraviolet; Infrared Source

CHAPTER 9

RAY OPTICS AND OPTICAL INSTRUMENTS

BRAIN MAP



MULTIPLE CHOICE QUESTIONS (1 MARK)

Q1. A convex lens of power 4D and a concave lens of power 3D are placed in contact. What is the equivalent power of the combination?

(a)7D (b) $\frac{4}{3}$D (c)1D (d) $\frac{3}{4}$D

ANS: C) 1D

Q2.An object approaches a convergent lens from the left of the lens with a uniform speed 5 m/s and stops at the focus. The image

(a)moves away from the lens with a uniform speed 5 m/s.

(b)moves away from the lens with a uniform acceleration.

(c)moves away from the lens with a non-uniform acceleration.

(d)moves towards the lens with a non-uniform acceleration.

ANS: C) moves away from the lens with a non-uniform acceleration

Q3. The refractive index of the material of an equilateral prism is $\sqrt{3}$, then the angle of minimum deviation is

(a) 45° (b) 60° (c) 37° (d) 30°

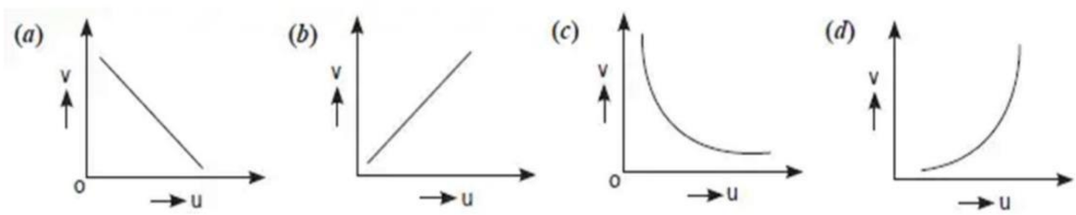
ANS: (b) 60°

Q4. An object is placed at the focus of the convex mirror. If its focal length is 20cm, the distance of image from the mirror is

(a)10cm (b)20cm (c)40cm (d)None

ANS: a) 10cm

Q5.In an experiment to find focal length of a concave mirror, a graph is drawn between the magnitude of u and v. The graph looks like:



ANS: (c) u – v curve is a rectangular parabola

Q6.Air bubble in water behaves as

(a)sometimes concave, sometimes convex lens (b)concave lens

(c)convex lens (d)always refracting surface

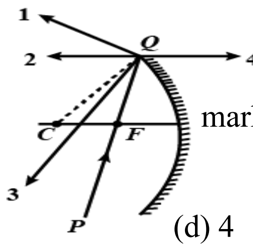
ANS: (b) Air bubble in water behaves as a concave lens.

Q7.A ray of light passes from glass (μ = 1.5) to water (μ = 1.33). The value of the critical angle of glass is __________________________.

(a)$\sin^{-1}$ (8/9) (b)$\sin^{-1}$($\sqrt{}$ 8/9) (c)$\sin^{-1}$ (½) (d) $\sin^{-1}$ (2/1)

ANS: a) $\sin^{-1}(8/9)$

Q8.The direction of ray of light incident on a concave mirror is shown by PQ while directions in which the ray would travel after reflection is shown by four rays marked 1, 2, 3 and 4. Which of the four rays correctly shows the direction of reflected ray?



(a) (b) 2 (c) 3 (d) 4

ANS: (b) is correct.

Q9. In the formation of a rainbow, the light from the sun on water droplets undergoes

(a) dispersion only. (b) only TIR. (c) dispersion, refraction and TIR. (d) scattering

ANS: . (c) dispersion, refraction and TIR

Q10. An object is placed at a distance of 0.5 m in front of a plane mirror. The distance between object and image will be

(a) 0.25 m (b) 0.5 m (c) 1.0 m (d) 2.0 m

ANS: (c) Distance between object and image = 0.5 + 0.5 = 1.0 m

ASSERTION AND REASON BASED QUESTIONS (1MARK)

The following questions consist of two statements – Assertion (A) and Reason (R). Answer these questions by selecting the appropriate option given below:

(a) Both A and R are true and R is the correct explanation of A.

(b) Both A and R are true but R is not the correct explanation of A.

(c) A is true but R is false.

(d) A is false and R is also false.

Q1.Assertion (A) : Higher is the refractive index of a medium or denser the medium, lesser is the velocity of light in that medium.

Reason (R) : Refractive index is inversely proportional to velocity.

Answer: (a) Both A and R are true and R is the correct explanation of A

Q2.Assertion (A) : Endoscopy involves use of optical fibres to study internal organs.

Reason (R) : Optical fibres are based on phenomena of total internal reflection.

Answer: (d) A is false and R is also false

Q3.Assertion (A) : If optical density of a substance is more than that of water, then the mass density of substance can be less than water.

Reason (R) : Optical density and mass density are not related.

Answer: (a) Both A and R are true and R is the correct explanation of A

Q4.Assertion (A) : Microscope magnifies the image.

Reason (R) : Angular magnification for image is more than object in microscope.

Answer: (a) Both A and R are true and R is the correct explanation of A

Q5.Assertion(A) : Plane mirror may form real image.

Reason : Plane mirror forms virtual image, if object is real.

Answer: (b) Both A and R are true but R is not the correct explanation of A.

SHORT ANSWER QUESTIONS-I (2-MARK)

Q1.What is total internal reflection and what are the conditions under which it occurs? Obtain relation between critical angle & refractive index.

ANS: The of light proceeding from an object in the denser medium return back to the same medium when incident at an angle greater than the critical angle for the pair of media is called total internal reflection. Conditions for TIR-light should travel from denser medium to rare medium.

Angle of incidence in the denser medium should be greater than the critical angle for the pair of media. $\mu = \frac{1}{\sin i}$

. Q2. (a)A convex lens is immersed in water of refractive index1.33.Will the lens behave as a converging or a diverging lens? Give reason.

(b) When monochromatic light travels from one medium to another its wavelength changes but frequency remains the same. Explain.

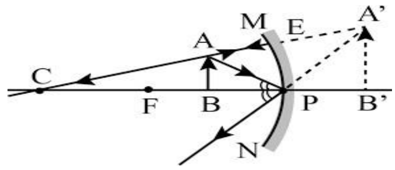
ANS: (a) This is because the refractive index of water (1.33) is less than the refractive index of the typical material (e.g., glass, around 1.5) of the convex lens. When the surrounding medium has a lower refractive index than the lens material, the light rays bend away from the normal as they pass from the lens into the water, causing them to diverge instead of converge.

(b) If v_1 and v_2 denote the velocity of light in medium 1and medium 2 respectively and λ_1 and λ_2 denote the wavelength of light in medium 1and medium 2. f = $\frac{v}{\lambda}$

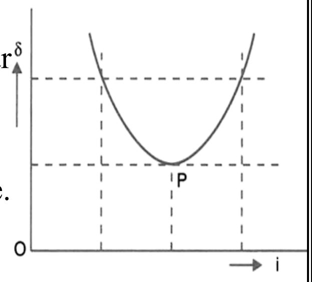
The above equation implies that when a wave gets refracted into a denser medium ($v_1 > v_2$) the wavelength and the speed of propagation decreases but the frequency v ($=\frac{v}{\lambda}$) remains the same.

Q3.Draw a ray diagram to show the image formation by a concave mirror when the object is placed between its focus and pole. Write the value and sign of magnification in this case.

ANS: m =positive and greater than 1



Q4.A plot, between the angle of deviation (δ) and angle of incidence (i), for a triangular prism is shown in figure:



Explain why any given value of 'δ' corresponds to two values of angle of incidence. State the significance of point P on the graph. ?

ANS: In general , any given value of deviation δ ,(except for i=e) corresponds to two values I and e. This is expected from the symmetry of I and e as δ=i+e–A ,i.e., δ remains the same if i and e are interchanged.

Point P is the point of minimum deviation .This is related to the fact that the path of the ray as shown in Figure can be traced back resulting in the same angle of deviation. At the minimum deviation δm, the refracted ray inside the prism becomes parallel to the base.

Q5. (a)Write two differences between linear and angular magnification.

(b)Three lenses with magnifications 2, 3 and 10 form a combination. What is its total magnification?

ANS: (a)Linear magnification Also known as lateral or transverse magnification, this is the ratio of the length of the image to the length of the object. It's constant for all objects and takes into account everything about the image.

Angular magnification This is the ratio of the tangents of the angles subtended by an object and its image from a given point. It only considers the size of the field of view that the image occupies

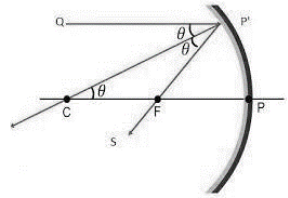
m=size of image/ size of object= h_2/h_1

(b) Total magnification,

$M= m_1\times m_2 \times m_3=2 \times 3\times 10 = 60$

Q 6. With the help of a ray diagram, obtain the relation between its focal length and radius of curvature.

ANS: The relationship between the focal length f and the radius of curvature R=2f.



From the geometry of the figure,

∠CP'Q = θ = I In ∠CP'F, θ=r

∴BF=FC (because i= r)

If the aperture of the mirror is small, B lies close to P, and therefore BF=PF Or FC = FP = PF

Or PC=PF+FC=PF+PF Or R = 2 PF = 2f   Or f=R/2

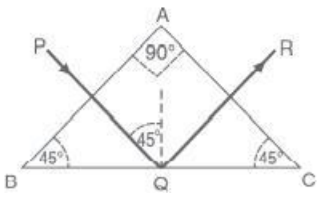
Similar relation holds for convex mirror also. In deriving this relation, we have assumed that the aperture of the mirror is small.

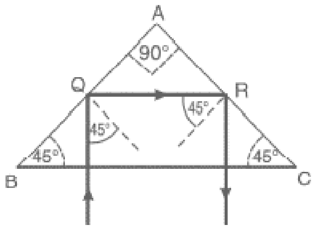
Q7. How does the power & focal length of a convex lens vary, if the incident red light is replaced by violet light?

ANS: when red light incident on a convex lens is replaced with violet light , the power of the lens increases and the focal length decreases. This is because violet light has a shorter wavelength and higher refractive index than red causing it to refract more strongly and converge at a shorter distance.

Q8.A right angled isosceles glass prism is made from glass of refractive index 1.5. Show that a ray of light incident normally on (i) one of the equal sides of this prism is deviated through 90° (ii) the hypotenuse of this prism is deviated through180°.

ANS:





Q9.a)When monochromatic light is incident on a surface separating two media, the reflected and refracted light both have the same frequency as the incident frequency. Explain why?

b)What are benefits of Lens Combination and making equivalent lens?

ANS: (a) When monochromatic light (light of a single frequency) is incident on a surface separating two media, both the reflected and refracted light maintain the same frequency as the incident light. This is because the frequency of light is determined by the source and remains unchanged during reflection or refraction. The interaction with the surface causes atoms in the material to oscillate at the same frequency as the incident light, and the emitted light (both reflected and refracted) inherits this frequency.

(b) Combining lenses and creating an equivalent lens offers several advantages, including adjusting focal length, improving image quality, controlling image characteristics, and enhancing light focus. These benefits are crucial in various optical instruments like telescopes and microscopes.

Q10. (a)A small telescope has an objective lens of focal length 144cm and an eyepiece of focal length 6.0cm. What is the magnifying power of the telescope? What is the separation between the objective and the eyepiece?.

(b) State one practical use each of convex mirror, concave mirror, convex lens and concave lens.

ANS(a) Given : f_0=144cm,fe=6.0cm.

Magnifying power of the telescope

m=f_0/fe=1446=24

Separation between objective and eye piece =|f_0+fe| =144+6=150cm

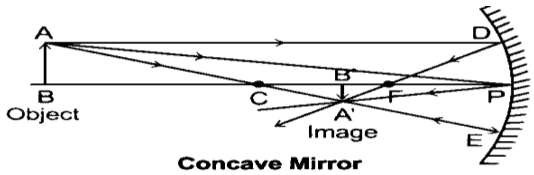
(b) A convex mirror is used as a rearview mirror in vehicles due to its ability to provide a wider field of view. A concave mirror is used in solar cookers to focus sunlight and generate heat. A convex lens is used in magnifying glasses to enlarge small objects. A concave lens is used in some types of eyeglasses to correct nearsightedness.

SHORT ANSWER QUESTIONS-II (3-MARKS)

Q1.An equi-convex lens of radius of curvature R is cut into two equal parts by a vertical plane ,so it becomes a Plano convex lens. If f is the focal length of the equi-convex lens, then what will be focal length of Plano convex lens?

ANS: $\frac{1}{f} = (\mu - 1)(\left[\frac{1}{R} - \frac{1}{(-R)}\right] = 2\frac{(\mu-1)}{R}$ and f'=R/(μ-1)   So, f'=2f

Q2.Derive mirror equation for a convex mirror for real image.



ANS: $\Delta ABC$and $\Delta A'B'C$are similar triangles. Similarly, ΔABP, and $\Delta A'B'P$ are also similar triangles.

1/u+1/v=1/f

Q3. a)A biconcave lens made of a transparent material of refractive index 1.25 is immersed in water of refractive index 1.33. Will the lens behave as a converging or a diverging lens? Give a reason.

b) A convex lens is placed in contact with a plane mirror. A point object at a distance of 20 cm on the axis of this combination has its image coinciding with itself. What is the focal length of the lens? Draw related Ray Diagram.

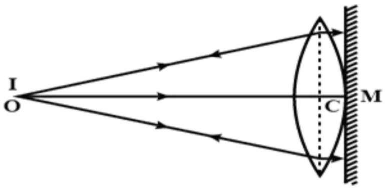
ANS: (a) $\frac{1}{f} = (\mu - 1)(\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$

We need to find the relative refractive index of the lens with respect to water. This is calculated using the formula:

μ_{rel}= =1.25/1.33≈0.940

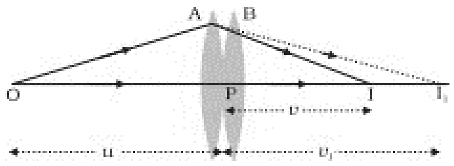
If the relative refractive index is less than 1, the lens will behave as a converging lens.

b) Figure shows a convex lens placed in contact with a plane mirror. An axial Point object is placed at a distance O at a distance, OC=20cm.As the image I Of the object coincides with O; Refracted by the plane mirror must be retracing their path. This would happen the rays refracted first from the lens and then when rays refracted by the convex lens fall normally on the mirror I.e, the Refracted rays form a beam parallel to principal axis of the lens. Hence the object O must be at the focus of the convex lens. f=CO=20 cm.



Q4.Using the ray diagram for a system of two lenses of focal lengths f_1 and f_2 in contact with each other, show that two lens system can be regarded as equivalent to a single lens of focal length f, where. Also write the relation for the equivalent power of the lens combination.

ANS: Let us consider the two thin lenses A and B forming the image I and I_1 respectively, from the object (O). For I the distance is u and for I_1 the distance is v_{1}.

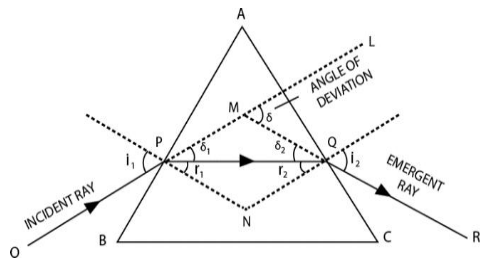


For lens 'A', the lens formula is; $\frac{1}{f_1} = \frac{1}{v_1} - \frac{1}{u}$ where $v_1$is the image distance, u is the object distance

For lens 'B', the lens formula is; $\frac{1}{f_2} = \frac{1}{v} - \frac{1}{v_1}$

On adding both we get, $\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$

Q5.Draw a ray diagram to show refraction of a ray of monochromatic light passing through a glass prism. Deduce the expression for the refractive index of glass in terms of angle of prism and angle of minimum deviation.



In the case of minimum deviation,

$\angle r_1 = \angle r_2 = \angle r$

$\delta = i_1 - r_1 + i_2 - r_2$, $\delta = i_1 + i_2 - (r_1 + r_2)$

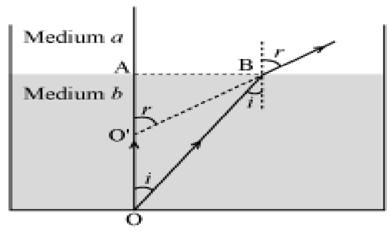
$r = A/2$ $i_1 + i_2 = A + \delta$

$A + \delta m = 2i$

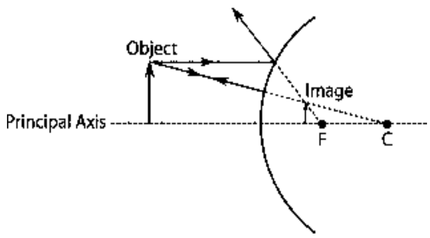
$n = \sin((A + D_m) / 2) / \sin(A / 2)$

Q6. Produce a relation between real depth and apparent depth.

ANS: $\frac{\boldsymbol{h_2}}{\boldsymbol{h_1}} = \frac{\text{Real depth}}{\text{apparent depth}} = \frac{\text{n denser}}{\text{n rarer}}$



Q7.Using MIRROR FORMULA, show that a convex mirror always produces a virtual image, independent of the location of the object & draw the related ray diagram.



ANS: For a convex mirror,>0and for an object on left, u<0

From mirror formula, $$\frac{1}{v} = \frac{1}{f} - \frac{1}{u}$$

As f *is+ve and* u *is –ve* thus, a convex mirror always produces a virtual image, independent of the location of the object

Q8.(a) How does the angle of minimum deviation produced by a prism change with increase in (i) the wavelength of incident light, and (ii) the refracting angle of prism?

(b)A glass prism is held in water. How is the angle of minimum deviation affected?

(c) When does a ray passing through a prism deviate away from its base?

ANS: (a). Changes in the angle of deviation as we increase:

(i)As we increase the wavelength, the angle of deviation decreases.

(ii)The angle of deviation increases with the increase in the angle of the prism

(b) When a glass prism is held in water, the angle of minimum deviation decreases.

(c)When the prism is immersed in a medium with refractive index higher than that of the prism material the ray will deviate away from the base.

Q9.Which two of the following lenses L_1, L_2 and L_3 will you select as objective and eyepiece for constructing the best possible (i) telescope (ii) microscope? Give reason to support your answer.(iii) the aperture of the objective of--------- is Preferred to be large?

Lenses	Power (P)	Aperture(A)
L_1	3 D	8cm
L_2	6 D	1 cm
L_3	10 D	1 cm

ANS: i) Telescope: L_1 as objective and L_2 as eye piece Reason: The objective should have large aperture and large focal length while the eye piece should have small a perjure and small focal length. Then the light Gathering power and magnifying power will be larger. (ii)Microscope: L_3 as objective and L_2 as eyepiece Reason: Both the lenses of the microscope should have short focal lengths and the focal length of the objective should be smaller than that of the eyepiece. Magnifying power will be larger for short focal lengths of objective and eyepiece. iii) The aperture is preferred to be large so that the telescope can collect as much as light coming from the distant object as possible.

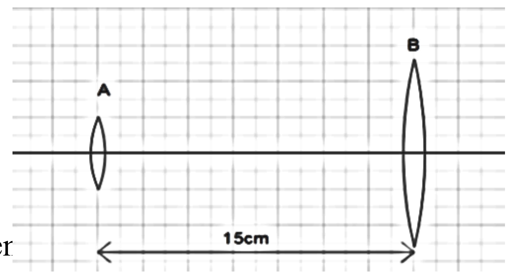
Q10.(a)Write the two important factors considered to increase the magnifying power of a refracting type telescope.

(b)Two convex lenses A and B of an astronomical telescope having focal lengths 5cm and 20 cm respectively, are arranged as shown in the

(i) Which one of two lenses you will select to use as objective lens and why?

(ii) What should be the change in the distance between the lenses to have the telescope in its normal adjustment position?

(iii) Calculate magnifying power of telescope in the normal adjustmer



ANS: (a) To increase the magnifying power of a refracting telescope, the two important factors to consider are the focal length of the objective lens and the focal length of the eyepiece.

(b) Lens B (20cm focal length) should be used as the objective lens.

In an astronomical telescope, the objective lens needs to have a longer focal length to gather light from distant objects effectively. Since lens B has a longer focal length (20cm) compared to lens A (5cm), it should be selected as the objective lens.

(ii) To have the telescope in normal adjustment, the distance between the lenses should be equal to the sum of their focal lengths. Distance needed = 5cm + 20cm = 25cm

(iii) The magnifying power of a telescope is calculated by dividing the focal length of the objective lens by the focal length of the eyepiece lens.

CASE BASED QUESTIONS (4 MARKS)

Q1.A telescope is a device used to observe distant objects by their emission, absorption, or reflection of electromagnetic radiation. Originally, it was an optical instrument using lenses, curved mirrors, or a combination of both to observe distant objects – an optical telescope. Nowadays, the word "telescope" is defined as a wide range of instruments capable of detecting different regions of the electromagnetic spectrum, and in some cases other types of detectors.The first known practical telescopes were refracting telescopes with glass lenses and were invented in the Netherlands at the beginning of the 17th century. They were used for both terrestrial applications and astronomy.The reflecting telescope, which uses mirrors to collect and focus light, was invented within a few decades of the first refracting telescope.

In the 20th century, many new types of telescopes were invented, including radio telescopes in the 1930s and infrared telescopes in the 1960s.

i) The magnifying power of an astronomical telescope in normal adjustment is 100. What is the focal length of the objectives and eyepiece of the distance between them is 101 cm?

(a)1 cm and 10 cm respectively (b)1 cm and 100 cm respectively

(c)10 cm and 1 cm respectively (d)100 cm and 1 cm respectively

ANS: (i) (a) 1 cm and 10 cm respectively

(ii)If the focal length of the objective lens is increased then

(a) Magnifying power of microscope will increase but that of telescope will decrease

(b) Magnifying power of microscope and telescope both will increase

(c) Magnifying power of microscope and telescope both will decrease

(d) The magnifying power of microscope will decrease but that of the telescope will increase

ANS: The correct option is d

(iii) The magnifying power of a telescope is 9. When it is adjusted for parallel rays, the distance between the objective and the eye-piece is found to be 20 cm. The focal lengths of the lenses are

(a).18 cm, 2 cm (b) 11 cm, 9 cm (c)10 cm, 10 cm (d) 15 cm, 5 cm

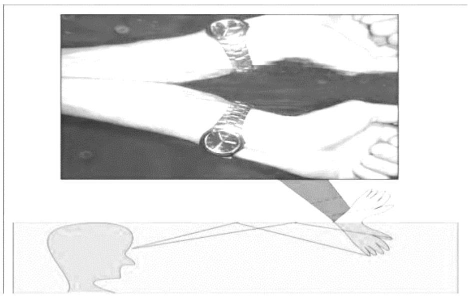
ANS: (a) 18 cm, 2 cm

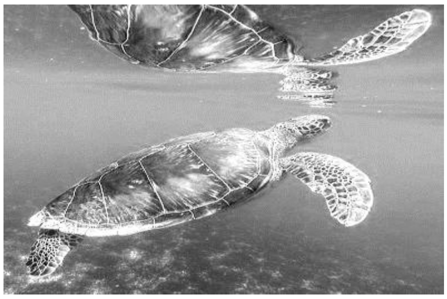
(iv) In a compound microscope, magnifying power is 95 and the distance of the object from the objective lens is 1/38 cm. The focal length of the objective lens ¼ cm. What is the magnification of eyepiece?

(a) 5 (b) 10 (c) 100 (d) 200

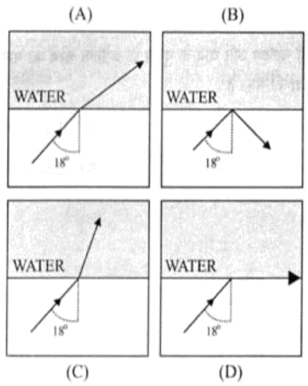
ANS: (a) 5

Q2. A ray of light travels from a denser to a rarer medium. After refraction, it bends away from the normal. When we keep increasing the angle of incidence, the angle of refraction also increases till the refracted ray grazes along the interface of two media. The angle of incidence for which it happens is called critical angle. If the angle of incidence is increased further the ray will not emerge and it will be reflected back in the denser medium. This phenomenon is called total internal reflection of light.





(i) A ray of light travels from a medium into the water at an angle of incidence of 18°. The refractive index of the medium is more than that of water and the critical angle for the interface between the two media is 20°. Which one of the following figures best represents the correct path of the ray of light?



ANS: (a)The incidence angle is smaller than the critical angle.

(ii)A point source of light is placed at the bottom of a tank filled with water, of refractive index μ, to a depth h. The area of the surface of water through which light from the source can emerge is:

(a)$\pi h^2/2(\mu^2-1)$ (b) $\pi h^2/(\mu^2-1)$ (c) $\pi h^2/(\sqrt{2}\sqrt{(\mu^2-1)})$ (d) $2\pi h^2/(\mu^2-1)$

ANS: ii) (b) $\pi h^2/(\mu^2-1)$

(iii)Is the formula "Real depth/Apparent depth =μ" valid if viewed from a position quite away from the normal?

ANS: No.

(iv)A diver in a swimming pool wants to signal his distress to a person lying on the edge of the pool by flashing his water proof flash light

(a) He must direct the beam vertically upwards

(b) He has to direct the beam horizontal

(c) He has to direct the beam at an angle to the vertical which is slightly less than the critical angle of incidence for total internal reflection

(d) He has to direction the beam at an angle to the vertical which is slightly more than the critical angle of incidence for the total internal reflection

ANS: c)

Q3. A comprehensive eye exam is simple and comfortable. It shouldn't take more than 45 to 90 minutes. Here is what the exam should include:

This is the part of an eye exam people are most familiar with. You will read an eye chart to determine how well you see at various distances. You cover one eye while the other is being tested. This exam will determine whether you have 20/20 vision or not.

Your doctor will ask you to look at an eye chart through a device called a phoroptor. The phoroptor contains different lenses. Your doctor may check how your pupils respond to light by shining a bright beam of light into your eye. Pupils usually respond by getting smaller. If your pupils widen or don't respond, this may reveal an underlying problem. Loss of side vision (peripheral vision) may be a symptom of glaucoma. This test can find eye problems you aren't aware of because you can lose side vision without noticing. A test called ocular motility evaluates the movement of your eyes. Your ophthalmologist looks to see if your eyes are aligned. They also check that your eye muscles are working properly Eye pressure testing, called tonometry, measures intraocular eye pressure, or IOP. Elevated IOP is one sign of glaucoma.

Your ophthalmologist uses a slit-lamp.

microscope to light up the front part of the eye. This includes the eyelids, cornea, iris and lens. This test checks for cataracts or any scars or scratches on your cornea.

i) The maximum magnification that can be obtained with a convex lens of focal length 2.5 cm is (the least distance of distinct vision is 25 cm)

a).10 b) 0.1 c) 62.5 d)11

ANS: d) 11

ii) The magnifying power of a magnifying glass is 6. The focal length of its lens in metres will be, if least distance of distinct vision is 25 *cm*

a)0.05 b) 0.06 c) 0.25 d) 0.12

ANS: a) 0.05

iii) Resolving power of human eye is:

a) 0.1 mm b) 1 mm c) 2 mm d)None of the above

ANS: a) 0.1mm

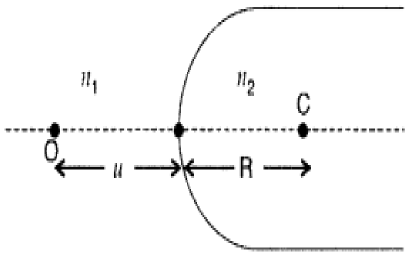
iv) In a simple microscope, if the final image is located at infinity then its magnifying power is

a)25/f　　b) D/25　　c) f/25　　d) f/D[+1]

ANS: a) 25/f

LONG ANSWER QOUESTIONS (5 MARKS)

Q1.(a) A point object 'O' is kept in a medium of refractive index n_1 in front of a convex spherical surface of radius of curvature R which separates the second medium of refractive index n_2 from the first one, as shown in the figure.



Draw the ray diagram showing the image formation and deduce the relationship between the object distance and the image distance in terms of n_1 n_2 and R.

(b)Write the basic assumptions in the derivation of lens maker's formula.

ANS: Derivation of

$$\frac{\mu_1}{V} - \frac{\mu_2}{V\prime} = \frac{\mu_1-\mu_2}{R_2}$$

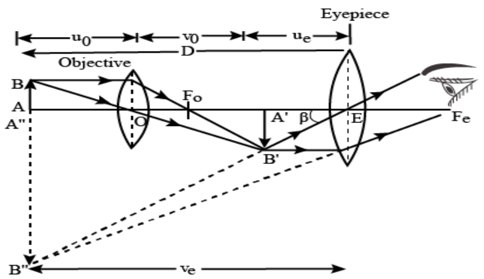
Assumptions:Aperture of the lens used should be very small The thickness of the lens should be less

Q2.Write any two advantages of a compound microscope over a simple microscope. Draw a ray diagram for the image formation at the LDDV by a compound microscope and explain it.

Explain,(i)Why must both the object and the eyepiece of a compound microscope have short focal lengths?-

(ii)While viewing through a compound microscope, why should our eyes be positioned not on the eyepiece but a short distance away from it for best viewing?

ANS:



$M = m_o \times m_e$

$M = -\frac{v_o}{u_o}\frac{D}{f_e}$ normal mode　$M = \frac{v_o}{u_o}\left(1+\frac{D}{f_e}\right)$ infinity

Now for large magnification, is to be large, so f_e should be small and u_o should be small. Now object is placed at a distance u_o from the objective which is slightly greater than its focal length f_o. So for u_o to be small, f_o should also be small.

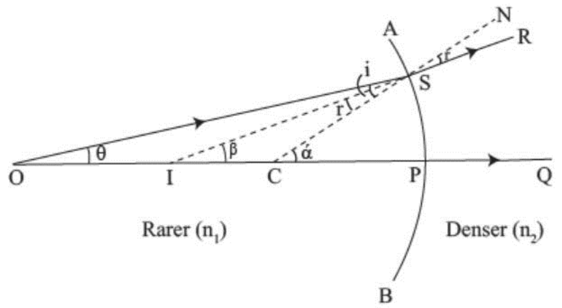
When we place our eyes too close to the eyepiece of a compound microscope,

We are unable to collect much refracted light. As a result, the field of view decreases substantially.Hence, the clarity of the image gets blurred.

Q3.(i)Draw a ray diagram showing the formation of the image by a point object on the principal axis of a spherical concave surface separating two media of refractive indices n_1 and n_2, when a point source is kept in the rarer medium of refractive index n1. Derive the relation between object and image distance in terms of refractive index of the medium and radius of curvature of the surface.

(ii) Light from a point source in air falls on a convex spherical glass surface of refractive index 1.5 and radius of curvature 20 cm. The distance of light source from the glass surface is 100 cm. At what position is the image formed?

ANS:



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

$$\frac{1.5}{v} - \frac{1}{(-100)} = \frac{1.5 - 1}{20}$$

V=100 cm hence image is formed 100 cm in the denser medium

Q4. Use the mirror equation to deduce that:

(a) an object placed between f and $2f$ of a concave mirror produces a real image beyond $2f$.

(b) a convex mirror always produces a virtual image independent of the location of the object.

(c) the virtual image produced by a convex mirror is always diminished in size and is located between the focus and the pole.

(d) an object placed between the pole and focus of a concave mirror produces a virtual and enlarged image.

Ans. (a) For a concave mirror, the focal length (f)is negative.

$\therefore f < 0$

When the object is placed on the left side of the mirror, the object distance (u)is negative.

$\therefore u < 0$

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

The object lies between f and 2f .Therefore 2f < u < f (therefore u and f are negative)

$\frac{1}{2f} > \frac{1}{u} > \frac{1}{f}$. Therefore, the image lies beyond $2f$.

(b) For a convex mirror, the focal length (f) is positive$\therefore f > 0$

when the object is placed on the left side of the mirror; the object distance (u) is negative. $\therefore u < 0$

For image distance v, we have the mirror formula: $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}, \frac{1}{v} < 0. therefore\ v > 0$. Thus, the image is formed on the back side of the mirror. Hence, a convex mirror always produces a virtual image, regardless of the object distance.

(c) For a convex mirror, the focal length (*f*) is positive.

When the object is placed on the left side of the mirror, the object distance (u) is negative

For image distance *v*, we have the mirror formula $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$

But we have u <0 so $\frac{1}{v}>\frac{1}{f}$. Hence v< f.

(d) **)** For a concave mirror, the focal length (*f*) is negative.

When the object is placed on the left side of the mirror, the object distance (u) is negative.

It is placed between the focus (*f*) and the pole. f > u > 0. So $\frac{1}{f}-\frac{1}{u}<0$.

For image distance *v*, we have the mirror formula: $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$

$\frac{1}{v}<0$ then v>0.

Q5. A compound microscope consists of an objective lens of focal length 2.0 cm and an eyepiece of focal length 6.25 cm separated by a distance of 15 cm. How far from the objective should an object be placed in order to obtain the final image at (a) the least distance of distinct vision (25 cm), and (b) at infinity? What is the magnifying power of the microscope in each case?

Ans. Focal length of the objective lens, f_1= 2.0 cm

Focal length of the eyepiece, f_2= 6.25 cm

Distance between the objective lens and the eyepiece, *d*= 15 cm

(a) Least distance of distinct vision, d = 25 cm

∴Image distance for the eyepiece, v_2= – 25 cm

Object distance for the eyepiece = u_2

According to the lens formula, we have the relation:

$\frac{1}{v_2}-\frac{1}{u_2}=\frac{1}{f_2}$

$\frac{1}{u_2}=\frac{1}{v_2}-\frac{1}{f_2}$

u_2= -5 cm

Image distance for the objective lens, v_1 = d+u_2 = 15-5 = 10cm.

Object distance for the objective lens = u_2

According to the lens formula, we have the relation: $\frac{1}{v_1}-\frac{1}{u_1}=\frac{1}{f_1}$, so u_1 = -2.5 cm.

Magnitude of the object distance, = 2.5 cm

The magnifying power of a compound microscope is given by the relation: m= $\frac{v_1}{|u_1|}\left[1+\frac{d}{f_2}\right]$

So m= 20. Hence, the magnifying power of the microscope is 20.

b) The final image is formed at infinity.

∴Image distance for the eyepiece, v_2 =∞

Object distance for the eyepiece = u_2

According to the lens formula, we have the relation:

$\frac{1}{v_2} - \frac{1}{u_2} = \frac{1}{f_2}$

$\frac{1}{\infty} - \frac{1}{u_2} = \frac{1}{6.25}$. Therefore u_2= -6.25 cm

Image distance for the objective lens, v_1 = d+u_2 = 15-6.25 = 8.75 cm Object distance for the objective lens = u_1

According to the lens formula, we have the relation: $\frac{1}{v_1} - \frac{1}{u_1} = \frac{1}{f_1}$, so u_1 = -2.59 cm

Magnitude of the object distance, = 2.59 cm

The magnifying power of a compound microscope is given by the relation: m= $\frac{v_1}{|u_1|}\left[\frac{d}{|u_2|}\right]$

Hence, the magnifying power of the microscope is 1

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WORKSHEET-1

1. Four lenses of focal lengths ± 15 cm and ± 150 cm are available for making a telescope. To produce the largest magnification, the focal length of the eyepiece should be 1

(a) + 15 cm (b) + 150 cm (c) – 150 cm (d) – 15 cm

Ans:________________________

2. A biconvex lens of focal length f is cut into two identical plano convex lenses. The focal length of each part will be 1

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

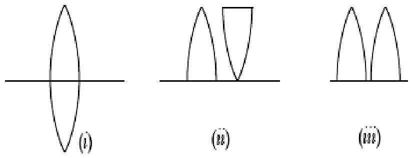
Ans:________________________

3. Assertion (A): Propagation of light through an optical fibre is due to total internal reflection taking place at the core-cladding interface.

Reason (R): Refractive index of the material of the cladding of the optical fibre is greater than that of the core. 1

Ans:______________________

4. A thin double convex lens of focal length f is broken into two equal halves at the axis. The two halves are combined as shown in figure. What is the focal length of combination in (ii) and (iii)? 2



Ans____

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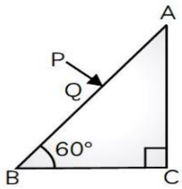
5. A ray PQ incident normally on the refracting face BA is refracted in the prism BAC made of material of refractive index 1.5. Complete the path of ray through the prism. From which face will the ray emerge? Justify your answer. 2



Ans:____

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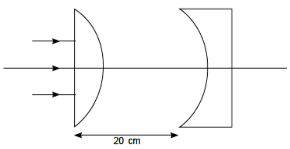
6. In the given figure the radius of curvature of curved face in the plano-convex and the planoconcave lens is 15 cm each. The refractive index of the material of the lenses is 1.5. Find the final position of the image formed. 2



Ans:____

7. Draw a neat labelled ray diagram of an astronomical telescope in normal adjustment. Explain briefly its working. 3

Ans:

8. Derive the prism formula and I-D curve. 3

Ans:

. (i). A beam of light converges at a point P. Draw ray diagrams to show where the beam will converge if (i) a convex lens, and (ii) a concave lens is kept in the path of the beam.

(ii) Derive Lens Maker's Formula 2+3

Ans:

:

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WORKSHEET-2

1. A ray of light of wavelength 600 nm propagates from air into a medium. If its wavelength in the medium becomes 400 nm, the refractive index of the medium is: 1

(a) 1.4 (b) 1.5 (c) 1.6 (d) 1.8

Ans:________________________

2. A ray of monochromatic light propagating in air, is incident on the surface of water. Which of the following will be the same for the reflected and refracted rays? 1

(a) Energy carried (b) Speed (c) Frequency (d) Wavelength

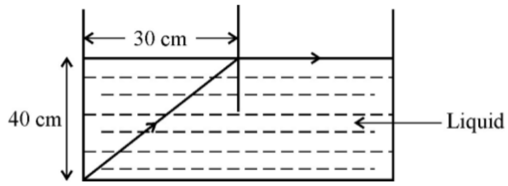
Ans:________________________

3. Assertion (A): If the focal length of two convex lenses is the same, the lens with the larger diameter will produce brighter images.

Reason (R): Convex lenses with larger diameters are able to focus light better. 1

Ans:________________________

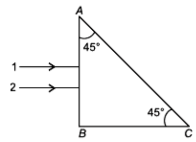
4. In the following ray diagram, calculate the speed of light in the liquid of unknown refractive index.



2

Ans:________________________

5. Two monochromatic rays of light are incident normally on the face *AB* of an isosceles right angled prism *ABC*. The refractive indices of the glass prism for the two rays 1 and 2 are respectively 1.35 and 1.45. Trace the path of these rays after entering through the prism.



2

Ans:________________________

6. Calculate the value of the angle of incidence when a ray of light incident on one face of an equilateral glass prism produces the emergent ray, which just grazes along the adjacent face. Refractive index of the prism is $\sqrt{2}$. 2

Ans:________________________

7. A convex lens made up of glass of refractive index 1.5 is dipped, in turn, in (i) a medium of refractive index 1.65, (ii) a medium of refractive index 1.33. (a) Will it behave as a converging or a diverging lens in the two cases? (b) How will its focal length change in the two media? 3

Ans:____

8. Draw a labelled ray diagram of a reflecting telescope. Mention its two advantages over the refracting telescope. 3

Ans:____

9. (a) Draw a labelled ray diagram of a compound microscope.
(b) Derive an expression for its magnifying power.
(c) Why is objective of a microscope of short aperture and short focal length? Give reason. 2+2+1

Ans:____

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WAVE OPTICS

NEED FULL FORMULA

- **Interference of light:-**

(i) If two waves of same intensity I_o interfere, then the resultant intensity will be

$I = 4 I_o \cos^2\frac{\phi}{2}$ where ϕ is the initial phase difference between the waves.

(ii) Resultant intensity at a point in the region of superposition is

$I = a_1^2 + a_2^2 + 2a_1a_2\cos\phi = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\phi$ where

$I_1 = a_1^2$ is the intensity of one wave & $I_2 = a_2^2$ is the intensity of other wave.

(iii)Condition for maxima: - Phase difference $\phi = 2n\pi$ & path difference $\Delta = n\lambda$ where n = 0,1,2,3,…..

(iv) Condition for minima: - Phase difference $\phi = (2n-1)\pi$ &

Path difference $\Delta = (2n-1)\frac{\lambda}{2}$ where n = 0,1,2,3,…..

(v) Fringe width $\beta = \frac{D\lambda}{d}$ where D = distance between the slits & the screen,

d = separation between the slits and λ is the wavelength of light used.

(vi) Angular fringe width , $\beta_\theta = \frac{\beta}{D} = \frac{\lambda}{d}$

(vii) Minimum amplitude, $A_{min} = (a_1 - a_2)$

(viii) Minimum intensity, $I_{min} = (a_1 - a_2)^2 = I_1 + I_2 - 2\sqrt{I_1 I_2}$

(ix) Minimum amplitude, $A_{max} = (a_1 + a_2)$

(x) Minimum intensity, $I_{min} = (a_1 + a_2)^2 = I_1 + I_2 + 2\sqrt{I_1 I_2}$

(xi) Position of n^{th} maxima, $y_n = \frac{nD\lambda}{d}$

(xii) Position of n^{th} minima, $y_n = (n - ½)\frac{D\lambda}{d}$

(xiii) In interference, the ratio of maximum intensity to minimum intensity, $\frac{I_{max}}{I_{min}} = \frac{(a_1+a_2)^2}{(a_1-a_2)^2}$

(xiv) In interference, the relation between slit width (w) , intensity (I) and amplitude (a):

$\frac{W_1}{w_2} = \frac{I_1}{I_2} = \frac{(a_1)^2}{(a_2)^2}$

(xv) The angular width of each fringe in interference pattern, $\Delta\theta = \frac{\beta}{D} = \frac{\lambda}{d}$

(xvi) In interference, Fringe width $\beta \propto \lambda$, $\beta \propto D$ and $\beta \propto$ 1/separation between the slits (d)

Diffraction of light: -

(i) The condition for the position of n^{th} minima : $d \sin\theta = n\lambda$

where d is the width of slit, θ is angle of diffraction and λ is the wavelength of light used.

(ii) Linear half-width of central maximum : $y = \frac{D\lambda}{d}$

(iii) Total linear width of central maximum : β_o or $2y = \frac{2D\lambda}{d}$

MULTIPLE CHOICE QUESTIONS (1 MARK)

1. The phenomenon which is **not** explained by Huygen's construction of wavefront:
(a) Reflection (b) Diffraction (c) Refraction (d) Origin of spectra

2. A 5% change in wavelength is observed in the light received from a distant star.
What is the speed of the moving star?
(a) c (b) 0.05 c (c) 20.0 c (d) 0.02 c

3. Which of the following statements doesn't correctly comply with Huygens' Principle of constructing a secondary wavefront from a primary wavefront?
(a) After some time interval, the new position of the wavefront is the surface tangent to the secondary wavelets.
(b) Secondary wavelets propagate outward through a medium with speeds characteristic of waves in that medium.
(c) A secondary wavefront is always a plane wavefront irrespective of whether the primary wavefront is planar or spherical.
(d) All points on a given primary wavefront are taken as point sources for the production of spherical secondary waves, called wavelets.

4. When coherent light waves interfere to produce alternate bands of dark and bright interference bands, which of the following statements correctly identify the energy and intensity distribution across the interference bands?
(I) Energy conservation is violated because energy disappears in the dark bands.
(II) Intensity at the bright bands is four times the square of the amplitude of the individual waves.
(III) The total energy leaving the slits is distributed among bright and dark bands, and energy is conserved.
(IV) Energy transferred by the light sources at the bright bands is same as carried by each of the individual waves.

(a) Statement I and II only (b) Statement I and IV only
(c) Statement II and III only (d) Statement II and IV only

5. A laser beam is used for locating distant objects because

(a). it is monochromatic (b). it is not chromatic (c). it is not observed (d). it has small angular spread

6. Two slits in Young's double slit experiment have widths in the ratio 81:1. The ratio of the amplitudes of light waves is

(a). 3 :1 (b). 3 : 2 (c). 9 :1 (d). 6:1

7. When interference of light takes place

(a). energy is created in the region of maximum intensity

(b). energy is destroyed in the region of maximum intensity

(c). conservation of energy holds good and energy is redistributed

(d). conservation of energy does not hold good

8. To observe diffraction, the size of the obstacle

(a). should be X/2, where X is the wavelength. (b) should be of the order of wavelength.

(c). has no relation to wavelength. (d). should be much larger than the wavelength

9. What is the geometric shape of the wavefront that originates when a plane wave passes through a convex lens?

(a). Converging spherical (b)Plane (c) . Diverging spherical (d) None of the above

10. A double slit interference experiment is carried out in air and the entire arrangement is dipped in water. The fringe width will

(a). increase (b).remain same (c) . decrease (d). disappear

Answers

1. (d) 2. (b) 3. (C) 4. (C) 5. (d) 6.(C) 7. (C) 8. (b) 9. (a) 10. (C)

ASSERTION-REASON BASED QUESTIONS (1 MARK)

In the following questions, a statement of assertion (A) is followed by a statement of Reason (R) .Choose the correct answer out of the following choices.

a) Both A and R are true and R is the correct explanation of A .
b) Both A and R are true and R is not the correct explanation of A .
c) A is true but R is false.
d) A is false and R is also false.

1. Assertion(A): light added to light can produce darkness.
Reason (R) : Interference of two coherent light waves produces darkness at the position of destructive interference.
Ans. (a)
2. Assertion(A) : It is not possible to have interference between the waves produced by two violins.
Reason(R) : To have interference, the phase difference between the two waves should be constant
Ans(.a)
3. Assertion(A) : In Young's double slit experiment ,all fringes are of equal width.
Reason(R): Fringe width does not depend on wavelength of light, distance between two slits and distance between of slits and screen
Ans. (C)
4. Assertion(A) : The maximum intensity is four times the intensity due to each wave of or identical coherent waves.
Reason(R): Intensity is proportional to square of amplitude.
Ans. (b)
5. Assertion(A): Angular width of central maximum in single slit diffraction decreases with increase in wavelength.
Reason(R): Angular width of central maximum in single slit diffraction does not depend on width of the slit.
Ans. (d)

SHORT ANSWER QUESTIONS (2 MARK)

Q1.(a) State Huygens' principle .

(b)Which property of light does not change when light wave is refracted

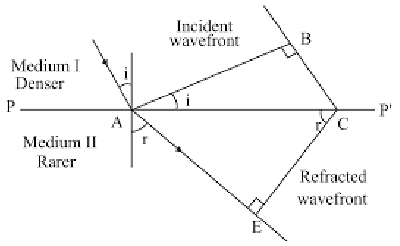
Ans.(a) Huygen's Principle :

(i) Each point on the wavefront acts as a fresh source of new disturbance, called secondary wavelets, which spread out in all directions with the same velocity as that of the original wave (ii) The forward envelope of these secondary wavelets drawn at any instant, gives the shape and position of new wavefront at that instant.
(b) frequency

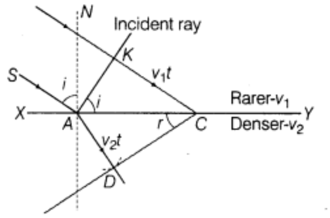
Q2. Define a wavefront. How is it different from a ray ?
Ans. Wavefront : Continuous locus of all the particles of a medium vibrating in the same phase is called wavefront.
Difference from a ray : (i) A ray is always normal to the wavefront at each point. (ii) A ray gives the direction of propagation of light wave while the wavefront is the surface of constant phase.

Q3.Using Huygens' Principle draw ray diagram for the following : (i) Refraction of a plane wave front incident on a rarer medium (ii) Refraction of a plane wave front incident on a denser medium
Ans.

(i)



(ii)



Q4. State two differences between interference and diffraction patterns.

Ans. Interference

1. It is due to superposition of two waves from two coherent sources
2. Width of fringes/bands is equal
3.All fringes have same intensity
Diffraction
1. It is due to superposition of secondary wavelets from different parts of the same wavefront
2. Fringes have different widths
3. Maxima have different intensity and intensity decreases rapidly with the order of maxima.

Q5. Write two methods of producing coherent sources with examples

Ans. Division of wave front method(any one example)
Division of amplitude method(any one example)

Q6.Light of wavelength 5000 Å falls on a plane reflecting surface. What are the wavelength and frequency of the reflected light? For what angle of incidence is the reflected ray normal to the incident ray?
Ans: Wavelength of incident light, λ = 5000 Å = 5000 X 10^{-10} m
Speed of light, c = 3 X 10^{8} m
Frequency of incident light is given by the relation, n = $\frac{C}{\lambda} = \frac{3X\ 10^{8}}{5000\ X10^{-10}}$ = 6 X 10^{14} HZ
The wavelength and frequency of incident light is the same as that of reflected ray.

Hence, the wavelength of reflected light is 5000 Å and its frequency is 6 × 10^{14}Hz.

When reflected ray is normal to incident ray, the sum of the angle of incidence, and angle of reflection, is 90°. According to the law of reflection, the angle of incidence is always equal to the angle of reflection. Therefore, the angle of incidence for the given condition is 45°.

Q7.Two coherent monochromatic light beams of intensities I and 4I superpose each other .Find the ratio of maximum and minimum intensities in the resulting beam.

Ans. Let the amplitudes of the two waves be a_1 and a_2.
Given:
We know that the ratio of maximum to minimum intensities is given by:
$(I_{max} / I_{min}) = ((a_1 + a_2)^2) / ((a_1 - a_2)^2)$
Substitute the values:
$= (\sqrt{I} + 2\sqrt{I})^2 / (\sqrt{I} - 2\sqrt{I})^2 = (3\sqrt{I})^2 / (-\sqrt{I})^2 = 9I / I = 9 / 1$
Therefore, the ratio of maximum to minimum intensities is 9:1.

Q8.Two slits are made 1 mm apart and the screen is placed 1 m away .What should be the width of each slit to obtain 10 maxima of the double slit pattern within the central maximum of the single slit pattern ?

Ans. If a is the size of single slit for diffraction pattern ,then for first maxima, $\theta = \frac{\lambda}{a}$

Angular separation of central maxima = $\frac{2\lambda}{a}$

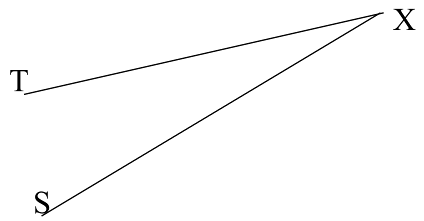
Angular size of fringe in interference pattern = $\alpha = \frac{\lambda}{d}$

For 10 maxima within central maxima of diffraction pattern, $10\alpha = \frac{2\lambda}{a}$

So $10(\frac{\lambda}{d}) = \frac{2\lambda}{a}$ Or $a = \frac{d}{5}$, Here d = distance between two slits = 1 mm

So $a = \frac{1\,mm}{5} = 0.2$ mm

Q9. Two waves from two coherent sources S and T superimpose at X as shown in the following figure .If X is a point on the second minima and $S_X - T_X$ is 4.5 cm ,calculate the wavelength of the waves.



Ans. For second minima ,n=1 Path difference = SX -TX = $(n+\frac{1}{2})\lambda$

So for n=2,S_X-T_X = $(1+\frac{1}{2})\lambda = \frac{3}{2}\lambda$, Given that $S_X - T_X$ = 4.5 cm , So $\frac{3}{2}\lambda$ = 4.5 cm

Or λ = 4.5 cm X $\frac{2}{3}$ = 3 cm , So wavelength of the waves is 3 cm.

Q10. In what way is diffraction from each slit related to the interference pattern in a double-slit experiment?

Ans. Diffraction from each slit is related to an interference pattern in a double-slit experiment in the following ways: The intensity of minima for diffraction is never zero, while for interference it is generally zero. All bright fringes for diffraction are not of uniform intensity, while for interference, these are of uniform intensity

SHORT ANSWER QUESTIONS (3 MARK)

Q1.Light of wavelength 550 nm is incident as parallel beam on a slit of width 0.1 mm. Find the angular width and the linear width of the principal maxima in the resulting diffraction pattern on a screen kept at a distance of 1.1 m from the slit, which of these width would not change if the screen were moved to a distance of 2.2 m from the slit?

Ans. λ=550 nm, d= 0.1 mm,D = 1.1m, ω = ?, β = ?
using ω = 2θ= 2λ/d, we get ω= .011 rad , using β=2λD/d ,we get β = 12.1 mm
When the screen is moved to 2.2 m from the slit, the angular width will not change, linear width will increase.

Q2.What is the effect on the interference fringes in Young's double slit experiment due to each of the following operations ? Justify your answers.

a) The screen is moved away from the plane of the slits.
b) The separation between slits is increased.
c) Wavelength of light is increased .

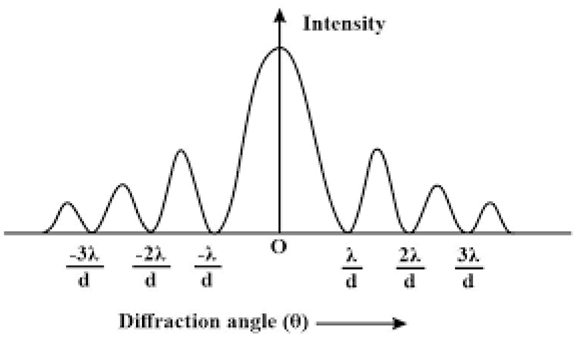
Ans.

a) Fringe width increases , as $\beta = \frac{D\lambda}{d}$ and β is directly proportional to D .
b) Fringe width decreases ,as β is inversely proportional to d.
c) Fringe width increases , as β is directly proportional to λ.

Q3. A plane wavefront of light of wavelength λ is incident normally on a narrow slit of width a and a diffraction pattern is observed on a screen at a distance D from the slit.

i) Depict the intensity distribution in the pattern observed .
ii) Obtain the expression for the first maximum from the central maximum.

Ans. i)



i) For maximum a sin θ (n+$\frac{1}{2}$) λ

For first maximum , n=1 , For small θ, a$\theta = \frac{3}{2}\lambda$

Or $\theta = \frac{3}{2a}\lambda$

Or $\frac{x}{D} = \frac{3\lambda}{2a}$ Or x = $\frac{3\lambda D}{2a}$

Q4.A parallel beam of light of wavelength 600 nm is incident normally on a slit of width 0.2 mm .If the resulting diffraction pattern is observed on a screen 1 m away ,find the distance of first minimum and second maximum from the central maximum.

Ans. Given:
Wavelength (λ) = 600 nm = 600 × 10^{-9} m Slit width (a) = 0.2 mm = 0.2 × 10^{-3} m
Distance to screen (D) = 1 m , For a single slit diffraction pattern:
Position of first minimum (y_1): y_1 = (λD) / a = (600 × 10^{-9} × 1) / (0.2 × 10^{-3})

$= 3 \times 10^{-3}$ m = 3 mm
y_2 =(n+1/2) X (λD) / a = (5/2λD) / a = 2.5 x 3 mm = 7.5 mm

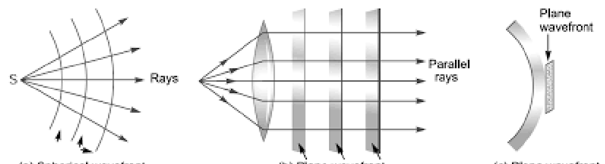
Q5.Explain the following by giving suitable reasons.

i) When monochromatic light is incident on a surface separating two media ,the reflected and refracted light have the same frequency as the incident frequency.
ii) When light travels from a rarer to a denser medium ,the speed decreases.Does this decrease in speed imply a reduction in the energy carried by the wave ?
iii) In the wave picture of light ,intensity is determined by the square of the amplitude of the wave .What determines the intensity in the photon picture of light ?

Ans. i) Reflection and refraction arise through interaction of incident light with atomic constituents of matter which vibrate with the same frequency as that of the incident light. Hence, frequency remains unchanged. ii) No. When light travels from a rarer to a denser medium, its frequency remains unchanged. Since the energy of a light wave depends on its frequency, the decrease in speed does not change the energy of light. iii) For a given frequency, the intensity of light in the photon picture is determined by the number of photons incident normally on a unit area in unit time

Q6.What is the shape of the wavefront in each of the following cases with the help of diagrams:

a) Light diverging from a point source
b) Light emerging out of a convex lens when a point source is placed at its focus
c) The portion of wavefront of light from a distant star intercepted by the earth



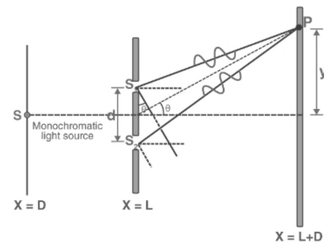
(a) Spherical wavefront (b) Plane wavefront (c) Plane wavefront

Ans

a) The wavefront will be spherical of increasing radius.
b) The shape of the wavefront is a plane.
c) The wavefront starting from star is spherical.As star is very far from the earth ,so the wavefront intercepted by earth is a very small portion of a sphere of large radius,which is a plane.So the wavefront intercepted by earth is plane.

Q7. i)In a Young's double slit experiment SS2 – SS1 = $\frac{\lambda}{4}$,where S1 and S2 are the two slits as shown in the figure .Find the path difference S2 P- S1P for constructive and destructive interference at P.

ii)What is the effect on interference fringes in Young's double slit experiment ,If the monochromatic source S is replaced by a source of white light ?



Ans. Net path difference between two waves reaching the point P on the screen is given by

$SS_2P – SS_1P = SS_2 – SS_1 + S_2P – S_1P = \frac{\lambda}{4} + S_2P – S_1P$
For constructive interference, $SS_2P – SS_1P = n\lambda$
So $S_2P – S_1P = n\lambda - \frac{\lambda}{4} = \lambda(n - \frac{1}{4})$ where n= 0,1,2,…..
For destructive interference ,$SS_2P – SS_1P = SS_2 – SS_1 + S_2P – S_1P == \frac{\lambda}{4} + S_2P – S_1P = (n+\frac{1}{2}) \lambda$
Where n= 0,1,2,……. So $S_2P – S_1P = (n+\frac{1}{2}) \lambda - \frac{\lambda}{4}$

Q8.In a diffraction pattern due to a single slit,how will the angular width of central maximum change, if (i)orange light is used in place of green light ,(ii)the screen is moved closer to the slit (iii)the slit width is decreased ? Justify your answer in each case.

Ans. Angular width of central maximum in diffraction due to single slit = $\frac{2\lambda}{a}$

Where λ = wavelength of light and a = width of single slit Since wavelength of orange light is greater than wavelength of green light, so angular width in first case will increase.
In the second case,since angular width of central maximum does not depend on distance between slit and screen ,so there will be no change in angular width of central maximum.If the slit width is decreased,then the angular width of central maximum will increase,since angular width of central maximum is inversely proportional to width of single slit for constant wavelength.

Q9. Monochromatic light of wavelength 589 nm is incident from air on a water surface. What are the wavelength, frequency and speed of (a) reflected, and (b) refracted light?Refractive index of water is 1.33.

Ans:Wavelength of incident monochromatic light, λ = 589 nm = 589 × 10^{-9} m
Speed of light in air, c = 3 × 10^{8}
Refractive index of water, μ = 1.33
(a)The ray will reflect back in the same medium as that of incident ray. Hence, the

$$\nu = \frac{c}{\lambda} = \frac{3\times10^{8}}{589\times10^{-9}} = 5.09\times10^{14}\text{ Hz}$$

wavelength, speed, and frequency of the reflected ray will be the same as that of the incident ray. Frequency of light is given by the relation,

Hence, the speed, frequency, and wavelength of the reflected light are 3 × 10^{8} m/s, 5.09×10^{14} Hz, and 589 nm respectively.

(b)Frequency of light does not depend on the property of the medium in which it is travelling. Hence, the frequency of the refracted ray in water will be equal to the frequency of the incident or reflected light in air.

Refracted frequency, ν = 5.09 ×10^{14} Hz

Speed of light in water is related to the refractive index of water as:

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

$$v = \frac{3\times10^{8}}{1.33} = 2.26\times10^{8}\text{ m/s}$$

Wavelength of light in water is given by the relation,

$$\lambda = \frac{v}{\nu} = \frac{2.26\ X\ 10^{8}}{5.09\ X\ 10^{14}} = 444.007\ \text{X}\ 10^{-9}\text{ m}$$
$$= 444.01\text{ nm}$$

Hence the speed, frequency and wavelength of refracted light are 2.26 X 10^{8} m/s, 444.01 nm and 5.09 X 10^{14} Hz respectively.

Q10. In a Young's double-slit experiment, the slits are separated by 0.28 mm and the screen is placed 1.4 m away. The distance between the central bright fringe and the fourth bright fringe is measured to be 1.2 cm. Determine the wavelength of light used in the experiment.

Ans: Distance between the slits, d = 0.28 mm = 0.28×10^{-3} m Distance between the slits and the screen, D = 1.4 m

Distance between the central fringe and the fourth (n = 4) fringe,

u = 1.2 cm = 1.2×10^{-2} m In case of a constructive

interference, we have the relation for the distance between the two fringes as: u=nλD/d

, Where,n = Order of fringes = 4 , λ = Wavelength of light used

$$\lambda = \frac{ud}{nD} = \frac{1.2\ X\ 10^{-2}\ X\ 0.28\ X\ 10^{-1}}{4\ X\ 1.4} = 600\text{ nm}$$

CASE BASED QUESTIONS (4 MARK)

Q1. Diffraction of light is the bending of light around the corners of an object whose size is comparable with the wavelength of light.Diffraction actually defines limits of ray optics.This limit for optical instruments is set by the wavelength of light.An experimental arrangement is set up to observe the diffraction pattern due to a single slit.In diffraction different wavelets interfere each other to produce fringe pattern on the screen.At the centre of the screen in diffraction due to single slit ,central maximum is found.The angular width of this central maximum depends on wavelength of light and width of the slit.The intensity of secondary maximum in single slit diffraction goes on decreasing with the increase of distance from the central maximum.

(i)If the width of slit in single slit diffraction is halved, then the angular width of central maximum will

a) decrease b) increase c) remain same d) none of the above

Ans. (b)

(ii)To observe diffraction ,the size of an obstacle

(a)Should be same order as wavelength (b) should be much larger than wavelength

(c)has no relation to wavelength (d)none of these

Ans. (a)

(iii) It is more difficult to observe diffraction with light waves because

(a)Light waves do not require any medium (b)wavelength of light waves is too small

(c)light waves are transverse in nature (d)speed of light is far greater

Ans. (b)

(iv)Angular width of central maximum of a diffraction pattern of a single slit does not depend upon

(a)distance between slit and source (b)wavelength of light used

(c) width of the slit (d)frequency of light used

Ans. (a)

Q2.Interference is the phenomenon of superposition of light waves of same frequency and constant phase difference travelling in same direction.The positions of maximum intensity are called maxima and the positions of minimum intensity are called minima. The intensity of one wave is directly proportional to square of its amplitude.Widths of fringes in interference are equal.Coherent sources are required for interference.Fringe width in interference depends wavelength of light ,distance between two slits and distance between screen and plane of slits.

i) Coherent sources of light are required for

a) Diffraction b) interference c) refraction d) reflection

Ans. (b)

(ii)Monochromatic light wave has fixed

a) frequency b) pressure c) temperature d) phase

Ans. (a)

(iii)If the distance between plane of slits and screen is doubled,the fringe width will

a) remain shame b) decrease c) increase d) none of the above

Ans. (c)

(iv). Intensity of fringe depends on

(a)Amplitude b) pressure c) frequency d) temperuture

Ans. (a)

(OR)

If the separation between two slits is halved,the fringe width will be increased by

(a) 3 times b) 4 times c) 2 times d) 5 times

Ans. (c)

LONG ANSWER TYPE QUESTIONS (5 MARK)

1. (i) Define a wavefront.

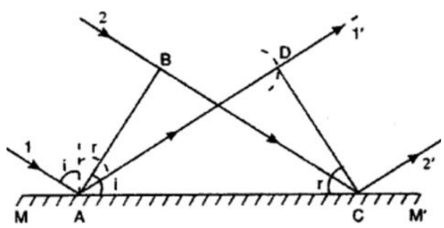
(ii)State the principle which tells us the construction of wavefront.

(iii)Using this principle ,verify the laws of reflection.

(iv)Find the path difference between any two points on a wavefront.

Ans.(i) A wavefront is a locus of particles of a medium vibrating in same phase.

(ii)Each point of the wavefront is the source of a secondary disturbance and the wavelets arising from these points spread out in all directions with the speed of the wave in the form of spheres. A common tangent drawn to all these spheres gives the new position of the wavefront at a later time.



AB is the incident plane wavefront.It makes an angle i withthe reflecting surface MN.According to Huygens' principle ,CE is the reflected wavefront. r is the angle made by the reflected wavefront with the reflecting surface MN.

In ΔAEC and in Δ ABC

$Angle\ E$ = Angle B (both right angle) , AC = AC (hypoteneous) , AE = BC (by construction)

So triangle AEC and triangle ABC are congruent under RHS criterion. , So angle i = angle r

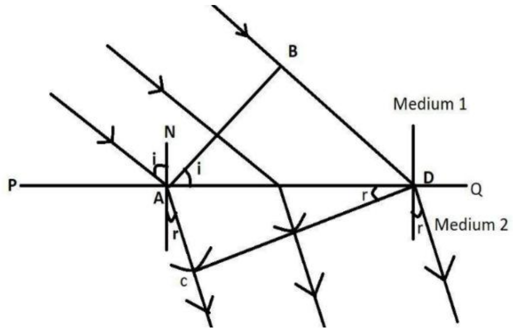
From the diagram,the incident ray perpendicular to incident wavefront AB ,the reflected ray perpendicular to reflected wavefront CE and the normal at the point of incidence A lie on the same plane.This proves the first law of reflection of light.

iii)The path difference between any two points on a wavefront is zero.

Q2.(i)Use Huygens' principle to show how a plane wavefront propagates from a denser to rarer medium.Hence,verify Snell's law of refraction.

(ii)Find the angular width of central maximum for light of wavelength 500 nm and slit width of 2mm in diffraction due to a single slit .Does this angular width change for change in wavelength of light ?

Ans.(i)



AB is the incident wavefront which touches the interface between denser medium and rarer medium first at A and touches at C after time τ.

v_1= speed of light in denser medium v_2= speed of light in rarer medium

Here $v_1 < v_2$

According to Huygens' principle , BC = $v_1 \tau$ and AE = $v_2 \tau$

In right angled triangle ABC Sin i $= \frac{BC}{AC} = \frac{v_1 \tau}{AC}$

In right angled triangle AEC Sin r $= v_2 \tau /AC$

Now $\frac{\text{Sin i}}{Sin\, r} = (\frac{v_1 \tau}{AC}) / (v_2 \tau /AC)$

$= \frac{v_1}{v_2} = n_{21}$ = refractive index of rarer medium with respect to denser medium

This verifies Snell's law of refraction.

ii)Here wavelength of light = λ = 500 nm = 500 X 10^{-9} m

Width of slit = a = 2mm = 2X 10^{-3} m

Width of central maximum = $\frac{2\lambda}{a} = \frac{2X500X10^{-9}}{2X\,10^{-3}\text{ m}}$ = 5X 10^{-5} m

Q3.(a) Define interference and coherent sources.

(b)Discuss the conditions for constructive and destructive interference at a point on the screen .Draw the graph showing variation of the resultant intensity in the interference pattern against position X on the screen.

(c)Compare and contrast the pattern which is seen with two coherently illuminated single slit producing diffraction .

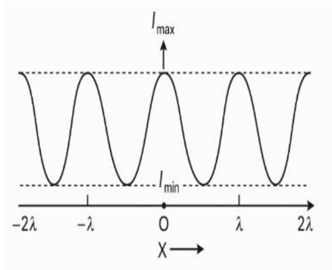
Ans. (a)The phenomenon of redistribution of intensity due to superposition of two waves of same frequency and constant initial phase difference is called interference.

The waves of same frequency and constant initial phase difference are coherent sources.

(b)For constructive interference, path difference x between two waves must be equal to nλ where n=0,1,2,3,….

For destructive interference, path difference x between two waves must be equal to(n+$\frac{1}{2}$)λ where n=0,1,2,3,….

(c)Comparison od two slit Young's interference pattern and single slit diffraction pattern



Both patterns are the result of wave nature of light;both patterns contain maxima and minima.
Interference pattern is the result of superposition of of two coherent waves while diffraction is the superposition of large number of wavelets originating from different points of wavefront in single slit.

In interference pattern ,all maxima are of same intensity,but in diffraction due to single slit all maxima are of different intensities.
In interference,all maxima are of same width,but in diffraction central maximum is twice the width of secondary maximum.

In single slit diffraction first minimum occurs at $\frac{\lambda}{a}$,while in interference pattern ,we get maximum at $\frac{\lambda}{a}$.

Q4.What is interference of light ?Write two essential conditions for sustained interference pattern to be produced on a screen? Draw a graph showing the variation of intensity versus the position on the screen in Young's experiment when both the slits are opened and one of the slits is closed.

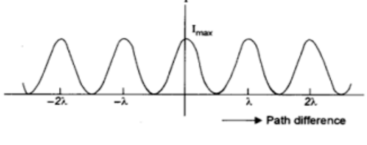
What is the effect on the interference pattern in Young's double slit experiment when:

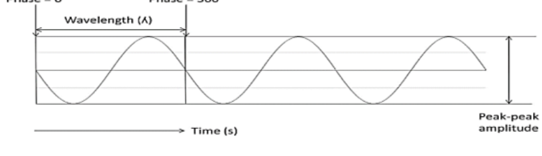
(i) Screen is moved closer to the plane of slits ?

(ii) Separation between two slits is increased ?

Explain your answer in each case.

Ans. Interference of light : When two waves of same frequency and constant initial phase difference travel in the same direction along a straight line simultaneously ,they superpose in such a way that the intensity of the resultant wave is maximum at certain points and minimum at certain other points .This phenomenon of redistribution of energy due to superposition of two waves of same frequency and constant initial phase difference is called interference.
Conditions for sustained interference of light waves
The sources should emit light waves of same frequency or wavelength and their initial phase should remain constant.
The interfering light waves should have same amplitudes.





(i) Fringe width decreases since fringe width is directly proportional to distance between plane of slits and screen
(ii) On increasing the separation between two slits ,the fringe separation decreases because fringe width is inversely proportional to distance between two slits.

WORKSHEET-1

Q1.The resultant intensity in interference of two waves having phase difference π is

a) 0 b) $4I_0$ c) $2I_0$ d) $3I_0$

Q2. The distance of first bright fringe from central bright fringe produced due to light of wavelength 500 nm with 10 m distance between the plane of two slits having distance 2mm in interference is

a) 1.5 mm b) 2.5 mm c) 4 mm d) 5 mm

Q3. The refractive index of glass is 1.5 .Find the speed of light in glass .Which colour of light between red and blue will travel slower inside the glass. Give reason for it. 2 marks

Ans

Q4. If the intensity of light at a point on a screen in interference for wavelength λ is K units ,then find the intensity of light at a point having path difference $\lambda/3$. 2 marks

Ans

Q5. Monochromatic light of wavelength 589 nm is incident from air on a water surface. Find the wavelength and speed of the refracted light. 2 marks

Ans

Q6. (a)The refractive index of glass is 1.5. What is the speed of light in glass? Speed of light in vacuum is 3.0×10^8 m s^{-1})

Ans

(b) Is the speed of light in glass independent of the colour of light? If not, which of the two colours red and violet travels slower in a glass prism? 2 mark

Ans

Q7.State the principle which gives the position of secondary wavefront at particular time. Construct a secondary wavefront from a primary wavefront by using this principle. 2 marks

Ans

Q8. Find the intensity at a point on a screen in Young's double slit experiment where the interfering waves of equal intensity have a path difference of $\frac{\lambda}{4}$ and $\frac{\lambda}{2}$. 2 marks

Ans

9. In Young's double slit experiment using light of wavelength 600 nm ,the slit separation is 0.8 mm and the screen is kept 1.6 m from the plane of the slits .Calculate the fringe width and the distance of of third minimum and fifth maximum from the central maximum. 3 marks

Ans

Q10. In Young's double-slit experiment using monochromatic light of wavelength λ, the intensity of light at a point on the screen where path difference is λ, is K units. What is the intensity of light at a point where path difference is $\lambda /3$? 3 marks

Ans

WORKSHEET- 2

Q1.If yellow light is replaced by red light, then the fringe width in interference will

i)Decrease ii)increase iii) remains same iv) first decrease then increase 1 mark

Q2.The angular width of central maximum in diffraction due to a single slit having width 5 mm produced due to light of wavelength 600 nm is

i)0.25 mm ii) 0.28 mm iii) 0.36 mm iv) 0.24 mm 1 mark

Q3.Why are coherent sources required to create sustained interference of light? Give one method to produce coherent sources. 2 marks

Ans

Q4.Write any two differences between interference and diffraction and write the conditions for interference and diffraction. 2 marks

Ans

Q5.For a definite wavelength of light, write two factors on which fringe width in Young's double slit experiment depends. Also write the reason for production of same width fringes in this experiment. 2 marks

Ans

Q6.Why is the interference pattern not detected, when two coherent sources are far apart? 2 marks

Ans

Q7.Draw the diagrams for intensity of fringes in interference and in diffraction. 2 marks

Ans

Q8.No interference pattern is detected when two coherent sources are infinitely close to each other. Why? 2 marks

Ans

Q9.A parallel beam of light of wavelength 600 nm is incident normally on a slit of width 0.2 mm. If the resulting diffraction pattern is observed on a screen 1 m away, find the distance of first minimum and second maximum from the central maximum. 3 marks

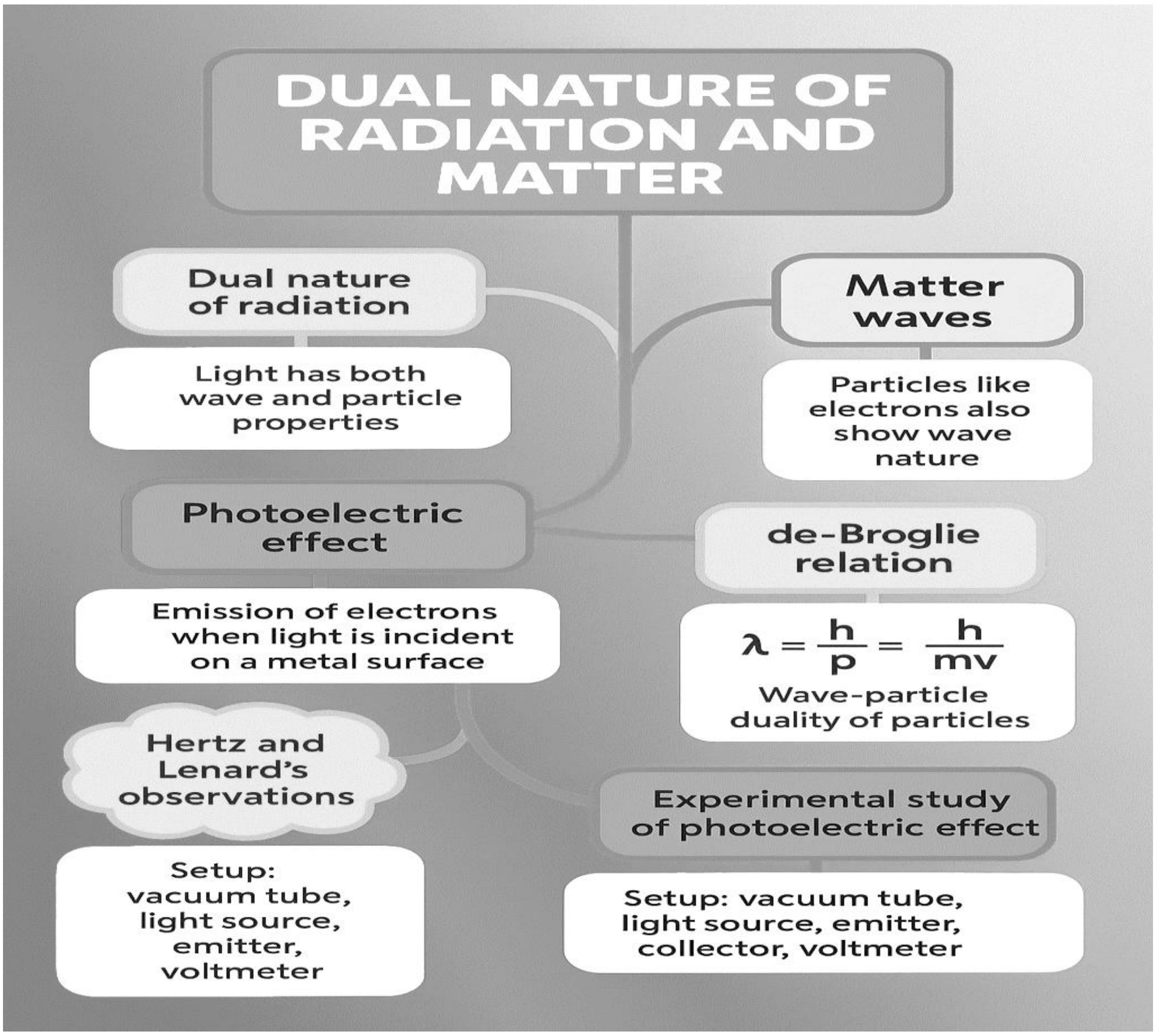
Ans

Q10.In a diffraction pattern due to a single slit, how will the angular width of central maximum change, if

i) green light is used in place of orange light,
ii)the screen is moved closer to the slit,
iii)the slit width is decreased? 3 marks
Ans

CHAPTER 11
DUAL NATURE OF RADIATION AND MATTER

MIND MAP



Important Formulas

1. Energy of a Photon (Einstein's Relation):

$$E=hv$$

   a. $h=6.63\times10^{-34}$ Jsh=6.63×10^{-34}Js (Planck's constant)

   b. vv = frequency of light

   c. $c=3\times108$ m/sc=3×108m/s (speed of light)

   d. λ = wavelength

2. Work Function ($\phi\phi$):

$$\phi=hv_0$$

   a. v_0 = threshold frequency

   b. λ_0 = threshold wavelength

3. Einstein's Photoelectric Equation:

$$K_{max}=h\nu-\phi$$

a. K_{max} = max kinetic energy of photoelectrons

4. Stopping Potential (V_0):

$$eV_0=K_{max}=h\nu-\phi$$

a. $e=1.6\times10^{-19}\,C$=1.6×10^{-19}C (electron charge)

5. Relation between maximum kinetic energy and stopping potential
K_{max}= ½ mv_{max}^2 = eV_0

6. de Broglie Wavelength (λ\):

$$\lambda=h/p=h/mv$$

a. p = momentum

b. m = mass, v = velocity

7. de Broglie Wavelength for Electron (accelerated by V):

$$\lambda=h/\sqrt{2meV}$$
$$\lambda(A^\circ)=12.27V$$

9. Photon Momentum:

$$p=h/\lambda$$

Threshold Wavelength (λ_0):
$$\lambda_0=hc/\phi$$

MCQs (1 mark each)

Q1.The momentum of a photon of wavelength λ is

a) hλ b) h/λ c) λ/h d) h/cλ

Answer: - 1) b) h/λ

Q2.Maximum KE of photo electrons is 4 e V Then the stopping potential is

a) 4 V b) 1.6 V c) 4 J d) 4 e V

Answer: - 2) a) 4 V

Q3.The slope of stopping potential vs frequency of the incident light graph is

a) e/h b) h/e c) h/c d) c/h

Answer: - 3) b) h/e

Q4.Photoelectric effect shows

a) wave like behavior of light b) particle like behavior of light

c)both wavelike and particle like behavior d) neither wave like nor particle like behavior of light.

Answer: - 4) b) particle like behavior of light

Q5.An electron and a proton have the same de Broglie wave length. Which of them have greater velocity. a) Electron b) proton. c) both a and b d) none of the above

Answer: - 5) a) Electron

Q6.The work function of a metal is hc/λ0 . If light of wavelength λ is incident on its surface , then the essential condition for the electron to come out from the metal surface is

a) λ > λ0 b. λ > 2 λ0 c. λ < λ0 d. λ < 2λ0

Answer: - 6) c) $\lambda < \lambda_0$

Q7.When monochromatic radiation of intensity I falls on a metal surface, the number of photoelectron and their maximum kinetic energy are n and k respectively. If the intensity of radiation is 21, the number of emitted photoelectron and their maximum kinetic energy will be

a) n and 2k b. 2n and 2k c. 2n and k d. n and k

Answer: - 7) c) 2n and k

Q8.The work function of caesium is 2.14 eV. Find the wavelength of the incident light if the photo current is brought to zero by a stopping potential of 0.60 volt :-

(a) 454 nm (b) 640 nm (c) 540 nm (d) None of these

Answer: - 8) a) 454 nm

Q9.The maximum K.E of the electrons emitted in photoelectric effect is related to the work function of metal as

a) It doesn't depend on work function

b) It decreases as the work function increases

c) It increases as the work function increases

d) It's value is doubled with the work function

Answer: - b) It decreases as the work function increases

Q10.What is the de-Broglie wavelength of an electron accelerated from rest through a potential difference of 100 volts?

(a) 12.3 Å (b) 1.23 Å (c) 0.123 Å d) None of these

Answer -b) 1.3 Å

Assertion and Reasoning (1 mark each)

Instructions: Mark the correct option:
(a) Both A and R are true, and R is the correct explanation of A.
(b) Both A and R are true, but R is not the correct explanation of A.
(c) A is true, R is false.
(d) A is false, R is true.

Q1.Assertion: Photoelectric emission is instantaneous.
Reason: Electrons absorb energy gradually over time.

Answer: - (c) A is true, R is false.

Q2.Assertion: All incident photons result in photoemission.
Reason: Energy of a photon must be greater than the work function.

Answer: - 2. (d) A is false, R is true.

Q3.Assertion: de Broglie wavelength is inversely proportional to the momentum.
Reason: Higher the momentum, smaller the wavelength.

Answer: - (a) Both A and R are true, and R is the correct explanation of A.

Q4.Assertion: Stopping potential increases with frequency.
Reason: Energy of emitted photoelectrons depends on frequency.

Answer: - (a) Both A and R are true, and R is the correct explanation of A.

Q5.Assertion: Wave nature of matter can be observed in daily life objects.
Reason: Wavelength associated with macroscopic objects is very small.

Answer: - (d) A is false, R is true.

Short Answer (2 marks each)

Q1.A radio transmitter of frequency of 880 kHZ and a power of 10 kW. Find the number of photons emitted per second.

Answer: - 16) N = Power / Energy per photon = $(10 \times 10^3$ W$) / (h \times \nu)$; $\nu = 880 \times 10^3$ Hz; $N = (10\times10^3)/(6.626\times10^{-34} \times 880\times10^3) \approx 1.72\times10^{25}$ photons/sec.

Q2.No photoelectrons are emitted from a surface, if the radiation is above 5000Ao with an unknown wavelength, the stopping potential is 3 V.Find the wavelength.

Answer: -17.) Use $eV = hc/\lambda \Rightarrow \lambda = hc/eV = (6.626\times10^{-34}\times3\times10^8)/(1.6\times10^{-19}\times3) \approx 414$ nm.

Q3.Two particles have same charge are accelerated by a given potential difference V. From the graph shown, find which one has more mass? Justify the same. (graph)

Answer: - The heavier particle will have a smaller acceleration and hence reach the plate slower. So the particle with slower response (lower V vs x slope) has more mass.

Q4.Why does the photoelectric effect not occur with all types of light?

Answer: - Because if the energy of the photons is less than the work function, electrons won't be emitted.

Q5.Calculate the kinetic energy of an electron ejected by 6 eV photon from a metal of work function 2 eV.

Answer: - KE = hf - φ = 6 eV - 2 eV = 4 eV.

Q6.Why is photoelectric emission not observed with visible light in sodium metal?

Answer: - Because the photons in visible light may not have energy greater than sodium's work function.

Q7.The graph shows the variation of stopping potential with frequency of incident radiation for two photosensitive metals A and B. Which one of the two has higher value of work function? Justify your answer. ns : comp 2021 Metal A has higher value of work function because and the intercept of the line of the given graph dependsThe work function for a certain metal is 4.2 eV . Will this metal give photoelectric emission for incident radiation of wavelength 330 nm?

Answer: - Metal A has higher work function as it needs higher frequency (x-intercept is larger).

Q8.Define de Broglie wavelength. Calculate the wavelength of a neutron moving with velocity 500 m/s. (Take (m = 1.675 × 10^{-27} , ext{kg}, h = 6.626 × 10^{-34} , ext{Js}))

Answer: - $\varphi = hc/\lambda = 6.626\times10^{-34}\times3\times10^{8} / (330\times10^{-9}) \approx 6.02\times10^{-19}$ J $\approx$ 3.76 eV; Since 3.76 < 4.2, no emission.

Q9.he threshold frequency for a given metal is $3.4\text{x}10^{14}$ HZ. If monochromatic radiation of frequency $6.8\text{x}10^{14}$ HZ are incidents on the metal. Find cut off potential for the photoelectrons.

Answer: - $\lambda = h/mv = 6.626\times10^{-34} / (1.675\times10^{-27} \times 500) \approx 7.91 \times10^{-10}$ m.

Short Answer (3 marks each)

Q1.Sketch the graph, showing the variation of stopping potential with frequency of incidents radiation for two photosensitive materials A and B having threshold frequency v_o is greater than $v_{o'}$ respectively. What information do you get from the graph?

Answer: - The graph is straight line. Metal with higher threshold frequency has higher work function.

Q2.Monochromatic light of frequency 6.0×10^{14} Hz is produced by a laser. the power entitled is 2.0×10^{-3} W. (a) What is the energy of a photon in the light beam? (b) How many photons per second, on an average, are emitted by the source?

Answer:- $E = h\nu = 6.626\times10^{-34} \times 6.0\times10^{14} = 3.98\times10^{-19}$ J
b) $N = P/E = 2\times10^{-3} / 3.98\times10^{-19} \approx 5.03\times10^{15}$ photons/sec

Q3.Calculate the frequency and energy of a photon having wavelength 620 nm.

Answer: - $\nu = c/\lambda = 3\times10^{8} / 620\times10^{-9} \approx 4.84\times10^{14}$ Hz; $E = h\nu = 6.626\times10^{-34} \times 4.84\times10^{14} \approx 3.21\times10^{-19}$ J $\approx$ 2 eV.

Q4.In experiment of photoelectric effect, the slope of the cut-off voltage vs frequency of incident light is found to be 4.12×10^{-15} Vs. Calculate the value of Planck's constant.

Answer: - Slope = $h/e = 4.12\times10^{-15}$ V·s $\Rightarrow h = e\times\text{slope} = 1.6\times10^{-19} \times 4.12\times10^{-15} \approx 6.6\times10^{-34}$ Js.

Q5.Light of frequency 7.21×10^{14} Hz is incident on a metal surface. Electrons with a maximum speed of 6.0×10^{5} m/s are ejected from the surface. What is the threshold frequency for photoemission of electrons?

Answer: - $K.E = \frac{1}{2}mv^2 = \frac{1}{2} \times 9.1\times10^{-31} \times (6\times10^{5})^2 \approx 1.64\times10^{-19}$ J $= hf - \varphi \Rightarrow f_0 = f - (KE/h) \approx 5.73\times10^{14}$ Hz.

Q6.A photon of energy 6.8 eV is incident on a metallic surface of work function 4.8 eV. Calculate the maximum kinetic energy of the emitted electrons and the stopping potential. Light of wavelength 450 nm is incident on a metal surface with work function 2.0 eV. Calculate the stopping potential.

Answer: -) $K.E = hf - \varphi = 6.8 - 4.8 = 2$ eV; Stopping potential = 2 V.

Q7.Draw a plot showing the variation of photoelectric current with collector plate potential for two different frequencies, v1 > v2, of incident radiation having the same intensity. In which case will the stopping potential be higher? Justify your answer.

Answer: - A graph is drawn below showing photoelectric current (I) on the Y-axis and collector plate potential (V) on the X-axis for two frequencies $\nu_1>\nu_2$. $E=h\nu$

Since $\nu_1 > \nu_2$, photons of frequency ν_1\nu_1ν1 have more energy:
E=hν

Therefore, photoelectrons emitted by ν1 have higher kinetic energy, requiring more negative potential (stopping potential) to stop them.

Hence, stopping potential is higher for ν1 than ν2.

Q8.Explain the effect of intensity and frequency of incident radiation on photoelectric current and stopping potential.

Answer: - Effect of Intensity:

- Photoelectric Current ↑ with Intensity ↑ (for fixed frequency).
- This is because more photons strike the metal → more electrons emitted.
- Intensity controls the number of photoelectrons, not their energy.

Effect of Frequency:

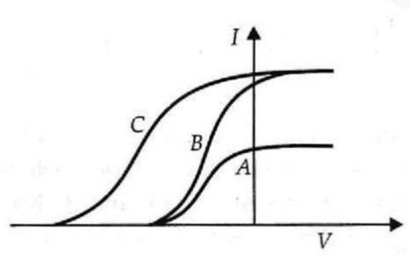
- Stopping Potential with Frequency (for fixed intensity).
- Higher frequency → photons have more energy (E = hν) → electrons come out with higher kinetic energy → higher stopping potential needed.
- Frequency controls the energy of photoelectrons, not their number.

Q9.A proton and an electron are moving with the same kinetic energy. Which one has greater de Broglie wavelength and why?

Answer: -) Intensity affects number of electrons; frequency affects their energy. Stopping potential depends only on frequency.

Case-Based Questions (4 marks each)

Q1. Photoelectric effect It is the phenomenon of emission of electrons from a metallic surface when light of a suitable frequency is incident on it. The emitted electrons are called photoelectrons. Nearly all metals exhibit this effect with ultraviolet light but alkali metals like lithium, sodium, potassium, cesium etc. show this effect even with visible light. It is an instantaneous process i.e. photoelectrons are emitted as soon as the light is incident on the metal surface. The number of photoelectrons emitted per second is directly proportional to the intensity of the incident radiation. The maximum kinetic energy of the photoelectrons emitted from a given metal surface is independent of the intensity of the incident light and depends only on the frequency of the incident light. For a given metal surface there is a certain minimum value of the frequency of the incident light below which emission of photoelectrons does not occur.



(i)In a photoelectric experiment plate current is plotted against anode potential.

(a) A and B will have same intensities while B and C will have different frequencies

(b) B and C will have different intensities while A and B will have different frequencies

(c) A and B will have different intensities while B and C will have equal frequencies

(d) B and C will have equal intensities while A and B will have same frequencies.

(ii) Photoelectrons are emitted when a zinc plate is

(a) Heated (b) hammered (b) Irradiated by ultraviolet light (d) subjected to a high pressure

(iii) The threshold frequency for photoelectric effect on sodium corresponds to a wavelength of 500 nm. Its work function is about

(a) 4x10−19 J (b) 1 J (c) 2x10−19 J (d) 3x10−19 J

(iv) The maximum kinetic energy of photoelectrons emitted from a surface when photons of energy 6 eV fall on it is 4 eV. The stopping potential is

(a) 2 V (b) 4 V (c) 6 V (d) 10 V

OR

(v)The minimum energy required to remove an electron from a substance is called its

(a) work function (b) kinetic energy (c) stopping potential (d) potential energy

Answer:- **(i)** (a) A and B will have same intensities while B and C will have different frequencies.

(ii): (c) Irradiated by ultraviolet light

(iii): (a) 4×10^{-19} J

(iv): (b) 4 V

OR

(v):The minimum energy required to remove an electron is called the **work function** → (a)

Q2.The discovery of the phenomenon of photoelectric effect has been one of the most important discoveries in modern science. The experimental observations associated with this phenomenon made us realize that our, till then, widely accepted picture of the nature of light – The electromagnetic (wave) theory of light – was quite inadequate to understand this phenomenon. A 'new picture' of light was needed and it was provided by Einstein through his 'photon theory' of light. This theory, regarded light as a stream of particles. Attempts to understand photoelectric effect thus led us to realize that light, which was being regarded as 'waves', could also behave like 'particles'. This led to the idea of 'wave-particle duality' vis-à-vis the nature of light. Attempts to understand this 'duality', and related phenomenon, led to far reaching, and very important developments, in the basic theories of Physics.

1) Which of the following phenomena explain the wave nature of light?

i) Interference ii) Diffraction iii) polarization iv) all of them

2) Wave –particle duality is shown by

i) Light only ii) matter only iii) both light and matter iv) None of them

3) The experiment to explain the wave nature of light i.e electromagnetic wave theory is given by

i) Hertz ii) Einstein iii) Lenard iv) Huygen

4) The concept of photoelectric effect given by Einstein explains that the light is a

i) Photon ii) Wave iii) Particle iv) Both

5) The practical application of the phenomenon of photoelectric effect and the concept of 'matter waves' is

i) Photocells ii) Automatic doors at shops and malls

iii) automatic light switches iv) All of them

Answers: 1) option iv 2) option iii 3) option i 4) iii 5) iv

Answer: -

1. (iv) All of them
2. (iii) Both light and matter
3. (i) Hertz
4. (iii) Particle
5. (iv) All of them (photocells, automatic doors, light switches, etc.)

Long Answer (5 marks each)

Q1.(What is the de Broglie wavelength of:-

(a) a bullet of mass 0.040 Kg travelling at the speed of 1.0 km/s,

(b) a ball of mass 0.060 kg moving at a speed of 1.0 m/s and

(c) a dust particle of mass 1.0×10^{-9} kg drifting with a speed of 2.2 m/s.?

Answer: -

1. Calculate de Broglie wavelength of:
a) Bullet:
$\lambda = h / mv = 6.626\times10^{-34} / (0.040 \times 1000) \approx 1.66\times10^{-35}$ m
b) Ball:
$\lambda = 6.626\times10^{-34} / (0.060 \times 1) \approx 1.10\times10^{-32}$ m
c) Dust particle:
$\lambda = 6.626\times10^{-34} / (1\times10^{-9} \times 2.2) \approx 3.01\times10^{-25}$ m

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Q2.(a)Derive an expression for de Broglie wavelength.

(b)Calculate de Broglie wavelength of an electron accelerated by 500 V.

Answer:- (a)Derive an expression for de Broglie wavelength:
From $p = mv$ and $\lambda = h/p$,
$\Rightarrow \lambda = h / mv$
This shows that matter has wave-like properties.

(b)Calculate de Broglie wavelength of electron accelerated by 500 V:
$\lambda = h / \sqrt{(2meV)}$
$= 6.626\times10^{-34} / \sqrt{(2 \times 9.1\times10^{-31} \times 1.6\times10^{-19} \times 500)}$
$\approx 1.74 \times 10^{-10}$ m

Q3.(a)Describe an experiment to study variation of photoelectric current with intensity and potential.

(b)What conclusions are drawn?

- Answer: - Increasing intensity increases number of electrons emitted (current increases).
- Increasing potential affects saturation and stopping voltage.
- Stopping potential is unaffected by intensity, only by frequency.
  Conclusion: Photoelectric current ∝ intensity, KE ∝ frequency.

Q4.(a)Compare energy and momentum of photon and electron having same wavelength.
(b)Which has higher energy and why?

Answer: - (a)Compare energy and momentum of photon and electron having same wavelength:

- Momentum = h/λ for both.
- Electron energy = $p^2/2m$
- Photon energy = hc/λ
  (b)Photon has higher energy due to light speed factor.

Q5.(a)Calculate the wavelength of photon required to eject electrons from a metal with work function 2.2 eV.

(b)If wavelength is 300 nm, find the kinetic energy of emitted electrons.

Answer: - Calculate photon wavelength for work function 2.2 eV.

(a) $\varphi = 2.2$ eV $= 3.52\times10^{-19}$ J

- $\lambda = hc/\varphi = 6.626\times10^{-34}\times3\times10^{8} / 3.52\times10^{-19} \approx 566$ nm

(b)If $\lambda = 300$ nm:
$E = hc/\lambda = 6.626\times10^{-34}\times3\times10^{8} / 300\times10^{-9} \approx 4.14$ eV
K.E. = 4.14 – 2.2 = 1.94 eV

WORKSHEET - 1

Multiple Choice Questions (1 Mark Each)

Q1. The de Broglie wavelength of a particle of mass m and velocity v is:

a) h/mv b) mv/h c) hv/m d) h/v

Q2. The stopping potential in a photoelectric experiment is 2V. The maximum kinetic energy of the emitted photoelectrons is:

a) 1 Ev b) 2 eV c) 3 eV d) 0.5 eV

Q3. Which of the following phenomena supports the particle nature of light?

a) Interference b) Diffraction c) Polarization d) Photoelectric effect

Q4. The work function of a metal is 2 eV. The threshold frequency will be:

a) 4.8×10^{14} Hz b) 2.5×10^{14} HZ c) 1.2×10^{15} Hz d) 3×10^{8} Hz

Q5. In a photoelectric experiment, increasing the intensity of light increases:

a) Stopping potential b) Maximum kinetic energy

c) Number of photoelectrons emitted d) Threshold frequency

Assertion and Reasoning (1 Mark Each)

Q1. Assertion: Photoelectric current increases with increase in light intensity.

Reason: More photons result in more photoelectrons

a) Both A and R are true, and R is the correct explanation of A.

b) Both A and R are true, but R is not the correct explanation of A.

c) A is true but R is false.

d) A is false but R is true.

Q2. Assertion: Light of frequency lower than threshold frequency can emit photoelectrons.

Reason: Energy of incident photons must be more than the work function.

a) Both A and R are true, and R is the correct explanation of A.

b) Both A and R are true, but R is not the correct explanation of A.

c) A is true but R is false.

d) A is false but R is true.

Short Answer Questions (2 Marks Each)

Q1. A photon and an electron have the same de Broglie wavelength. Which has more energy and why?

Q2. How does Einstein's photoelectric equation explain the existence of a threshold frequency?

Competency-Based Question (3 Marks)

Q1. A 100 W sodium lamp emits monochromatic light of wavelength 590 nm. Assuming 10% efficiency, calculate the number of photons emitted per second. ($h = 6.63 \times 10^{-34}$ Js, $c = 3 \times 10^{8}$ m/s)

Long Question (5 Marks)

Q1. A student performs a photoelectric experiment using two different metals A and B. The stopping potential for A is higher than B when exposed to the same light source.

a) What does this tell you about the work functions of A and B?

b) If the frequency of incident light is doubled, what will happen to the photoelectric current and stopping potential?

c) Draw the graph between kinetic energy and frequency for both metals.

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WORKSHEET - 2

Q1.A photocell connected in an electrical circuit is placed at a distance 'd'from the source of light. As a result, current I flow in the circuit.what will be the current in the circuit,when the distance is reduced to d/2.

a) I b) 2I c) 4I d). I /2

Q2.The kinetic energy of photon and that of an alpha particle and 4 eV and 1 e respectively. The ratio of the de Broglie wavelength associated with them will be

a) 2:1. B)1:1. c)1:2. D) 4:1

Q3.The stopping potential in a photoelectric experiment is 2V. The maximum kinetic energy of the emitted photoelectrons is:
a) 1 Ev b) 2 eV c) 3 eV d) 0.5 eV

Q4.For a photosensitive surface, the work function is 3.3×10^{-19} J. Calculate the threshold frequency.
a) 15×10^{14} Hz b) 25×10^{14} Hz c) 5×10^{14} Hz d) 55×10^{14} Hz

Q5.In photoelectric effect, why should the photoelectric current increase as the intensity of monochromatic radiation incident on photosensitive surface is increased. Why?

Q6.Plot a graph showing the variation of Photo Current Vs collector potential for three different intensities $I_1>I_2>I_3$, two of which have same frequency V and third has frequency V1 >V

Q7. The work function of caesium metal is 2.14eV. When the light of frequency $6 \times \mathbf{10^{14\ Hz}}$ is incident on the metal surface, photoemission of electrons occurs. Find the following:

(a) The maximum kinetic energy of the emitted electrons
(b) Stopping potential
(c) The maximum speed of the emitted photoelectrons(3)

Q8. Light of frequency 7.21 x 1014 Hz is incident in a metal surface. Electrons with a maximum speed of 6.0 x 105 m/s are ejected from the surface. What is the threshold frequency for the photoemission of electrons?

Q9.Plot suitable graph to show the variation of Photo current with the collector plate potential for the incidents radiation of

I) Same intensity but different frequencies V1, v2and v3(V1<v2<v3)

II) Same frequency but different intensities I1, I2, I3 (I1<I2<I3)

****

ANSWERS

1. When distance is reduced from d to d/2, the intensity increases by a factor of 4 (Intensity $\propto 1/d^2$). Since photoelectric current $\propto$ intensity, the new current = 4I.
   Answer: (c) 4I

2. Given KE_photon = 4 eV, KE_alpha = 1 eV. The de Broglie wavelength $\lambda \propto 1/\sqrt{(mK)}$.
   Because mass of alpha particle is much more than photon, the wavelength of the alpha particle will be smaller.
   Answer: (a) 2:1

3. Maximum kinetic energy of photoelectrons = e × Stopping Potential = 2 eV.
   Answer: (b) 2 Ev

4. Threshold frequency $f_0 = \varphi / h = (3.3 \times 10^{-19}$ J) / $(6.626 \times 10^{-34}$ Js) $\approx 5 \times 10^{14}$ Hz
   Answer: (c) 5×10^{14} Hz

5. Photoelectric current increases with intensity because higher intensity means more photons hit the surface per unit time, resulting in more emitted electrons.
   Answer: Current increases due to more emitted photoelectrons.

6. Graph showing Photo Current vs. Collector Potential for different intensities ($I_1 > I_2 > I_3$) will show same threshold but higher saturation current for higher intensity.
   (Graph will be added manually)

7. (a) $E = hf = 6.626\times10^{-34} \times 6\times10^{14} = 3.976\times10^{-19}$ J = 2.48 eV
   K.E. = 2.48 − 2.14 = 0.34 eV
   (b) Stopping potential = 0.34 V
   (c) $v = \sqrt{(2K.E./m)} = \sqrt{(2\times0.34\times1.6\times10^{-19} / 9.1\times10^{-31})} \approx 3.45 \times 10^5$ m/s

8. K.E. = $\frac{1}{2} mv^2 = 0.5 \times 9.1\times10^{-31} \times (6.0\times10^5)^2 \approx 1.64\times10^{-19}$ J
   $E_{photon} = hf = 6.626\times10^{-34} \times 7.21\times10^{14} \approx 4.78\times10^{-19}$ J
   Work function = 4.78 - 1.64 = 3.14×10^{-19} J
   Threshold frequency = $\varphi/h = 3.14\times10^{-19} / 6.626\times10^{-34} \approx 4.74\times10^{14}$ Hz

9. Graph

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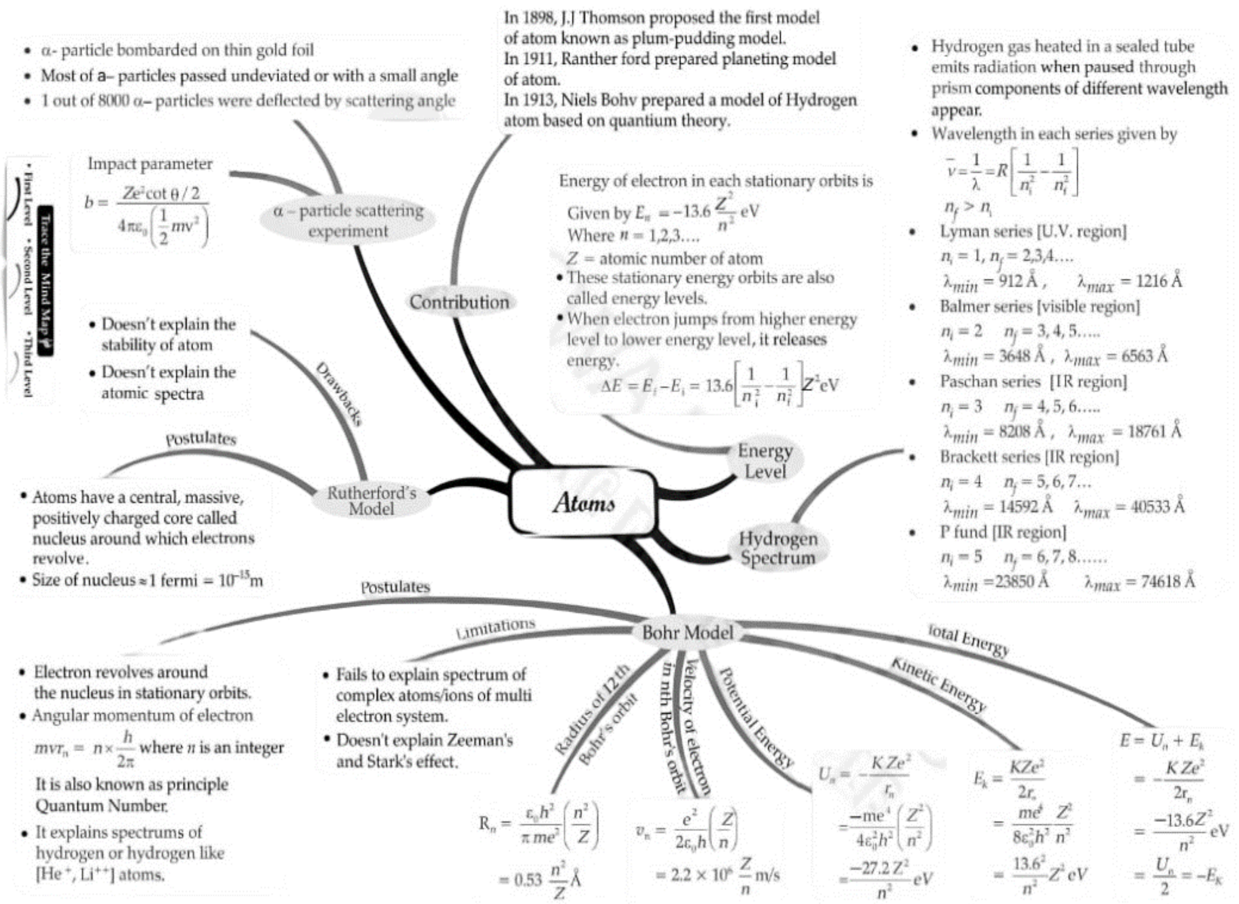
CHAPTER 12

ATOMS MIND MAP



MCQs

Q1.In the second orbit of H-atom, the velocity of the electron will be:

(a) 2.18×10^6 m/s (b) 1.09×10^6 m/s (c) 3×10^6 m/s (d) 1.18×10^6 m/s

ANS: b

Q2.The radius of the fourth Bohr orbit of hydrogen atom is approximately:

(a) 0.53 A° (b) 1.06 A° (c) 2.12 A° (d) 5.3 A°

ANS: c

Q3.The energy of an electron in the nth orbit of hydrogen atom is proportional to:

(a) n (b) $\frac{1}{n^2}$ (c) $\frac{1}{n}$ (d) n^2

ANS: b

Q4.Which of the following statements about Bohr's model is incorrect?

(a) Electrons revolve in stable orbits without radiating energy.

(b) Angular momentum of electron is quantized.

(c) Energy is emitted or absorbed only when electron jumps between orbits.

(d) It explains fine structure of hydrogen spectra.

ANS: d

Q5.The wavelength of the first line of Lyman series is approximately:

(a) 1216 A° (b) 6563 A° (c) 4861 A° (d) 4102 A°

ANS: a

Q6.When an electron jumps from n=4 to n=2 in hydrogen atom, the number of possible spectral lines emitted is:

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

ANS: c

Q7.In Rutherford's alpha particle scattering experiment, which of the following changes would lead to an increase in the scattering angle θ of an alpha particle?

(a) Increasing the velocity of the alpha particle

(b) Decreasing the atomic number Z of the target nucleus

(c) Decreasing the impact parameter b

(d) Increasing the distance of closest approach

ANS: c

Q8.According to the Rutherford's atomic model, the electrons inside the atom

(a) stationary (b) not stationary (c) centralized (d) none of these

ANS: b

Q9.The total energy of an electron in the first excited state of hydrogen atom is about -3.4 eV. Its kinetic energy in this state is

(a) - 3.4 eV (b) 3.4 eV (c) -6.8 eV (d) 6.8 Ev

ANS: b

Q10.When hydrogen atom is in its first excited level, it's radius is

(a) four times its ground state radius (b) twice times its ground state radius

(c) same times its ground state radius (d) half times its ground state radius.

ANS: a

Assertion-Reason Questions

a) Assertion and reason both are correct statements, and reason is the correct explanation for the assertion.

b) Assertion and reason both are correct statements, but reason is not the correct explanation for the assertion.

c) Assertion is a correct statement, but reason is a wrong statement.

d) Assertion is a wrong statement, but reason is a correct statement

Q1.Assertion (A): According to Bohr's model, the angular momentum of an electron in a stationary orbit is quantized.

Reason (R): Electron in an atom can have any arbitrary value of angular momentum.

ANS: C

Q2.Assertion (A): The frequency of revolution of an electron in Bohr's orbit increases with increase in principal quantum number n.

Reason (R): The electron moves faster in higher orbits because it is farther from the nucleus.

ANS: D

Q3.Assertion (A): The energy required to remove an electron from the first orbit of hydrogen atom is 13.6 eV.

Reason (R): The energy of an electron in the nth orbit of hydrogen atom is given by En = - 13.6/n^2 eV.

ANS: A

Q4.Assertion (A): According to Rutherford's model, the electrons revolving around the nucleus continuously emit electromagnetic radiation.

Reason (R): Any accelerated charged particle emits electromagnetic radiation.

ANS: A

Q5.Assertion (A): The spectral lines in hydrogen atom become closer and closer as we go to higher series limits.

Reason (R): The energy difference between successive levels decreases with increase in principal quantum number n.

ANS: A

Short Answer Questions (2 M)

Q1.State two important postulates of Bohr's model of hydrogen atom.

Ans: Electrons revolve in stable orbits without emitting radiation.

Angular momentum quantized: $L=nh/2\pi$

Q2.A hydrogen atom is in its third excited state. It de-excites by releasing a photon of the longest wavelength. What is the ratio of the velocity of the electron in the third excited state to the new state?.

Ans: Hydrogen atom is in its third excited state. So $n_i = 4$.

Longest wavelength means smallest energy difference, i.e. transition to nearest lower level.

So $n_f = 3 \Rightarrow v \propto \frac{1}{n} \Rightarrow \frac{v_4}{v_3} = \frac{n_3}{n_4} = \frac{3}{4}$

Q3.In the hydrogen spectrum why are the spectral lines in a series getting closer together as we go to higher excited states?

Ans: Lines get closer because: $\Delta E = E_{n+1} - E_n \propto 1/n^2$ Decreases with n, so lines crowd.

Q4.The energy of the electron in the excited state of this hydrogen-like atom drops from – 13.6 eV to -1.5 eV. Specify the different ways in which this transition can occur? (Give formula, no need for calculation.)

Ans: -1.5 eV and -13.6 eV corresponds to n=3 and n=1 state

There are two possible ways in which the electron can jump from n=3 to n=1 states.

n=3 to n=1

n=3 to n=2 to n=1

Q6.Calculate the wavelength of the photon emitted when an electron in a hydrogen atom transitions from n = 3 to n = 2.

Ans: For n = 3→2 $1/\lambda = R(1/2^2 - 1/3^2) = 1.097\times10^7\times5/36 \approx 1.52\times10^6\ m^{-1}$

So, $\lambda \approx 656$ nm

Q7.The energy of an electron orbiting in the atom is negative. Explain what is the significance of negative energy of an electron in an atom?

Ans: Negative energy means electron is **bound**, work needed to free it.

Q8.Explain why Rutherford's atomic model could not explain the stability of the atom.

Ans: Rutherford model fails because accelerated electrons should spiral into nucleus, atom collapse.

Q9.What is the ratio of radii of the orbits corresponding to first excited state and ground state, in a hydrogen atom?

Ans: Ratio of radii for n=2, n=1 : $r_2/r_1 = 4/1 = 4$

Q10.Define ionisation energy. What is its value for hydrogen atoms?

Ans: Ionization energy: energy to remove electron from ground state. For H is 13.6 eV.

Short Answer Questions (3 M)

Q1.An ultraviolet radiation falls on a H atom. If the H atom is in the ground state when the incident photon of wavelength 80 nm falls on it, will the H atom get excited to the higher energy levels? OR will the H atom get ionizd?

Ans: $E = \frac{hc}{\lambda} = 2.486\times10^{-18}$ J = 15.54eV > ionization energy of H atom in ground state (13.6eV)

Q2.Why is the classical Rutherford model for an atom of electron orbiting around the nucleus not able to explain the atomic structure?

Ans: Rutherford fails because electrons should radiate, lose energy, spiral into nucleus.

Q3.A difference of 2.3 eV separates two energy levels in an atom. What is the frequency of radiation emitted when the atom make a transition from the upper level to the lower level?

Ans: $\Delta E = 2.3\ eV = 3.68\times10^{-19}$ J
$\nu = \Delta E/h = 3.68\times10^{-19}/6.63\times10^{-34} \approx 5.55\times10^{14}$ Hz

Q4.The ground state energy of hydrogen atom is –13.6 eV. What are the kinetic and potential energies of the electron in this state?

Ans: KE = −E = +13.6eV
PE = 2E = −27.2eV

Q5.Using the Bohr's model calculate the speed of the electron in a hydrogen atom in the n = 1, 2 levels.

Ans: Speed in hydrogen:
$v_n = (2.18\times10^6)/n$ m/s
$v_1 = 2.18\times10^6$, $v_2 = 1.09\times10^6$

Q6.A hydrogen atom initially in the ground level absorbs a photon, which excites it to the n = 4 level. Determine the wavelength and frequency of photon.

Ans: $E_4 - E_1 = -0.85 - (-13.6) = 12.75$eV
$\lambda = 12400/12.75 \approx 973$ A°

Q7.A 12.5 eV electron beam is used to bombard gaseous hydrogen at room temperature. What series of wavelengths will be emitted?

Ans: 12.5 eV excites up to n=3 (13.6–1.51=12.09 eV). So emits **Balmer & Paschen lines.**

Q8.The radius of the innermost electron orbit of a hydrogen atom is 5.3×10^{-11} m. What are the radii of the n = 2 and n =3 orbits?

Ans: $r_2 = 4r_1 = 2.12\times10^{-10}$
$r_3 = 9r_1 = 4.77\times10^{-10}$

Q9.In the Rutherford scattering experiment, the distance of closest approach for an α -particle is d_0 . If α -particle is replaced by a proton, then how much kinetic energy in comparison to α -particle will be required to have the same distance of closest approach d_0 ?

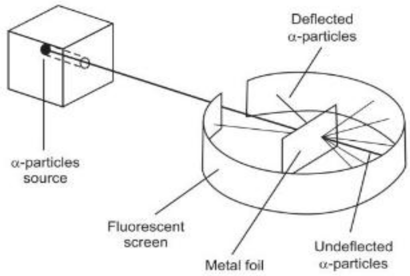
Ans: Closest approach: $E_k = \frac{1}{4\pi\epsilon_0}\frac{Zze^2}{d_0}$
proton (Z=1) $\Longrightarrow KE_p = \frac{KE\alpha}{2}$

Q10.Define ionization energy. How would the ionization energy change when electron in hydrogen atom is replaced by a particle of mass 200 times that of the electron but having the same charge?

Ans: New ionization energy increases by 200, since: $E \propto m/n^2$

Case Based Questions

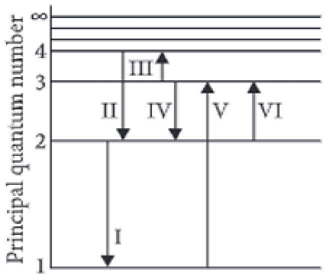
Q1.A radioactive source emitting alpha-particles was enclosed within a protective lead shield. The radiation was focused into a narrow beam after passing through a slit in a lead screen. A thin section of gold foil was placed in front of the slit and a screen coated with zinc sulphide to render it fluorescent served as a counter to detect alpha-particles. As each alpha-particle struck the fluorescent screen, it produced a burst of light called a scintillation, which was visible through a viewing microscope attached to the back of the screen. The screen itself was movable, allowing to determine whether or not any a-particles were being deflected by the gold foil.



Read the given passage carefully and give the answer of the following questions:

(i) The particles which were deflected backwards in Rutherford's experiment were hit upon by:
(a) nucleus (b) empty space (c) electrons (d) protons
Ans: (a) mass of atom is centered on nucleus.
(ii) According to the Rutherford's atomic model, the whole atom is:
(a) positively charged (b) negatively charged (c) neutral (d) None of these
Ans: neutral
(iii) Rutherford in his atomic model could not explain the behaviour of which of the following?
(a) Proton (b) Neutron (c) Electron (d) Neutrino
Ans: electron
(iv) Electron revolves around the nucleus in orbits which have:
(a) variable energy (b) fixed energy (c) infinite energy (d) zero energy
Ans: fixed

Q2.Bohr's model explains the spectral lines of hydrogen atomic emission spectrum. While the electron of the atom remains in the ground state, its energy is unchanged. When the atom absorbs one or more quanta of energy, the electrons moves from the ground state orbit to an excited state orbit that is further away.



The given figure shows the energy level diagram of the hydrogen atom. Several transitions are marked as I, II, III and so on.
(i)In which transition is a Balmer series photon absorbed?
(a) II (b) III (c) IV (d) VI
Ans: **(c)**
(ii)The wavelength of the radiation involved in the transition II is
(a) 291 nm (b) 364 nm (c) 487 nm (d) 652 nm
Ans: 364 nm
(iii)Which transition will occur when a hydrogen atom is irradiated with radiation of wavelength 103 nm?
(a) I (b) II (c) IV (d) V
Ans: transition I
(iv)The Balmer series for the H-atom can be observed
(a) if we measure the frequencies of light emitted when an excited atom falls to the ground state
(b) if we measure the frequencies of light emitted due to transitions between excited states and the first excited state
(c) in any transition in a H-atom
(d) none of these.

Ans: transitions to n=2.

Q2.The Bohr model of the hydrogen atom was a major advancement in understanding atomic structure. According to this model, electrons revolve in specific circular orbits around the nucleus without radiating energy. These orbits correspond to discrete energy levels. When an electron jumps from a higher energy level to a lower one, it emits a photon of definite energy, resulting in the line spectra observed in experiments. The model successfully explained the spectral lines of hydrogen and introduced the concept of quantized angular momentum.

(i)The energy associated with the nth orbit in a hydrogen atom is given by:
(a) $E_n = -13.6 \times n^2$ eV (b) $E_n = -13.6/n$ eV
(c) $E_n = -13.6/n^2$ eV (d) $E_n = 13.6 \times n$ eV

Ans: (c)

(ii) The angular momentum of an electron in the nth orbit according to Bohr's model is:

(a) $nh/2\pi$ (b) nh/π (c) h/n (d) nh

Ans: angular momentum $mvr = nh/2\pi$

(iii) The transition of an electron from n=4 to n=2in a hydrogen atom will result in:

(a) Absorption of a photon (b) Emission of a photon

(c) Ionization of the atom (d) No change in energy

Ans: (b) Emission of a photon

(iv) The wavelength of light emitted during an electronic transition in hydrogen depends on:

(a) The sum of initial and final orbit numbers

(b) The product of initial and final orbit numbers

(c) The difference between initial and final orbit numbers

(d) The inverse of the difference in the reciprocals of the squares of orbit numbers

Ans: (d) inverse of difference in squares

Long Answer Questions

Q1.It is found experimentally that 13.6 eV energy is required to separate a hydrogen atom into a proton and an electron. Compute the orbital radius and the velocity of the electron in a hydrogen atom.

Ans: Given energy = 13.6 eV, r_1=0.53A°, $v_1=2.18\times10^6$ m/s

Q2.In a Geiger-Marsden experiment, what is the distance of closest approach to the nucleus of a 7.7 MeV a-particle before it comes momentarily to rest and reverses its direction?

Ans: Closest approach: $d= (1/4\pi\epsilon 0)2Ze2/E_k$

Q3.The electron in a given Bohr orbit has a total energy of 1.5eV Calculate its

1. Kinetic energy
2. Potential energy
3. Wavelength of radiation emitted, when this electron makes a transition to the ground state. (Given, energy in the ground state −13.6 eV and Rydberg's constant = $1.09 \times 10^7\ m^{-1}$)

Ans: Given total 1.5eV,

KE = −E = +1.5eV, PE = -2KE = −3eV

$\lambda = 1/R(1/1^2-1/n^2)$

Q4.Explain Bohr's atomic model and derive the expression for the radius of the nth orbit.

(a) State any two main postulates of Bohr's atomic model.

(b) Derive the expression for the radius of the nth orbit of a hydrogen atom.

Ans: (a) Bohr's two postulates:

1. Electrons revolve in fixed, stable orbits without radiating energy.
2. An electron can only revolve in those orbits for which its angular momentum is an integral multiple of h/(2π), where 'h' is Planck's constant. Mathematically, this is expressed as $mvr=nh/2\pi$.

(b) Bohr postulates, derive $r_n = (n^2h^2\epsilon_0)/\pi me^2$

Q5.Derive the expression for energy of an electron in a hydrogen atom and explain the significance of negative energy.

(a) Derive the expression for the total energy of the electron in the nth orbit.

(b) What is the physical significance of negative energy in the Bohr model?

Ans: (b) n the Bohr model, negative energy signifies that the electron is bound to the nucleus. A free electron (infinitely far from the nucleus) is defined to have zero energy. Therefore, a negative energy indicates that energy must be supplied to remove the electron from the atom and make it free. The more negative the energy, the more tightly bound the electron.

WORKSHEET - 1

Each question carries 2 marks.

Q1. What is the significance of Rutherford's alpha-particle scattering experiment in understanding atomic structure?

Q2.State Bohr's postulates for the hydrogen atom. Explain how these postulates helped in explaining the stability of the atom.

Q3.Define ionization energy. How does it vary along a period and a group in the periodic table?

Q4.Calculate the wavelength of the second line of the Balmer series in the hydrogen spectrum. (Given: Rydberg constant, $R_H=1.097\times10^7\ m^{-1}$)

Q5.Explain why the classical theory failed to account for the observed spectrum of hydrogen, and how Bohr's model resolved this issue.

WORKSHEET - 2

Each question carries 2 marks.

Q1.State the drawbacks of Rutherford's atomic model. How did Bohr's model overcome these limitations?

Q2.Derive the expression for the radius of the nth Bohr orbit in a hydrogen atom.

Q3.What is the de Broglie wavelength of an electron moving with a kinetic energy of 100 eV? (Given: mass of electron me=9.1×10^{-31} kg)

Q4.Explain how de Broglie's hypothesis supports Bohr's quantization condition for angular momentum.

Q5.The first line of the Lyman series in the hydrogen spectrum has a wavelength of 1216 Å. Calculate the wavelength of the second line.

WORKSHEET 1 ANSWERS

1. Explains atom's structure — mostly empty, dense nucleus.
   Answer: Led to nuclear model with central positive nucleus.

2. Quantized orbits, angular momentum, energy emission on transition.
   Answer: Postulates explain discrete energy levels and atomic stability.

3. Energy to remove outermost electron.
   Answer: Increases across period, decreases down group.

4. 5Use $1/\lambda = RH(1/2^2 - 1/4^2)$
   Answer: 487 nm

5. Classical predicts collapse, Bohr introduces quantization.
   Answer: Bohr's model explains discrete lines and atomic stability.

WORKSHEET 2 ANSWERS

1. Rutherford couldn't explain stability; Bohr quantized orbits.
Answer: Bohr solved instability and explained line spectra.

2. Use $mv^2/r = kZe^2/r^2$ and quantized angular momentum.
Answer: $r_n = \varepsilon_0 h^2 n^2 / (\pi m e^2 Z)$

3. $\lambda = h/\sqrt{(2mE)}$
Answer: ≈ 0.123 nm

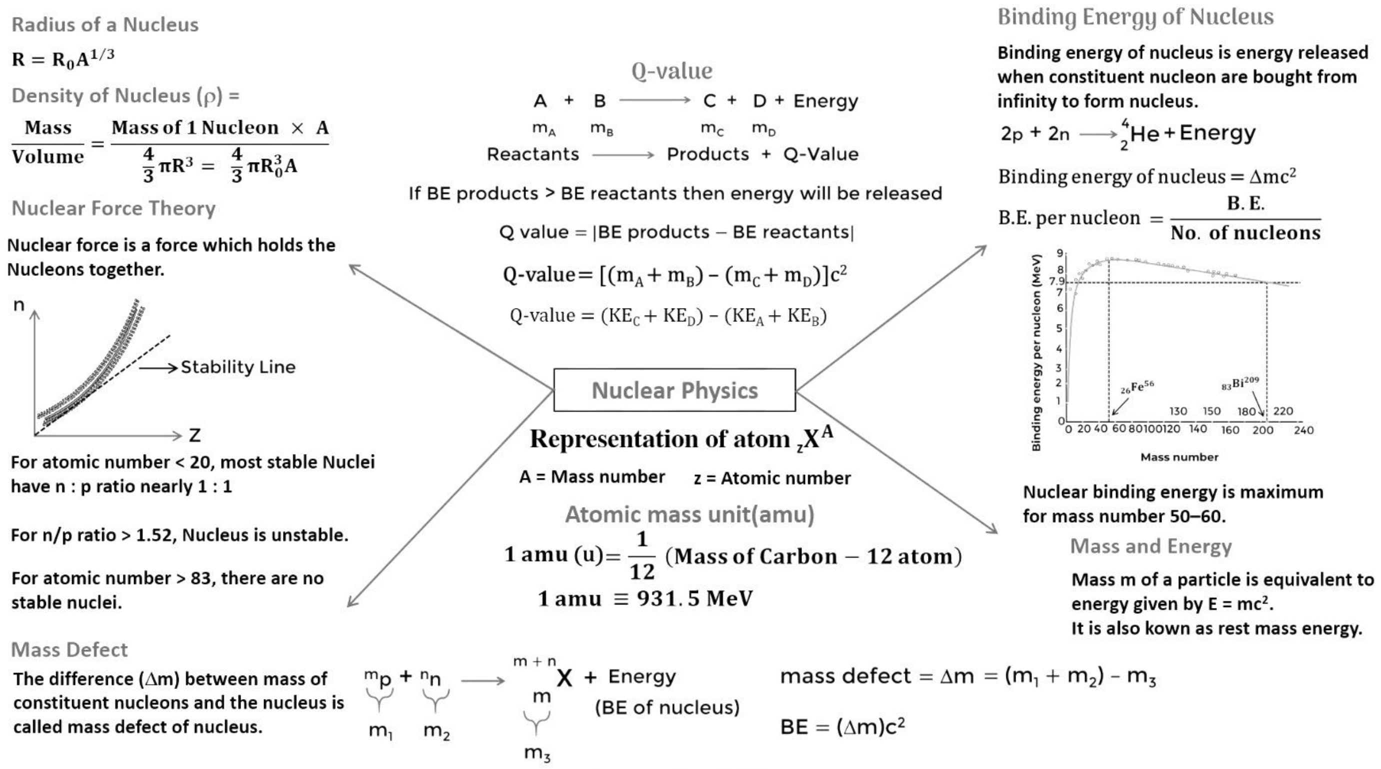
4. Standing wave condition: $2\pi r = n\lambda$
Answer: Leads to $mvr = nh/2\pi$

5. Use Rydberg formula ($n_1 = 3$, $n_2 = 1$)
Answer: 1025 Å

CHAPTER-13

NUCLEI

MIND MAP



Gist of the chapter:

Size of Nucleus: Nucleus does not have a well-defined boundary but its radius is about 10^{-15}m. $R = R_0 A^{1/3}$

Where $R_0 = 1.2 \times 10^{-15}$ m is a constant which is the same for all nuclei and A is the mass number of the nucleus.

Nucleus Density: Mass of nucleus, M = A amu = A x 1.66×10^{-27} kg

Nuclear Volume, V= $4/3\ \pi R^3 = 4/3\ \pi A R_0^3 = 4\ 3\ \pi (1.2 \times 10^{-15})^3$ A m3 = 7.24 x 10-45 A m3

Nucleus Density, $\rho = M/V = 2.29 \times 10^{17}$ kg m^{-3} .

The energy equivalent of 1 g of substance. Here, m = 1 g = 10^{-3} kg,

$E = m c^2 = 10^{-3} (3 \times 10^8)^2 = 9 \times 1013$ J

Energy Equivalent to 1 amu or 1 u

1 amu = 1 u = 1.66×10^{-27} kg

C = speed of light = 3×10^8 m s^{-1}

$E = m c^2 = 1.66\times10^{-27} (3\times10^8)^2 = 1.49\times10^{-10}$ Joule

1MeV = 1.6×10^{-13} J

E = 1.6×10^{-13} x 1.49×10^{-10} = 931.6 MeV

Mass Defect: It is the difference between the rest mass of the nucleus and the sum of the masses of the nucleons composing a nucleus is known as mass defect.

$\Delta m = [\ Zm_p + (A – Z)\ m_n\ ] - M$

Binding Energy: It is the energy required to break up a nucleus into its constituent parts and place them at an infinite distance from one another.

$E_b = \Delta M c^2$ Binding Energy per nucleon: $Eb = \Delta M c^2 / A$

MCQ QUESTIONS

Q1- If m_X, m_n and m_p represents masses of X nucleus, a neutron and a proton, respectively.

Then : (A) $m_X < (A - Z) m_n + Z m_p$

(B) $m_X = (A - Z) m_p + Z m_n$

(C) $m_X = (A - Z) m_n + Z m_p$

(D) $m_X > (A - Z) m_n + Z m_p$

Answer- (A) (Hint- Mass of nucleus is less than mass of free nucleon)

Q2.Ratio of the radii of the nuclei with mass numbers 8 and 27 would be
(a) 27/8 (b) 8/27 (c) 2/3 (d) 3/2
ANS-C (Hint-Radius is proportional to $A^{1/3}$)

Q3- Average binding energy is maximum for
(a) C^{12} (b) Fe^{56} (c) U^{235} (d) Po^{210}
Ans- B

Q4- The mass density of a nucleus of mass number A is :

(a) $A^{1/3}$ (b) $A^{2/3}$ (c) A^3 (d) A

Q5- In the nuclear reaction $^{14}{}_7N + {}_2He^4 \longrightarrow X + {}_1H^1$ represents :

(a) $^{16}O_7$ (b) $^{17}N_7$ (c) $^{17}O_8$ (d) $^{16}N_7$

ASSERTION AND REASON QUESTIONS

Select the most appropriate Answer from the options given below:
(a) Assertion is true, reason is true; reason is a correct explanation for assertion.
(b) Assertion is true, reason is true; reason is not a correct explanation for assertion
(c) Assertion is true, reason is false
(d) Assertion is false, reason is true

Q1- **Assertion :** Density of all the nuclei is same.
Reason : Radius of nucleus is directly proportional to the cube root of mass number
Ans-A

Q2- **Assertion :** The mass number of a nucleus is always less than its atomic number.
Reason : Mass number of a nucleus may be equal to its atomic number.
Ans-B

Q3- **Assertion :** The binding energy per nucleon, for nuclei with atomic mass number A > 100, decrease with A.
Reason : The forces are weak for heavier nuclei.
Ans-A

Q4- **Assertion :** Neutrons penetrate matter more readily as compared to protons.
Reason : Neutrons are slightly more massive than protons.
Ans-B

Q5- Assertion (A) : Nuclear fission reactions are responsible for energy generation in the Sun.

Reason (R) : Light nuclei fuse together in the nuclear fusion reactions.
Ans-D

SHORT ANSWER TYPE QUESTIONS(2 MARKS)

Q1-Find the energy equivalent of one atomic mass unit in MeV. Using this, express the mass defect of $^{16}O_8$

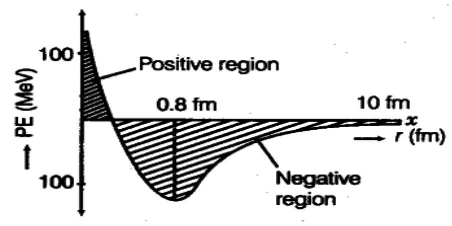
Solution- 1u = 1.6605 × 10^{-27} kg To convert it into energy units, we multiply it by c^2 and find that energy equivalent = 1.6605 × 10^{-27} × (2.9979 × $10^8)^2$ kg m2/s2 = 1.4924 × 10^{-10} J

= 0.9315 × 10^9 eV = 931.5 MeV or, 1u = 931.5 MeV/c2

For $^{16}O_8$, ΔM = 0.13691 u = 0.13691×931.5 MeV/c2 = 127.5 MeV/c2

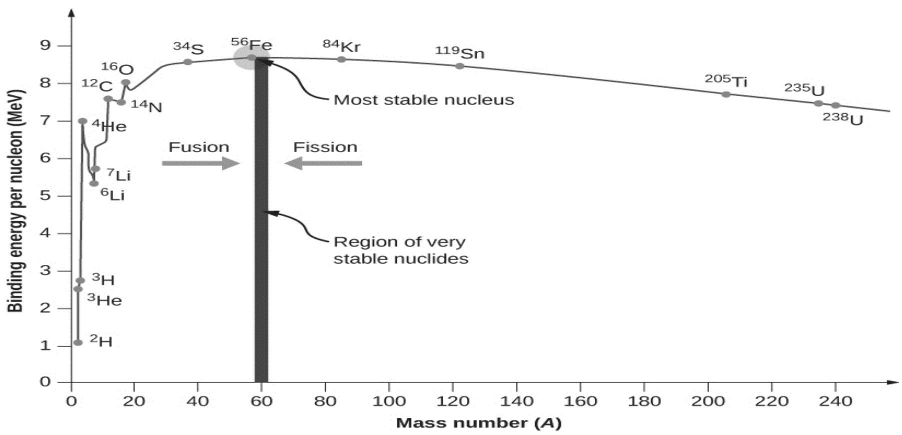
Q2- Draw a plot showing the variation of potential energy of a pair of nucleons as a function of their separation. Mark the regions where the nuclear force is (a) attractive and (b) repulsive.

Solution-



Q3- Using the curve for the binding energy per nucleon as a function of mass number A, identify the region of nuclear fission and nuclear fusion .

Solution-



Q4- A heavy nucleus X of mass number 240 and binding energy per nucleon 7.6 MeV is split into two fragments Y and Z of mass numbers 110 and 130. The binding energy per nucleon in Y and Z is 8.5MeV per nucleon. Calculate the energy Q released per fission in MeV.

Ans-

240 ×7.6=1824 MeV
240×8.5=2040 MeV
2040×1824=216 MeV
Q5- Write characteristic properties of nuclear force.
Refer NCERT text book

SHORT ANSWER TYPE QUESTIONS(3 MARKS)

Q1- (A)Imagine the fission of a $_{26}Fe^{56}$ into two equal fragments of $_{13}Al^{28}$ nucleus. Is the fission energetically possible? Justify your answer by working out Q value of the process.

(B) Why is the density of a nucleus much more than that of an atom ?

Answer-(A)Given: m ($_{26}Fe^{56}$) = 55.93494u, m ($_{13}Al^{28}$) = 27.98191u.

Mass Difference = 55.93494 – 2 x 27.98191 = -0.02888u.

Fission not possible.

(B) Because the whole mass of the nucleus is concentrated at the centre of atom in a small space.

Q2- (A)Given the mass of iron nucleus as 55.85u and A=56, find the nuclear density?

(B) Calculate the energy equivalent of 1 g of substance.

Solution- (A)mass of Fe = 55.85 u = 9.27×10^{-26} kg

Nuclear density = mass/ volume = 2.29×10^{17} kg m^{-3}

(B) Solution Energy, E = $10^{-3} \times (3 \times 10^8)^2$ J

E = $10^{-3} \times 9 \times 10^{16} = 9 \times 1013$ J

Q3- Calculate the energy released in MeV in the following nuclear reaction

$^{238}U_{92} \longrightarrow {}^{234}Th_{90} + {}^{4}He_2 + Q$

Mass of $^{238}U_{92}$= 238.05079 u

Mass of $^{234}Th_{90}$ = 234.043630 u

Mass of $^{4}He_2$= 4.002600 u

1u= 931.5 Mev/c^2

Solution-

Nuclear reaction is $^{238}U_{92} \longrightarrow {}^{234}Th_{90} + {}^{4}He_2 + Q$

Energy released , Q= $\Delta m \times c^2$

$=(M_U - M_{Th} - M_{He}) \times c^2$

= 0.00456×931.5 Mev/C2

= 4.25 Mev

CBQ (4 MARKS)

Q1-**Read the passage given below and answer the following questions**: Neutrons and protons are identical particle in the sense that their masses are nearly the same and the force, called nuclear force, does into distinguish them. Nuclear force is the strongest force. Stability of nucleus is determined by the neutron proton ratio or mass defect or packing fraction. Volume of nucleus depends on the mass number. Whole mass of the atom (nearly 99%) is centred at the nucleus.

(i) The correct statements about the nuclear force is/are

(a) charge independent (b) short range force

(c) non-conservative force (d) all of these. Ans-D

(ii) The range of nuclear force is the order of

(a) 2×10^{-10} m (b) 1.5×10^{-20} m (c) 1.2×10^{-4} m (d) 1.4×10^{-15} m

Ans-D

(iii) A force between two protons is same as the force between proton and neutron. The nature of the force is

(a) electrical force (b) weak nuclear force (c) gravitational force (d) strong nuclear force

Ans-D

(iv) All the nucleons in an atom are held by

(a) nuclear forces (b) vander waal's forces (c) tensor forces (d) coulomb forces

Ans-A

Q2-Einstein was the first to establish the equivalence between mass and energy. According to him, whenever a certain mass (Δm) disappears in some process the amount of energy released is E = Δm *c2, where c is the velocity of light in vacuum =3 x 10^8 m/s. The reverse is also true i.e. whenever energy E disappears an equivalent mass Δm = E/ c2 appears. Read the above passage and answer any 04 from the following –

i) What is the energy released when 1a.m.u mass disappears in a nuclear reaction?

a) 1.49 x10^{-10} J b) 1.49 x10^{-13} J c) 1.49 x10^{10} J d) 1.49 x10^{-10} MJ
Ans- B

ii)Which of the following process releases energy?

a)Nuclear Fission b)Nuclear Fusion c)Both (a) and (b) d)None

Ans- C

iii)Which process is used in today's nuclear power plant to harness nuclear energy?

a)Nuclear Fission b)Nuclear Fusion c)Both (a) and (b) d)None

Ans-A

iv)Which of the following is used as Moderator in a Nuclear Reactor?

a)Deuterium Water b)Normal Water c)Mineral Water

Ans-A

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WORK SHEET - 1

MCQ(1 MARK EACH)

Q1- Isotones are nuclides having :

(A) same number of neutrons but different number of protons

(B) same number of protons but different number of neutrons

(C) same number of protons and also same number of neutrons

(D) different number of protons and also different number of neutrons

Q2-m_X, m_n and m_p represents masses of X nucleus, a neutron and a proton, respectively.

Then : (A) $m_X < (A – Z) m_n + Z m_p$ (B) $m_X = (A – Z) m_p + Z m_n$

(C) $m_X = (A – Z) m_n + Z m_p$ (D) $m_X > (A – Z) m_n + Z m_p$

Q3- Ratio of the radii of the nuclei with mass numbers 8 and 27 would be

(a)27/8 (b) 8/27 (c) 2/3 (d) 3/2

Q4- Average binding energy is maximum for

(a) C^{12} (b) Fe^{56} (c) U^{235} (d) Po^{210}

ASSERTION AND REASON QUESTIONS (1 MARK EACH)

Select the most appropriate Answer from the options given below:

(a) Assertion is true, reason is true; reason is a correct explanation for assertion.

(b) Assertion is true, reason is true; reason is not a correct explanation for assertion

(c) Assertion is true, reason is false

(d) Assertion is false, reason is true.

Q5- Assertion (A) : Nuclear fission reactions are responsible for energy generation in the Sun.

Reason (R) : Light nuclei fuse together in the nuclear fussion reactions.

Ans-

Q6- Assertion : The binding energy per nucleon, for nuclei with atomic mass number A > 100, decrease with A.
Reason : The forces are weak for heavier nuclei.

Ans-

SHORT ANSWER TYPE QUESTIONS(2 MARKS)

Q7- Calculate binding energy per nucleon (in MeV) of ${}_6C^{12}$.

Given : mass of Carbon= 12.000000 u

Mass of neutron = 1.008665 u

Mass of proton = 1.007825 u

Q8-(a) Briefly discuss three characteristics of the forces between nucleons.

(b) Which out of $X^{8}{}_{4}$ and $Y^{5}{}_{3}$ nuclei is more stable and why?

SHORT ANSWER TYPE QUESTIONS(3 MARKS)

Q9-(a) Draw a plot of potential energy of a pair of nucleons as a function of their separation. Write two important conclusions that can be drawn from the plot.

(b) Show that the density of the nuclear matter is the same for all nuclei.

Q10- Find the energy equivalent of one atomic mass unit in MeV.

Using this, express the mass defect of $^{16}O_8$

CBQ(4 MARKS)

Q11- **Read the passage given below and answer the following questions**: Neutrons and protons are identical particle in the sense that their masses are nearly the same and the force, called nuclear force, does into distinguish them. Nuclear force is the strongest force. Stability of nucleus is determined by the neutron proton ratio or mass defect or packing fraction. Volume of nucleus depends on the mass number. Whole mass of the atom (nearly 99%) is centred at the nucleus.

(i) The correct statements about the nuclear force is/are

(a) charge independent (b) short range force (c) non-conservative force (d) all of these.

(ii) The range of nuclear force is the order of

(a) 2×10^{-10} m (b) 1.5×10^{-20} m (c) 1.2×10^{-4} m (d) 1.4×10^{-15} m

(iii) A force between two protons is same as the force between proton and neutron. The nature of the force is

(a) electrical force (b) weak nuclear force (c) gravitational force (d) strong nuclear force

(iv) All the nucleons in an atom are held by

(a) nuclear forces (b) Vander Waal's forces (c) tensor forces (d) coulomb forces

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WORK SHEET-2

MCQ(1 MARK EACH)

Q1- Which of the following quantities is not conserved in a nuclear reaction?

(a) Mass (b) Charge (c) Momentum (d) None of the above

Q2- Binding energy per nucleon of a stable nucleus is

(a) 8 eV (b) 8 KeV (c) 8MeV (d) 8 BeV

Q3- Binding energy per nucleon of a stable nucleus is

(a) 8 eV (b) 8 KeV (c) MeV (d) 8 BeV

Q4- Average binding energy is maximum for

(a) C^{12} (b) Fe^{56} (c) U^{235} (d) Po^{210}

ASSERTION AND REASON QUESTIONS (1 MARK EACH)

Select the most appropriate Answer from the options given below:

(a) Assertion is true, reason is true; reason is a correct explanation for assertion.

(b) Assertion is true, reason is true; reason is not a correct explanation for assertion

(c) Assertion is true, reason is false

(d) Assertion is false, reason is true.

Q5- Assertion: Naturally , thermonuclear fusion reaction is not possible on earth.

Reason : For thermonuclear fusion to take place, extreme condition of temperature and pressure are required

Ans-

Q6- Assertion : Neutrons penetrate matter more readily as compared to protons.

Reason : Neutrons are slightly more massive than protons.

Ans-

SHORT ANSWER TYPE QUESTIONS (2 MARKS)

Q7- A heavy nucleus X of mass number 240 and binding energy per nucleon 7.6 MeV is split into two fragments Y and Z of mass numbers 110 and 130. The binding energy per nucleon in Y and Z is 8.5MeV per nucleon. Calculate the energy Q released per fission in MeV.

Q8-(a) Briefly discuss three characteristics of the forces between nucleons.

(b) Which out of $X^{8}{}_{4}$ and $Y^{5}{}_{3}$ nuclei is more stable and why ?

SHORT ANSWER TYPE QUESTIONS (3 MARKS)

Q9-(a) Draw a plot of potential energy of a pair of nucleons as a function of their separation. Write two important conclusions that can be drawn from the plot.

(b) Show that the density of the nuclear matter is the same for all nuclei.

Q10- When four hydrogen nuclei combine to form a helium nucleus estimate the amount of energy in MeV released in this process of fusion. (Neglect the masses of electrons and neutrons). Given i) Mass of Hydrogen = 1.007825 u ii) Mass of helium nucleus = 4.002603 u, 1u = 931MeV / c2

CBQ (4 MARKS)

Q11-

Nuclear fission reaction is the nuclear reaction which is induced by neutron. For example in the fission of uranium, the energy of the order of 200 MeV per fissioning nucleus is released. While the nuclear reaction in which two or more nuclei get fused together to form the larger nucleus is called as nuclear fusion reaction.

The nuclear fusion which is initiated by increasing the temperature of the system is called as thermonuclear fusion.

The controlled fusion reaction are initiated to produce steady power. The heat energy created on the sun is due to the nuclear fusion reaction. While the huge amount of energy released after the explosion of atom bomb is only due to the nuclear fission reaction.

(i) For which value of multiplication factor the operation of the reactor is said to be critical___

a) $K > 1$ b) $K < 1$ c) $K = 1$ d) $K = 0$

(ii) The source of energy output in the interior of the stars is due to ____

a) thermo nuclear fission b) thermonuclear fusion

c) controlled thermonuclear fission d) none

(iii) The temperature of the interior of the sun is ___

a) 1.5×10^{7} K b) 1.5×10^{10} K c) 1.5×10^{19} K d) 1.5×10^{15} K

(iv) In Maharashtra where is nuclear reactor located?

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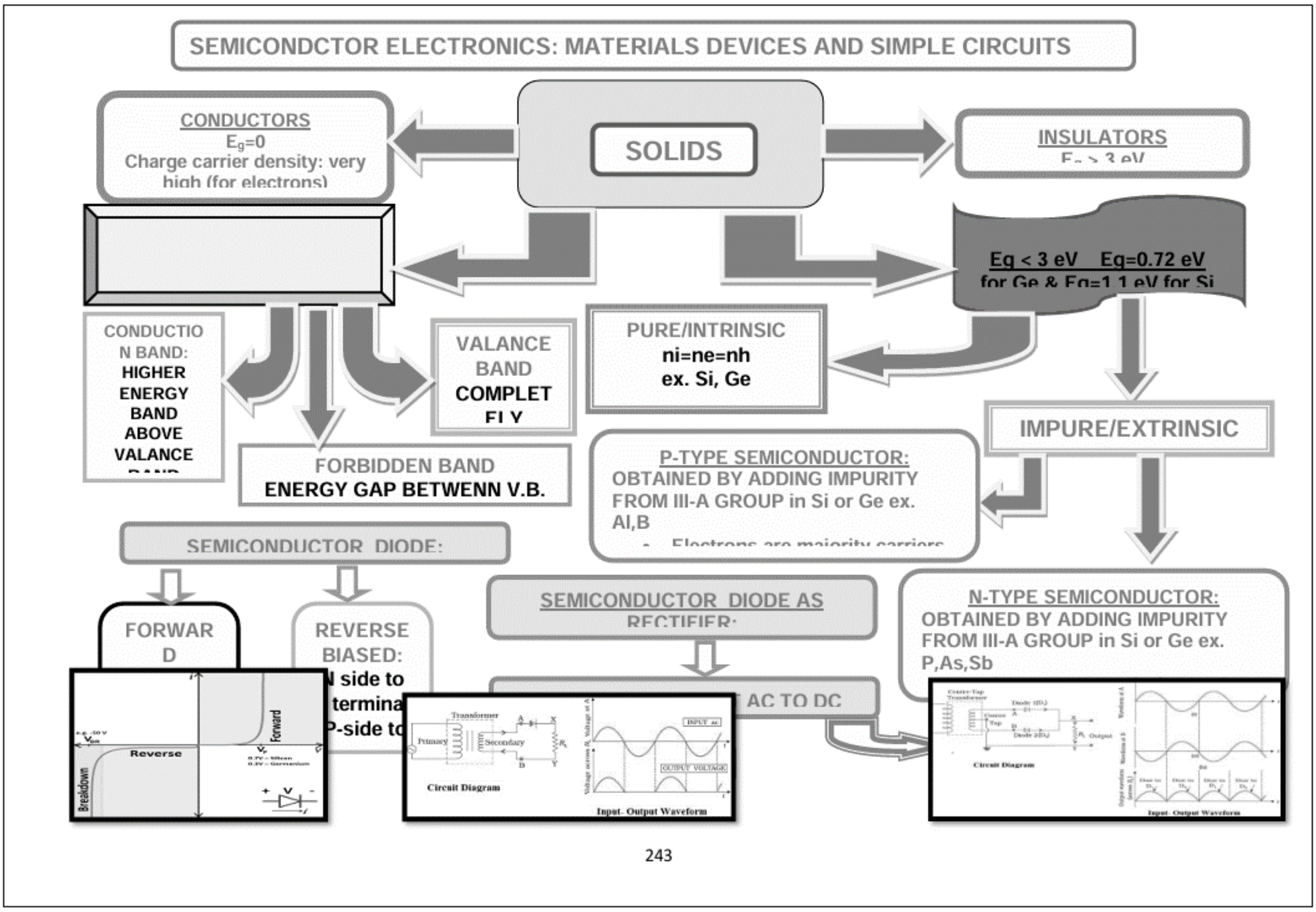
CHAPTER 14

SEMICONDUCTORS

MIND MAP



MULTIPLE CHOICE QUESTIONS

Q1. An *n*-type semiconductor is electrically

(a). Positive (b). Negative

(c). May be positive or negative (d). Neutral

ANS: (d)

Q2. In an unbiased p-n junction, holes diffuse from the p-region to n-region because

(a). free electrons in the n-region attract them.

(b). they move across the junction by the potential difference.

(c). hole concentration in p-region is more as compared to n-region.

(d). All the above.

ANS: (c)

Q3. A pure semiconductor has

(a). An infinite resistance at 0°C (b). A finite resistance which does not depend upon temperature (c). A finite resistance which increases with temperature (d). A finite resistance which decreases with temperature

QANS: (d)

4. There is no hole current in conductors because they have

(a). high conductivity (b). high electron density

(c). no valence bond (d). overlapping of valence and conduction bands

ANS: (d)

Q5. On increasing the reverse bias to a large value in a PN-junction diode, current

(a). Increases slowly (b). Remains fixed

(c). Suddenly increases (d). Decreases slowly

ANS: (c)

Q6. Which statement is correct?

(a). N-type Germanium is negatively charged and P-type Germanium is positively charged

(b). Both N-type and P-type Germanium are neutral

(c). N-type Germanium is positively charged and P-type Germanium is negatively charged

(d). Both N-type and P-type Germanium are negatively charged

ANS: (b)

Q7. Carbon, silicon and germanium atoms have four valence electrons each. Their valence and conduction band are separated by energy band gaps represented by $(E_g)_c$, $(E_g)_{Si}$ and $(E_g)_{Ge}$ respectively. Which one of the following relationships is true in their case?

(a). $(E_g)_c > (E_g)_{Si}$ (b). $(E_g)_c = (E_g)_{Si}$

(c). $(E_g)_c < (E_g)_{Ge}$ (d). $(E_g)_c < (E_g)_{Si}$

ANS: (a)

Q8. The impurity atoms with which pure silicon should be doped to make a p-type semiconductor are those of:

(a). Phosphorus (b). Boron

(c). Antimony (d). Aluminum

ANS: (d)

Q9. In a p-n junction diode not connected to any circuit

(a). The potential is the same everywhere

(b). The p-type side is at a higher potential than the n-type side

(c). There is an electric field at the junction directed from the n-side to p-type side

(d). There is an electric field at the junction directed from the p-type side to the n-type side

ANS: (c)

Q10. The dominant mechanisms for motion of charge carriers in forward and reverse biased silicon p-n junction are

(a). Drift in forward bias, drift in reverse bias

(b). Diffusion in forward bias, drift in reverse bias

(c). Diffusion in both forward and reverse bias

(d). Drift in both forward and reverse bias

ANS: (b)

ASSERTION – REASON QUESTIONS

Q1. Assertion: If the temperature of a semiconductor is increased then its resistance decreases.
Reason: The energy gap between conduction band and valence band is very small.

ANS: (a)

Q2. Assertion: In semiconductors, thermal collisions are responsible for taking a valence electron to the conduction band.
Reason: The number of conduction electrons go on increasing with time as thermal collisions continuously take place.

ANS: (c)

Q3. Assertion: Silicon is preferred over germanium for making semiconductor devices.
Reason: The energy gap in germanium is more than the energy gap in silicon.

ANS: (c)

Q4. Assertion: When two semi-conductor of p and n type are brought in contact, they form p-n junction which act like a rectifier.
Reason: A rectifier is used to convent alternating current into direct current.

ANS: (b)

Q5. Assertion: The diffusion current in a p-n junction is from the p-side to the n-side.
Reason: The diffusion current in a p-n junction is greater than the drift current when the junction is in forward biased.

ANS: (b)

SHORT ANSWER QUESTIONS (2 MARK)

Q1. The hole and electron concentration in the intrinsic semiconductor of germanium at room temperature is $2 \times 10^{18}\ m^{-3}$. After doping with an element Q, the concentration of electrons in the doped semiconductor becomes $6 \times 10^{22}\ m^{-3}$. The concentration of germanium atoms is $6 \times 10^{30}\ m^{-3}$.

(a) Is Q trivalent or pentavalent element? Give reason.

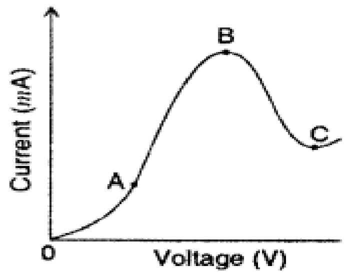
(b) What is the ratio of atoms of element Q and germanium in the doped semiconductor?

ANS: (a) Intrinsic carrier concentration of Ge: $n_i = p_i = 2 \times 10^{18}\ m^{-3}$
Electron concentration after doping: $n = 6 \times 10^{22}\ m^{-3}$
Concentration of germanium atoms: $N_{Ge} = 6 \times 10^{30}\ m^{-3}$

Since the doping has increased the electron concentration far beyond the intrinsic value ($n \gg n_i$), electrons are the majority carriers, and holes become the minority carriers.
This indicates that the doping element Q is a pentavalent atom, which donates extra electrons to the conduction band.

(b) Assuming each Q atom donates one free electron, the number of Q atoms added is approximately equal to the increase in electron concentration:
⇒ $N_Q \approx n = 6 \times 10^{22}\ m^{-3}$
Total Ge atoms per m^3: $N_{Ge} = 6 \times 10^{30}\ m^{-3}$
Ratio of Q atoms to Ge atoms:
⇒ $N_Q / N_{Ge} = (6 \times 10^{22}) / (6 \times 10^{30}) = 10^{-8}$
The ratio of Q atoms to Ge atoms is $1 : 10^8$

Q2. (i) The graph shown in the figure represents a plot of current versus voltage for a given semi-conductor. Identify the region, if any, over which the semi-conductor has a negative resistance.



(ii) How is forward biasing different from reverse biasing in a p-n junction diode?

ANS: (i) Between the region B and C, the semiconductor has a negative resistance.

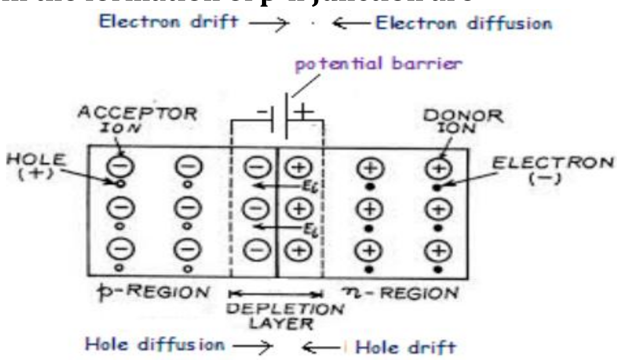
(ii) Forward biasing: If the positive terminal of a battery is connected to a p-side and the negative terminal to the n-side, then the p-n junction is said to be forward biased. Here the applied voltage V opposes the barrier voltage V_B. As a result of this

- the effective resistance across the p-n junction decreases.
- the diffusion of electrons and holes into the depletion layer which decreases its width.

Reverse biasing: If the positive terminal of a battery is connected to the n-side and negative terminal to the p-side, then the p-n junction is said to be reverse biased.
The applied voltage V and the barrier potential V_B are in the same direction. As a result of this

- the resistance of the p-n junction becomes very large.
- the majority charge carriers move away from the junction, increasing the width of the depletion layer.

Q3. Explain briefly, the tow process involved in the formation of p-n junction a p-n junction is formed. Define the term Potential barrier and depletion region.
The two processes in volved in the formation of p-n junction are



(i) Diffusion: Movement of majority carriers (electrons move from n to p side& holes move from p to n side) across the junction due to difference in concentration

(ii) Drift: Due to electric field of the depletion layer minority carriers move across the junction (electrons move from p to n side and holes move from n to p side).
Depletion layer: The space charge region formed near the junction due to diffusion of majority carriers.
Barrier potential: When drift current is equal to diffusion current, the potential difference across the junction is called barrier potential.
Q4. (i) Can we differentiate conductors, semiconductors and insulators on the basis of their energy band diagrams? If yes, how?

(ii) As far as we are aware, despite having a lot of holes, p-type semiconductors are electrically neutral. Why?

ANS:

(i) Energy band diagrams of conductors, semiconductors and insulators.

(ii) Semiconductors contain equal number of electrons and protons. Holes simply mean the absence of electron.

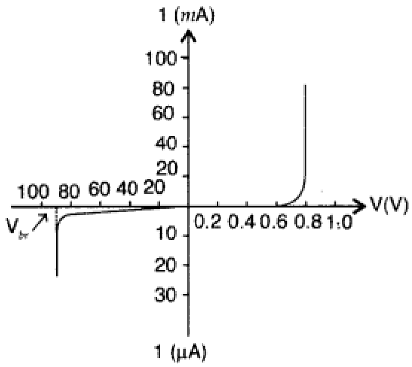
SHORT ANSWER QUESTIONS (3 MARK)

Q1. Explain, with the help of a circuit diagram, the working of a p-n junction diode as a half-wave rectifier.

ANS: Circuit diagram and working.

2. The figure given below shows the V-I characteristic of a semiconductor diode.
(i) Identify the semiconductor diode used.
(ii) Draw the circuit diagram to obtain the given characteristic of this device.

(iii) What happens when the voltage reaches the value V_{br}?



ANS:

(i) Si diode, (ii) Circuit diagram, (iii) Diode breaks down

Q3. Draw a labelled diagram of a full wave rectifier circuit. State its working principle. Show the input-output waveforms.

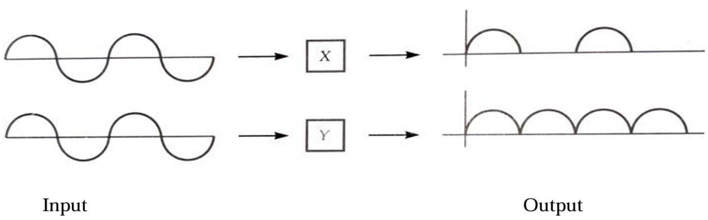
(ii) In half-wave rectification, what is the output frequency if the input frequency is 50 Hz. What is the output frequency of a full-wave rectifier for the same input frequency.

ANS:

(i) Theory, (ii) 25 Hz, 50 Hz

Q4. (i) Draw the energy band diagram when intrinsic semiconductor (Ge) is doped with impurity atoms of Antimony (Sb). Name the extrinsic semiconductor so obtained and majority charge carriers in it.

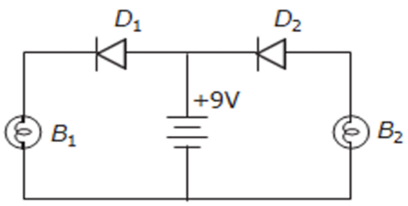
(ii) An a.c. signal (input waveform) is fed into two devices/circuits X and Y and the corresponding waveform in the two cases shown in figure. Name the devices/circuits X and Y. Also draw their detailed circuit diagrams.



ANS:

(i) n-type semiconductor, electrons, (ii) X – Half wave rectifier, Y – Full wave rectifier

Q5. (i) In following diagram, which bulb out of B_1 and B_2 will glow and why?



(ii) The maximum wavelength at which solid begin to absorb energy is 10000 Å. Calculate the energy gap of a solid (in eV).

(iii) Draw the input and output waveforms of half-wave rectifier and full wave rectifier.

ANS:

(i) Bulb B_1 will glow as diode D_1 is forward biased and D_2 is reverse biased.

(ii) $E = \frac{hc}{\lambda}$ = 1.24 eV

(iii) Theory

Q6. (i) What is knee voltage in the forward bias characteristics of a p-n junction diode?

(ii) Why does the current suddenly increase after the voltage increases beyond knee voltage?

(iii) What are the ranges of conductivity of conductors, semiconductors and insulators?

ANS:

(i) The knee voltage (also called threshold voltage or cut-in voltage) is the minimum forward voltage at which a p-n junction diode starts to conduct significant current.

(ii) Once the applied forward voltage exceeds the potential barrier (~0.7 V for Si), the depletion region becomes very narrow, allowing:

Majority carriers (electrons from n-side and holes from p-side) to easily cross the junction.

As a result, there is a sudden and exponential increase in current.

(iii) Conductors: ~ $10^2 – 10^8$ S m^{-1},
Semiconductors: ~ $10^5 – 10^{-6}$ S m^{-1},
Insulators: ~ $10^{-11} – 10^{-19}$ S m^{-1}

CASE BASED QUESTIONS

Q1. Read the following paragraph and answer the questions

p-n junction is a semiconductor diode. It is obtained by bringing p-type semiconductor in close contact with n- type semiconductor. A thin layer is developed at the p- n junction which is devoid of any charge carrier but has immobile ions. It is called depletion layer. At the junction a potential barrier appears, which does not allow the movement of majority charge carriers across the junction in the absence of any biasing of the junction. p-n junction offers low resistance when forward biased and high resistance when reverse biased.

(i) Name the two important processes that occur during the formation of a p-n junction.

(ii) Can we take one slab of p-type semiconductor and physically join it to another n-type semiconductor to get p-n junction? Give reason.

(iii) Explain how the width of depletion region in a p-n junction diode change, when the junction is- (a) forward biased (b) reverse biased.

(iv) Draw V-I characteristic of a p-n junction diode in (a) forward bias and (b) reverse bias

ANS:

(i) (a) Diffusion (b) drift

(ii) No, because continuous contact at the atomic level will not be possible at the junction

(iii) (a) Width of depletion region decreases in forward bias

Reason: In the forward bias, external battery pushes the majority charge carriers towards the junction.

(b) Width of depletion region increases in reverse bias.

(iv) Theory

Q2. On the basis of energy bands materials are also defined as metals, semiconductors and insulators. These semiconductors are classified as intrinsic semiconductors and extrinsic semiconductors also. Intrinsic semiconductors are those semiconductors which exist in pure form. And intrinsic semiconductors have number of free electrons is equal to number of holes. The semiconductors doped with some impurity in order to increase its conductivity are called as extrinsic semiconductors. Two types of dopants are used they are trivalent impurity and pentavalent impurity also. The extrinsic semiconductors doped with pentavalent impurity like Arsenic, Antimony, Phosphorus etc are called as n – type semiconductors. In n-type semiconductors electrons are the majority charge carriers and holes are the minority charge carriers. When trivalent impurity is like Indium, Boron, Aluminium etc are added to extrinsic semiconductors then p type semiconductors will be formed. In p-type semiconductors holes are majority charge carriers and electrons are the minority charge carriers.

i) Some semiconductors are called impure semiconductors or extrinsic semiconductors. How do we make them?
ii) What is ratio of number of holes and number of electrons in an intrinsic semiconductor?
iii) Doping is necessary for making semiconductors. Discuss why?
iv) What are majority charge carriers in p-type semiconductor?

ANS: (i) An extrinsic semiconductor is a doped semiconductor in which impurities are added to a pure (intrinsic) semiconductor (like silicon or germanium) to increase its conductivity.

(ii) 1:1

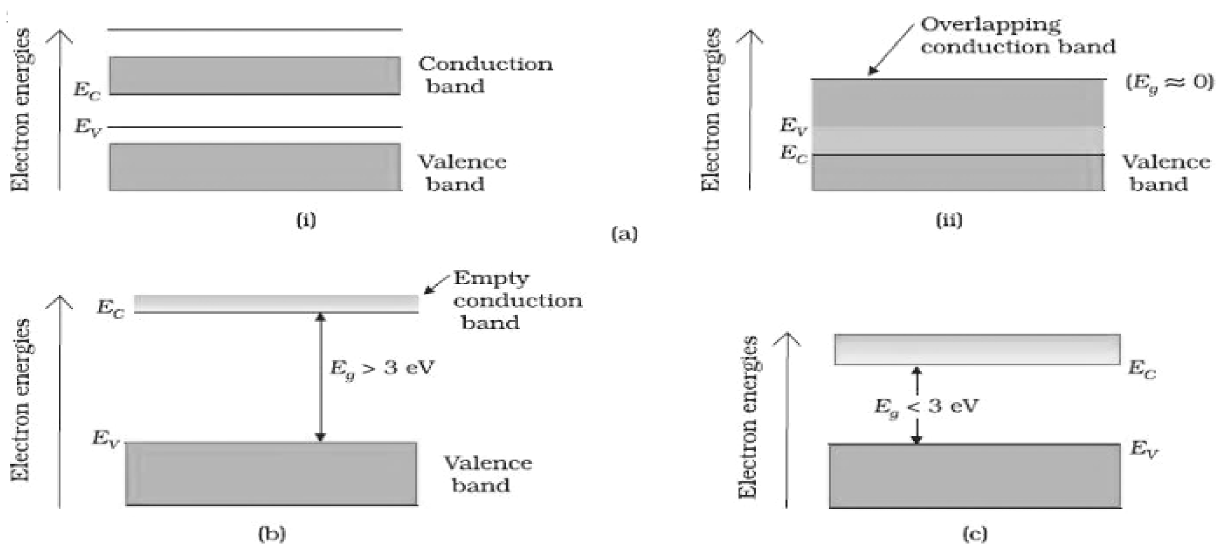
(iii) Doping is necessary because pure semiconductors have very low conductivity at room temperature.

Benefits of doping:

- Increases the number of charge carriers (electrons or holes).
- Enables the formation of p-type and n-type semiconductors.
- Allows control over conductivity for use in diodes, transistors, and other electronic devices.

(iv) Holes are majority charge carriers in p-type semiconductor.

Q3. From Bohr's atomic model, we know that the electrons have well defined energy levels in an isolated atom. But due to interatomic interactions in a crystal, the electrons of the outer shells are forced to have energies different from those in isolated atoms. Each energy level splits into a number of energy levels forming a continuous band. The gap between top of valence band and bottom of the conduction band in which no allowed energy levels for electrons can exist is called energy gap. Following are the energy band diagrams for conductor fig (ii), for insulators fig (b) and for semiconductors fig (c).



i) In an insulator energy band gap is

(a) Eg= 0eV (b) Eg> 3eV (c) Eg< 3eV (d) None of this

ii) In a semiconductor, separation between conduction and valence band is of the order of

(a) E_g= 0eV (b) E_g> 3eV (c) E_g< 3eV (d) None of these

iii) Based on the band theory of conductors, insulators and semiconductors, the forbidden gap is smallest in

(a) conductor (b) insulators (c) semiconductors (d) All of these

iv) Solids having highest energy level partially filled with electrons are

(a) semiconductor (b) conductor (c) insulator

ANS: (i) b, (ii) c, (iii) a, (iv) a

LONG ANSWER QUESTIONS

Q1. (a) Draw the typical shape of the V-I characteristics of p-n junction diode both in its (i) forward, (ii) reverse bias configuration. How do we infer, from these characteristics, that a diode can be used to rectify alternating voltages?

(b) The conduction band of a solid X is partially filled and for Solid Y is empty at 0 K but for Y it is also partially filled at room temperature. State whether X and Y are a conductor, a semiconductor or an insulator? Also draw the energy band diagram for X and Y.

(c) The ratio of number density of free electrons to holes, n_e/n_h, for three different materials, A, B and C are (i) equal to one, (ii) more than one and (iii) less than one respectively. Name the type of semiconductor to which A, B and C belong. Draw labelled energy band diagrams for the materials.

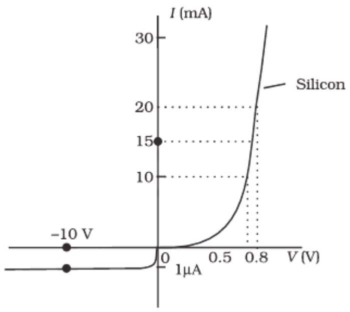
ANS:

(a) Characteristic diagrams

(b) X is a semiconductor and Y is an insulator.

(c) (i) Extrinsic (ii) n-type (iii) p-type

Q2. (a) Name the device whose I-V characteristics are shown below. Draw the circuit diagram for studying these V-I characteristics. How are these characteristics made use of in rectification?



(b) Suppose a pure Si crystal has 5×10^{28} atoms m^{-3}. It is doped by 1ppm concentration of pentavalent As. Calculate the number of electrons and holes. Given that $n_i = 1.5\times10^{16}$ m^{-3}.

ANS:

(a) It is a p-n junction diode. Diode conducts only in one direction when it is forward biased and does not conduct when it is reverse biased. This property is used in rectification.

(b) $n_h = 5 \times 10^{22}\ m^{-3}$, $n_e = 4.5 \times 10^{9}\ m^{-3}$

Q3.(i) What is doping? Write the name of the impurities used to fabricate p type & n type Semiconductor.

(ii) Draw the energy band diagram of conductor, insulator and semiconductor.

ANS:

(i) Doping is the process of intentionally adding a small amount of impurity atoms to a pure (intrinsic) semiconductor (such as silicon or germanium) to increase its electrical conductivity.

- The impurities introduce additional charge carriers—either free electrons or holes—in the semiconductor.

Impurities Used:

For n-type Semiconductor:

- Impurity type: Pentavalent atoms (5 valence electrons)
- Examples: Phosphorus (P), Arsenic (As), Antimony (Sb)
- These donate extra electrons, increasing electron concentration.

For p-type Semiconductor:

- Impurity type: Trivalent atoms (3 valence electrons)
- Examples: Boron (B), Gallium (Ga), Indium (In)
- These create holes by accepting electrons, increasing hole concentration.

(ii) Energy level diagrams.

Q4. (i) A diode is connected in series with a 3 V battery and a 30 Ω resistor. A drift current of

10 μA flows through the diode.

(a) What is the potential drop across the diode?

(b) Is the diode forward-biased or reverse-biased? Draw a circuit diagram to represent the above connections.

(ii) Describe the formation of the depletion area and potential barrier in a junction diode using a diagram.

ANS:

(i) (a) Potential Drop Across the Diode:

Using Ohm's Law:

$V_R = I \times R = (10 \times 10^{-6}\ A) \times (30\ \Omega) = 3 \times 10^{-4}\ V = 0.0003\ V$

Total voltage supplied = Voltage across resistor + Voltage across diode

$V = V_R + V_D \Rightarrow V_D = V - V_R$

$V_D = 3 - 0.0003 = 2.9997\ V$

Potential drop across the diode = 2.9997 V

(b) Drift current is the current due to minority carriers.

In reverse bias, current is very small (in μA), dominated by drift current.

In forward bias, current is much larger (in mA), dominated by diffusion current.

Since the current is very small (10 μA) and the voltage drop across the diode is nearly the entire battery voltage (~3 V), the diode is not conducting significantly.

The diode is reverse-biased.

****

WORKSHEET - 1

MULTIPLE CHOICE QUESTIONS

Q1. An *n*-type semiconductor is electrically

A. Positive B. Negative C. May be positive or negative D. Neutral

ANS:

Q2. In an unbiased p-n junction, holes diffuse from the p-region to n-region because

(a) free electrons in the n-region attract them.

(b) they move across the junction by the potential difference.

(c) hole concentration in p-region is more as compared to n-region.

(d) All the above.

ANS:

Q3. A pure semiconductor has

A. An infinite resistance at 0°C

B. A finite resistance which does not depend upon temperature

C. A finite resistance which increases with temperature

D. A finite resistance which decreases with temperature

ANS:

Q4. There is no hole current in conductors because they have

A. high conductivity B. high electron density

C. no valence band D. overlapping of valence and conduction bands

ANS:

SHORT ANSWER QUESTIONS (2 MARK)

Q5. The hole and electron concentration in the intrinsic semiconductor of germanium at room temperature is 2×10^{18} m^{-3}. After doping with an element Q, the concentration of electrons in the doped semiconductor becomes 6×10^{22} m^{-3}. The concentration of germanium atoms is 6×10^{30} m^{-3}.

(a) Is Q trivalent or pentavalent element? Give reason.

(b) What is the ratio of atoms of element Q and germanium in the doped semiconductor?

ANS:

Q6. A p-n junction diode has a depletion layer of thickness 500 nm and an electric field 16×10^5 V/m.

(a). Find the barrier potential created.

(b). Determine the minimum kinetic energy (in eV) that the conduction electrons must have so that they can diffuse from n-side onto p-side, in case of:

i. the junction is unbiased

ii. the junction is forward biased at 0.5 V

iii. the junction is reverse biased at 0.5 V

ANS:

Q7. (i) Discuss the process through which a p-n junction is created and what is the role of doping in increasing the conductivity of the semiconductor.

(ii) The depletion region changes when the doping concentration changes. Explain.

ANS:

SHORT ANSWER QUESTIONS (3 MARK)

Q8. (i) Explain, with the help of a circuit diagram, the working of a p-n junction diode as a half-wave rectifier.

(ii) An electron with an initial energy of 0.9eV diffuses from the n-side to the p-side of a diode whose potential barrier is 0.7eV. What is the energy of the electron when it just diffuses from the n-side to the p-side?

A. 1.5eV B. 0.9eV C. 0.7eV D. 0.2eV

ANS:

Q9. A diode is connected in series with a 3 V battery and a 30 Ω resistor. A drift current of 10 μA flows through the diode.

(a) What is the potential drop across the diode?

(b) Is the diode forward-biased or reverse-biased? Draw a circuit diagram to represent the above connections.

ANS:

CASE BASED QUESTIONS

Q10. Read the following paragraph and answer the questions

p-n junction is a semiconductor diode. It is obtained by bringing p-type semiconductor in close contact with n- type semiconductor. A thin layer is developed at the p- n junction which is devoid of any charge carrier but has immobile ions. It is called depletion layer. At the junction a potential barrier appears, which does not allow the movement of majority charge carriers across the junction in the absence of any biasing of the junction. p-n junction offers low resistance when forward biased and high resistance when reverse biased.

(i) Name the two important processes that occur during the formation of a p-n junction.

(ii) Can we take one slab of p-type semiconductor and physically join it to another n-type semiconductor to get p-n junction? Give reason.

(iii) Explain how the width of depletion region in a p-n junction diode change, when the junction is- (a) forward biased (b) reverse biased.

(iv) Draw V-I characteristic of a p-n junction diode in (a) forward bias and (b) reverse bias

ANS:

ANSWERS WORKSHEET I

1. d 2. C 3. D 4. D 5. (a) Q is a pentavalent element.

Reason: The electron concentration increases significantly upon doping, indicating that Q donates extra electrons. Hence, it is pentavalent.

(b) Ratio of atoms of element Q to germanium atoms:

Electron concentration after doping = $6 \times 10^{22}\ m^{-3}$ Germanium atom concentration = $6 \times 10^{30}\ m^{-3}$

⇒ Ratio = $(6 \times 10^{22}) / (6 \times 10^{30}) = 10^{-8}$ Answer: $1 : 10^8$

6. (a) Barrier potential (V) = Electric field (E) × depletion width (d)

$E = 16 \times 10^5$ V/m, d = 500 nm = 500×10^{-9} m

⇒ $V = E \times d = (16 \times 10^5) \times (500 \times 10^{-9}) = 0.8$ V

Barrier potential = 0.8 V

(b) Minimum kinetic energy required for conduction electrons:

i. For unbiased junction → KE = barrier potential = 0.8 eV

ii. For forward bias at 0.5 V → KE = 0.8 - 0.5 = 0.3 eV

iii. For reverse bias at 0.5 V → KE = 0.8 + 0.5 = 1.3 eV

7. (i) A p-n junction is created by joining p-type and n-type semiconductors. Doping introduces impurity atoms:

Trivalent atoms create p-type semiconductors with holes as majority carriers.

Pentavalent atoms create n-type semiconductors with electrons as majority carriers.

The junction forms a depletion region due to diffusion of carriers, which sets up an electric field and potential barrier.

Doping increases the number of charge carriers, thereby enhancing conductivity.

(ii) When doping concentration increases: The number of majority carriers increases.

The width of the depletion layer decreases for high doping.

This affects the barrier potential and the response of the junction to applied voltage.

Lightly doped junctions have wider depletion regions, while heavily doped ones have thinner regions.

8. (i) Theory

(ii) Initial energy of electron = 0.9 Ev Potential barrier = 0.7 eV

As the electron moves across the junction, it loses 0.7 eV due to the barrier.

Final energy = 0.9 eV - 0.7 eV = 0.2 eV Answer: D. 0.2 eV

9. Given: V = 3 V, R = 30 Ω, Drift current I = 10 μA = 10×10^{-6} A

(a) Potential drop across the resistor = I × R = $(10 \times 10^{-6}$ A$) \times 30\ \Omega = 3 \times 10^{-4}$ V

Potential drop across diode = V - IR = 3 V - 0.0003 V = 2.9997 V

Answer: Approximately 3 V

(b) Since current is very small, the diode must be reverse biased.

10. (i) The two important processes are:

- Diffusion of charge carriers (electrons and holes)
- Formation of depletion layer due to recombination of electrons and holes

(ii) No, we cannot just physically join two slabs. A proper junction must be formed by diffusion process at the atomic level to allow carrier movement and formation of depletion region. A mechanical join would not result in proper junction behavior.

(iii) (a) In forward bias: Depletion region narrows as applied voltage reduces the potential barrier.

(b) In reverse bias: Depletion region widens as reverse voltage increases the potential barrier.

(iv) V-I characteristics:

- Forward bias: Exponential increase in current after threshold voltage (~0.7 V for Si)
- Reverse bias: Small reverse saturation current until breakdown

WORKSHEET - 2

MULTIPLE CHOICE QUESTIONS

Q1. On increasing the reverse bias to a large value in a PN-junction diode, current

(a). Increases slowly (b). Remains fixed

(c). Suddenly increases (d). Decreases slowly

ANS:

Q2. Which statement is correct?

(a). N-type Germanium is negatively charged and P-type Germanium is positively charged

(b). Both N-type and P-type Germanium are neutral

(c). N-type Germanium is positively charged and P-type Germanium is negatively charged

(d). Both N-type and P-type Germanium are negatively charged

ANS:

Q3. Carbon, silicon and germanium atoms have four valence electrons each. Their valence and conduction band are separated by energy band gaps represented by $(E_g)_c$, $(E_g)_{Si}$ and $(E_g)_{Ge}$ respectively. Which one of the following relationships is true in their case?

(a). $(E_g)_c > (E_g)_{Si}$ (b). $(E_g)_c = (E_g)_{Si}$

(c). $(E_g)_c < (E_g)_{Ge}$ (d). $(E_g)_c < (E_g)_{Si}$

ANS:

Q4. The impurity atoms with which pure silicon should be doped to make a p-type semiconductor are those of:

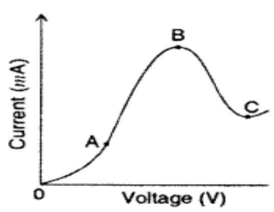
(a). Phosphorus (b). Boron

(c). Antimony (d). Aluminum

ANS:

SHORT ANSWER QUESTIONS (2 MARK)

Q5. (i) The graph shown in the figure represents a plot of current versus voltage for a given semi-conductor. Identify the region, if any, over which the semi-conductor has a negative resistance.



(ii) How is forward biasing different from reverse biasing in a p-n junction diode?

ANS:

Q6. (i) Explain how a depletion region is formed in a junction diode.

(ii) The current in the forward bias is known to be more (~mA) than the current in the reverse bias (~µA). What is the reason, then, to operate the photodiode in reverse bias?

ANS:

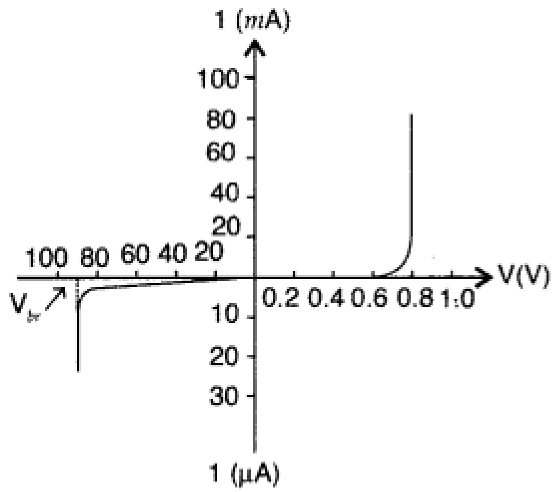
Q7. (i) Can we differentiate conductors, semiconductors and insulators on the basis of their energy band diagrams? If yes, how?

(ii) As far as we are aware, despite having a lot of holes, p-type semiconductors are electrically neutral. Why?

ANS:

SHORT ANSWER QUESTIONS (3 MARK)

Q8. The figure given below shows the V-I characteristic of a semiconductor diode.



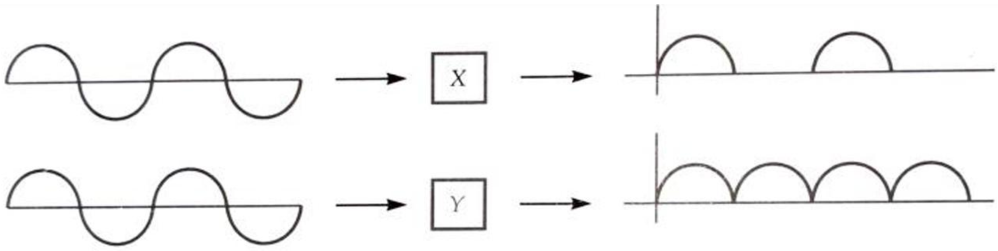
(i) Is this diode Si or Ge?
(ii) Draw the circuit diagram to obtain the given characteristic of this device.

(iii) The diode behaves differently below 0.8 V and above it. Explain this behaviour.

ANS:

Q9. (i) Draw the energy band diagram when intrinsic semiconductor (Ge) is doped with impurity atoms of Antimony (Sb). Name the extrinsic semiconductor so obtained and majority charge carriers in it.

(ii) An a.c. signal (input waveform) is fed into two devices/circuits X and Y and the corresponding waveform in the two cases shown in figure. Name the devices/circuits X and Y. Also draw their detailed circuit diagrams.



Input Output

ANS:

CASE BASED QUESTIONS

Q10. Read the following paragraph and answer the questions

p-n junction is a semiconductor diode. It is obtained by bringing p-type semiconductor in close contact with n- type semiconductor. A thin layer is developed at the p- n junction which is devoid of any charge carrier but has immobile ions. It is called depletion layer. At the junction a potential barrier appears, which does not allow the movement of majority charge carriers across the junction in the absence of any biasing of the junction. p-n junction offers low resistance when forward biased and high resistance when reverse biased.

(i) Name the two important processes that occur during the formation of a p-n junction.

(ii) Can we take one slab of p-type semiconductor and physically join it to another n-type semiconductor to get p-n junction? Give reason.

(iii) Explain how the width of depletion region in a p-n junction diode change, when the junction is- (a) forward biased (b) reverse biased.

(iv) Draw V-I characteristic of a p-n junction diode in (a) forward bias and (b) reverse bias

ANS:

WORKSHEET 2 ANSWERS

1. c

2. b

3. a

4. b

5. (i) Between the region B and C, the semiconductor has a negative resistance.

(ii) Forward biasing: If the positive terminal of a battery is connected to a p-side and the negative terminal to the n-side, then the p-n junction is said to be forward biased. Here the applied voltage V opposes the barrier voltage V_B. As a result of this

- the effective resistance across the p-n junction decreases.
- the diffusion of electrons and holes into the depletion layer which decreases its width.

Reverse biasing: If the positive terminal of a battery is connected to the n-side and negative terminal to the p-side, then the p-n junction is said to be reverse biased.
The applied voltage V and the barrier potential V_B are in the same direction. As a result of this

- the resistance of the p-n junction becomes very large.
- the majority charge carriers move away from the junction, increasing the width of the depletion layer.

6. (i) As soon as a p-n junction is formed, the majority charge carriers begin to diffuse from the regions of higher concentration to the regions of lower concentrations. Thus the electrons from the n-region diffuse into the p-region and where they combine with the holes and get neutralised. Similarly, the holes from the p-region diffuse into the n-region where they combine with the electrons and get neutralised. This process is called electron-hole recombination.

(ii) The fractional increase in majority carriers is much less than the fractional increase in minority carriers. Consequently, the fractional change due to the photo-effects on the minority carrier dominated reverse bias current is more easily measurable than the fractional change in the majority carrier dominated forward bias current.

7. (i) Energy band diagrams of conductors, semiconductors and insulators.

(ii) Semiconductors contain equal number of electrons and protons. Holes simply mean the absence of electron.

8. (i) This is a Si diode as its Knee voltage is 0.8 V.

(ii) Theory

(iii) Before knee voltage the bias voltage opposes the barrier potential and tries to decrease it but once they become equal the barrier resistance essentially become zero and current increases exponentially.

9. (i) n-type semiconductor is formed.

(ii) X – half wave rectifier, Y – full wave rectifier

10. (i) (a) Diffusion (b) drift

(ii) No, because continuous contact at the atomic level will not be possible at the junction

(iii) (a) Width of depletion region decreases in forward bias

Reason: In the forward bias, external battery pushes the majority charge carriers towards the junction.

(b) Width of depletion region increases in reverse bias.

(iv) Theory

Series : X4YZW

SET ~ 2

रोल नं.
Roll No.

प्रश्न-पत्र कोड
Q.P. Code 55/4/2

परीक्षार्थी प्रश्न-पत्र कोड को उत्तर-पुस्तिका के मुख-पृष्ठ पर अवश्य लिखें।
Candidates must write the Q.P. Code on the title page of the answer-book.

भौतिक विज्ञान (सैद्धान्तिक)
PHYSICS (Theory)

*निर्धारित समय : **3** घण्टे* | *अधिकतम अंक : **70***

*Time allowed : **3** hours* | *Maximum Marks : **70***

नोट / NOTE #

(I) कृपया जाँच कर लें कि इस प्रश्न-पत्र में मुद्रित पृष्ठ **31** हैं।
Please check that this question paper contains **31** printed pages.

(II) प्रश्न-पत्र में दाहिने हाथ की ओर दिए गए प्रश्न-पत्र कोड को परीक्षार्थी उत्तर-पुस्तिका के मुख-पृष्ठ पर लिखें।
Q.P. Code given on the right hand side of the question paper should be written on the title page of the answer-book by the candidate.

(III) कृपया जाँच कर लें कि इस प्रश्न-पत्र में **33** प्रश्न हैं।
Please check that this question paper contains **33** questions.

(IV) **कृपया प्रश्न का उत्तर लिखना शुरू करने से पहले, उत्तर-पुस्तिका में यथा स्थान पर प्रश्न का क्रमांक अवश्य लिखें।**
Please write down the Serial Number of the question in the answer-book at the given place before attempting it.

(V) इस प्रश्न-पत्र को पढ़ने के लिए 15 मिनट का समय दिया गया है। प्रश्न-पत्र का वितरण पूर्वाह्न में 10.15 बजे किया जाएगा। 10.15 बजे से 10.30 बजे तक परीक्षार्थी केवल प्रश्न-पत्र को पढ़ेंगे और इस अवधि के दौरान वे उत्तर-पुस्तिका पर कोई उत्तर नहीं लिखेंगे।
15 minute time has been allotted to read this question paper. The question paper will be distributed at 10.15 a.m. From 10.15 a.m. to 10.30 a.m., the candidates will read the question paper only and will not write any answer on the answer-book during this period.

General Instructions :

Read the following instructions carefully and follow them :

(i) *This question paper contains* ***33*** *questions.* ***All*** *questions are* ***compulsory.***

(ii) *This question paper is divided into* ***five*** *sections –* ***Sections A, B, C, D*** *and* ***E.***

(iii) *In* ***Section A*** *– Questions no.* ***1*** *to* ***16*** *are Multiple Choice type questions. Each question carries* ***1*** *mark.*

(iv) *In* ***Section B*** *– Questions no.* ***17*** *to* ***21*** *are Very Short Answer type questions. Each question carries* ***2*** *marks.*

(v) *In* ***Section C*** *– Questions no.* ***22*** *to* ***28*** *are Short Answer type questions. Each question carries* ***3*** *marks.*

(vi) *In* ***Section D*** *– Questions no.* ***29*** *and* ***30*** *are case study-based questions. Each question carries* ***4*** *marks.*

(vii) *In* ***Section E*** *– Questions no.* ***31*** *to* ***33*** *are Long Answer type questions. Each question carries* ***5*** *marks.*

(viii) *There is no overall choice given in the question paper. However, an internal choice has been provided in few questions in all the Sections except Section A.*

(ix) *Kindly note that there is a separate question paper for Visually Impaired candidates.*

(x) *Use of calculators is* ***not*** *allowed.*

You may use the following values of physical constants wherever necessary :

$c = 3 \times 10^8$ m/s

$h = 6{\cdot}63 \times 10^{-34}$ Js

$e = 1{\cdot}6 \times 10^{-19}$ C

$\mu_0 = 4\pi \times 10^{-7}$ T m A^{-1}

$\varepsilon_0 = 8{\cdot}854 \times 10^{-12}$ C^2 N^{-1} m^{-2}

$\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9$ N m^2 C^{-2}

Mass of electron $(m_e) = 9{\cdot}1 \times 10^{-31}$ kg

Mass of neutron $= 1{\cdot}675 \times 10^{-27}$ kg

Mass of proton $= 1{\cdot}673 \times 10^{-27}$ kg

Avogadro's number $= 6{\cdot}023 \times 10^{23}$ per gram mole

Boltzmann constant $= 1{\cdot}38 \times 10^{-23}$ JK^{-1}

SECTION A

1. An electric dipole of dipole moment $1{\cdot}0 \times 10^{-12}$ Cm lies along x-axis. An electric field of magnitude $2{\cdot}0 \times 10^{4}$ NC^{-1} is switched on at an instant in the region. The unit vector along the electric field is $\frac{\sqrt{3}}{2}\hat{i} + \frac{1}{2}\hat{j}$. The magnitude of the torque acting on the dipole at that instant is :

   (A) $0{\cdot}5 \times 10^{-6}$ Nm
   (B) $1{\cdot}0 \times 10^{-8}$ Nm
   (C) $2{\cdot}0 \times 10^{-8}$ Nm
   (D) $4{\cdot}0 \times 10^{-8}$ Nm

2. When the switch of the circuit is turned on, the filament of the bulb glows instantaneously because :

   (A) the electrons coming from the power source move fast through the initially empty filament.
   (B) the filament may be old having low resistance.
   (C) electric field is established instantaneously across the filament which pushes the electrons.
   (D) free electrons in the filament travel with the speed of light.

3. A particle with charge q moving with velocity $\vec{v} = v_0 \hat{i}$ enters a region with magnetic field $\vec{B} = B_1 \hat{j} + B_2 \hat{k}$. The magnitude of force experienced by the particle is :

   (A) $qv_0 (B_1 + B_2)$
   (B) $q\sqrt{v_0 (B_1 + B_2)}$
   (C) $q v_0 \sqrt{(B_1^2 + B_2^2)}$
   (D) $q \sqrt{v_0 (B_1^2 + B_2^2)}$

4. A bar magnet is initially at right angles to a uniform magnetic field. The magnet is rotated till the torque acting on it becomes one-half of its initial value. The angle through which the bar magnet is rotated is :

   (A) 30°
   (B) 45°
   (C) 60°
   (D) 75°

5. The materials having negative magnetic susceptibility are :

   (A) diamagnetic
   (B) paramagnetic
   (C) ferromagnetic
   (D) non-magnetic

6. When current in a coil changes at a steady rate from 8 A to 6 A in 4 ms, an emf of 1·5 V is induced in it. The value of self-inductance of the coil is :

(A) 6 mH (B) 12 mH

(C) 3 mH (D) 9 mH

7. The electric field in space between the plates of a parallel plate capacitor (each of area $2{\cdot}5 \times 10^{-3}$ m^2) is changing at the rate of 4×10^{6} Vm^{-1}s^{-1}. The displacement current between the plates of the capacitor is :

(A) $1{\cdot}8 \times 10^{-5}$ A (B) $3{\cdot}47 \times 10^{-6}$ A

(C) $8{\cdot}85 \times 10^{-8}$ A (D) $6{\cdot}32 \times 10^{-4}$ A

8. A long straight wire is held vertically and carries a steady current in upward direction. The shape of magnetic field lines produced by the current-carrying wire are :

(A) horizontal straight lines directed radially out from the wire.

(B) straight lines parallel to the current-carrying wire.

(C) concentric horizonal circles around the wire.

(D) coaxial helixes around the wire.

9. Which of the following is an electrical conductor at room temperature ?

(A) Sn

(B) Mica

(C) Si

(D) C

10. The magnification produced by a spherical mirror is $- 2 \cdot 0$. The mirror used and the nature of the image formed will be

(A) Convex and virtual

(B) Concave and real

(C) Concave and virtual

(D) Convex and real

11. Choose the correct statement :

(A) Photons of light show diffraction whereas electrons do not show diffraction.

(B) Electrons have momentum whereas photons do not have momentum.

(C) Photons of light and electrons both exhibit dual nature.

(D) All electromagnetic radiations do not have photons.

12. A beam of red light and a beam of blue light have equal intensities. Which of the following statements is true ?

(A) The blue beam has more number of photons than the red beam.

(B) The red beam has more number of photons than the blue beam.

(C) Wavelength of red light is lesser than wavelength of blue light.

(D) The blue light beam has lesser energy per photon than that in the red light beam.

Questions number ***13*** *to* ***16*** *are Assertion (A) and Reason (R) type questions. Two statements are given — one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer from the codes (A), (B), (C) and (D) as given below.*

(A) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).

(B) Both Assertion (A) and Reason (R) are true, but Reason (R) is ***not*** the correct explanation of the Assertion (A).

(C) Assertion (A) is true, but Reason (R) is false.

(D) Both Assertion (A) and Reason (R) are false.

13. *Assertion (A) :* For monochromatic incident radiation, the emitted photoelectrons from a given metal have speed ranging from zero to a certain maximum value.

Reason (R) : Each metal has a definite work function.

14. *Assertion (A) :* In double slit experiment if one slit is closed, diffraction pattern due to the other slit will appear on the screen.

Reason (R) : For interference, at least two waves are required.

15. *Assertion (A) :* A series LCR circuit behaves as a pure resistive circuit at resonance.

Reason (R) : At resonance, $X_L = X_C$ gives $\omega = \frac{1}{\sqrt{LC}}$.

16. *Assertion (A) :* n-type semiconductor is not negatively charged.

Reason (R) : Neutral pentavalent impurity atom doped in intrinsic semiconductor (neutral) donates its fifth unpaired electron to the crystal lattice and becomes a positive donor.

SECTION B

17. In an intrinsic semiconductor, carrier's concentration is 5×10^8 m^{-3}. On doping with impurity atoms, the hole concentration becomes 8×10^{12} m^{-3}.

(a) Identify (i) the type of dopant and (ii) the extrinsic semiconductor so formed.

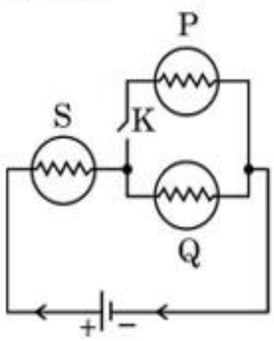
(b) Calculate the electron concentration in the extrinsic semiconductor. *2*

18. In a double slit experiment, the two slits are 1·5 mm apart. The slits are illuminated by a mixture of lights of wavelengths of 600 nm and 400 nm and the interference pattern is observed on a screen 1·5 m away from the slits. Find the minimum distance of the point from the central maximum at which bright fringes of the interference patterns of the two wavelengths coincide. *2*

19. Find the focal length of plano-convex lens of refractive index 1·5 and radius of curvature 10 cm when it is immersed in a liquid of refractive index 1·25. *2*

20. Find the ratio of minimum to maximum wavelength of radiations emitted when electron jumps from higher energy state into ground state of hydrogen atom. *2*

21. (a) In the given figure, three identical bulbs P, Q and S are connected to a battery.



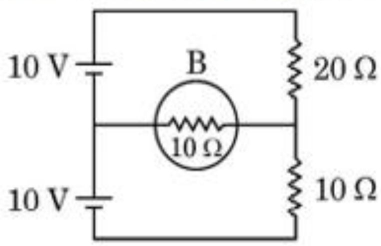
(i) Compare the brightness of bulbs P and Q with that of bulb S when key K is closed.

(ii) Compare the brightness of the bulbs S and Q when the key K is opened.

Justify your answer in both cases. *2*

OR

(b) Two cells of emf 10 V each, two resistors of 20 Ω and 10 Ω and a bulb B of 10 Ω resistance are connected together as shown in the figure. Find the current that flows through the bulb. *2*



SECTION C

22. Explain the following observations using Einstein's photoelectric equation : *3*

(a) Photoelectric emission does not occur from a surface when the frequency of the light incident on it is less than a certain minimum value.

(b) It is the frequency, and not the intensity of the incident light which affects the maximum kinetic energy of the photoelectrons.

(c) The cut-off voltage (V_0) versus frequency (ν) of the incident light curve is a straight line with a slope $\frac{h}{e}$.

23. (a) A charged particle q moving with a velocity $\vec{v}$ is subjected to a uniform magnetic field $\vec{B}$ acting perpendicular to $\vec{v}$. If a uniform electric field $\vec{E}$ is also set up in the region along the direction of $\vec{B}$, describe the path followed by the particle and draw its shape.

(b) How will the magnetic field inside a long solenoid be affected when :

(i) the radius of the turns of the solenoid is increased,

(ii) the length of solenoid as well as the total number of its turns are doubled ? *3*

24. (a) Differentiate between magnetic flux through an area and magnetic field at a point.

(b) A bar magnet is held with its length along the axis of a closed coil. Initially the south pole of the magnet faces the coil. If the magnet is moved towards the coil, explain how a current is induced in the coil and in what direction. *3*

25. (a) State any three characteristics of electromagnetic waves.

(b) Briefly explain how and where the displacement current exists during the charging of a capacitor. *3*

26. (a) Define 'wavefront' of a light wave. A plane wavefront is refracted from a convex lens. Draw the shape of the refracted wavefront.

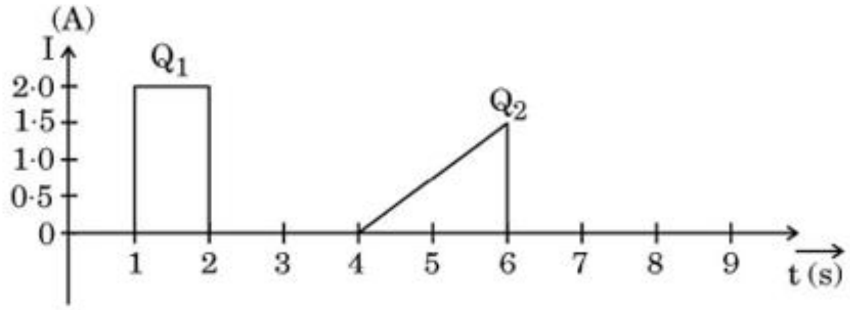
(b) A plane wave travelling in a medium is incident on a plane surface separating this medium from a rarer medium. Draw a diagram to show refraction of the wave. Hence, verify Snell's law. *3*

27. (a) What are majority and minority charge carriers of p-type and n-type semiconductors ?

(b) Explain briefly the formation of diffusion current and drift current in a p-n junction diode. *3*

28. (a) (i) Derive an expression for the resistivity of a conductor in terms of number density of free electrons and relaxation time.

(ii) The figure shows the plot of current through a cross-section of wire over two different time intervals. Compare the charges (Q_1 and Q_2) that pass through the cross-section during these time intervals. *3*



OR

(b) (i) A battery of emf E and internal resistance r is connected to a variable external resistance R.

(I) Obtain the expression for current I in the circuit and the value of maximum current the battery can supply.

(II) Obtain the terminal voltage V across the battery and its maximum possible value.

(ii) The above battery sends a current I_1 when $R = R_1$ and a current I_2 when $R = R_2$. Obtain the internal resistance of the battery in terms of I_1, I_2, R_1 and R_2. *3*

SECTION D

*Questions number **29** and **30** are Case Study-based questions. Read the following paragraphs and answer the questions that follow.*

29. A hydrogen atom consists of an electron revolving in a circular orbit of radius r with certain velocity v around a proton located at the nucleus of the atom. The electrostatic force of attraction between the revolving electron and the proton provides the requisite centripetal force to keep it in the orbit. According to Bohr's model, an electron can revolve only in certain stable orbits. The angular momentum of the electron in these orbits is some integral multiple of $\frac{h}{2\pi}$, where h is the Planck's constant.

Further, when an electron makes a transition from one orbit of higher energy to that of lower energy, a photon is emitted having energy equal to the difference between energies of the initial and final states. Assuming the mass and charge of an electron as m and e respectively, answer the following questions.

(i) The expression for the speed of electron v in terms of radius of the orbit (r) and physical constant ($K = \frac{1}{4\pi\varepsilon_0}$) is : *1*

(A) $\frac{Ke^2}{mr}$ (B) $\frac{Ke^2}{mr^2}$

(C) $\sqrt{\frac{Ke^2}{mr}}$ (D) $\sqrt{\frac{Ke^2}{mr^2}}$

(ii) The total energy of the atom in terms of r and physical constant K is : *1*

(A) $\frac{Ke^2}{r}$ (B) $-\frac{Ke^2}{2r}$

(C) $\frac{Ke^2}{2r}$ (D) $\frac{3}{2}\frac{Ke^2}{r}$

(iii) A photon of wavelength 500 nm is emitted when an electron makes a transition from one state to the other state in an atom. The change in the total energy of the electron and change in its kinetic energy in eV as per Bohr's model, respectively will be : *1*

(A) 2·48, – 2·48 (B) – 1·24, 1·24

(C) – 2·48, 2·48 (D) 1·24, – 1·24

(iv) (a) In Bohr's model of hydrogen atom, the frequency of revolution of electron in its n^{th} orbit is proportional to : *1*

(A) n

(B) $\frac{1}{n}$

(C) $\frac{1}{n^2}$

(D) $\frac{1}{n^3}$

OR

(b) An electron makes a transition from – 3·4 eV state to the ground state in hydrogen atom. Its radius of orbit changes by : (radius of orbit of electron in ground state = 0·53 Å) *1*

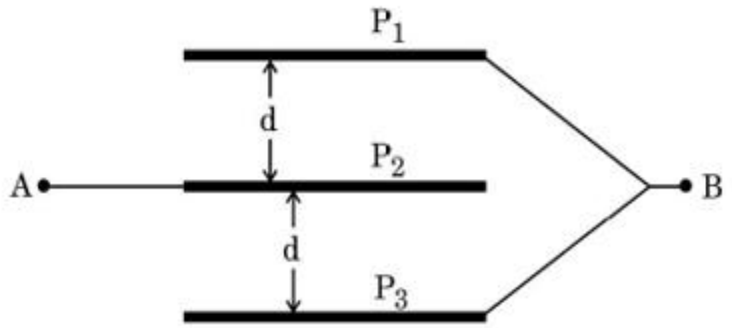
(A) 0·53 Å

(B) 1·06 Å

(C) 1·59 Å

(D) 2·12 Å

30. A parallel plate capacitor consists of two conducting plates kept generally parallel to each other at a distance. When the capacitor is charged, the charge resides on the inner surfaces of the plates and an electric field is set up between them. Thus, electrostatic energy is stored in the capacitor. The figure shows three large square metallic plates, each of side 'L' held parallel and equidistant from each other. The space between P_1 and P_2 and P_2 and P_3 is completely filled with mica sheets of dielectric constant 'K'. The plate P_2 is connected to point A and other plates P_1 and P_3 are connected to point B. Point A is maintained at a positive potential with respect to point B and the potential difference between A and B is V.



(i) The capacitance of the system between A and B will be : *1*

(A) $\frac{\varepsilon_0 KL^2}{d}$ (B) $\frac{\varepsilon_0 KL^2}{2d}$

(C) $\frac{2\varepsilon_0 KL^2}{d}$ (D) $\frac{2\varepsilon_0 Kd}{L^2}$

(ii) The charge on plate P_1 is : *1*

(A) $\frac{\varepsilon_0 VKL^2}{2d}$ (B) $\frac{\varepsilon_0 VKL^2}{d}$

(C) $\frac{2\varepsilon_0 VKL^2}{d}$ (D) $\frac{\varepsilon_0 VKL^2}{4d}$

#

(iii) The electric field in the region between P_1 and P_2 is : *1*

(A) $\frac{V}{d}$ (B) $\frac{2V}{d}$

(C) $\frac{V}{2d}$ (D) $\frac{d}{V}$

(iv) (a) The separation between the plates of same area (L^2) of a parallel plate air capacitor having capacitance equal to that of this system, will be : *1*

(A) $\frac{d}{K}$ (B) $\frac{2d}{K}$

(C) $\frac{d}{2K}$ (D) $\frac{d}{4K}$

OR

(b) If the source of potential difference applied between A and B is removed, and then A and B are connected by a conducting wire, the net charge on the system will be : *1*

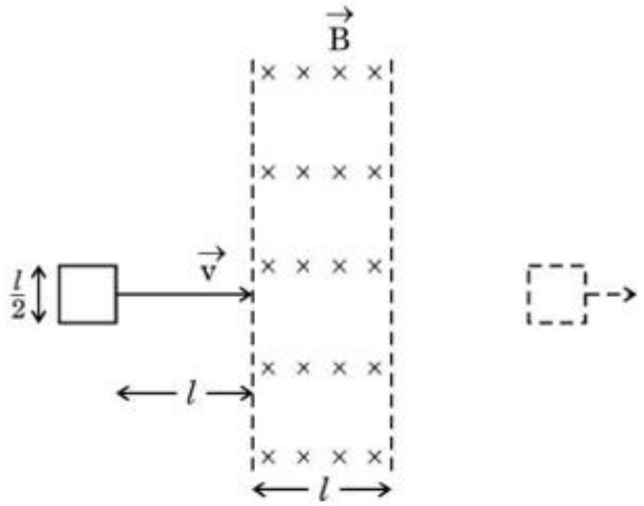
(A) $\frac{\varepsilon_0 VKL^2}{4d}$ (B) $\frac{\varepsilon_0 VKL^2}{2d}$

(C) $\frac{\varepsilon_0 VKL^2}{d}$ (D) Zero

SECTION E

31. (a) (i) State Lenz's law and explain how this law is a consequence of conservation of energy principle.

(ii) A square shaped loop of side $\frac{l}{2}$ is initially lying outside a region of uniform magnetic field $\vec{B}$ as shown in the figure. The loop is moved towards right with a constant velocity $\vec{v}$ till it goes out of the region of magnetic field.



(I) What will be the directions of induced current when the loop enters the field and when it leaves the field ?

(II) Draw the plots showing the variation of magnetic flux ϕ linked with the loop with time t and variation of induced emf E with time t. Mark the relevant values of E, ϕ and t on the graphs. 5

OR

(b) (i) Differentiate between peak and rms values of alternating current. How are they related ?

(ii) A current element X is connected across an ac source of emf $V = V_0 \sin 2\pi\nu t$. It is found that the voltage leads the current in phase by $\frac{\pi}{2}$ radian. If element X was replaced by element Y, the voltage lags behind the current in phase by $\frac{\pi}{2}$ radian.

(I) Identify elements X and Y by drawing phasor diagrams.

(II) Obtain the condition of resonance when both elements X and Y are connected in series to the source and obtain expression for resonant frequency. What is the impedance value in this case ? 5

32. (a) (i) An object is placed 30 cm from a thin convex lens of focal length 10 cm. The lens forms a sharp image on a screen. If a thin concave lens is placed in contact with the convex lens, the sharp image on the screen is formed when the screen is moved by 45 cm from its initial position. Calculate the focal length of the concave lens.

(ii) Calculate the angle of minimum deviation of an equilateral prism. The refractive index of the prism is $\sqrt{3}$. Calculate the angle of incidence for this case of minimum deviation also. 5

OR

(b) (i) A physics teacher wants to demonstrate interference with the help of double slit experiment using a laser beam of 633 nm wavelength. Since the hall is large enough, interference pattern is formed on the wall 5·0 m from the slits. For clear and comfortable view by all the students they want the fringe width 5 mm.

(I) Find the slit separation for obtaining the desired interference pattern.

(II) How far will the first minimum be from the central maximum ?

(ii) A parallel beam of light of wavelength 650 nm passes through a slit of width 0·6 mm. The diffraction pattern is obtained on a screen kept 60 cm away from the slit. Find the distance between first order minima on both sides of the central maximum. 5

33. (a) (i) Two point charges + q and – q are held at (a, 0) and (– a, 0) in x-y plane. Obtain an expression for the net electric field due to the charges at a point (0, y). Hence, find electric field at a far off point (y >> a).

(ii) Three point charges of – 2 nC, – 1 nC, and + 5 nC are kept at the vertices A, B and C of an equilateral triangle of side 0·2 m. Find the total amount of work done in shifting the charges from A to A_1, B to B_1 and C to C_1. Here A_1, B_1 and C_1 are the midpoints of sides AB, BC and CA, respectively. 5

OR

(b) (i) Show that Gauss's theorem is consistent with Coulomb's law. Using it, derive an expression for the electric field due to a uniformly charged thin spherical shell of radius r at a point at a distance y from the centre of the shell such that (I) y > r, and (II) y < r.

(ii) A point charge of + 2 nC is kept at the origin of a three-dimensional coordinate system. Find the type and magnitude of the charge which should be kept at (0, 0, – 6m) so that the potential due to the system becomes zero at (0, 0, 2m). 5

Series : YXZW2

SET ~ 1

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Roll No.

कोड नं.
Code No. **55/2/1**

परीक्षार्थी प्रश्न-पत्र कोड को उत्तर-पुस्तिका के मुख-पृष्ठ पर अवश्य लिखें ।
Candidates must write the Q.P. Code on the title page of the answer-book.

भौतिक विज्ञान (सैद्धान्तिक)

PHYSICS (Theory)

निर्धारित समय : 3 घण्टे
Time allowed : 3 hours

अधिकतम अंक : 70
Maximum Marks : 70

नोट / NOTE

(I) कृपया जाँच कर लें कि इस प्रश्न-पत्र में मुद्रित पृष्ठ **23** हैं ।
Please check that this question paper contains **23** printed pages.

(II) कृपया जाँच कर लें कि इस प्रश्न-पत्र में **33** प्रश्न हैं ।
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(IV) **कृपया प्रश्न का उत्तर लिखना शुरू करने से पहले, उत्तर-पुस्तिका में यथा स्थान पर प्रश्न का क्रमांक अवश्य लिखें ।**
Please write down the serial number of the question in the answer-book at the given place before attempting it.

(V) इस प्रश्न-पत्र को पढ़ने के लिए 15 मिनट का समय दिया गया है । प्रश्न-पत्र का वितरण पूर्वाह्न में 10.15 बजे किया जाएगा । 10.15 बजे से 10.30 बजे तक परीक्षार्थी केवल प्रश्न-पत्र को पढ़ेंगे और इस अवधि के दौरान वे उत्तर-पुस्तिका पर कोई उत्तर नहीं लिखेंगे ।
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~

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(vi) *In* **Section D :** *Question numbers* **29** *&* **30** *are case study-based questions. Each question carries* **4** *marks.*

(vii) *In* **Section E :** *Question numbers* **31** *to* **33** *are Long Answer type questions. Each question carries* **5** *marks.*

(viii) *There is no overall choice given in the question paper. However, an internal choice has been provided in few questions in all the Sections except Section* **A**.

(ix) *Kindly note that there is a separate question paper for Visually Impaired candidates.*

(x) *Use of calculators is* **not** *allowed.*

You may use the following values of physical constants wherever necessary :

$c = 3 \times 10^8$ m/s

$h = 6.63 \times 10^{-34}$ Js

$e = 1.6 \times 10^{-19}$ C

$\mu_0 = 4\pi \times 10^{-7}$ T m A^{-1}

$\varepsilon_0 = 8.854 \times 10^{-12}$ C^2 N^{-1} m^{-2}

$\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9$ N m^2 C^{-2}

Mass of electron (m_e) = 9.1×10^{-31} kg.

Mass of neutron = 1.675×10^{-27} kg.

Mass of proton = 1.673×10^{-27} kg.

Avogadro's number = 6.023×10^{23} per gram mole

Boltzman's constant = 1.38×10^{-23} JK^{-1}

SECTION – A

1. Two charges –q each are placed at the vertices A and B of an equilateral triangle ABC. If M is the mid-point of AB, the net electric field at C will point along 1

(A) CA (B) CB

(C) MC (D) CM

2. A student has three resistors, each of resistance R. To obtain a resistance of $\frac{2}{3}$R, she should connect 1

(A) all the three resistors in series.

(B) all the three resistors in parallel.

(C) two resistors in series and then this combination in parallel with the third resistor.

(D) two resistors in parallel and then this combination in series with the third resistor.

3. A 1 cm straight segment of a conductor carrying 1 A current in x direction lies symmetrically at origin of Cartesian coordinate system. The magnetic field due to this segment at point (1m, 1m, 0) is 1

(A) $1.0 \times 10^{-9}\,\hat{k}$ T (B) $-1.0 \times 10^{-9}\,\hat{k}$ T

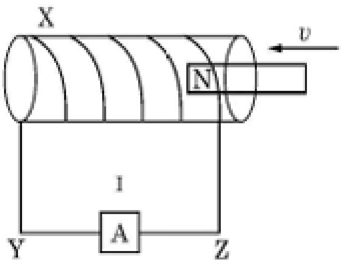
(C) $\frac{5.0}{\sqrt{2}} \times 10^{-10}\,\hat{k}$ T (D) $-\frac{5.0}{\sqrt{2}} \times 10^{-10}\,\hat{k}$ T

4. The magnetic field due to a small magnetic dipole of dipole moment 'M' at a distance 'r' from the centre along the axis of the dipole is given by 1

(A) $\frac{\mu_0}{4\pi} \times \frac{2M}{r^3}$ (B) $\frac{\mu_0}{4\pi} \times \frac{M}{r^3}$

(C) $\frac{\mu_0}{4\pi} \times \frac{M}{2r^3}$ (D) $\frac{\mu_0}{4\pi} \times \frac{2M}{r^2}$

5. In the figure X is a coil wound over a hollow wooden pipe. 1

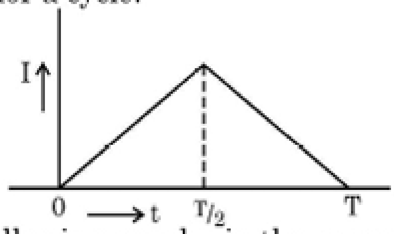


A permanent magnet is pushed at a constant speed v from the right into the pipe and it comes out at the left end of the pipe. During the entry and the exit of the magnet, the current in the wire YZ will be from

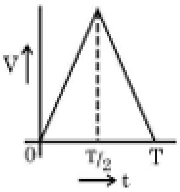
(A) Y to Z and then Y to Z (B) Z to Y and then Y to Z

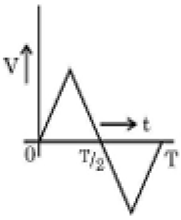
(C) Y to Z and then Z to Y (D) Z to Y and then Z to Y

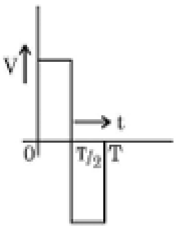
6. The alternating current I in an inductor is observed to vary with time t as shown in the graph for a cycle. 1

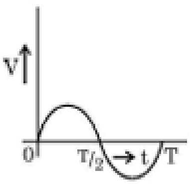


Which one of the following graphs is the correct representation of wave form of voltage V with time t ?

(A) 

(B) 

(C) 

(D) 

7. A transformer is connected to a 200 V ac source. The transformer supplies 3000 V to a device. If the number of turns in the primary coil is 450, then the number of turns in its secondary coil is – 1

(A) 30 (B) 450
(C) 4500 (D) 6750

8. Which one of the following statements is correct ?
Electric field due to static charges is 1
(A) conservative and field lines do not form closed loops.
(B) conservative and field lines form closed loops.
(C) non-conservative and field lines do not form closed loops.
(D) non-conservative and field lines form closed loops.

9. A tub is filled with a transparent liquid to a height of 30.0 cm. The apparent depth of a coin lying at the bottom of the tub is found to be 16.0 cm. The speed of light in the liquid will be 1

(A) 1.6×10^8 m s^{-1} (B) 2.0×10^8 m s^{-1}
(C) 3.0×10^8 m s^{-1} (D) 2.5×10^8 m s^{-1}

10. Atomic spectral emission lines of hydrogen atom are incident on a zinc surface. The lines which can emit photoelectrons from the surface are members of 1
(A) Balmer series
(B) Paschen series
(C) Lyman series
(D) Neither Balmer, nor Paschen nor Lyman series

11. The energy of an electron in a hydrogen atom in ground state is –13.6 eV. Its energy in an orbit corresponding to quantum number n is –0.544 eV. The value of n is **1**

(A) 2 (B) 3
(C) 4 (D) 5

12. When the resistance measured between p and n ends of a p-n junction diode is high, it can act as a/an – **1**

(A) resistor (B) inductor
(C) capacitor (D) switch

For Questions **13** to **16**, two statements are given – one labelled Assertion (A) and other labelled Reason (R). Select the correct answer to these questions from the codes (A), (B), (C) and (D) as given below :

(A) If both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of Assertion (A).
(B) If both Assertion (A) and Reason (R) are true but Reason (R) is not the correct explanation of Assertion (A).
(C) If Assertion (A) is true but Reason (R) is false.
(D) If both Assertion (A) and Reason (R) are false.

13. **Assertion (A)** : In a semiconductor diode the thickness of depletion layer is not fixed. **1**
Reason (R) : Thickness of depletion layer in a semiconductor device depends upon many factors such as biasing of the semiconductor.

14. **Assertion (A)** : In Bohr model of hydrogen atom, the angular momentum of an electron in n^{th} orbit is proportional to the square root of its orbit radius r_n. **1**
Reason (R) : According to Bohr model, electron can jump to its nearest orbits only.

15. **Assertion (A)** : Out of Infrared and radio waves, the radio waves show more diffraction effect. **1**
Reason (R) : Radio waves have greater frequency than infrared waves.

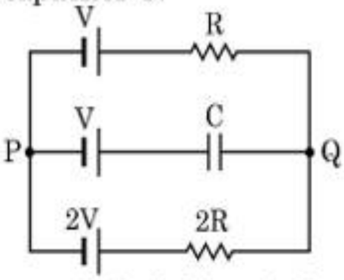
16. **Assertion (A)** : In an ideal step-down transformer, the electrical energy is not lost. **1**
Reason (R) : In a step-down transformer, voltage decreases but the current increases.

SECTION – B

17. (a) Two wires of the same material and the same radius have their lengths in the ratio 2 : 3. They are connected in parallel to a battery which supplies a current of 15 A. Find the current through the wires. **2**

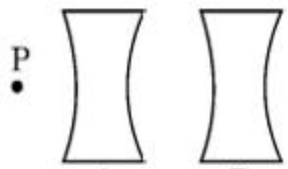
OR

(b) In the circuit three ideal cells of e.m.f. V, V and 2V are connected to a resistor of resistance R, a capacitor of capacitance C and another resistor of resistance 2R as shown in figure. In the steady state find (i) the potential difference between P and Q and (ii) potential difference across capacitor C.



18. In a double-slit experiment, 6^{th} dark fringe is observed at a certain point of the screen. A transparent sheet of thickness t and refractive index n is now introduced in the path of one of the two interfering waves to increase its phase by $2\pi (n - 1) t/\lambda$. The pattern is shifted and 8^{th} bright fringe is observed at the same point. Find the relation for thickness t in terms of n and λ. **2**

19. Two concave lenses A and B, each of focal length 8.0 cm are arranged coaxially 16 cm apart as shown in figure. An object P is placed at a distance of 4.0 cm from A. Find the position and nature of the final image formed. **2**



20. A light of wavelength 400 nm is incident on metal surface whose work function is 3.0×10^{-19} J. Calculate the speed of the fastest photoelectrons emitted. **2**

21. The threshold voltage of a silicon diode is 0.7 V. It is operated at this point by connecting the diode in series with a battery of V volt and a resistor of 1000 Ω. Find the value of V when the current drawn is 15 mA. **2**

SECTION – C

22. (a) A cell of e.m.f. E and internal resistance r is connected with a variable external resistance R and a voltmeter showing potential drop *V* across R. Obtain the relationship between *V*, E, R and r. **3**

(b) Draw the shape of the graph showing the variation of terminal voltage V of the cell as a function of current I drawn from it. How one can determine the e.m.f. of the cell and its internal resistance from this graph ?

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23. (a) In a region of a uniform electric field $\vec{E}$, a negatively charged particle is moving with a constant velocity $\vec{v} = -v_0\hat{i}$ near a long straight conductor coinciding with XX' axis and carrying current I towards –X axis. The particle remains at a distance d from the conductor. 3

(i) Draw diagram showing direction of electric and magnetic fields.

(ii) What are the various forces acting on the charged particle ?

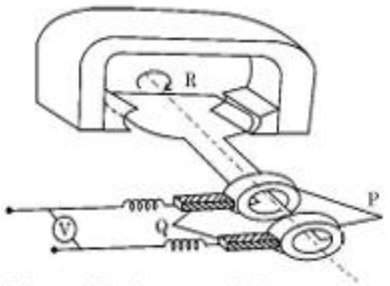
(iii) Find the value of v_0 in terms of E, d and I.

OR

(b) Two infinitely long conductors kept along XX' and YY' axes are carrying current I_1 and I_2 along –X axis and –Y axis respectively. Find the magnitude and direction of the net magnetic field produced at point P(X, Y).

24. (a) State Lenz's law. 3

(b) In the given figure :



(i) Identify the machine.

(ii) Name the parts P and Q and R of the machine.

(iii) Give the polarities of the magnetic poles.

(iv) Write the two ways of increasing the output voltage.

25. (a) The electric field $\vec{E}$ of an electromagnetic wave propagating in north direction is oscillating in up and down direction. Describe the direction of magnetic field $\vec{B}$ of the wave. 3

(b) Are the wave length of radio waves and microwaves longer or shorter than those detectable by human eyes ?

(c) Write main use of each of the following in human life :

(i) Infrared waves (ii) Gamma rays

26. (a) When a parallel beam of light enters water surface obliquely at some angle, what is the effect on the width of the beam ? 3

(b) With the help of a ray diagram, show that a straw appears bent when it is partly dipped in water and explain it.

(c) Explain the transmission of optical signal through an optical fibre by a diagram.

27. (a) Show the variation of binding energy per nucleon with mass number. Write the significance of the binding energy curve. **3**

(b) Two nuclei with lower binding energy per nucleon form a nuclei with more binding energy per nucleon.

(i) What type of nuclear reaction is it ?

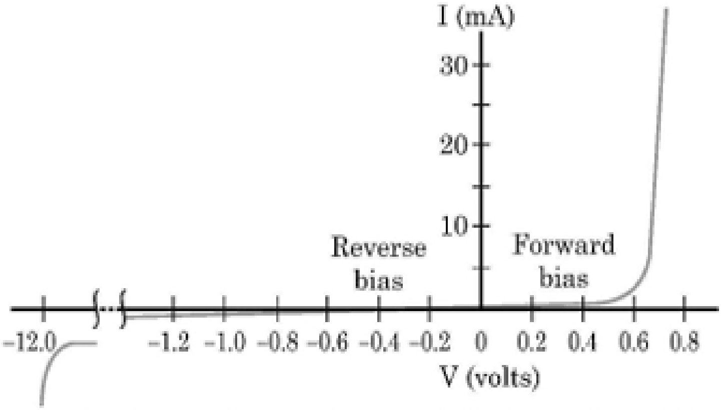
(ii) Whether the total mass of nuclei increases, decreases or remains unchanged ?

(iii) Does the process require energy or produce energy ?

28. (a) What are majority and minority charge carriers in an extrinsic semiconductor ? **3**

(b) A p-n junction is forward biased. Describe the movement of the charge carriers which produce current in it.

(c) The graph shows the variation of current with voltage for a p-n junction diode.



Estimate the dynamic resistance of diode at V = –0.6 volt.

SECTION – D

Question numbers **29** and **30** are case study based questions. Read the following paragraphs and answer the questions that follow.

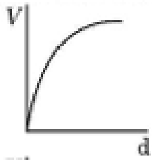
29. A parallel plate capacitor has two parallel plates which are separated by an insulating medium like air, mica, etc. When the plates are connected to the terminals of a battery, they get equal and opposite charges and an electric field is set up in between them. This electric field between the two plates depends upon the potential difference applied, the separation of the plates and nature of the medium between the plates. **4 × 1 = 4**

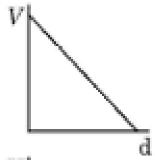
(i) The electric field between the plates of a parallel plate capacitor is E. Now the separation between the plates is doubled and simultaneously the applied potential difference between the plates is reduced to half of its initial value. The new value of the electric field between the plates will be :

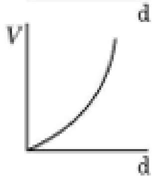
(A) E (B) 2E

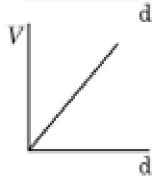
(C) $\frac{E}{4}$ (D) $\frac{E}{2}$

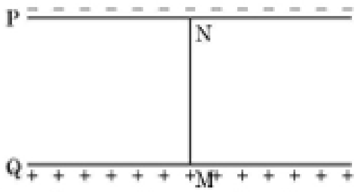
(ii) A constant electric field is to be maintained between the two plates of a capacitor whose separation d changes with time. Which of the graphs correctly depict the potential difference (V) to be applied between the plates as a function of separation between the plates (d) to maintain the constant electric field ?

(A) 

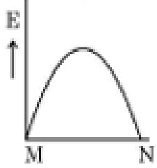
(B) 

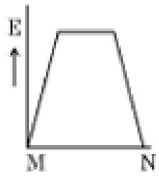
(C) 

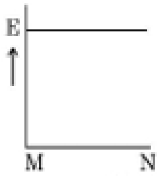
(D) 

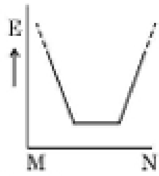
(iii) 

In the above figure P, Q are the two parallel plates of a capacitor. Plate Q is at positive potential with respect to plate P. MN is an imaginary line drawn perpendicular to the plates. Which of the graphs shows correctly the variations of the magnitude of electric field strength E along the line MN ?

(A) 

(B) 

(C) 

(D) 

(iv) Three parallel plates are placed above each other with equal displacement $\vec{d}$ between neighbouring plates. The electric field between the first pair of the plates is $\vec{E}_1$ and the electric field between the second pair of the plates is $\vec{E}_2$. The potential difference between the third and the first plate is –

(A) $(\vec{E}_1 + \vec{E}_2) \cdot \vec{d}$ (B) $(\vec{E}_1 - \vec{E}_2) \cdot \vec{d}$

(C) $(\vec{E}_2 - \vec{E}_1) \cdot \vec{d}$ (D) $\frac{d(E_1 + E_2)}{2}$

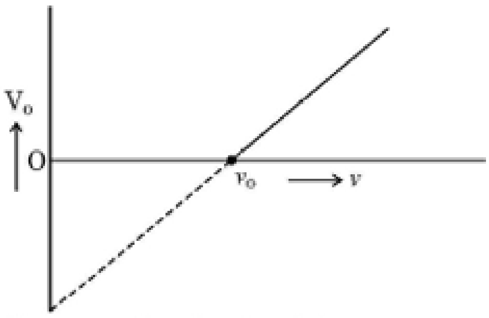
OR

(iv) A material of dielectric constant K is filled in a parallel plate capacitor of capacitance C. The new value of its capacitance becomes

(A) C (B) $\frac{C}{K}$

(C) CK (D) $C\left(1 + \frac{1}{K}\right)$

30. When a photon of suitable frequency is incident on a metal surface, photoelectron is emitted from it. If the frequency is below a threshold frequency (ν_o) for the surface, no photoelectron is emitted. For a photon of frequency $\nu(\nu > \nu_o)$, the kinetic energy of the emitted photoelectrons is $h(\nu - \nu_o)$. The photocurrent can be stopped by applying a potential V_o called 'stopping potential' on the anode. Thus maximum kinetic energy of photoelectrons $K_m = eV_o = h(\nu - \nu_o)$. The experimental graph between V_o and ν for a metal is shown in figure. This is a straight line of slope m. **4 × 1 = 4**



(i) The straight line graphs obtained for two metals

(A) coincide each other.
(B) are parallel to each other.
(C) are not parallel to each other and cross at a point on ν-axis.
(D) are not parallel to each other and do not cross at a point on ν-axis.

(ii) The value of Planck's constant for this metal is

(A) $\frac{e}{m}$ (B) $\frac{1}{me}$

(C) me (D) $\frac{m}{e}$

(iii) The intercepts on ν-axis and V_o-axis of the graph are respectively :

(A) $\nu_o, \frac{h\nu_o}{e}$ (B) $\nu_o, h\nu_o$

(C) $\frac{h\nu_o}{e}, \nu_o$ (D) $h\nu_o, \nu_o$

OR

~

(iii) When the wavelength of a photon is doubled, how many times its wave number and frequency become, respectively ?

(A) $2, \frac{1}{2}$ (B) $\frac{1}{2}, \frac{1}{2}$

(C) $\frac{1}{2}, 2$ (D) 2, 2

(iv) The momentum of a photon is 5.0×10^{-29} kg. m/s. Ignoring relativistic effects (if any), the wavelength of the photon is

(A) 1.33 μm (B) 3.3 μm

(C) 16.6 μm (D) 13.3 μm

SECTION – E

31. (a) (i) A small conducting sphere A of radius r charged to a potential V, is enclosed by a spherical conducting shell B of radius R. If A and B are connected by a thin wire, calculate the final potential on sphere A and shell B. 5

(ii) Write two characteristics of equipotential surfaces. A uniform electric field of 50 NC^{-1} is set up in a region along $+x$ axis. If the potential at the origin (0, 0) is 220 V, find the potential at a point (4m, 3m).

OR

(b) (i) What is difference between an open surface and a closed surface ? Draw elementary surface vector $d\vec{S}$ for a spherical surface S.

(ii) Define electric flux through a surface. Give the significance of a Gaussian surface. A charge outside a Gaussian surface does not contribute to total electric flux through the surface. Why ?

(iii) A small spherical shell S_1 has point charges $q_1 = -3$ μC, $q_2 = -2$ μC and $q_3 = 9$ μC inside it. This shell is enclosed by another big spherical shell S_2. A point charge Q is placed in between the two surfaces S_1 and S_2. If the electric flux through the surface S_2 is four times the flux through surface S_1, find charge Q.

32. (a) (i) What is the source of force acting on a current-carrying conductor placed in a magnetic field ? Obtain the expression for force acting between two long straight parallel conductors carrying steady currents and hence define 'ampere'. 5

~

(ii) A point charge q is moving with velocity $\vec{v}$ in a uniform magnetic field $\vec{B}$. Find the work done by the magnetic force on the charge.

(iii) Explain the necessary conditions in which the trajectory of a charged particle is helical in a uniform magnetic field.

OR

(b) (i) A current carrying loop can be considered as a magnetic dipole placed along its axis. Explain.

(ii) Obtain the relation for magnetic dipole moment $\vec{M}$ of current carrying coil. Give the direction of $\vec{M}$.

(iii) A current carrying coil is placed in an external uniform magnetic field. The coil is free to turn in the magnetic field. What is the net force acting on the coil ? Obtain the orientation of the coil in stable equilibrium. Show that in this orientation the flux of the total field (field produced by the loop + external field) through the coil is maximum.

33. (a) (i) A thin pencil of length (f/4) is placed coinciding with the principal axis of a mirror of focal length f. The image of the pencil is real and enlarged, just touches the pencil. Calculate the magnification produced by the mirror. **5**

(ii) A ray of light is incident on a refracting face AB of a prism ABC at an angle of 45°. The ray emerges from face AC and the angle of deviation is 15°. The angle of prism is 30°. Show that the emergent ray is normal to the face AC from which it emerges out. Find the refraction index of the material of the prism.

OR

(b) (i) Light consisting of two wavelengths 600 nm and 480 nm is used to obtain interference fringes in a double slit experiment. The screen is placed 1.0 m away from slits which are 1.0 nm apart.

(1) Calculate the distance of the third bright fringe on the screen from the central maximum for wavelength 600 nm.

(2) Find the least distance from the central maximum where the bright fringes due to both the wavelengths coincide.

(ii) (1) Draw the variation of intensity with angle of diffraction in single slit diffraction pattern. Write the expression for value of angle corresponding to zero intensity locations.

(2) In what way diffraction of light waves differs from diffraction of sound waves ?