KENDRIYA VIDYALAYA SANGATHAN
VARANASI REGION

Study Material for
CBQ and Slow Learners

PHYSICS

तत् त्वं पूषन् अपावृणु

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COMPENTENCY BASED QUESTIONS WITH SOLUTIONS

CONTENT CREATED BY-

S.No.	NAME OF KV	NAME OF TEACHER	NAME OF TOPIC
1	AFS BAMRAULI	MR. MANOJ KUMAR SHARMA	ELECTRIC CHARGES AND FIELDS
2	NEW CANTT SHIFT -II	MR. SUNIL KUMAR VISHWAKARMA	ELECTROSTATIC POTENTIAL AND CAPACITANCE
3	OLD CANTT	MR. SK PANDEY	CURRENT ELECTRICITY
4	IIIT JHALWA	AYUSH AGRAWAL	MOVING CHARGES AND MAGNETISM
5	MUGHAL SARAI	MR. KRISHNA KUMAR SINGH	MAGNETISM AND MATTER
6	GORAKHPUR-I AFS	MR. KAMAL KUMAR OJHA	ELECTROMAGNETIC INDUCTION
7	VARANASI BLW	MR. SHIV PRAKASH	ALTERNATING CURRENT
8	VARANASI BLW	MR. BRIJESH KUMAR CHAURASIA	EM WAVES
9	BHU	MD PERWEJ ALAM	RAY OPTICS
10	BHU II SHIFT	MR DHARM PRAKASH PANDEY	WAVE OPTICS
11	AFS MANAURI	MR. PRADEEP KUMAR SHARMA	DUAL NATURE OF LIGHT
12	MANKAPUR	MR. WARIS ALI KHAN	ATOMS AND NUCLEI
13	KV AMHAT	MR. ABHISHEK TIWARI	ELECTRONIC DEVICES

MINIMUM LEVEL OF LEARNING (MLL) QUESTIONS WITH SOLUTIONS FOR SLOW LEARNERS

CONTENT CREATED BY-

S.N	NAME OF KV	NAME OF TEACHER	CHAPTER NAME
1	GORAKHPUR-I AFS	MR. VISHAL SRIVASTAVA	ELECTRIC CHARGES AND FIELDS, ELECTROSTATIC POTENTIAL AND CAPACITANCE , CURRENT ELECTRICITY
2	OLD CANTT	MR. HANUMAN PRASAD PANDEY	MOVING CHARGES AND MAGNETISM , MAGNETISM AND MATTER

3	GORAKHPUR-II FCI	MR. NATHUNI PRASAD	ELETROMAGNETIC INDUCTION AND ALTERNATING CURRENT
4	ALLAHABAD CHHEOKI	MR. AJAY KUMAR SHARMA	EM WAVES, RAY OPTICS
5	CHOPAN	MR. ALOK SRIVASTAVA	WAVE OPTICS, DUAL NATURE OF MATTER AND RADIATION
6	BHU	MR. SANDEEP KUMAR SINGH	ATOMS AND NUCLEI, ELECTRONIC DEVICES

PREVIOUS YEAR'S QUESTIONS ASKED IN BOARD EXAMINATIONS QUESTIONS WITH SOLUTION-

CONTENT CREATED BY-

S.N	**NAME OF KV**	**NAME OF TEACHER**	**CHAPTER NAME**
1	GORAKHPUR-I AFS	MR. VISHAL SRIVASTAVA	ELECTRIC CHARGES AND FIELDS, ELECTROSTATIC POTENTIAL AND CAPACITANCE , CURRENT ELECTRICITY
2	OLD CANTT	MR. HANUMAN PRASAD PANDEY	MOVING CHARGES AND MAGNETISM , MAGNETISM AND MATTER
3	GORAKHPUR-II FCI	MR. NATHUNI PRASAD	ELETROMAGNETIC INDUCTION AND ALTERNATING CURRENT
4	ALLAHABAD CHHEOKI	MR. AJAY KUMAR SHARMA	EM WAVES, RAY OPTICS
5	CHOPAN	MR. ALOK SRIVASTAVA	WAVE OPTICS, DUAL NATURE OF MATTER AND RADIATION
6	BHU	MR. SANDEEP KUMAR SINGH	ATOMS AND NUCLEI, ELECTRONIC DEVICES

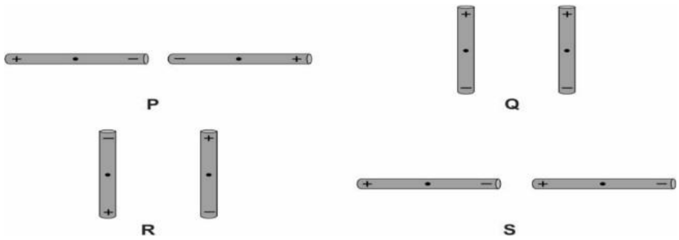
COMPETENCY BASED QUESTIONS WITH SOLUTIONS

ELECTRIC CHARGES AND FIELDS

SECTION A

Multiple Choice Questions

Q1. Two insulated rods have opposite static charges at their ends. The charged rods are mounted at their centres so that they are free to rotate in the plane of the screen. The two rods can be held in the following 4 orientations as shown below.



Identify which of these orientations are stable such that they return to their original orientation if slightly displaced.

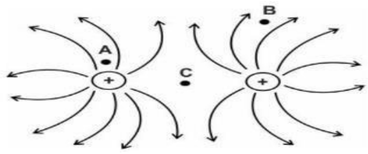
(a) Orientations P and Q are stable. Orientations R and S are unstable.

(b) Orientations Q and R are stable. Orientations P and S are unstable.

(c) Orientations Q and S are stable. Orientations P and R are unstable.

(d) Orientations P and R are stable. Orientations Q and S are unstable.

Q2. Electric field lines are pictorial representations of electric fields due to static charges on the plane of a paper.



Study the given electric field representation and identify one INCORRECT qualitative impression given by this representation.

(a) The electric field at point A is stronger than at point B.

(b) The electric field distribution is two-dimensional.

(c) The electric field at point C is zero.

(d) The electric field always points away from a positive charge.

Q3. For a Gaussian surface through which the net flux is zero, the following statements COULD be true.

P) No charges are inside the Gaussian surface.

Q) The net charge inside the surface is zero.

R) The electric field is zero everywhere on the surface.

S) The number of field lines entering is equal to the number of lines exiting the surface.

Which of the statements is/are DEFINITELY true?

(a) Only statement Q

(b) Both statements P and S

(c) Both statements Q and R

(d) Both statements Q and S

Q4. A lightning conductor is made of a conducting material with one of its ends earthed while the other end has several sharp metal spikes. It protects the building from lightning by either neutralizing or conducting the charge of the cloud in the sky to the ground.

Identify ONE statement from below given that DOES NOT contribute to the correct explanation of the working principle of a lightning conductor.

(a) Charge density on the surface of metal spikes is inversely proportional to the radius of curvature.

(b) Charges are distributed uniformly on the surface of conductors irrespective of their shapes.

(c) The surface of a charged conductor behaves as an equipotential surface.

(d) Charges reside only on the outside of a charged conductor.

Q5. A polythene piece rubbed with wool is found to have a negative charge of 3.2×10^{-7}C. Which of the following is true?

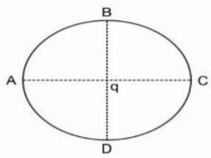
(a) 2×10^{12} electrons have been removed from the polythene

(b) 4×10^{12} electrons have been removed from the polythene

(c) 2×10^{12} electrons have been added to the polythene

(d) 4×10^{12} electrons have been added to the polythene

Q6. A charge q = +2 C is located at the center of a circle of radius 2 m. A unit positive test charge is moved along the circle.



Identify the correct statement.

(a) Work done in moving a test charge from A to C is maximum.

(b) Work done in moving a test charge from A to B or from A to D is minimum.

(c) Work done in moving a test charge from A to B to C to D is more than from A to D.

(d) Work done in moving a test charge between any two points along the circle is zero.

Q7. 15 charged particles with the same charge (q) are placed on the x-axis. They are symmetrically distributed on both sides of the y-axis. The distance between any two consecutive particles is R/3 and one of the charges is at the origin.

What is the electric flux through a sphere centred at the origin having a radius of 1.5R?

(a) $15q/\epsilon_0$

(b) $8q/\epsilon_0$

(c) $9q/\epsilon_0$

(d) $5q/\epsilon_0$

Q8. Two positively charged ions carrying equal charges repel each other by a force of 3.7×10^{-9} N when separated by a distance 5 Å from each other. How many electrons are missing from each ion?

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

Q9. The charges on two spheres are +7μC and -5 μC respectively. They experience a force f. If an ADditional charge of-2 μC is given to each of them the force between them Is
(a) F
(b) F/2
(c) F/√3
(d) 2F

Q10. A positive charge Q is placed at the center of a neutral conducting metal sphere and an electric field E is applied outside the sphere. Then
(a) Force on Q is due to E is zero
(b) Net force on Q is zero
(c) Net force on Q and conducting shell as a single system is zero
(d) Net force on the shell due to E is zero

Assertion and Reason

Two statements are given below. One is labelled Assertion (A) and the other is labelled Reason (R). Read the statements carefully and choose the option that correctly describes statements A and R.

Q11. **Assertion (A):** An electric dipole is in stable equilibrium when placed in a uniform electric field with its dipole moment opposite to the field.
Reason (R): No torque acts on an electric dipole when its dipole moment is in a direction opposite to the field.
(a) Both assertion and reason are true and reason is the correct explanation for assertion.
(b) Both assertion and reason are true but reason is not the correct explanation of assertion.
(c) Assertion is true but reason is false.
(d) Assertion is false but reason is true.

Q12. **Assertion (A):** A negatively charged body means that the body has gained electrons while a positively charged body means the body has lost some of its electrons.
Reason (R): Charging process involves transfer of electrons.
(a) Both assertion and reason are true and reason is the correct explanation for assertion.
(b) Both assertion and reason are true but reason is not the correct explanation of assertion.
(c) Assertion is true but reason is false.
(d) Assertion is false but reason is true.

Q13. **Assertion (A):** When a body is charged, its mass changes.
Reason (R): Charge is quantized.
(a) Both assertion and reason are true and reason is the correct explanation for assertion.

(b) Both assertion and reason are true but reason is not the correct explanation of assertion.
(c) Assertion is true but reason is false.
(d) Assertion is false but reason is true.

Q14. **Assertion (A):** An electron has negative charge by definition.
Reason (R): Charge of a body depends on its velocity.
(a) Both assertion and reason are true and reason is the correct explanation for assertion.
(b) Both assertion and reason are true but reason is not the correct explanation of assertion.
(c) Assertion is true but reason is false.
(d) Assertion is false but reason is true.

Q15. **Assertion (A):** Electric field lines are continuous curves in free space.
Reason (R): Electric field lines start from negative charge and terminate at positive charge.
(a) Both assertion and reason are true and reason is the correct explanation for assertion.
(b) Both assertion and reason are true but reason is not the correct explanation of assertion.
(c) Assertion is true but reason is false.
(d) Assertion is false but reason is true.

SECTION B

Q16. A metallic spherical shell has an inner radius R_1 and outer radius R_2. A charge Q is placed at the center of the spherical cavity. What will be the surface charge density on (i) the inner surface and (ii) the outer surface?

Q17. A thin metallic spherical shell of radius R carries a charge Q on its surface. A point charge Q/2 is placed at its center C and another charge +2Q is placed outside the shell at a distance x from the center as shown.
Find (i) the force on the charge at the center of the shell and at the point A .
(ii) the electric flux through the shell.

Q18. Four-point charges qA = 2 μC, qB = −5 μC, qC = 2 μC, and qD = −5 μC are located at the corners of a square ABCD of side 10 cm. What is the force on a charge of 1 μC placed at the center of the square?

Q19. A system has two charges $q_A = 2.5 \times 10^{-7}$ C and $q_B = -2.5 \times 10^{-7}$ C located at points A: (0, 0, −15 cm) and B: (0, 0, +15 cm), respectively. What are the total charge and electric dipole moment of the system?

Q20. (a) An electrostatic field line is a continuous curve. That is, a field line cannot have sudden breaks. Why not?
(b) Explain why two field lines never cross each other at any point?

SECTION C

Q21. Define the term dipole moment of an electric dipole indicating its direction. Write its S.I unit. An electric dipole is placed in a uniform electric field. Deduce the expression for the Torque acting on it.

Q22. Two point charges +q and +9q are separated by a distance of 10 a. Find the point on the line joining the two changes where electric field is zero?

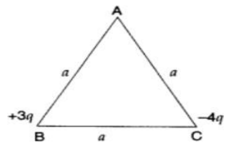
Q23. Two spherical conductors of radii R_1 and R_2 ($R_2 > R_1$) are charged. If they are connected by a conducting wire, find out the ratio of the surface charge densities on them.

Q24. Use Gauss's law to derive the expression for the electric field ($\vec{E}$) due to a straight uniformly charged infinite line of charge λ Cm^{-1}.

Q25. Two point charges + 3q and – 4q are placed at the vertices 'B' and 'C' of an equilateral triangle ABC of side 'a' as given in the figure. Obtain the expression for

(i) the magnitude and

(ii) the direction of the resultant electric field at the vertex A due to these two charges.



SECTION D

Q26. 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.

(i) 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.

(ii) The force per unit charge is known as

(a) electric flux

(b) electric field

(c) electric potential

(d) electric current

(iii) The SI unit of electric field is

(a) N/m

(b) N-m

(c) N/C

(d) N/C^2

(iv) 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

(v) At a particular point, Electric field depends upon

(a) Source charge Q only

(b) Test Charge q_0 only.
(c)Both Q and q_0
(d)Neither Q nor q_0

Q27. A Faraday cage or Faraday shield is an enclosure made of a conducting material. The fields within a conductor cancel out with any external fields, so the electric field within the enclosure is zero. These Faraday cages act as big hollow conductors you can put things in to shield them from electrical fields. Any electrical shocks the cage receives pass harmlessly around the outside of the cage.

(i) Which of the following material can be used to make a Faraday cage?
(a) Plastic
(b) Glass
(c) Copper
(d) Wood

(ii) Example of a real-world Faraday cage is
(a) Car
(b) plastic box
(c) lightning rod
(d) metal rod

(iii) 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

(iv) 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

(v) A point charge of 2C is placed at centre of Faraday cage in the shape of cube with surface of 9 cm edge. The number of electric field lines passing through the cube normally will be-
(a) $1.9X10^5$ Nm^2/C entering the surface
(b) $1.9X10^5$ Nm^2/C leaving the surface
(c) $2.26X10^5Nm^2/C$ leaving the surface
(d) $2.26X10^5Nm^2/C$ entering the surface

SECTION E

Q28. (a) State Gauss's theorem in electrostatics. Using it, prove that the electric field at a point due to a uniformly charged infinite plane sheet is independent of the distance.
(b) How the field is directed if (i) the sheet is positively charged, (ii) negatively charged?

Q29. A thin conducting spherical shell of radius R has charge Q spread uniformly over its surface. Using Gauss's law, derive an expression for an electric field at a point (i) outside the shell (ii) at the surface of the shell and (iii) inside the shell. Draw a graph of electric field E(r) with distance r from the centre of the shell for $0 \le r \le \infty$

(Solution)

SECTION A

MCQ

A1. (C) Orientations Q and S are stable. Orientations P and R are unstable.

A2. (B) The electric field distribution is two-dimensional.

A3. (D) Both statements Q and S

A4. (B) 4×10^{12} electrons have been removed from the polythene

A5. (C) 2×10^{12} electrons have been added to the polythene

A6. (D) Work done in moving a test charge between any two points along the circle is zero.

A7. (C) $9q/\in_0$

A8. (B) 2

A9. (A) F

A10. (A) Net force on Q is zero

Assertion and Reason

A11. (D) Assertion is false but reason is true.

A12. (A) Both assertion and reason are true and reason is the correct explanation for assertion.

A13. (B) Both assertion and reason are true but reason is not the correct explanation of assertion.

A14. (C) Assertion is true but reason is false.

A15. (C) Assertion is true but reason is false.

SECTION B

A16. Change -Q is induced on the inner surface and charge +Q is induced on the surface of the cavity. Therefore surface charge density on the inner surface = $-Q/4\pi R^2$
Surface charge density on the outer surface $=Q/4\pi R^2$

A17. Net force on the charge Q/2placed at the center of the shell is zero .
(i) Force on the charge 2Q kept at point A at distance r from the center is F=E x 2Q

$$=\frac{1}{4\pi g_0}\frac{(+\frac{Q}{2}+Q)}{R^2}\text{x}2Q$$

ii) electric flux through the shell , $\Phi_E = \frac{Q/2}{g_0} = \frac{Q}{2g_0}$

A18. The charges of equal magnitude and same sign are at the corners of same diagonal. So they will exhibit equal and opposite forces at the charge situated at center, cancelling out each other. So, the force is zero Newton.

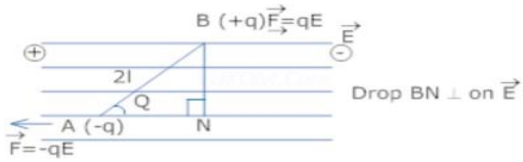
A19. Total charge of electric dipole = zero coulomb Magnitude of Dipole moment,
|p| = (Magnitude of either charge) × (Distance between 2 charges) = q.2a
Given, 2a = 30 cm, q = 2.5×10^{-7} C = $(2.5 \times 10^{-7}) \times (30) = 7.5 \times 10^{-8}$ C-m

A20. (a) The direction of electric field is given by tangent at each point on the curve. At sudden breaks, the field will have more than one direction which is not possible. That's why electrostatic field line is a continuous curve.

(b) At the crossing point there will be two directions of electric field at that point given by the two tangents. This cannot happen, and so two field lines never cross each other at any point

SECTION C

A21. Electric dipole moment is defined as the product of the magnitude of either charge and the length of dipole as $\vec{p} = q\vec{2l}$. Its direction is from –ve to +ve charge. Its S.I. unit is coulomb meter (Cm)



Consider a dipole placed in uniform electric field and makes an angle (θ) with the electric field ($\vec{E}$), Since two forces acts on the charges constituting an electric dipole which are equal and opposite in direction, thus a torque acts on the dipole which makes the dipole rotate.

And Torque $r = Either\ force\ x \perp Distance$

Here force F = qE

And $\frac{BN}{AB} = sin\theta$ ⇒ BN = AB $sin\theta$ = 2l $sin\theta$

∴ r = qE x 2l $sin\theta$ = pE $sin\theta$

⇒$\vec{r} = \vec{p} \times \vec{E}$

A22. Let P be the point where test charge (+q_o) is present then electric field at point. P will be zero if Field at point. P due to +q = field at point P due to + 9q————1

Now $\vec{E}_A = \frac{(+q)}{x^2}$ and $\vec{E}_B = \frac{k(+9q)}{(10a-x)^2}$

Substituting in equation 1 we have

$\frac{(+q)}{x^2} = \frac{k(+9q)}{(10a-x)^2}$ ⇒ $9x^2 = (10a - x)^2$ ⇒3x = 10a – x ⇒ 4x = 10a

∴ x = $\frac{10}{4}$ a = 2.5 a, from the charge +q

and 10a – x = 10a -2.5a = 7.5 a from the charge +9q

A23. When two charged spherical conductors of Radii R1 and R2 respectively (R2 > R1) are connected by a conducting wire, we know that the common potential (V) is given by,

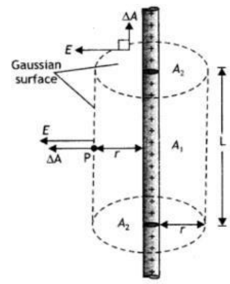
V = $\frac{q1}{c_1} = \frac{q2}{c_2}$

∵ C for a spherical capacitor = $4\pi\epsilon_0$R

we have V = $\frac{q1}{4\pi g_0 R_1} = \frac{q2}{4\pi g_0 R_2}$ ⇒ $\frac{q1}{R_1} = \frac{q2}{R_2}$

⇒$\frac{q_1}{q_2} = \frac{R_1}{R_2}$

∴ $\frac{\sigma_1}{\sigma_2} = \frac{q_1}{4\pi g_0 R_1^2} \times \frac{4\pi g_0 R_2^2}{q_2} = \frac{q_1}{q_2} \times \frac{R_2^2}{R_1^2}$

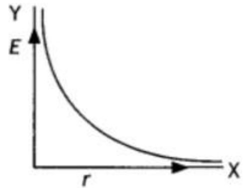


Thus $\frac{\sigma_1}{\sigma_2} = \frac{R_1}{R_2} \times \frac{R_2^2}{R_1^2} = \frac{R_2}{R_1}$

A24. Consider an infinitely long, thin wire charged positively and having uniform linear charge density λ. The symmetry of the charge distribution shows that must be perpendicular to the tine charge and directed outwards. As a result of this symmetry, we consider a Gaussian surface in the form of a cylinder with arbitrary radius r and arbitrary Length L. with its ends perpendicular to the wire as shown in the figure. Applying Gauss's theorem to curved surface dA_1 and circular surface dA_2.

Φ E $dA_1 \cos 0° +$ E $dA_2 \cos 90° = \frac{q}{\varepsilon_0} = \frac{\lambda l}{\varepsilon_0}$ [$\because \lambda = q/l$]

Or $E.2\pi rl = \frac{\lambda l}{\varepsilon_0} \Rightarrow E = \frac{\lambda l}{2\pi r l \varepsilon_0} = \frac{\lambda}{2\pi r \varepsilon_0}$



This is the expression for the electric field due to an infinitely long thin wire.

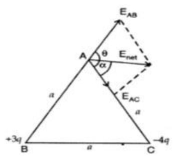
The graph is as shown.

A25. (i) the magnitude

$|\vec{E}_{AB}| = \frac{3}{4\pi\varepsilon_0 a^2} = 3E$, where $E = \frac{q}{4\pi\varepsilon_0 r^2}$

$|\vec{E}_{AC}| = \frac{4}{4\pi\varepsilon_0 a^2} = 4E$

$E_{net} = \sqrt{(3E)^2 + (4E)^2 + 2(3E)x(4E)(-\frac{1}{2})}$



$\left\{ \begin{array}{l} \because \theta = 120° \\ \cos 120° = -\frac{1}{2} \end{array} \right\}$

$E_{net} = \sqrt{9E^2 + 16E^2 - 12E^2} = \sqrt{13E^2} = E\sqrt{13} = \frac{q\sqrt{13}}{4\pi\varepsilon_0 a^2}$

(ii) Direction

$\tan\alpha = \frac{E_{AB} \sin 120°}{E_{AC} + E_{AB}\cos 120°} = \frac{3E \times \frac{\sqrt{3}}{2}}{4E + 3(-\frac{1}{2})}$

$\tan\alpha = \frac{3E\sqrt{3} \times 2}{2 \times 55E} = \frac{3\sqrt{3}}{5} \therefore \alpha = \tan^{-1}\frac{3\sqrt{3}}{5}$

SECTION D

A26. (i) (a) always continuous.

(ii) (b) electric field

(iii) (c) N/C

(iv) (b) mg/e

(v) (a) Source charge Q only

A27. (i) (c) Copper

(ii) (a) Car

(iii) (c) Zero

(iv) (c) -q

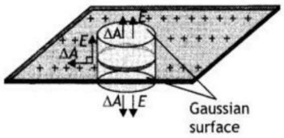
(v) (b) $1.9 X 10^5$ Nm^2/C leaving the surface

SECTION E

A28. It states, "The net electric flux through any Gaussian surface is equal to $1/\varepsilon_0$ times the net electric charge enclosed by the surface.

Mathematically, $\Phi = \int \vec{E}.\vec{ds} = q/\varepsilon_0$

Consider an infinite plane sheet of charge. Let a be the uniform surface charge density, i.e. the charge per unit surface area. From symmetry, we find that the electric field must be perpendicular to the plane of the sheet and that the direction of E on one side of the plane must be opposite to its direction on the other side as shown in the figure below. In such a case let us choose a Gaussian surface in the form of a cylinder with its axis perpendicular to the sheet of charge, with ends of area A. The charged sheet passes through the middle of the cylinder's length so that the cylinder's ends are equidistant from the sheet. The electric field has a normal component at each end of the cylinder and no normal component along the curved surface of the cylinder. As a result, the electric flux is linked with only the ends and not the curved surface.



Therefore by the definition of electric flux, the flux Linked with the Gaussian surface is given by

$\Phi = \oint \vec{E}.\vec{dA}$

$\Phi = EA + EA = 2EA$ ... (1)

But by Gauss's Law

$\Phi = q/\varepsilon_0 = \sigma A/\varepsilon_0$ [$\because q = \sigma A$] ... (2)

From equations (1) and (2), we have

$2EA = \sigma A/\varepsilon_0$ ... (3)

$E = \sigma/2\varepsilon_0$ ....(4)

This gives the electric field due to an infinite plane sheet of charge which is independent of the distance from the sheet.

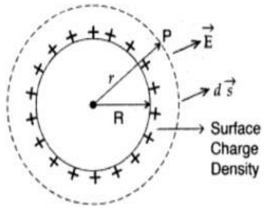
(b) (i) directed outwards

(ii) directed inwards.

A29. Electric field at a point outside the shell :

(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. From Gauss's theorem, $\phi = \oint_S \vec{E}.\vec{dS} = \frac{q_m}{g_0}$

Flux ϕ through S'



$\phi = \oint_{S'} \vec{E}.\vec{dS} = \oint_{S'} EdS = E4\pi r^2$

$\Rightarrow E4\pi r^2 = \frac{q_m}{g_0}$

$\Rightarrow E = \frac{m}{4\pi r^2 g_0}$

(ii) At the surface r = R

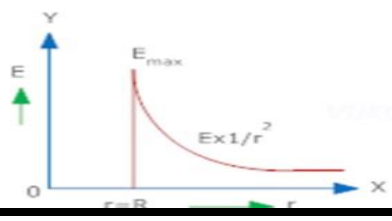
$E = \frac{q_m}{4\pi R^2 g_0}$

(iii) Inside the Surface

$E4\pi r^2 = \frac{q_m}{g_0}$ since inside the suface $q_m = 0$

Therefore E =0

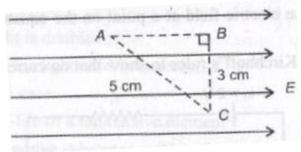
Graph of electric field E(r) :

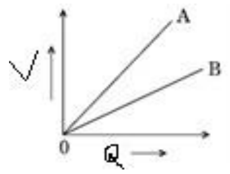
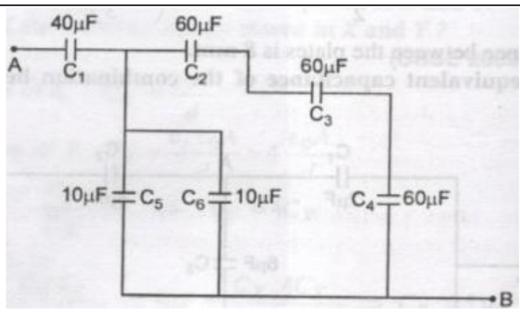


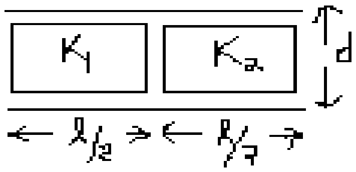
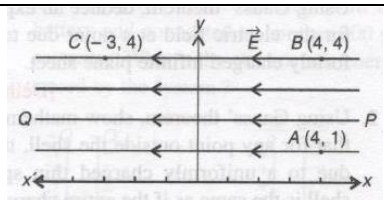
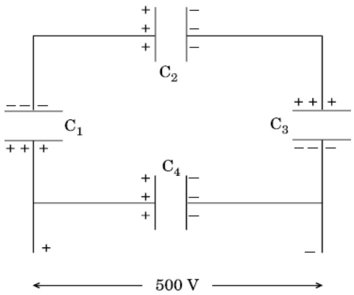
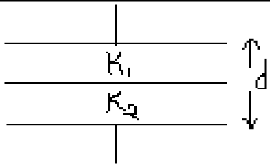
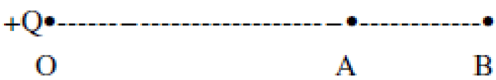
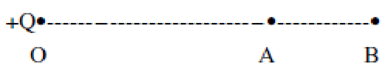
e) E=0

COMPETENCY BASED QUESTIONS WITH SOLUTIONS

Electric potential and capacitance

SN	Question	Marks
1	Name the physical quantity whose S.I. unit is JC^{-1} (a) Electric potential (b) Electric Field (c) Electric potential Energy (d) Electric dipole moment	1
2	The absolute potential at a point P which is 2 m from a point charge of +5μC is given by (a) 45 kV (b) 22.5 kV (c) 110 kV (d) 11.5 kV	1
3	What is the amount of work done in moving a point charge $1C$ around a circular arc of radius $'2\ cm'$ at the centre of which another point charge $'4C'$ is located? (a) 8 J (b) 4 J (c) 0 J (d) 1 J	1
4	Two point charges $20 \text{ X } 10^{-6}$C and $-4 \text{ X } 10^{-6}$C are separated by a distance of 50 cm in air. What is the electrostatic potential energy of the system? (a) $-$ 1 J (b) $-$ 1.44 J (c) 1.44 J (c) 1 J	1
5	Which one of the following statements is false in respect of equipotential surface? (a) No work is done in moving a test charge from one point to another over an equipotential surface (b) Electric field is always parallel to the equipotential surface at every point (c) No two equipotential surfaces can intersect each other (d) Equipotential surfaces are closer in regions of strong field and farther in Regions of weak field.	1
6	Three points A, B & C lie in a uniform electric field (E) of 5 X 10^3 NC^{-1} as shown in figure. Find potential difference between A and C. (a) 100V (b) 250V (c) 200V (d) 25 V  	1
7	A parallel plate capacitor is charged by a battery. Once it is charged battery is removed. Now a dielectric material is inserted between the plates of the capacitor, which of the following does not change? (a) Electric field between the plates (b) Potential difference across the plates (c) Charge on the plates (d) Energy stored in the capacitor.	1
8	Three capacitors of capacitances 1μf, 2μF & 3μF are connected in series and a potential difference of 11V is applied across the combination them the potential difference across the plates of 1μF capacitor is (a) 2V (b) 4V (c) 1V (d) 6V	1
9	A hollow metal sphere of radius 10 cm is charged such that the potential on its surface is 5 V. What is the potential at the centre of the sphere? (a) 2.5V (b) 4V (c) 1.5V (d) 5V	1

10	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. Then (a) $C_A=C_B$ (B) $C_A>C_B$ (c) $C_A<C_B$ (d) $C_A=C_B=0$  	1
Section-B(Assertion and reason)		
For Questions 11 to 15, two statements are given –one labelled Assertion (A) and other labelled Reason (R). Select the correct answer to these questions from the options as given below. (a) If both Assertion and Reason are true and Reason is correct explanation of Assertion. (b) If both Assertion and Reason are true but Reason is not the correct explanation of Assertion. (c) If Assertion is true but Reason is false. (d) If both Assertion and Reason are false.		
11	Assertion (A):Every point in electric field, a particle with charge q possesses a certain electrostatic potential energy. Reason(R): the work done by an electrostatic field in moving a charge from one point to another depends only on the initial and the final points and is independent of the path taken to go from one point to the other.	1
12	Assertion (A):The potential due to a dipole depends not just on r but also on the Angle between the position vector r and the dipole moment vector p. Reason(R): The electric dipole potential falls off, at large distance, as $1/r^2$, not as 1/r, characteristic of the potential due to a single charge.	1
13	Assertion (A): Equipotential surface through a point is normal to the electric field at that point. Reason(R): If the field were not normal to the equipotential surface, it would have non-zero component along the surface.	1
14	Assertion (A): Molecules of oxygen (O_2) and hydrogen (H_2) are non-polar molecules. Reason(R): In a non-polar molecule, the centres of positive and negative Charges coincide.	1
15	Assertion (A): The equipotential surfaces due to uniform electric field not intersect each other. Reason(R): There will be only one values of the electric potential at a point.	1
Section-C(SA-2marks)		
16	A slab of material of dielectric constant *K* has the same area as that of the plates of a parallel plate capacitor but has the thickness 3d/4, where d is the separation between the plates. Find out the expression for its capacitance when the slab is inserted between the plates of the capacitor.	2
17	Find the equivalent capacitance of the combination of capacitors between the points A and B as shown in figure. Also calculate the total charge that flows in the circuit when a 100 V battery is connected between the points A and B.  	2
18	Two charges 3×10^{-8} C and -2×10^{-8} C are located 15 cm apart. At what point on the line joining the two charges is the electric potential zero? Take the potential at infinity to be zero.	2

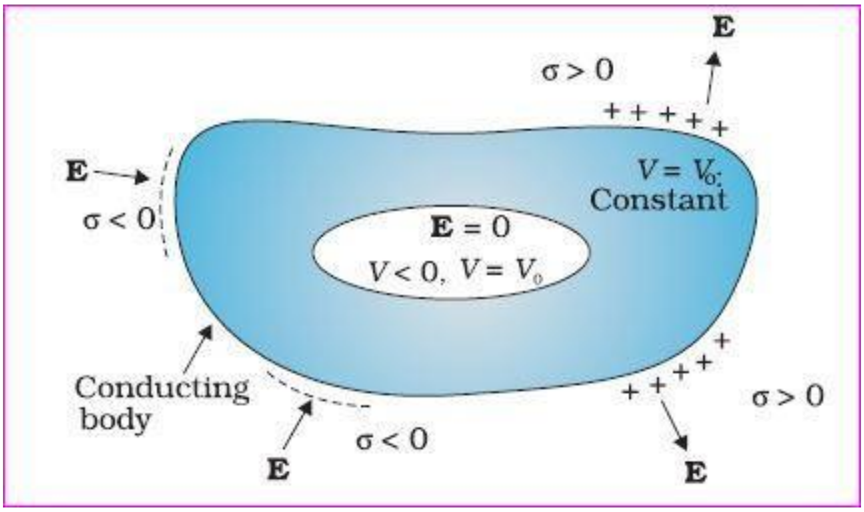
19	Two dielectric slabs of dielectric constants K_1 and K_2 are filled in between the two plates, each of area A, of the Parallel plate capacitor as shown. Find net capacitance of the capacitor. 	2
20	A uniform electric field E of 300 N/C is directed along PQ. A,B and C are three points in the field having x and y co-ordinates (in metres) as shown in figure. Calculate the potential difference between- (i) A and B and (ii) B and C. 	2
	Section-D(SA-3marks)	
21	Two point charges $20 \times 10^{-6} C$ and $-4 \times 10^{-6} C$ are separated by a distance of $50\ cm$ in air. Find- (i) the point on the line joining the charges, where the electrostatic potential is zero. (ii) calculate the electrostatic potential energy of the system.	3
22	A network of four capacitors each of 10 μF capacitance is connected to a 500 V supply as shown in the figure. Determine the – (i) Equivalent capacitance of the network and (ii) Charge on each capacitor. 	3
23	Three capacitors of capacitances C_1, C_2 & C_3 are connected (a) in series (b) in parallel. Show that the energy stored in the series combination is the same as that in the parallel combination.	3
24	A parallel plate capacitor of plate area A and separation d is filled with dielectrics of dielectric constants K_1 and a K_2 shown in the figure. Find the net capacitance of the capacitor. 	3
25	If the battery is disconnected after charging a parallel plate capacitor and then dielectric slab is inserted then what will be the effect on its – (i) charge (ii) capacitance (iii) potential difference (iv) electric field, (v) energy stored ? Justify your answer	3
	Section-E(LA-5marks)	
26	(i) Derive an expression for the potential at a point along the axial line of a short dipole. For this dipole draw a plot showing the variation of potential V versus r, where r ($r \gg 2a$), is the distance from the point charge $-q$ along the line joining the two charges.  (ii) A point charge $+Q$ is placed at a point O as shown in the figure. Is the potential difference $V_A - V_B$ positive, negative or zero ? Justify your answer. 	5

27	(i) What is a capacitor? Deduce an expression for the capacitance of a parallel plate capacitor with air as the medium between the plates. (ii) A dielectric slab of thickness‘t’ is introduced without touching between the plates of a parallel plate capacitor separated by a distance ‘d’ ($t < d$). Derive an expression for the capacitance of the capacitor.	5

Section-F(Case Study Based)

28 **Electrostatic shielding:** 4

Whatever be the charge on the conductor and the external fields in which it might be placed. The electric field inside a charged spherical shell is zero. But the vanishing of electric field in the (charge-free) cavity of a conductor is, as mentioned above, a very general result. A related result is that even if the conductor is charged or charges are induced on a neutral conductor by an external field, all charges reside only on the outer surface of a conductor with cavity.
The proofs of the results noted in Fig. are omitted here, but we note their important implication.



Whatever be the charge and field configuration outside, any cavity in a conductor remains shielded from outside electric influence: the field inside the cavity is always zero. This is known as electrostatic shielding. The effect can be made use of in protecting sensitive instruments from outside electrical influence.

(i) A metallic shell having inner radius R_1 and outer radii R_2 has a point charge Q kept inside the cavity. Electric field in the region $R_1 < r < R_2$ where r is the distance from the centre is given by

(a) depends on the value of r
(b) Zero
(c) Constant and nonzero everywhere
(d) None of the above

(ii) The electric field inside the cavity is depend on

(a) Size of the cavity
(b) Shape of the cavity
(c) Charge on the conductor
(d) None of the above

(iii) Electrostatic shielding is based

(a) electric field inside the cavity of a conductor is less than zero

(b) electric field inside the cavity of a conductor is zero
(c) electric field inside the cavity of a conductor is greater than zero
(d) electric field inside the cavity of a plastic is zero

(iv) During the lightning thunderstorm, it is advised to stay
(a) inside the car
(b) under trees
(c) in the open ground
(d) on the car

OR

(iv a)Which of the following material can be used to make a Faraday cage (based on electrostatic shielding)
(a) Plastic (b) Glass
(c) Copper (d) Wood

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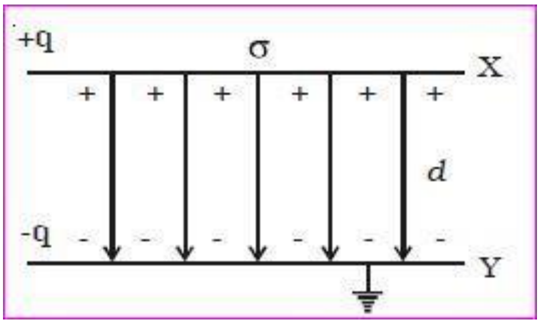
29 <u>Capacitance of a parallel plate capacitor:</u> 4

The parallel plate capacitor consists of two parallel metal plates X and Y each of area A, separated by a distance d, having a surface charge density σ as shown in figure. The medium between the plates is air. A charge +q is given to the plate X. It induces a charge –q on the upper surface of earthed plate Y. When the plates are very close to each other, the field is confined to the region between them. The electric lines of force starting from plate X and ending at the plate Y are parallel to each other and perpendicular to the plates. The capacitance is directly proportional to the area (A) of the plates and inversely proportional to their distance of separation (d). The capacitance (C) of the parallel plate capacitor is given by $C= \epsilon_0 A/d$. if the region between the two plates is filled with dielectric like mica or oil. Its capacitance increased by ϵ_r times of the medium.



(i) The potential difference between the two plates of a parallel plate capacitor is ____ (Q is magnitude of charge on each plate of area A separated by a distance d)

(a) $Qd/(\varepsilon_o A)$ (b) $d\varepsilon_o/AQ$
(c) $Ad/(\varepsilon_o Q)$ (d) $QA/d\varepsilon_o$

(ii) A capacitor is charged by a battery and the charging battery is disconnected and a dielectric slab is inserted in it. Then for the capacitor….
(a) Charge remains constant
(b) Charge increases
(c) Potential difference remains constant
(d) Potential difference increases

(iii)A parallel plate capacitor has a capacitance of 10 μF. If the distance between two plates is doubled then the new capacitance will be
(a) 20 μF (a) 15 μF (a) 10 μF (a) 5 μF

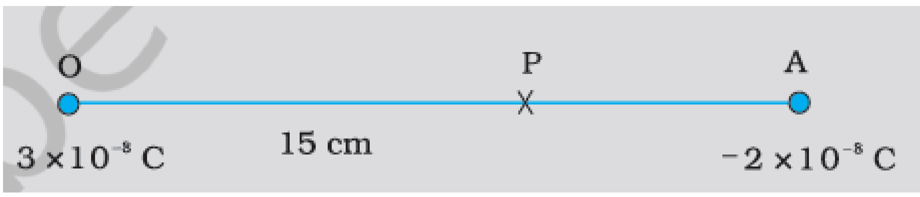
(iv) Capacitance of a parallel plate capacitor does not depend on:
(a) Area of the plates
(b) Type of metal used for plates
(c) Separating distance between the plates

	(d) Dielectric constant of the medium between the plates OR (iv *)A parallel plate air capacitor with no dielectric between the plates is connected to a constant voltage source. What happens to the capacitance if a dielectric of dielectric constant k = 2 is inserted between the plates? (a) Capacitance decreases (b) Capacitance increases by two times (c)Capacitance remains unchanged (d) insufficient data	

ELECTROSTATIC POTENTIAL AND CAPACITANCE

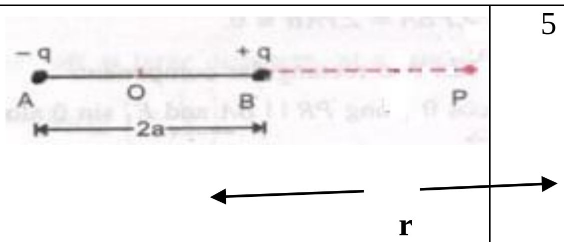
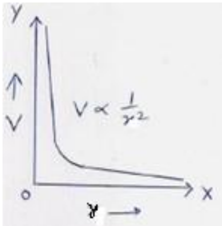
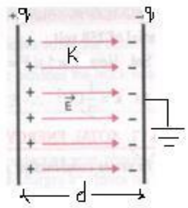
Solution:

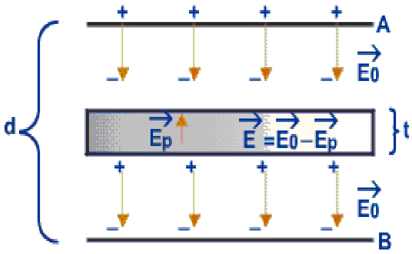
Section-A(MCQ)		
SN	Answer/Solution	Marks
1	(a) Electric potential V=w/q	1
2	(b) 22.5 V= k Q/r $=9X10^9$ X $5X10^{-6}$ /2 =22.5 V	1
3	(c) 0 J No work done in bringing a charge from one point to another on an equipotential suface.	1
4	(b) − 1.44 J $U = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r} = -9X10^9 \text{ X} \frac{20 \text{ X } 10^{-6} \text{ X } 4 \text{ X } 10^{-6}}{50X\ 10^{-2}} =$ − 1.44 J	1
5	(b) Electric field is always parallel to the equipotential surface at every point At an equipotential surface $V_1 = V_2$ Hence work done, $W = q_0(V_1 - V_2) = 0$ ⇨ F S cos θ = 0, ⇨ cos θ = 0 ⇨ $\theta = 90^0$ Electric field is always perpendicular to the equipotential surface at every point	1
6	(c) 200V The line joining B to C is perpendicular to electric field, so potential of B = potential of i.e., $V_B = V_C$. Distance AB = 4cm Potential difference between A and C = E x (AB) = 5 x 10^3 x (4 x 10^{-2}) = 200volt	1
7	(c) Charge on the plates	1

8	(d) 6V Equivalent Capacitance = 6/11 X 10 $^{-6}$ F Total charge of the combination, Q=CV = 6 X 10 $^{-6}$ F Potential difference across the plates of the first capacitor, $V_1=Q/C_1=6V$	1
9	(d) 5V because potential of a metallic sphere remains unchanged inside the sphere	1
10	(c) $C_A<C_B$ **Reason :** $C = \frac{q}{V}$ If V = constant then C a q As $q_B > q_A \Rightarrow C_B > C_A$	1
Section-B(Assertion and reason)		
11	B	1
12	B	1
13	A	1
14	A	1
15	A	1
Section-C(SA-2marks)		
16	$V = E_0(d-t) + \frac{E_0}{K}t = E_0\left[(d-3d/4) + \frac{3d/4}{K}\right] = \frac{E_0 d}{4}(1+\frac{3}{K}) = \frac{V_0}{4}(\frac{K+3}{K})$ $C = \frac{q_0}{V} = \frac{q_0}{\frac{V_0}{4}(\frac{K+3}{K})} = \frac{4K}{(K+3)}\frac{q_0}{V_0} = \frac{4K}{(K+3)}C_0$	2
17	The equivalent capacitance of C_5&C_6 is. $C_{56}=C_5+C_6 \Rightarrow C_{56}=10+10 \Rightarrow C56=20\mu F$ The Equivalent Capacitance of C_2, C_3 & C_4 connected in series C_{234}= 20µF Now . C_{56} & C_{234} are in parallel The equivalent capacitance is C_{23456} =40µF C_1 and C_{23456} are in series The equivalent capacitance is C_{123456}= 20µF The charge is follows. Q=CV ⇒Q=20µF×100V ⇒Q=2mC	2
18	Let us take the origin O at the location of the positive charge. The line joining the two  charges is taken to be the *x*-axis; the negative charge is taken to be on the right side of the origin. Let P be the required point on the x-axis where the potential is zero. If x is the X-coordinate of P, obviously x must be positive. (There is no possibility of potentials due to the two charges adding up to zero for $x < 0$.) If x lies between O and A, we have	2

	$\frac{1}{4\pi\epsilon_0}\left[\frac{3X\,10^{-8}}{x\,X\,10^{-2}}+\frac{2X\,10^{-8}}{(15-x)X\,10^{-2}}\right]=0$ $\frac{3}{x}+\frac{2}{15-x}=0$ Which gives *x* = 9 cm. If x lies on the extended line OA, the required condition is $\frac{3}{x}+\frac{2}{x-15}=0$ Which gives *x* = 45 cm. Thus, electric potential is zero at 9 cm and 45 cm away from the positive charge on the side of the negative charge	
19	$C=C_1+C_2=\frac{K_1\epsilon_0 A/2}{d}+\frac{K_2\epsilon_0 A/2}{d}$ $\Rightarrow C=\frac{\epsilon_0 A}{2d}(K_1+K_2)=\frac{\epsilon_0 A}{d}\left(\frac{K_1+K_2}{2}\right)=\left(\frac{K_1+K_2}{2}\right)C_0$	2
20	(i) No work is done in moving a unit positive charge from *A* to *B* because the displacement of the charge is perpendicular to the electric field. Thus the points *A* and *B* are at the same potential. $\therefore \Delta V_{BA}=0$ Work is done by the electric field as the positive charge moves from *B* to *C* (i.e., in the direction of *E*). Thus the point *C* is at a lower potential than the point *B*. $\Delta V_{CB}=-E\,\Delta x=-300\,NC^{-1}\times 7\,m=-2100\,V$. Points *A* and *B* lie on an equipotential surface. So V_{AB}= -2100 V	2
Section-D(SA-3marks)		
21	**[Ans. (i)** $\frac{1}{4\pi\epsilon_0}\frac{q_1}{r_1}+\frac{1}{4\pi\epsilon_0}\frac{q_2}{r_2}=0 \Rightarrow \frac{20\,X\,10^{-6}}{x}+\frac{-4\,X\,10^{-6}}{(50-x)}=0$ $\Rightarrow \frac{20}{x}=\frac{4}{(50-x)} \Rightarrow x=\frac{250}{6}=41\,cm$ **(ii)** $U=\frac{1}{4\pi\epsilon_0}\frac{q_1q_2}{r}=-9X10^9\,X\,\frac{20\,X\,10^{-6}\,X\,4\,X\,10^{-6}}{50X\,10^{-2}}=-1.44$ J	3
22	(i) equivalent capacitance of the network and (ii) charge on each capacitor $\frac{1}{C'}=\frac{1}{C_1}+\frac{1}{C_2}+\frac{1}{C_3}=\frac{1}{10}+\frac{1}{10}+\frac{1}{10}=\frac{3}{10} \Rightarrow C'=\frac{10}{3}\mu F$ $\Rightarrow$ equivalent capacitance, $C=C'+C_4=\frac{10}{3}+10=\frac{40}{3}\mu F$	3

	(ii) charge on C_4, $q_4 = C_4 \text{ X } V = 10 \text{ X } 10^{-6} \text{ X } 500 = 5 \text{ X } 10^{-3} C$ $$q_1 = q_2 = q_3 = C' \text{ X } V = \frac{10}{3} \text{ X } 10^{-6} \text{ X } 500 = \frac{5}{3} \text{ X } 10^{-3} C$$	
23	**(i) In series,** $U_s = \frac{Q^2}{2C_s} = \frac{1}{2} Q^2 \left(\frac{1}{C_s}\right) = \frac{1}{2} Q^2 \left(\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}\right) = \frac{1}{2}\frac{Q^2}{C_1} + \frac{1}{2}\frac{Q^2}{C_2} + \frac{1}{2}\frac{Q^2}{C_3}$ ⇨ $U_s = U_1 + U_2 + U_3$ **(ii) In parallel,** $U_P = \frac{1}{2} C_P V^2 = \frac{1}{2}(C_1 + C_2 + C_3)V^2 = \frac{1}{2} C_1 V^2 + \frac{1}{2} C_1 V^2 + \frac{1}{2} C_1 V^2$ ⇨ $U_P = U_1 + U_2 + U_3$	3
24	$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} = \frac{1}{\frac{K_1 \varepsilon_0 A}{d/2}} + \frac{1}{\frac{K_2 \varepsilon_0 A}{d/2}} = \frac{d/2}{K_1 \varepsilon_0 A} + \frac{d/2}{K_2 \varepsilon_0 A}$ ⇨ $\frac{1}{C} = \frac{d}{2\varepsilon_0 A}\left(\frac{1}{K_1} + \frac{1}{K_2}\right) = \frac{d}{2\varepsilon_0 A}\left(\frac{K_1 + K_2}{K_1 K_2}\right)$ ⇨ $C = \left(\frac{2K_1K_2}{K_1 + K_2}\right) C_0$	3
25	Given that, A parallel plate capacitor is charged by a battery. The battery is disconnected and a dielectric slab with its thickness equal to the plate separation is inserted between the plates. (i).The battery is disconnected so the charge on capacitor remains constant. (ii).The capacitance without dielectric is $C = \frac{A\epsilon_0}{d}$ When dielectric slab is inserted, then the capacitance $C' = \frac{kA\epsilon_0}{d}$ $C' = kC$ Where, k = constant (iii) We need to calculate the electric field intensity between the plates Using formula of electric field $E = \frac{V}{d}$ Where, V = potential difference and d = separation between the plates. Potential difference decreases and d remains the same and electric field also decreases. (iv). potential difference $V = \frac{Q}{C}$ As C increases and Q remains the same since the battery is disconnected, the	3

	potential difference between the plate's decreases. (v) energy store $U = \frac{1}{2}\frac{Q^2}{C}$ As Q is constant So, Capacitance will be increases then stored energy will be decreases.	
Section-E(LA-5marks)		
26	(i)Let V_1 and V_2 be the electric potential at P due to $-q$ and $+q$ charges respectively then  $V_1 = \frac{-q}{4\pi\varepsilon_0(r+a)}$ & $V_2 = \frac{q}{4\pi\varepsilon_0(r-a)}$ Resultant electric potential at P $V = V_1 + V_2 = \frac{-q}{4\pi\varepsilon_0(r+a)} + \frac{q}{4\pi\varepsilon_0(r-a)}$ $= \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{(r-a)} - \frac{1}{(r+a)}\right] = \frac{q}{4\pi\varepsilon_0}\left[\frac{r+a-(r-a)}{(r^2-a^2)}\right]$ ⇨ $V = \frac{1}{4\pi\varepsilon_0}\frac{2qa}{(r^2-a^2)}$ ⇨ $V = \frac{1}{4\pi\varepsilon_0}\frac{p}{(r^2-a^2)}$ $[\because p = 2qa]$  Obviously, if $r \gg a$, then $V = \frac{1}{4\pi\varepsilon_0}\frac{p}{r^2}$ **(ii)** Positive as $V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$ ⇨ $V \propto \frac{1}{r}$]	5
27	**(i)Capacitor :**It is an arrangement required to increase the capacity of a conductor so that a large amount of charge can be stored in it without changing its dimensions  **Capacitance of ‖ plate capacitor :** let us consider a parallel plate capacitor filled with a medium of dielectric constant K as shown Electric field between the plates $E = \frac{\sigma}{\varepsilon_0 K} = \frac{q}{\varepsilon_0 KA}$ ⇨ potential difference between the plates $V = E\,d = \frac{q\,d}{\varepsilon_0 KA}$ ⇨ $C = \frac{q}{V} = \frac{q}{\frac{q\,d}{\varepsilon_0 KA}} = \boldsymbol{K}\frac{\varepsilon_0 \boldsymbol{A}}{\boldsymbol{d}}$ If air is as the medium between the plates then, $K = 1$	5

	⇨ $C_0 = \frac{\varepsilon_0 A}{d}$ (ii) Electric field between the plates in air $E_0 = \frac{q}{\varepsilon_0 A}$ Electric field in dielectric slab $E = E_0 - E_p = E_0 - \frac{\sigma_p}{\varepsilon_0} = \frac{E_0}{K} = \frac{q}{\varepsilon_0 K A}$ ⇨ potential difference between the plates $V = E_0 (d - t) + \frac{E_0}{K} t = E_0 [(d - t) + \frac{t}{K}] = \frac{q}{\varepsilon_0 A} [(d - t) + \frac{t}{K}]$ ⇨ $C = \frac{q}{V} = \frac{q}{\frac{q}{\varepsilon_0 A}[(d-t)+\frac{t}{K}]}$ ⇨ $C = \frac{\varepsilon_0 A}{(d-t)+\frac{t}{K}}$ 	
Section-F(Case Study Based)		
28	i. b ii. d iii. b iv. a OR iv*. C	4
29	i. a ii. a iii. d iv. b OR iv*. B	4

MCQ

Q.1 In an electrical cable there is a single wire of radius 9 mm of copper. Its resistance is 5 ohms. The cable is replaced by 6 different insulated copper wires, the radius of each wire is 3mm. Now the total resistance of the cable will be

(a) 9 A (b) 0.9 A (c) 1/9 A (d) 1/0.9 A

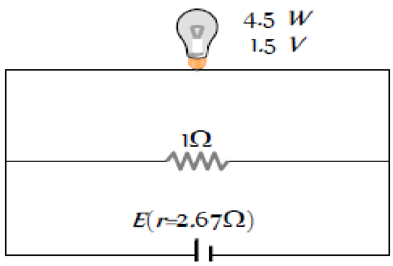
Q.2 When connected across the terminals of a cell, a voltmeter measure 5V and a connected ammeter measures 10 A of current. A resistance of 2 ohms is connected across the terminals of the cell. The current flowing through this resistance will be

(a) 2.5 A (b) 2.0 A (c) 5.0 A (d) 7.5 A

Q.3 There are three resistance coils of equal resistance. The maximum number of resistances you can obtain by connecting them in any manner you choose, being free to use any number of the coils in any way is

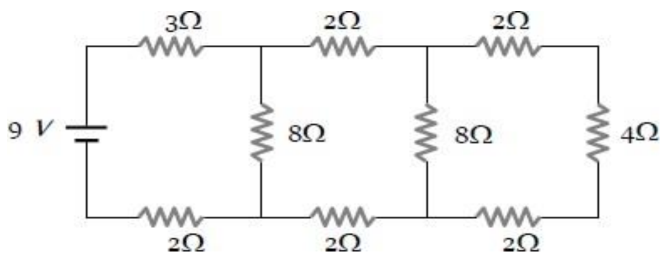
(a) 3 (b) 4 (c) 6 (d) 5

Q.4 A torch bulb rated as 4.5 W; 1.5 V is connected as shown in the figure. The e.m.f. of the cell needed to make the bulb glow at full intensity is



(a) 4.5 V (b) 1.5 V (c) 2.67 V (d) 13.5 V

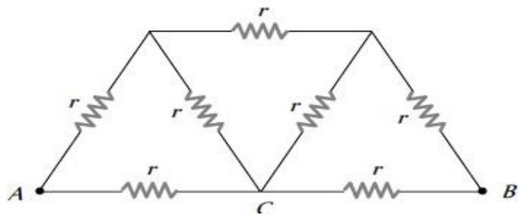
Q.5 In the circuit shown in the figure, the current through



(a) The 3 ohm resistor is 0.50A (b) The 3 ohm resistor is 0.25 A

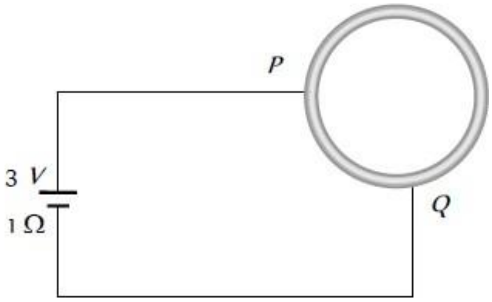
(c) The 4 ohm resistor is 0.50A (d) The 4 ohm resistor is 0.25 A

Q.6 In the circuit shown, the value of each resistance is r, then equivalent resistance of circuit between points A and B will be



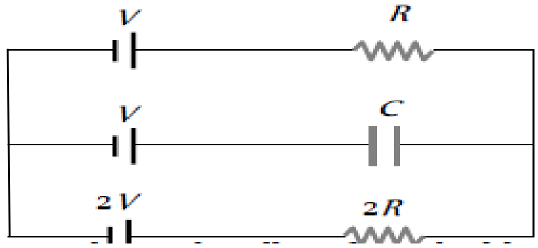
(a) (4/3) r (b) 3r / 2 (c) r / 3 (d) 8r / 7

Q.7 A wire of resistance 10 ohm is bent to form a circle. P and Q are points on the circumference of the circle dividing it into a quadrant and are connected to a Battery of 3 V and internal resistance 1 ohm as shown in the figure. The currents in the two parts of the circle are



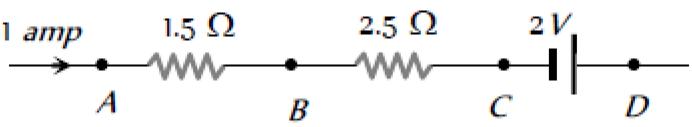
(a) 6/23 A and 18/23 A
(b) 5/26 A and 15/26 A
(c) 4/25 A and 12/25 A
(d) 3/25 A and 9/25 A

Q.8 In the given circuit, with steady current, the potential drop across the capacitor must be



(a) V (b) V / 2 (c) V / 3 (d) 2V / 3

Q.9 In the circuit element given here, if the potential at point B, V = 0, potentials of A and D are given as



(a) V_A = - 1.5 V, V_D = +2 V
(b) V_A = +1.5 V, V_D = +2 V
(c) V_A = +1.5 V, V_D = +0.5 V
(d) V_A = +1.5 V, V_D = -0.5 V

Q.10 The current in a conductor varies with time t as $I = 2t + 3t^2$ where I is in ampere and t in seconds. Electric charge flowing through a section of the conductor during t = 2 sec to t = 3 sec is- (a) 10 C (b) 24 C (c) 33 C (d) 44 C

SOLUTION

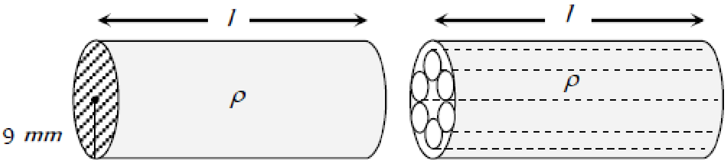
Q.1

(a) Initially : Resistance of given cable

$$R = \rho \frac{l}{\pi \times (9 \times 10^{-3})^2} \quad \text{...(i)}$$

Finally : Resistance of each insulated copper wire is

$R' = \rho \frac{l}{\pi \times (3 \times 10^{-3})^2}$. Hence equivalent resistance of cable $R_{eq} = \frac{R'}{6} = \frac{1}{6} \times \left(\rho \frac{l}{\pi \times (3 \times 10^{-3})^2} \right)$ ....(ii)



On solving equation (i) and (ii) we get $R_{eq} = 7.5\ \Omega$

Q.2

(b) Emf $E = 5V$, Internal resistance $r = \frac{5}{10} = 0.5\Omega$

Current through the resistance $i = \frac{5}{(2 + 0.5)} = 2A$

Q.3 (b) Maximum number of resistances = $2^{n-1} = 2^{3-1} = 4$

Q.4

(d) Current in the bulb $= \frac{P}{V} = \frac{4.5}{1.5} = 3A$

Current in 1 Ω resistance $= \frac{1.5}{1} = 1.5A$

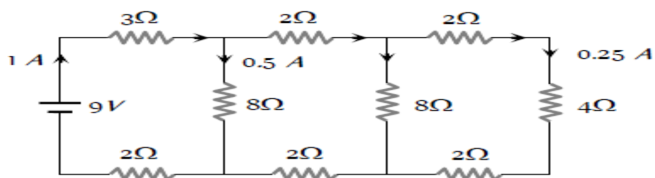
Hence total current from the cell $i = 3 + 1.5 = 4.5A$

By using $E = V + ir \Rightarrow E = 1.5 + 4.5 \times (2.67) = 13.5V$

Q.5

(d) Equivalent resistance of the circuit $R = 9\Omega$

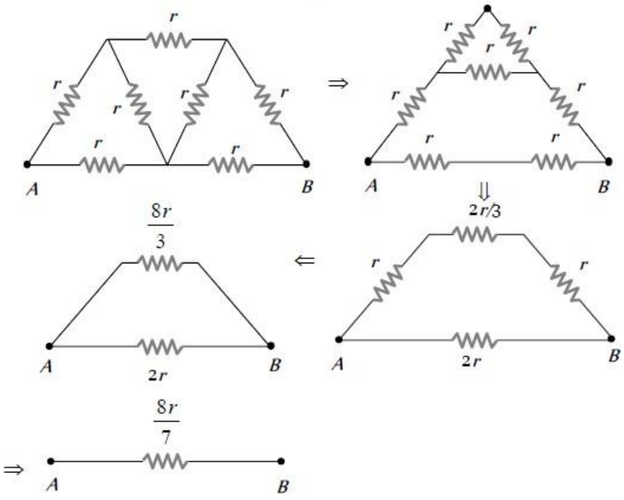
$\therefore$ Main current $i = \frac{V}{R} = \frac{9}{9} = 1A$



After proper distribution, the current through 4Ω resistance is 0.25 A.

Q.6

(d) The given circuit can be simplified as follows.



Q.7

(a) In the following figure

Resistance of part *PNQ*;

$R_1 = \frac{10}{4} = 2.5\Omega$ and

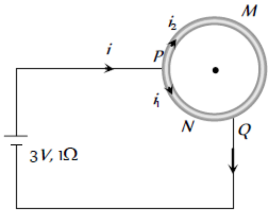
Resistance of part *PMQ*;

$R_2 = \frac{3}{4} \times 10 = 7.5\Omega$

$R_{eq} = \frac{R_1 R_2}{R_1 + R_2} = \frac{2.5 \times 7.5}{(2.5 + 7.5)} = \frac{15}{8}\Omega$.

Main Current $i = \frac{3}{\frac{15}{8} + 1} = \frac{24}{23} A$

So, $i_1 = i \times \left(\frac{R_2}{R_1 + R_2}\right) = \frac{24}{23} \times \left(\frac{7.5}{2.5 + 7.5}\right) = \frac{18}{23} A$



and $i_2 = i - i_1 = \frac{24}{23} - \frac{18}{23} = \frac{6}{23} A$.

Q. 8

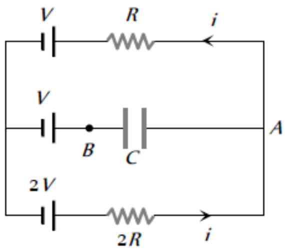
(c) Moving anticlockwise from *A*

$-iR - V + 2V - 2iR = 0$

or $3iR = V$ or $i = \frac{V}{3R}$

$V_A - V_B = iR + V - V = iR$

$\Rightarrow$ Potential drop across $C = \frac{V}{3}$



Q. 9

(d) Potential difference between A and B

$V_A - V_B = 1 \times 1.5$

$\Rightarrow V_A - 0 = 1.5V \Rightarrow V_A = 1.5V$

Potential difference between B and C

$V_B - V_C = 1 \times 2.5 = 2.5V$

$\Rightarrow 0 - V_C = 2.5V \Rightarrow V_C = -2.5V$

Potential difference between C and D

$V_C - V_D = -2V \Rightarrow -2.5 - V_D = -2 \Rightarrow V_D = -0.5V.$

Q. 10

(b) $dQ = Idt \Rightarrow Q = \int_{t=2}^{t=3} Idt = \left[2\int_2^3 tdt + 3\int_2^3 t^2 dt\right]$

$= \left[t^2\right]_2^3 + \left[t^3\right]_2^3 = (9-4) + (27-8) = 5 + 19 = 24C.$

Q11. Assertion and Reason Questions -

Read the assertion and reason carefully to mark the correct option out of the options given below:

(a) If both assertion and reason are true and the reason is the correct explanation of the assertion.

(b) If both assertion and reason are true but reason is not the correct explanation of the assertion.

(c) If assertion is true but reason is false.

(d) If assertion is false but reason is true.

Q.11 Assertion: The resistivity of a semiconductor increases with temperature.

Reason: The atoms of a semiconductor vibrate with larger amplitude at higher temperatures thereby increasing its resistivity

Q.12 Assertion: The temperature coefficient of resistance is positive for metals and negative for p-type semiconductor.

Reason: The effective charge carriers in metals are negatively charged whereas in p-type semiconductor they are positively charged.

Q.13 Assertion: Electric appliances with metallic body have three connections, whereas an electric bulb has a two pin connection.

Reason: Three pin connections reduce heating of connecting wires.

Q.14 Assertion: In meter bridge experiment, a high resistance is always connected in series with a galvanometer.

Reason: As resistance increases current through the circuit Increases.

Q.15 Assertion: Electric field outside the conducting wire which carries a constant current is zero.

Reason: Net charge on conducting wire is zero.

ANSWERS

Q.11 (d) Resistivity of a semiconductor decreases with the temperature. The atoms of a semiconductor vibrate with larger amplitudes at higher temperatures thereby increasing it's conductivity not resistivity.

Q.12 (b) The temperature co-efficient of resistance for metal is positive and that for semiconductor is negative. In metals free electrons (negative charge) are charge carriers while in P-type semiconductors, holes (positive charge) are majority charge carriers.

Q.13 (c) The metallic body of the electrical appliances is connected to the third pin which is connected to the earth. This is a safety precaution and avoids eventual electric shock. By doing this the extra charge flowing through the metallic body is passed to earth and avoid shocks. There is nothing such as reducing of the heating of connecting wires by three pin connections.

Q.14 (c) The resistance of the galvanometer is fixed. In meter bridge experiments, to protect the galvanometer from a high current, high resistance is connected to the galvanometer in order to protect it from damage.

Q.15 (a) When current flows through a conductor it always remains uncharged, hence no electric field is produced outside it.

2 Marks

Q. 16 Two conducting wires X and Y of same diameter but different materials are joined in series across a battery. If the number density of electrons in X is twice that in Y, find the ratio of drift velocity of electrons in the two wires.

ANSWER: $I \propto nv_d$ i.e. V_{dx}/V_{dy}
= ny/nx = ½

Q.17 Two cells each of emf E and internal resistances r1 and r2 are connected in series to an external resistance R. Can a value of R be selected such that the potential difference of the first cell is 0.

ANSWER- $I = 2\mathcal{E}/(R + r1 + r2)$
Potential diff. for first cell $V1 = \mathcal{E} - I\, r1 = 0$
$\mathcal{E} = (2\, \mathcal{E}\, r1)/R + r1 + r2$
Solving these we get, R = r1 - r2

Q.18 How does the balancing point of a Wheatstone bridge get affected when (i) Position of cell and Galvanometer are interchanged? (ii) Position of the known and unknown resistances is interchanged?

ANSWER

(1) There will be no change in the balance point condition of Wheatstone bridge even if galvanometer and cell are interchanged.

(2) Position of known and unknown resistance is interchanged. 1. There will be no change in the balance point condition of Wheatstone bridge even if galvanometer and cell are interchanged.

Q.19 A set of n-identical resistors, each of resistance R ohm when connected in series have an effective resistance of X ohm and when the resistors are connected in parallel the effective resistance is Y ohm. Find the relation between R , X and Y ?

ANSWER

n – resistors connected in series

X = nR........................1)

n – Resistors connected in parallel

Y =R/n........................2)

Multiply eg. (1) & (2)

$XY = R^2$

$R = (XY)^{1/2}$

Q.20 Under what condition will the current in a wire be the same when connected in series and in parallel of n identical cells each having internal resistance r and external resistance R?

ANSWER

Let emf of each cell be 'E'.

If cells are connected in series:

current through 'R' =nE/nr+R

If cells are connected in parallel:

current through 'R' =nE/r+nR

For the currents to be equal,

r+nR=nr+R

⇒r=R

3 Marks

Q.21 A number of identical cells, n, each of emf E, internal resistance r connected in series are charged by a d.c. source of emf E', using a resistor R.

(i) Draw the circuit arrangement.

(ii) Deduce the expressions for (a) the charging current and (b) the potential difference across the combination of the cells.

ANSWER

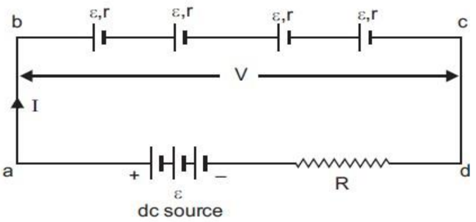
(i) The circuit arrangement is shown in fig.

(ii) Applying Kirchhoff's second law to the circuit *abcda*

$$-n\varepsilon - I(nr) - IR + \varepsilon' = 0$$

$$\Rightarrow \qquad I = \frac{\varepsilon' - n\varepsilon}{R + nr}$$

(a) Charging current, $I = \dfrac{\varepsilon' - n\varepsilon}{R + nr}$ ...(a)



(b) Potential difference across the combination V is given by

$$-V - IR + \varepsilon' = 0$$

$$\Rightarrow \qquad V = \varepsilon' - IR$$

$$\Rightarrow \qquad V = \varepsilon' - \frac{(\varepsilon' - n\varepsilon)}{R + nr} \qquad \Rightarrow \qquad V = \frac{\varepsilon'(R + nr) - \varepsilon' + n\varepsilon}{R + nr}$$

$$\Rightarrow \qquad V = \frac{\varepsilon'(R + nr - 1) + n\varepsilon}{R + nr}$$

Q.22 A conductor of length 'l' is connected to a d.c. source of potential 'V'. I the length of the conductor is tripled, stretching it, keeping 'V" constant. Explain how do the following factors vary in the conductor -(I) drift speed of electrons (II) resistance

ANSWER

(i) drift speed of an electron

Vd a 1/l

when the wire length is tripled, drift velocity gets one third

(ii) resistance of conductor

R=ρa/l

mass of the wire remains the same in both the conditions

mass before stretching = mass after stretching

$m_1=m_2$

$v_1\rho_1 = v_2\rho_2$ $\quad$ $a_1l_1 = a_2l_2$

$a_1l=a_2(3l)$

$\Rightarrow a_2=3a_1$

R=ρa′l′=ρ3a3l=9aρl=9R

new resistance is 9 times the original resistance.

Q.23 A boy has two wires of iron and copper of equal length and diameter. He first joins the two wires in series and passes electric current through this combination which increases gradually with time. After that he joins them in parallel and repeat the process of passing the current in this arrangement also. Which wire will glow first in each case and why?

ANSWER

We know that resistivity of iron is more than that of copper.

In series combination, the same current I flows through iron and copper wires.

Heat produced, $H=I^2Rt=I^2\rho l/A$

i.e. H a ρ

As $\rho_{iron} > \rho_{Cu}$

So,

$H_{iron} > H_{Cu}$.

Therefore, iron will start glowing first in series combination. In parallel combination, the voltage V is same across iron and copper wires,

So Heat produced, $H=V_2t/R=V^2tA/\rho l$

i.e., H a 1/ρ

As, $\rho_{iron} > \rho_{Cu}$

So,

$H_{iron} < H_{Cu}$

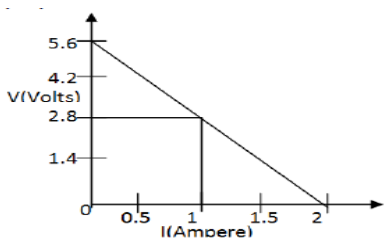
Therefore, copper will start glowing first in parallel combination of wires.

Q.24 4 cells of identical emf E1, internal resistance r are connected in series to a variable resistor. The following graph shows the variation of terminal voltage of the combination with the current output.

(i) What is the emf of each cell used?

(ii) For what current from the cells, does maximum power dissipation occur in the circuit?

(iii) Calculate the internal resistance of each cell



ANSWER

$4E = 5.6$ $E = 1.4$ V

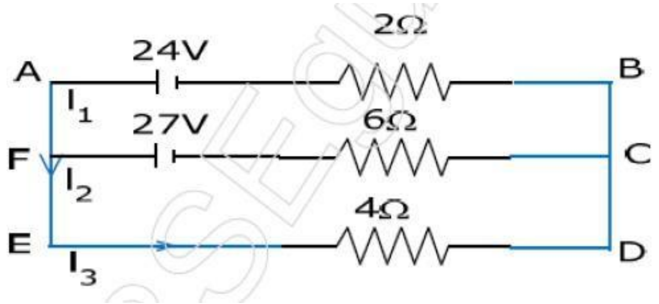
When I = 1A, V = 2.8/4 = 0.7V

Internal resistance, r= (E – V)/I = 0.7Ω

The output power is maximum when internal resistance = external resistance

$= 4r.I_{max} = 4E/ (4r + 4r) = 1A$

Q.25 Using Kirchoff's law, determine the current I_1 , I_2 and I_3 for the network shown.



ANSWER

Applying junction rule at point F

$I_1 = I_2 + I_3$-----------------------(1)

Loop rule for BAFCB

$2I_1 + 6I_2 – 24 + 27 = 0$

$2I_1 + 6I_2 + 3 = 0$-------- (2)

Loop rule for FCDEF

$27 + 6I_2 – 4I_3 = 0$ -------- (3)

Solving eg . (1) , (2) & (3) we get

I_1 =3A,

I_2 = -1.5A,

I_3 = 4.5A

Case Based Study

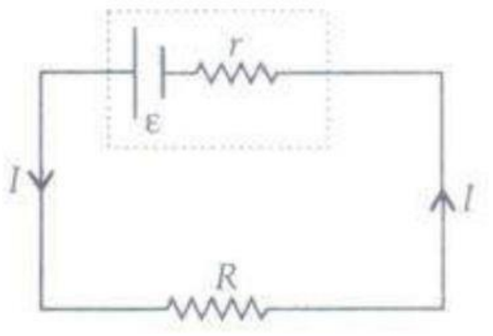
Q. 26 Emf of a cell is the maximum potential difference between two electrodes of the cell when no current is drawn from the cell. Internal resistance is the resistance offered by the electrolyte of a cell when the electric current flows through it. The internal resistance of a cell depends upon the following factors;

(i) distance between the electrodes

(ii) nature and temperature of the electrolyte

(iii) nature of electrodes

(iv) 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 and its value is always less than the emf of the cell in a closed circuit. It can be written as V = E - Ir.

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

a) during charging b) during discharging

c) both a and b d) I= 0

(ii) A cell of emf ε 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. internal resistance of the cell and emf of the cell are

a)1Ω, 6.5 V b) 5Ω, 6.5 V c) 1Ω, 7.5 V d) 5Ω, 7.5 V

(iii) Choose the wrong statement.

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

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

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

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

(iv) An external resistance R is connected to a cell of internal resistance r, the maximum current flows in the external resistance, when

(a) R = r (b) R < r (c) R> r (d) R=0

ANSWER

(i) d) I= 0

(ii) a)1Ω, 6.5 V

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

(iv) (d) R=0

Q.27 When a conductor does not have a current through it, its conduction electrons move randomly, with no net motion in any direction. When the conductor does have a current through it, these electrons actually still move randomly, but now they tend to drift with a drift speed Vd in the direction opposite to the applied electric field that causes current. The drift speed is very small as compared to the speeds in the random motion. For example, in the copper conductors of household wiring, electron drift speeds are perhaps 105 m/s to 103 m/s, where as the random speed is around 10 ms^{-1}.

(i) The electron drift speed is estimated to be only a few mm s -1 for currents in the range of a few amperes? How is current established almost the instant a circuit is closed?

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

(iii) 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?

(iv) 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?

ANSWER

(i) As soon as a circuit is closed, everywhere in conductor, electric field is set up (with the speed of light), and the conduction of electron at every point experience a drift.

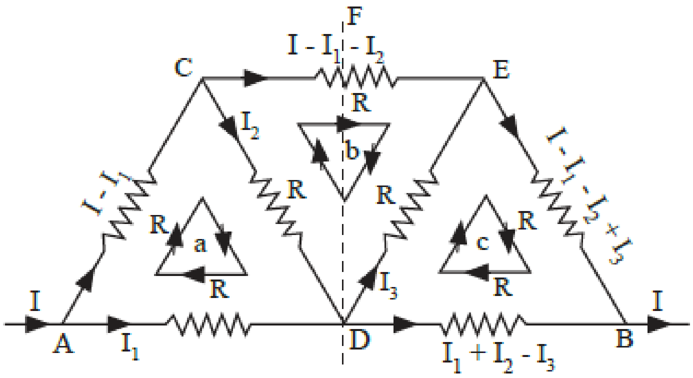
(ii) Each conduction electron does accelerate, and gain speed until it collides with a positive ion of a conductor, thereby losing its drift speed after collision again it gains kinetic energy but suffers a collision again and so on. Therefore, on the average, electron acquire only a drift speed.

(iii) As number of the density of electrons (≈ 1029 m-3) is very large, therefore current flowing is large.

(iv) No. When electric field is applied, the net drift of the electrons is from lower to higher potential. But locally electrons collide with ions and may change its direction during the course of their motion.

5 Marks

Q.28 Calculate equivalent resistance between A and B.



ANSWER

After distribution of current using Kirchhoff's

Loop rule for,

Loop a:

$-(I - I_1)R - I_2R + I_1R = 0$

$2I_1 - I_2 = 1$

Loop b:

$-(I - I_1 - I_2)R + I_2R + I_3R = 0$

$I_1 + 2I_2 + I_3 = I$

Loop c:

$-I_3R - (I - I_1 - I_2 + I_3)R + (I_1 + I_2 - I_3)R = 0$

$2I_1 + 2I_2 - 3I_3 = I$

Solving -

$I_1 = 4/7\ I$

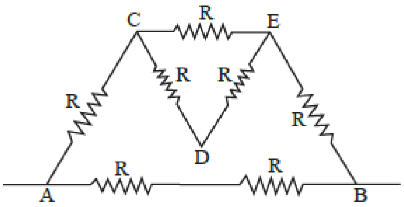
$I_2 = 1/7\ I$

$I_3 = 1/7\ I$

Where $I_2 = I_3$

So, no distribution of current takes place at D so it is

a pseudo junction. The equivalent circuit becomes,



Resistance of triangle DCE is R parallel to

(R+R) = 2/3R

Resistance of network other than AB

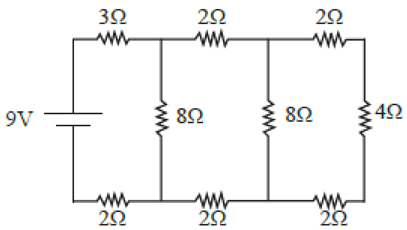
= R + 2/3R + R = 8/3R

Equivalent resistance between AB -

$1/R_{eq} = 1/2R + 1/[(8/3)R]$

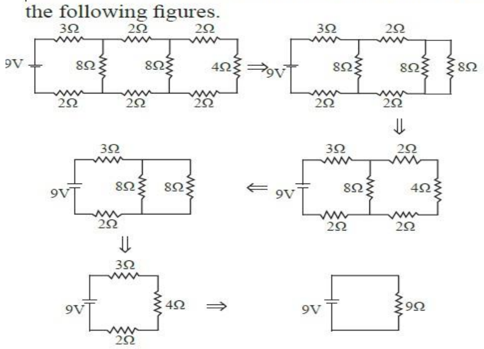
$R_{eq} = 8/7R$

Q.29 Find the current through 4 ohm resistor.



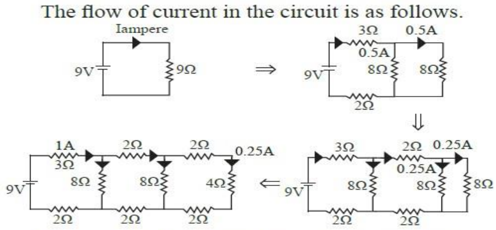
ANSWER

The net resistance of the circuit is 9 Ω as shown in the following figures.



$$I = \frac{V}{R} = \frac{9}{9} = 1.0\ \text{A}$$

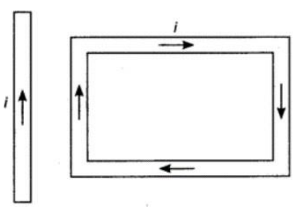
The flow of current in the circuit is as follows.



The current divides into two equal parts if passes through two equal resistances in parallel. Thus, current through 4 Ω resistor is 0.25 A.

COMPETENCY BASED QUESTIONS WITH SOLUTIONS

Magnetic Effect of Current and Magnetism

MCQ		
1.	Biot-Savart law indicates that the moving electrons (velocity v) produce a magnetic field B such that (a) B perpendicular to v (b) B || v (c) it obeys inverse cube law. (d) it is along the line joining the electron and point of observation	
2.	A current carrying circular loop of radius R is placed in the x-y plane with centre at the origin. Half of the loop with $x > 0$ is now bent so that it now lies in the $y – z$ plane. (a) The magnitude of magnetic moment now diminishes. (b) The magnetic moment does not change. (c) The magnitude of B at (0.0.z), z» R increases. (d) The magnitude of B at (0, 0, z), z » R is unchanged	
3.	An electron is projected with uniform velocity along the axis of a current carrying long solenoid. Which of the following is true? (a) The electron will be accelerated along the axis. (b) The electron path will be circular about the axis. (c) The electron will experience a force at 45° to the axis and hence execute a helical path. (d) The electron will continue to move with uniform velocity along the axis of the solenoid.	
4.	A rectangular loop carrying a current i is situated near a long straight wire such that the wire is parallel to the one of the sides of the loop and is in the plane of the loop. If a steady current I is established in wire as shown in figure, the loop will  (a) rotate about an axis parallel to the wire. (b) move away from the wire or towards right. (c) move away from the wire or towards right. (d) remain stationary.	
5.	A circular coil of radius 4 cm and of 20 turns carries a current of 3 amperes. It is placed in a magnetic field of intensity of 0.5 weber/m². The magnetic dipole moment of the coil is (a) 0.15 Am^2 (b) 0.3 Am^2 (c) 0.45 Am^2 (d) 0.6 Am^2	

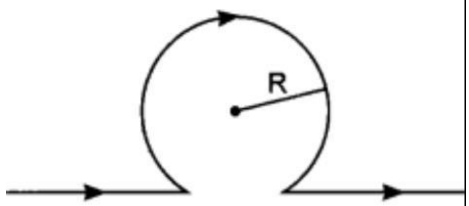
6. The strength of magnetic field at the centre of circular coil is

(a) $\frac{\mu_0 I}{R}\left(1-\frac{1}{\pi}\right)$

(b) $\frac{\mu_0 I}{\pi R}$

(c) $\frac{\mu_0 I}{2R}\left(1-\frac{1}{\pi}\right)$

(d) $\frac{\mu_0 I}{2R}\left(1+\frac{1}{\pi}\right)$



7. If a charged particle moves through a magnetic field perpendicular to it

(a) both momentum and energy of particle change.

(b) momentum as well as energy are constant.

(c) energy is constant but momentum changes.

(d) momentum is constant but energy changes.

8. The maximum current that can be measured by a galvanometer of resistance 40 Ω is 10 mA.

It is converted into voltmeter that can read upto 50 V. The resistance to be connected in

the series with the galvanometer is

(a) 2010 Ω (b) 4050 Ω (c) 5040 Ω (d) 4960 Ω

9. A charged particle is moving on circular path with velocity v in a uniform magnetic field B,

if the velocity of the charged particle is doubled and strength of magnetic field is halved,

then radius becomes

(a) 8 times (b) 4 times (c) 2 times (d) 16 times

10. Two a-particles have the ratio of their velocities as 3 : 2 on entering the field. If they move in different circular paths, then the ratio of the radii of their paths is

(a) 2 : 3 (b) 2 : 3 (c) 4 : 9 (d) 9 : 4

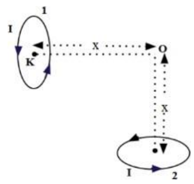
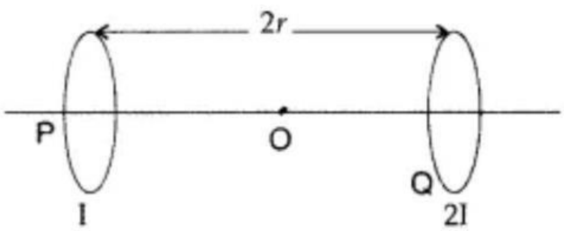
ASSERTION REASONING

11. Assertion: The magnetic field produced by a current element is zero when the observation point lies along the line of the current element.

Reason: In the Biot-Savart law, the magnetic field at a point is proportional to the cross product of the current element dl\mathbf{dl}dl and the vector r\mathbf{r}r, which joins the current element to the point of observation. If r\mathbf{r}r is parallel to dl\mathbf{dl}dl, the cross product becomes zero.

12. Assertion: The magnitude of the magnetic force on a moving charge is directly proportional to the speed of the charge.

	Reason: The magnetic force on a moving charge is given by F=qvBsin, where v is the speed of the particle and B is the magnetic field strength. Thus, the force increases with increasing speed.	
13.	**Assertion: If two parallel wires carrying current in opposite directions are placed close to each other, they will repel each other.** **Reason**: When currents flow in opposite directions, the magnetic fields they create interact in such a way that they produce a repulsive force between the wires, as predicted by the Lorentz force law.	
14.	**Assertion: A galvanometer can be converted into an ammeter by adding a high-resistance shunt in parallel.** **Reason**: To convert a galvanometer into an ammeter, a low-resistance shunt is connected in parallel, not a high-resistance one. This ensures that most of the current bypasses the galvanometer, allowing it to measure larger currents without damaging it.	
15.	A galvanometer is converted into a voltmeter by connecting a low-value resistor in series with it. **Reason**: A low-value resistor is used to minimize the resistance in the circuit and allow the galvanometer to measure a broader range of voltages accurately.	
	2 MARK QUESTIONS	
16	Write the condition under which an electron will move undeflected in the presence of crossed electric and magnetic fields.	
17	Write the underlying principle of a moving coil galvanometer.	
18	Define one tesla using the expression for the magnetic force acting on a particle of charge q moving with velocity ~*v* in a magnetic field *B* .	
19	A flat overhead electrical cable carries a current of 90 A in the east to west course. What is the direction and magnitude of the magnetic field due to the current 1.5 m below the line?	
20	A current carrying loop is free to turn in a uniform magnetic field B. Under what conditions, will the torque acting on it be (i) minimum and (ii) maximum?	
	3 MARK QUESTIONS	
21	A wire carrying a current of 8 A makes an angle of 300 with the direction of a Uniform	

	magnetic field of 0.15 T. Find the magnitude of magnetic force per unit length on the wire.	
22	A flat overhead electrical cable carries a current of 90 A in the east to west course. What is the direction and magnitude of the magnetic field due to the current 1.5 m below the line?	
23	A solenoid 50 cm long has 4 layers of windings of 350 turns each. The radius of the lower layer is 1.4 cm. If the current carried is 6.0 A, estimate the magnitude of magnetic flux density i) near the centre of the solenoid on its axis ii) outside the solenoid near its centre.	
24	Two smaller circular loops, marked 1 and 2 carrying equal currents are placed with the geometrical axes perpendicular to each other to each other as shown in figure. Find the magnitude and direction of the net magnetic field produced at the point O. 	
	5 MARKS	
25	The current sensitivity of a moving coil galvanometer increases by 20% when its resistance is increased by a factor 2. Calculate by what factor the voltage sensitivity changes.	
26	(A) Explain the principle, construction and working of moving coil galvanometer with sufficient theory. (B) Write a note on its a) current sensitivity and b) voltage sensitivity. OR Two identical circular loops, P and Q, each of radius r and carrying current I and 21 respectively are lying in parallel planes such that they have a common axis. The direction of current in both the loops is clockwise as seen from O which is equidistant from both the loops. Find the magnitude of the net magnetic field at point O 	
27	(a) Write, using Biot-Savart law, the expression for the magnetic field *B* due to an	

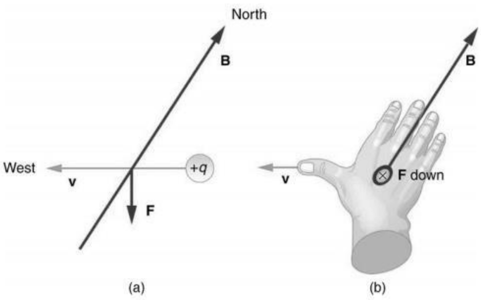
	element *I* carrying current I at a distance r from it in a vector form. Hence derive the expression for the magnetic field due to a current carrying loop of radius R at a point P distant x from its centre along the axis of the loop. (b) Explain how Biot-Savart law enables one to express the Ampere's circuital law in the integral form **OR** (a) Explain, using a labelled diagram, the principle and working of a moving coil galvanometer. (i) What is the function of uniform radial magnetic field, (ii) What is the function of soft iron core? (b) Define the terms (i) current sensitivity and (ii) voltage sensitivity of a galvanometer. (iii) Why does increasing the current sensitivity not necessarily increase voltage sensitivity?	

28

Right-Hand Rule

If a charged particle is in motion in a magnetic field with a speed or velocity (suppose v), in the magnetic field (suppose B), then it will feel a force which is magnetic force (F). The direction or the angle of this force can be calculated with the help of right-hand rule.

According to this rule, when you point the fingers of the right hand in the direction of the magnetic field, with the velocity of the positive charged particle coming out of your thumb, then the direction of this force on the particle is in the direction where your palm is open.



Right-Hand Rule

28 (A) Using the right-hand rule, which direction does the magnetic force on a positive charge moving in a magnetic field point if the velocity is directed into the page and the magnetic field is directed to the right?

A) Upward

B) Downward

C) Into the page

D) Out of the page

28 (B) **The magnetic force on a moving charge is given by** F=qvBsinθ. **If the velocity of the charge is perpendicular to the magnetic field, what is the magnitude of the force?**

A) F=0

B) F=qvB

C) F=qvBsinθ

D) F=qvBcosθ

28 (C) What happens to the magnetic force on a charged particle if the velocity of the particle is doubled while keeping the magnetic field strength constant?

A) The force is halved.

B) The force remains the same.

C) The force is doubled.

D) The force is quadrupled.

28 (D) If the magnetic field and velocity of a positive charge are both in the same direction, what is the direction of the magnetic force?

A) Zero, because there is no force

B) Perpendicular to both the magnetic field and the velocity

C) In the direction of the magnetic field

D) Opposite to the velocity

29 Magnetic Field due to a Straight Current-Carrying Wire

Consider a long, straight wire carrying a steady current I. You are tasked with finding the magne field at a point located at a distance r from the wire. Using the Biot-Savart Law, the magnetic fiel due to a small element of current I is given by:

$$d\mathbf{B} = \frac{\mu_0 I}{4\pi} \frac{d\mathbf{l} \times \hat{r}}{r^2}$$

where $\hat{r}$ is the unit vector from the current element to the point of observation.

29(A) What is the magnetic field at the center of a circular loop of radius R carrying current I?

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

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

C) $B = \frac{\mu_0 I}{2\pi R}$

D) $B = \frac{\mu_0 I}{2R^2}$

29(B) What will be the direction of the magnetic field at a point located perpendicular to a current-carrying wire?

A) Parallel to the wire

B) Parallel to the plane containing the wire and the observation point

C) Perpendicular to the plane containing the wire and the observation point

D) In the direction of the current flow

29(C) What is the direction of the magnetic field at the center of a current-carrying circular loop?

A) Parallel to the plane of the loop

B) Perpendicular to the plane of the loop

C) Radial outward from the center

D) Radial inward toward the center

29(D) How does the Biot-Savart law account for the distance between the current element and the observation point?

A) The magnetic field is inversely proportional to the square of the distance.

B) The magnetic field is directly proportional to the distance.

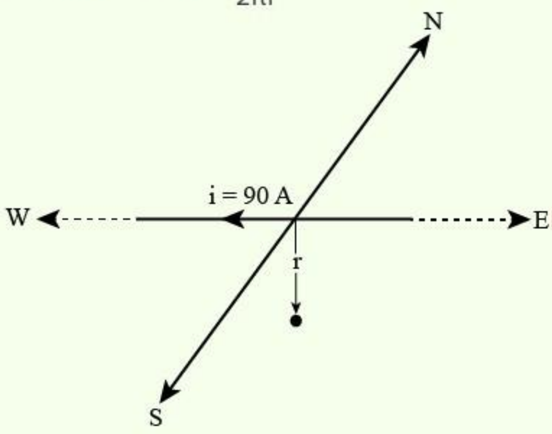
C) The magnetic field is independent of the distance.

D) The magnetic field is inversely proportional to the distance.

Magnetic Effect of Current and Magnetism (SOLUTION)

MCQ		
1.	(a) B perpendicular to v	
2.	(a) The magnitude of magnetic moment now diminishes.	
3.	(d) The electron will continue to move with uniform velocity along the axis of the solenoid.	
4.	(c) move toward the wire or towards left.	
5.	(b) 0.3 Am^2	
6.	$(d)\ \frac{\mu_0 I}{2R}\left(\frac{1}{\pi} - 1\right)$	
7.	(c) energy is constant but momentum changes.	
8.	(d) 4960 Ω	

9.	(b) 4 times	
10.	(a) 3 : 2	
	ASSERTION REASONING	
11.	(a) Both Assertion (A) and Reason (R) are the true and Reason (R) is a correct explanation of Assertion (A).	
12.	(a) Both Assertion (A) and Reason (R) are the true and Reason (R) is a correct explanation of Assertion (A).	
13.	(a) Both Assertion (A) and Reason (R) are the true and Reason (R) is a correct explanation of Assertion (A).	
14.	(d) Assertion (A) is false and Reason (R) is false.	
15.	(d) Assertion (A) is false and Reason (R) is false.	
	2 MARK QUESTIONS	
16	*Crossed electric and magnetic fields is that when electric and magnetic fields are perpendicular to each other, so under such circumstances, electrons will move undeflected due to electric force on electron which gets balanced by magnetic force acting on it.* Hence, qE = qvB where, q = **charge** , E = **electric field** , B = *magnetic field* , v = *velocity of the electron* *As, q = v show charge on electron, so eE = evB then v = E/B*	
17	A moving coil galvanometer operates on the principle that when a current-carrying coil is placed within a magnetic field, it experiences a torque, causing the coil to rotate, with the deflection of the coil being directly proportional to the magnitude of the current flowing through it.	

18	One tesla is the magnetic field in which a charge of 1 C moving with a velocity ms^{-1} , normal to the magnetic field, experiences a force of 1 N. $B = \frac{F}{qv\ sin\ \theta}$ If F = 1 N, q = 1C, v = 1 ms^{-1}, $\theta = 90°$ then SI unit of $B = \frac{1N}{1C.1\ ms^{-1}.\ \sin 90^o}$ = 1 NA^{-1} m^{-1} = 1 tesla .
19	Hint: "Magnetic field due to infinite wire" Formula Used: B = $\frac{\mu_0 i}{2\pi r}$  Here long straight wire means length of wire (l) >>> r So, this wire can be treated as infinite wire and magnetic field at a distance r below the line B = $\frac{\mu_0 i}{2\pi r}$ Here, i = 90 A, r = 1.5 m Putting values, B = $\frac{4\pi \times 10^{-7} \times 90}{2\pi \times 1.5}$ B = 1.2×10^{-5} Tesla Direction of magnetic field is finding out by "right hand rule" or "palm rule" which is towards south. Final Answer: 1.2×10^{-5} T towards south
20	(i) Minimum torque is experienced by the loop when the area vector is parallel or antiparallel to magnetic field. (ii) Maximum torque is acting on the loop when area vector is perpendicular the magnetic field.

3 MARK QUESTIONS

21

Current in the wire, I = 8 A

Magnitude of the uniform magnetic field, B = 0.15 T

Angle between the wire and magnetic field, θ = 30°.

Magnetic force per unit length on the wire is given as: $F = BI\,sin\theta$

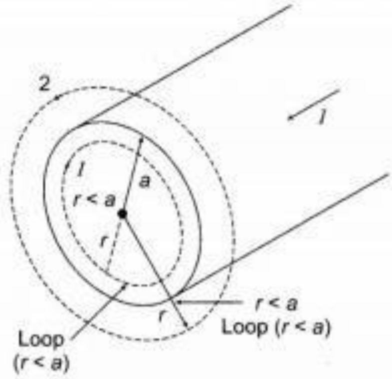
$= 0.15 \times 8 \times 1 \times \sin 30°$

$= 0.6 \text{ N m}^{-1}$

Hence, the magnetic force per unit length on the wire is 0.6 N m–1.

22

The current is distributed uniformly across the cross-section of radius a.



∴ Current passes per unit cross-section = $\frac{I}{\pi a^2}$

∴ Current passes through the cross-section of radius r is

$$I' = \left(\frac{I}{\pi a^2} \times \pi r^2\right) = \frac{Ir^2}{a^2} \quad \text{...(i) (1/2)}$$

(i) Consider a loop of radius r whose centre lies at the axis of wire where, $r < a$ as shown in figure inside the wire.

Applying Ampere's circuital law,

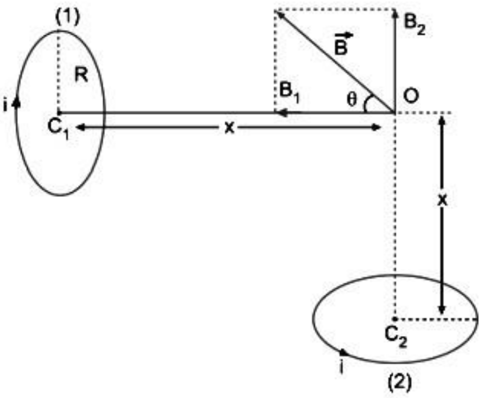
$$\oint \mathbf{B} \cdot dl = \mu_0 I' \quad \text{(1/2)}$$

$$\oint B dl \cos 0° = \mu_0 \left(\frac{Ir^2}{a^2}\right) \quad \text{[From Eq. (i)]}$$

$$B \oint dl = \mu_0 \frac{Ir^2}{a^2}$$

$$B \times 2\pi r = \frac{\mu_0 I r^2}{a^2} \Rightarrow B = \frac{\mu_0 I r}{2\pi a^2} \quad \text{(1/2)}$$

$$\Rightarrow \quad B \propto r$$

	$\because \quad B = \frac{\mu_0 I}{2\pi a^2} r$ $\Rightarrow \quad B \propto r$ **(1/2)** Now, the value of magnetic field on the surface of wire, i.e. $r = a$ $B = \frac{\mu_0 I}{2\pi a^2} \times a = \frac{\mu_0 I}{2\pi a}$ **(1/2)**	
23	Here, $l = 50cm = 0.50m, r = 1.4cm = 1.4 \times 10^{-2}m, I = 6.0A,$ No. of turns per unit length, $n = \frac{4 \times 350}{0.50} = 2800m^{-1}$ (i) The magnitude of $\vec{B}$ near the centre of solenoid on the axis is $B = \mu_0 nI = 4\pi \times 10^{-7} \times 2800 \times 6.0 = 2.11 \times 10^{-2}T$ (ii) The magnitude of $\vec{B}$ near the end of solenoid on the axis is $B = \frac{\mu_0 nI}{2} = \frac{2.11 \times 10^{-2}}{2} = 1.05 \times 10^{-2}T$ (iii) Outside the solenoid, the magnetic field is negligibly small as compared to that inside the solenoid.	
24	Magnetic field due to coil 1 at point O $\overrightarrow{B_1} = \frac{\mu_0 iR^2}{2(R^2+x^2)^{3/2}}$ along $\overrightarrow{OC_1}$ Magnetic field due top coil 2 at point O $\overrightarrow{B_2} = \frac{\mu_0 iR^2}{2(R^2+x^2)^{3/2}}$ along $\overrightarrow{C_2O}$  $B = \sqrt{B_1^2 + B_2^2} = \sqrt{2}B_1 (\text{as } B_1 = B_2)$ $= \sqrt{2}\frac{\mu_0 iR^2}{2(R^2+x^2)^{3/2}}$	

	As R<< x $B = \frac{\sqrt{2}\mu_0 \text{ iR}^2}{2.x^3} = \frac{\mu_0}{4\pi} \cdot \frac{2\sqrt{2}.\mu_0 i\,(\pi R^2)}{x^3}$ $= \frac{\mu_0}{4\pi} \frac{2\sqrt{2}.\mu_0 i\,A}{x^3}$ where A = πR^2 is area of loop. $\tan\,\theta = \frac{B_2}{B_1} \Rightarrow \tan\,\theta = 1\ (\because B_2 = B_1)$ $\Rightarrow\ \theta = \frac{\pi}{4}$ where A = πR^2 is area of loop. $\tan\,\theta = \frac{B_2}{B_1} \Rightarrow \tan\,\theta = 1\ (\because B_2 = B_1)$ $\Rightarrow\ \theta = \frac{\pi}{4}$ ∴ $\overrightarrow{B}$ is directed at an angle $\frac{\pi}{4}$ with the direction of magnetic field $\overrightarrow{B_1}$.
25	• We know that the voltage sensitivity is given as, $\Rightarrow V_s = \left(\frac{I_s}{R}\right)$ -----(1) Where V_s = voltage sensitivity, I_s = current sensitivity, and R = resistance • When the resistance is increased by factor 2, $\Rightarrow R' = 2R$ -----(2) $\Rightarrow I_s' = I_s + 20\%$ of I_s $\Rightarrow I_s' = I_s + \frac{20}{100} I_s$ $\Rightarrow I_s' = 1.2 I_s$ -----(3) $\Rightarrow V_s' = \frac{I_s'}{R'}$ $\Rightarrow V_s' = \frac{1.2 I_s}{2R}$ -----(4) By equation 1 and equation 4, $\Rightarrow V_s' = 0.6 V_s$ -----(5) • The change in voltage sensitivity is given as, $\Rightarrow \%\Delta V = \frac{V_s' - V_s}{V_s} \times 100$ $\Rightarrow \%\Delta V = \frac{0.6V_s - V_s}{V_s} \times 100$ $\Rightarrow \%\Delta V = -40\%$
5 MARKS	
26	Moving Coil Galvanometer **Moving coil galvanometer is an electromagnetic device that can measure small values of current. It consists of permanent horseshoe magnets, coil, soft iron core,**

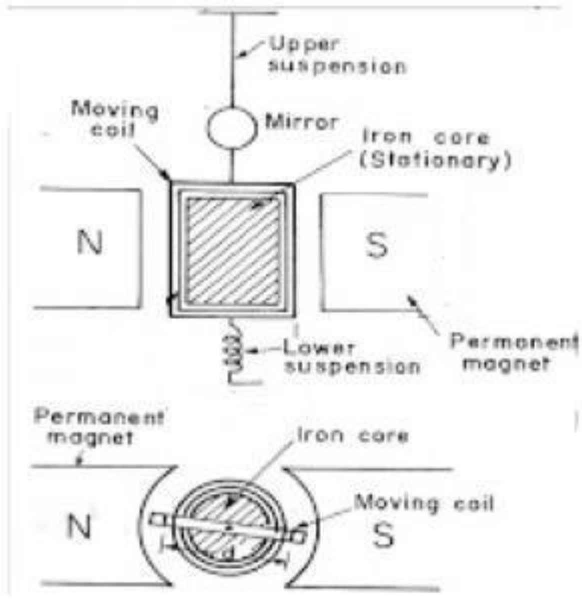
pivoted spring, non-metallic frame, scale, and pointer.

Principle of Moving Coil Galvanometer

Torque acts on a current-carrying coil suspended in the uniform magnetic field. Due to this, the coil rotates. Hence, the deflection in the coil of a moving coil galvanometer is directly proportional to the current flowing in the coil.

Construction of Moving Coil Galvanometer

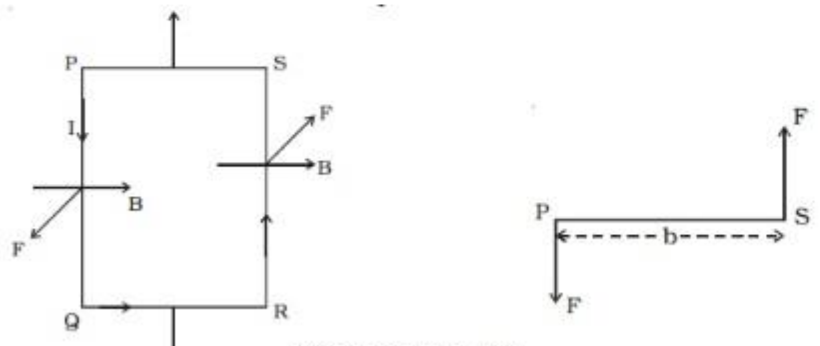
It consists of a rectangular coil of a large number of turns of thinly insulated copper wire wound over a light metallic frame. The coil is suspended between the pole pieces of a horseshoe magnet by a fine phosphor – bronze strip from a movable torsion head. The lower end of the coil is connected to a hairspring of phosphor bronze having only a few turns.



The other end of the spring is connected to a binding screw. A soft iron cylinder is placed symmetrically inside the coil. The hemispherical magnetic poles produce a radial magnetic field in which the plane of the coil is parallel to the magnetic field in all its positions. A small plane mirror attached to the suspension wire is used along with a lamp and scale arrangement to measure the deflection of the coil.

Working of Moving Coil Galvanometer

Let PQRS be a single turn of the coil. A current I flows through the coil. In a radial magnetic field, the plane of the coil is always parallel to the magnetic field. Hence the sides QR and SP are always parallel to the field. So, they do not experience any force. The sides PQ and RS are always perpendicular to the field.



Torque on the coil

PQ = RS = *l*, length of the coil and PS = QR = b, breadth of the coil. Force on PQ, F = BI (PQ) = BI*l*. According to Fleming's left-hand rule, this force is normal to the plane of the coil and acts outwards.

Force on RS, F = BI (RS) = BI*l*. This force is normal to the plane of the coil and acts inwards. These two equal, oppositely directed parallel forces having different lines of action constitute a couple and deflect the coil. If there are *n* turns in the coil, the moment of the deflecting couple = *n* BI*l* – b

Hence the moment of the deflecting couple = *n*BIA

The suspension wire twists when the coil deflects. On account of elasticity, a restoring couple is set up in the wire. This couple is proportional to the twist. If θ is the angular twist, then, the moment of the restoring couple = Cθ, where C is the restoring couple per unit twist. At equilibrium, deflecting couple = restoring couple nBIA = Cθ

Hence we can write, nBIA = Cθ

I = (C / nBA) × θ where C is the torsional constant of the spring; i.e. the restoring torque per unit twist. A pointer attached to the spring indicates the deflection θ on the scale.

The Sensitivity of Moving Coil Galvanometer

The sensitivity of a Moving Coil Galvanometer is the ratio of the change in deflection of the galvanometer to the change in current. Therefore we write, Sensitivity = dθ/di. If a galvanometer gives a larger deflection for a small current it is a sensitive galvanometer. The current in Moving Coil galvanometer is: I = (C/nBA) × θ

Therefore, θ = (nBA/C) × I. Differentiating on both sides wrt I, we have: dθ/di = (nBA/C).

To sum up, the sensitivity of Moving Coil Galvanometer increases by:

- Increasing the no. of turns and the area of the coil,
- Increasing the magnetic induction and
- Decreasing the couple per unit twist of the suspension fibre.

(b) Current sensitivity and voltage sensitivity are both measures of a galvanometer's deflection in response to current or voltage:

- **Current sensitivity**

  The amount a galvanometer deflects per unit of current flowing through it. The equation for current sensitivity is

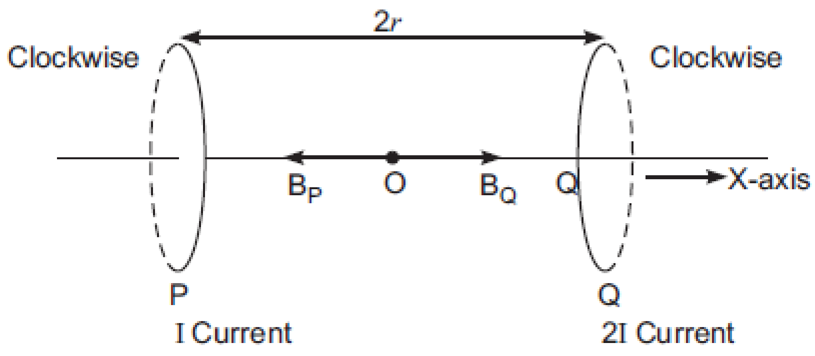
$Is=\theta/I.$

- **Voltage sensitivity**

The amount a galvanometer deflects per unit of potential difference applied across it. The equation for voltage sensitivity is Vs=θ / V

.

OR



$$|\vec{B}_P| = \frac{\mu_0 r^2 I}{2(r^2+r^2)^{3/2}} = \frac{u_0 I}{4\sqrt{2}r} \quad \text{Pointing towards } P$$

$$|\vec{B}_Q| = \frac{\mu_0 (2I) r^2}{2(r^2+r^2)^{3/2}} = \frac{\mu_0 I}{4\sqrt{2}r} \quad \text{Pointing towards Q}$$

$$|\vec{B}| = |\vec{B}_Q| - |\vec{B}_p| = \frac{\mu_0 I}{4\sqrt{2}r}$$

So, **magnetic** field at point O has a magnitude $\mu_0 I/(4\sqrt{2}r)$

27 (a) Statement and formula of Biot-Savart Law

(b) Derivation of magnetic field due to circular loop on its axis

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

OR

(a) Derivation of the magnetic force between two parallel current caring wire placed at some distance apart.

	Force on conductor A is directed towards conductor B. $dF = \left(I_1 d\vec{l} \times \vec{B}_2\right)$ $= I_1 dl \frac{\mu_0 I_2}{2\pi r}\left(\hat{k} \times \hat{i}\right)$ $d\vec{F} = \frac{\mu_0 I_1 I_2 dl}{2\pi r}\hat{j}$ Force per unit length of the conductor A, $\frac{\vec{F}}{l} = \frac{-\mu I_1 I_2}{2\pi r}\hat{j}$ Attractive force – direction of electric current is same. Repulsive force – direction of electric current is opposite. (b) Define 1 ampere on the basis of magnetic force between two parallel current caring wire. An ampere is that much current which when flowing through each of the two infinitely long straight condu in vacuum 1 meter apart results in a force of 2×10^{-7} Nm^{-1} on each of the conductors. (c) Fleming's left-hand rule states that if you hold your left hand's thumb, forefinger, and middle finger at right angles to each other, then the thumb points to the direction of the force, the forefinger points to the direction of the magnetic field, and the middle finger points to the direction of the electric current.	
28	**28 (i) B) Downward** **28 (ii) B) F=qvB** **28 (iii) C) The force is doubled.** **28 (iv) A) Zero, because there is no force**	
29	29 (i) (A) $\frac{\mu 0 I}{2R}$ **29 (ii) C) Perpendicular to the plane containing the wire and the observation point** **29 (iii) B) Perpendicular to the plane of the loop** **29 (iv) A) The magnetic field is inversely proportional to the square of the distance.**	

MAGNETISM AND MATTER

MCQ

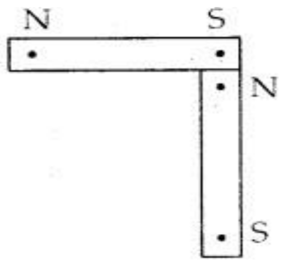
1-Magnetism in substances is caused by

(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

2- Which of the following is a diamagnetic material?
a) Sodium b) Calcium c) Oxygen (at STP) d) Nitrogen (at STP)

3- 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) 2M (c) M/$\sqrt{2}$ (d) M/2

4- 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/L (d) M × L

5- The magnetic field strength due to a short bar magnet directed along its axial line at a distance r is B. What is its value at the same distance along the equatorial line?
(a) B (b) 2B (c) $B/2$ (d) $B/4$

6- The neutral point in the magnetic field of a horizontally placed bar magnet is a point where the magnetic field due to that bar magnet is:
(a) zero (b) more than that of earth
(c) less than that of earth (d) equal to that of earth

7- A bar magnet of the magnetic moment 5 Am2 has poles 20 cm apart. Calculate the pole strength.

(a) 250 Am (b) 4 Am (c) 100 Am (d) 25 Am

8- If a hole is made at the centre of a bar magnet, then its magnetic moment

(a) Does not change (b) Decreases (c) Increases (d) Vanishes

Ans MCQ 1- c 2- d 3- a 4-c 5- c 6- d 7-d 8-a

ASSERTION REASONING

Assertion reason type questions-

Two statements are given –one labelled Assertion (A) and other labelled Reason (R). Select the correct answer to these questions from the options as given below.

a) If both Assertion and Reason are true and Reason is correct explanation of Assertion.

b) If both Assertion and Reason are true but Reason is not the correct explanation of Assertion.

c) If Assertion is true but Reason is false.

d) If both Assertion and Reason are false

1- Assertion (A): The magnetic field lines inside a solenoid are similar to the magnetic field lines inside a bar magnet.
Reason (R): A solenoid behaves like a bar magnet with a north pole at one end and a south pole at the other, creating magnetic field lines similar to that of a bar magnet.

2- Assertion (A): A paramagnetic material becomes diamagnetic at very low temperatures.
Reason (R): At very low temperatures, thermal energy decreases, leading to increased alignment of atomic magnetic dipoles, making the paramagnetic material behave like a diamagnetic material.

3- Assertion (A): The Curie temperature is the temperature above which a ferromagnetic material loses its magnetic properties.
Reason (R): At the Curie temperature, the thermal agitation disrupts the alignment of atomic magnetic dipoles in ferromagnetic materials, causing them to become paramagnetic.

4- Assertion (A): The magnetization curve of a ferromagnetic material exhibits hysteresis.
Reason (R): Hysteresis is the property of ferromagnetic materials where the magnetic induction lags behind the magnetizing force, resulting in a loop-like magnetization curve.

ANSWER— 1- (a) 2- (b) 3- (a) 4- (a)

2 MARKS QUESTIONS

1- Does a bar magnet exert a torque on itself due to its own field? Does one element of a current- carrying wire exert a force on another element of the same wire?

Ans. No, a bar magnet does not exert a force or torque on itself due to its own field. But an element of a current carrying conductor experiences force due to another element of the conductor. Q

2- The poles of a magnet cannot be separated. How does this statement derive support from the magnetic dipole behavior of a current loop?

Ans. A current loop behaves as a magnetic dipole. It’s one face behaves as N -pole, while the other as S-pole. As the two faces of the current loop cannot be separated from each other, it follows that the magnetic poles developed on the two faces also cannot be separated from each other.

3- Relative permeability of a material, $\mu_r = 0.5$. Identify the nature of the magnetic material and write its relation to magnetic susceptibility.
Answer:

1. Diamagnetic material
2. $\mu_r = 1 + X_m$

4-A bar magnet of magnetic moment M is aligned parallel to the direction of a uniform magnetic field B. What is the work done to turn the magnet, so as the alignment of its magnetic moment?
(i) Opposite to the field direction
(ii) Normal to the field direction?
Ans. Since work done W = MB $(\cos\theta_1 - \cos\theta_2)$
(i) $\theta_1 = 0^\circ$ and $\theta_2 = 180^\circ$
$\rightarrow W = MB(\cos 0 - \cos 180^\circ)$
W = MB 1− (−1)
W = 2MB
(ii) $\theta_1 = 0^\circ$ and $\theta_2 = 90^\circ$
W = MB $(\cos\ 0 - \cos\ 90^\circ)$
W = MB

3MARKS QUESTIONS

1- Draw the magnetic field lines for a current carrying solenoid when a rod made of (a) copper, (b) aluminium and (c) iron are inserted within the solenoid as shown.

Ans- (a) When a bar of diamagnetic material (copper) is placed in an external magnetic field, the field lines are repelled or expelled and the field inside the material is reduced. (b) When a bar of paramagnetic material (Aluminium) is placed in an external field, the field lines gets concentrated inside the material and the field inside is enhanced. (c) When a ferromagnetic material (Iron) is placed in an internal magnetic field, the field lines are highly concentrated inside the material

2- Write three points of differences between para-, dia- and ferro- magnetic materials, giving one example for each.

Ans-

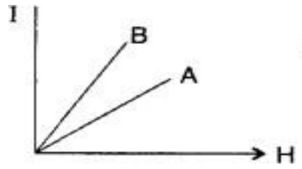
	DIAMAGNETIC	PARAMAGNETIC	FEROMAGNETIC
1	$-1 < \chi m \leq 0$	$0 < \chi m < \mathcal{E}$	$\chi m > 1$
2	$0 \leq \mu r\ 1$	$1 \leq \mu r < (1+\mathcal{E})$	$\mu r > 1$
3	$\mu < \mu 0$	$\mu > \mu 0$	$\mu \gg \mu 0$

Examples: Diamagnetic materials: Bi, Cu, Pb, Si, water, NaCl, Nitrogen (at STP)

Paramagnetic materials: Al, Na, Ca, Oxygen (at STP), Copper chloride

Ferromagnetic materials: Fe, Ni, Co, Alnico

3- The figure shows the variation of intensity of magnetisation versus the applied magnetic field intensity, H, for two magnetic materials A and B:



(a) Identify the materials A and B.
(b) Why does the material B, has a larger susceptibility than A, for a given field at constant temperature?
Answer:

(a) As $\chi_m = \frac{I}{H}$

Slope of the line gives magnetic susceptibilities.
For magnetic material B, it is giving higher +ve value.
So material is 'ferromagnetic'.
For magnetic material A, it is giving lesser +ve value than 'B'.
So material is 'paramagnetic'.
(b) Larger susceptibility is due to characteristic 'domain structure'. More number of mag¬netic moments get aligned in the direction of magnetising field in comparision to that for paramagnetic materials for the same value of magnetising field.

4- 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.
Answer:
Magnetic moment due to a circular coil,

$$NIA = NI\,(\pi R^2) \qquad \ldots(i)$$

Magnetic moment due to square coil,

$$NIA = NI\left(\frac{2\pi R}{4}\right)^2$$

$\because$ Circumference of a circle of radius is $2\pi R$, which makes 4 sides of a square

Hence one side of a square $= \frac{2\pi R}{4} = \frac{\pi R}{2}$

$$\text{Ratio} = \frac{(M)_{sq}}{(M)_{cir}} = \frac{\frac{NI(\pi^2 R^2)}{4}}{NI(\pi R^2)}$$

$$= \frac{\pi}{4} = \frac{3.14}{4} = \frac{32}{40} = \frac{4}{5} = \mathbf{4:5} \quad [\because 3.14 \approx 3.2$$

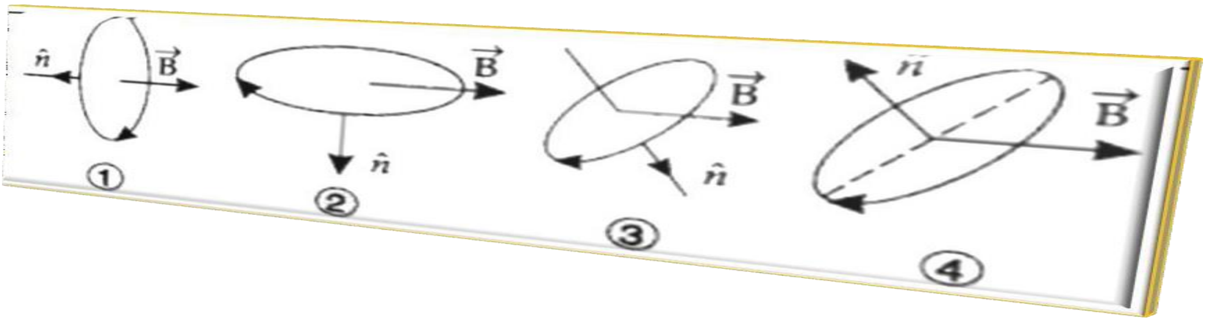
CASE STUDY

Current loop behaves like a magnetic dipole and has a magnetic field. They behave just like a magnet. Interesting part is, it depends upon the direction of current in a loop which decides whether the magnetic field line is in outward or inward direction. With the help of this outward and inward direction of magnetic field, North and South poles get decided. Anticlockwise direction of current creates north pole (outward direction magnetic field) and clockwise direction of current creates a south pole (inward direction magnetic field). Magnetic dipole moment M with the circular current loop carrying a current I and of area A. The magnitude of m is given by |m|=I x A Current in the circular coil produces a magnetic field and amperes found that the magnetic field created due to the circular coil is similar to the magnetic field due to a bar magnet. Wood screw head sign shows that the direction of the screw is inward because we are not able to see the pointed part of the screw and so the direction is inward. This inward direction of the screw denotes the direction of the magnetic field.

i. A thin circular wire carrying a current I, has a magnetic moment M. The shape of a wire is changed to a square and it carries the same current. It will have a magnetic moment-

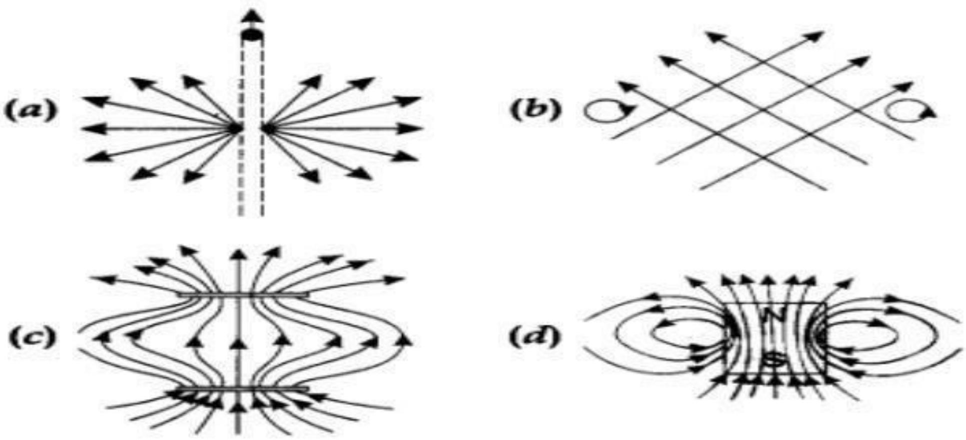
(a) 4M/π2 (b) M (c) πM /4 (d) 4M/πA

ii. Current carrying loop is placed in a uniform magnetic field in four different orientations as shown in figure. Arrange them in the decreasing order of potential energy.



(a) 4, 2, 3,1 (b) 1, 4, 2, 3 (c) 4, 3, 2,1 (d) 1, 2, 3, 4

iii. Point out the correct direction of the magnetic field in the given figure



iv. A bar magnet of magnetic moment m is placed in uniform magnetic field B such that m is parallel to B . In this position, the torque and force acting on it are________and _____respectively –

(a) 0 ,0 (b) m x B , mB (c) m . B , mB (d) m x B , m . B

ANSWER—(i) d (ii) b (iii) c (iv) b

COMPETENCY BASED QUESTIONS

ELECTROMAGNETIC INDUCTION

MCQ

1. The direction of the induced field can be predicted by____________

a. Kepler’s law (b)Newton’s law (c)Lenz’s law (d) Faraday’s law

Ans: c

2. Fill in the blanks: Electric generator converts mechanical energy into_______

a. Chemical energy (b) Thermal energy (c) Electrical energy (d) Solar energy

Ans: c

3. The phenomenon called electromagnetic induction was first investigated by

a. Newton (b) Kepler (c) Faraday (d) Galileo

Ans: c

4. 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: c

5. Factors that affect the voltage generation in Faraday’s experiment is

a. Number of Coils
b. Changing Magnetic Field
c. Changing Environment
d. Option a) and b)

Ans: d

6. Define magnetic flux.

Ans: The number of magnetic field lines passing through a given closed surface gives magnetic flux.

7. Lenz’s law is derived from_____.

a. Kepler’s law (b) Newton’s law (c) Coulomb’s Law (d) Faraday’s law

Ans: d

8. State true or false: Eddy currents flow in closed loops in planes perpendicular to the magnetic field.

a. TRUE b. FALSE

Ans: True

9. The SI unit of magnetic flux is

a. Kilogram b. Weber c. Second d. Candela

Ans: b

10. The induced voltage is found according to Faraday's law using the formula_____

a. $e = N \times d\Phi dt$ b. $e = N \times d\Phi/dt$ c. $e = N + d\Phi dt$ d. $e = N – d\Phi dt$

Ans: b

Assertion and reasons

Of the following statements, mark the correct Answers as

A - If both Assertion and Reason are true and Reason is the correct explanation of the Assertion.

B - If both Assertion and Reason are true but Reason is not the correct explanation of Assertion.

C - If Assertion is true but Reason is false.

D - If both Assertion and Reason are false.

E - If Assertion is false but Reason is true

11. **Assertion** - Making and breaking of current in a coil produce no momentary current in the neighboring coil of another circuit

Reason - Momentary current in the neighboring coil of another circuit is an eddy current

Ans : D

12. **Assertion -** Faraday laws are consequence of conservation of energy

Reason - In a purely resistive AC circuit, the current lags behind the emf in phase .

Ans : B

13. **Assertion -** Only a change in magnetic flux through a coil maintain a current in the coil if the current is continues

Reason - The presence of large magnetic flux through a coil maintains a current in the coil if the current continues.

Ans : C

14. **Assertion**- magnetic flux can produce induced emf .

Reason - Faraday established induced emf experimentally.

Ans : E

15. **Assertion** - Inductance coil are made of copper

Reason - Induced current is more in wire having less resistance.

Answer : A

2 Marks Questions

16. What are the methods of generating induced emf?

Ans: Induced emf by changing the magnetic field B

- Induced emf by changing the area of coil
- Induced emf by changing the relative orientation of the coil and the magnetic field

17. What are the factors on which self-inductance depends?

Ans: L = (μ0 N2 A) / l

- It depends on number of turns N
- It depends on area of cross section A
- Permeability of core material μ0

18. When the current changes from +2A to – 2A in 0.05s, an e.m.f of 8V is induced in the coil. The coefficient of self induction of coil is?

Ans: Given – E = 8V . E = | L dI/dT |

L=E/dI|dT
E = (8 V × 0.05) /4
E = 0.1 H

19. Two coils of self inductance 2mH and 8 mH are placed so close together that the effective flux in one coil is completely linked with the other. The mutual inductance between these coil is?

Ans: Given – L1 = 2 mH
L2 = 8 mH
M = √(L1 × L2)
M = √(2 × 8)
M = 4 Mh

20. In an a.c generator, a coil with N turns all of the same area A and total resistance R, rotates with frequency ω in a magnetic field B. What is the maximum value of e.m.f. generated in coil ?

Ans: |E| = |-dϕ/dt|

E = dϕ/dt . E = d (NBA cos θ)/ dt

E = NBA sinθ dθ/dt

E = NABω--------------------------- ω = dθ/dt , sinθ= 1

3 marks questions

21. The current in a self-inductance L = 40mH is to be increased uniformly from the 1 A to 11 A in 4 milliseconds. The e.m.f. induced in the inductor during the process ?

Ans: Given – L = 40mH   dt = 4 milliseconds

dI = 11 – 1 = 10 |E| = |-L dI/dt|

E = (40 × 10-3 × 10) / 4 × 10-3------------------------ dI = 11-1=10

E = 100 V

22. In EMI, why is the induced emf not dependent on the résistance of the coil?

Ans: E = -dϕ/dt [ϕ = NBA cosθ]

dϕ – change of flux   dt – change of time

N – number of turns   B – Magnetic energy

Does not depend on resistance of coil

According to above equation it seems that it is independent of resistance of coil

When you write E = IR and finding current then there will be role of resistance

23. What is mutual induction? Two coils have a mutual inductance 0.005 H. The current changes in the first coil according to equation I = I0 Sin ωt, where I0 = 10 A and ω = 100 π rad-1 . Then what is the maximum value of e. m. f. in the second coil ?

Ans: Mutual inductance – When two coils are brought in proximity with each other then the magnetic field in one of the coils tends to link with the other coil. This leads to generation of voltage in the second coil. This property of the coil that affects or changes the current and voltage in the secondary coil is called mutual inductance.

Given – M = 0.005 H

Use formula   E=MdI/dt

=0.005*d/dt(iosinwt) =0.005*iowcoswt

Emax =0.0005*10*100π = 5 π volt

24. A long solenoid has 500 turns. When a current of 2A is passed through it, the resulting magnetic flux linked with each turn of the solenoid is 4×10-3 Wb. The self inductance of the solenoid is

Ans: Given – Φ = 500 turns × 4×10-3 Wb

I = 2 A   Φ = LI   L = ϕ/I

L = 500 × 4 × 10-3/ 2

L = 1000 ×10-3 H   L = 1 H

Long Questions

25. A small town with a demand of 800 kW of electric power at 220 V is situated 15 km away from an electric plant generating power at 440 V. The resistance of the two wire line carrying power is 0.5Ω per km. The town gets 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.

Ans: Line resistance = 30 X 0.5 = 15Ω rms current in the line . 800 x 1000 W / 4000 V = 200 A

(a) Line power loss = (200 A)2 x 15 Ω = 600 kW.

(b) Power supply by the plant = 800 kW + 600 kW = 1400 kW.

(c) Voltage drop on the line = 200 A 15Ω = 3000 V. The step-up transformer at the plant is 440 V - 7000 V.

A coil of wire enclosing an area 100 cm2 is placed with its plane making an angle 600 with the magnetic field of strength 10-1T. What is the flux through the coil? If magnetic field is reduced to zero in 10-3 s, then find the induced emf?

26. A magnetic field of 2 × 10-2 T acts at right angles to a coil of area 100 cm2 with 50 turns. The average e.m.f. induced in the coil is 0.1v, when it is removed from the field in the time t. the value of t is ?

Ans: Given – N = 50

B = 2 × 10-2 T A = 100 cm2 E = 0.1 v

|E| = |-dϕ/dt| |E| = |ϕ2 – ϕ1/dt|

dt = |0 – NBA cos0 / 0.1| --------------------------0˚ because it acts as a right angle of a coil

dt = |0 – 50 × 2 ×10-2 × 100 × 10-4 cos0/ 0.1|

dt = 0.1 s

Case based

27. 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 reverses in direction periodically. In most of the electric power circuits, the waveform of alternating current is the sine wave.

1. 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: a

2. 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:c

28. An inductor is simply a coil or a solenoid that has a fixed inductance. It is referred to as a choke. The usual circuit notation for an inductor is as shown. Let a current i flows through the inductor from A to B. Whenever electric current changes through it, a back emf is generated. If the resistance of the inductor is assumed to be zero (ideal inductor) then induced emf in it is given by e=VB-VA = - L di / dt Thus, potential drops across an inductor as we move in the direction of current. But potential also drops across a pure resistor when we move in the direction of the current. The main difference between a resistor and an inductor is that while a resistor opposes the current through it, an inductor opposes the change in current through it.

Now answer the following questions.

(1) How does inductor behave when

(a) a steady current flow through it? (b) a steadily increasing current flows through it?

(c) a steadily decreasing current flows through it?

(d) Name the phenomenon in which change in current in a coil induces EMF in the coil itself?

Competency Based Questions with Solutions

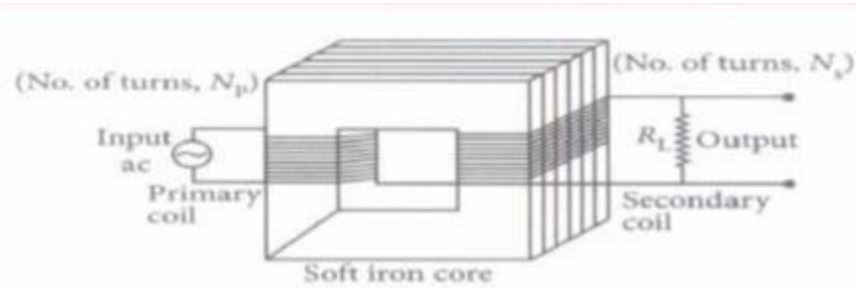
Alternating Current

	MCQ	
Q.1	In a pure inductive circuit, the current- (a) lags behind the applied emf by an angle π (b) lags behind the applied emf by an angle π / 2 (c) leads the applied emf by an angle π /2 (d)applied emf are in same phase	
Q.2	The potential differences across the resistance, capacitance and inductance are 80 V, 40 V and 100 V respectively in an L-C-R circuit, the power factor for this circuit is- (a) 0.4 (b) 0.5 (c) 0.75 (d) 1.0	
Q.3	One 60 V, 100 W bulb is to be connected to 100 V, 50 Hzac- source. The potential drop across the inductor is (f = 50 Hz) - (a) 80 V (b) 40V (c) 10 V (d) 20V	
Q.4	A capacitor of capacitance C has reactance X. If capacitance and frequency become double, then the capacitive reactance will be (a) 2X (b) 4X (c) X/2 (d) X/4	
Q.5	In a transformer, the no. of turns of primary and secondary coil are 500 and 400 respectively. If 220 V is supplied to the primary coil, then ratio of currents in primary and secondary coils is (a) 4:5 (b) 5:4 (c) 5:9 (d) 9:5	
Q.6	When ac- source is connected across series R-L-C combination, maximum power loss will occur provided (a) current and voltage are in phase (b) Current from source is minimum (c) Inductance is minimum (d) Capacitance is maximum	
Q.7	An AC voltage source of variable angular frequency ω and fixed amplitude V connected in series with a capacitance C and an electric bulb of resistance R (inductance zero). When ω is increased (a) The bulb glows dimmer (b) The bulb glows brighter (c) Net impedance of circuit is unchanged (d) Total impedance of the circuit increases	
Q.8	The core of a transformer is laminated, so as to (a) make it light weight (b) make it robust and strong (c) increase the secondary voltage (d) reduce energy loss due to eddy current	
Q.9	Electrical energy is transmitted over large distances at high alternating voltages. Which of the following statements incorrect? (a) For a given power level, there is a lower current. (b) Lower current implies less power loss. (c) Transmission lines can be made thinner. (d) It is easy to reduce the voltage at the receiving end using step-down transformers.	
Q.10	The instantaneous values of EMF and the current in a series AC circuit are $E = E_0 \sin \omega t$ and $I = I_0 \sin (\omega t + \pi/3)$ respectively, then it is – (a) necessarily a RL circuit (b) necessarily a RC circuit (c) necessarily a LCR circuit (d) can be RC or LCR circuit	
	Assertion & Reason	

	Of the following statements, mark the correct Answers as- A - if both Assertion and Reason -- are true and Reason -- is correct explanation of the Assertion. B - if both Assertion and Reason -- are true but Reason -- is not correct explanation of Assertion. C - if Assertion is true but Reason -- is false. D - if both Assertion and Reason -- are false. E - if Assertion is false but Reason -- is true	
Q.1	Assertion-- The mutual induction of two coils is doubled, if the self-inductance of the primary or secondary coil is doubled Reason -- Mutual induction is proportional to self-inductance of primary and secondary coils	
Q.2	Assertion- Faraday laws are consequence of conservation of energy Reason -- In a purely resistive AC circuit, the current lags behind the emf in phase	
Q.3	Assertion-- An AC generator is based on the phenomenon of self-induction Reason -- in single coil we consider, self-induction only	
Q.4	Assertion-- An AC doesn't show any magnetic effect Reason -- AC varies with time	
Q.5	Assertion-- In LCR circuit resonance can take place Reason -- resonance can take place if inductance and capacitive reactance are equal and opposite	
	2 Marks Questions	
Q.1	What is meant by wattles current?	
Q.2	Define: (i) rms value of AC current (ii)Q factor in LCR series circuit	
Q.3	Draw phasor diagram for an LCR circuit for the cases (i) the voltage across the capacitor is greater than that across the inductor (ii) voltage across inductor is greater than that across the capacitor.	
Q.4	Reactance of a capacitor of capacitance C for an alternating current of frequency (400/π) Hz is 25Ω . Find the value of capacitance C.	
Q.5	Write the name of any four types of energy losses in the Transformer.	
	3 Marks Questions	
Q.1	How do R, X_L and X_c get affected when the frequency of applied AC is doubled?	
Q.2	Define root mean square value of a.c voltage. Deduce relation between rms and peak value of ac current.	
Q.3	Obtain the resonant frequency and Q factor of a series LCR circuit with L= 3H, C= 27μF and R= 7.4 Ω. Write two different ways to improve quality factor of a series LCR circuit	
Q.4	Why is the use of ac voltage preferred over dc voltage? Give three reasons.	
	5 Marks Questions	
Q.1	(a) State the principle and working of ac generator with the help of a labelled diagram. (b) An ac generator consists of a coil of 50 turns and an area of 2.5m^2 rotating at an angular speed of 60 rad/s in a uniform magnetic field of B= 0.3T between two fixed pole pieces. The resistance of the circuit including that of the coil is 500Ω (i) What is the maximum current drawn from the generator? (ii)What is the flux through the coil when current is zero? (iii)What is the flux when current is maximum?	
Q.2	The primary coil of an ideal step-up transformer has 100 turns and transformation ratio is also 100. The input voltage and power are 220 V and 1100 W respectively. Calculate (a) the number of turns in the secondary coil. (b) the current in the primary coil. (c) the voltage across the secondary coil. (d) the current in the secondary coil. the power in the secondary coil.	

Case study Based

1. 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 longdistance 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 turn's 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.



1.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.

2.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

3.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.
It increases the efficiency of solar panel operation

4.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

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

Q.2 Electrical Energy Transmission And Distribution:

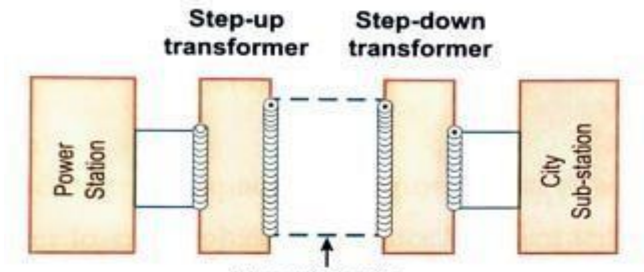


Figure: Long distance power transmissions

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. There the voltage stepped down.it is further stepped down at distributing sub- station and utility poles before a power supply of 240 v reaches our homes.

(i) Which of the following statement is true?

a. Energy is created when a transformer steps up the voltage.
b. A transformer is designed is 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 stepped up (Vs>Vp) and the arrangement is called step up transformer.
b. the voltage stepped down (Vs<Vp) and the arrangement is called step down transformer

c. the current stepped up (Is>Ip) and the arrangement is called step up transformer.
d. the current stepped down (Is>Ip) and the arrangement is called step down transformer.

OR

We need to setup 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

(iii) A power transmission line feeds input power at 2300V to a step down transformer with its primary winding having 4000 turns. The number of turns in the secondary in order to get output power at 230V are -

a. 4 b. 40 c. 400 d. 4000

(iv) The metal alloy that is more suitable for making cores of transformers is

a. Steel b. soft iron c. copper d. brass

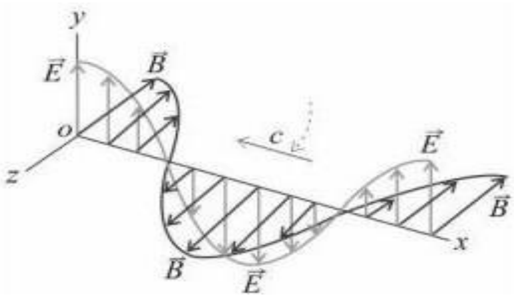
SOLUTIONS/ANSWER

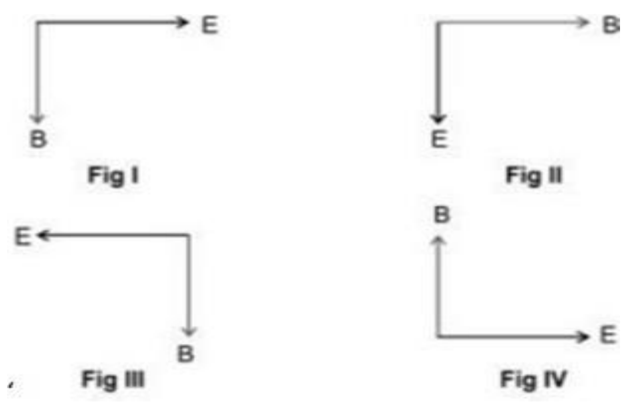
	MCQ	MM
Q.1	(b) lags behind the applied emf by an angle $\pi / 2$	1
Q.2	(a) 0.8	1
Q.3	(a) 80V	1
Q.4	(d) X/4	1
Q.5	(a) 4:5	1
Q.6	(a) current and voltage are in phase	1
Q.7	(b) The bulb glows brighter	1
Q.8	(d) reduce energy loss due to eddy current	1
Q.9	(b) Lower current implies less power loss.	1
Q.10	(d) can be RC or LCR circuit	1

	Assertion & Reason	
Q.1	Ans – C	1
Q.2	Ans – C	1
Q.3	Ans – E	1
Q.4	Ans – B	1
Q.5	Ans – A	1
	2 Marks Questions	
Q.1	Definition of wattless current.	1
Q.2	(i) Definition of rms value of current (ii) Definition of Q Factor	1 + 1
Q.3	Phaser diagram for an LCR circuit for the case (i) $V_C > V_L$ and (ii) $V_L > V_C$	1 + 1
Q.4	$X_c = 1/\omega C = 1/ 2\pi fC$ Or $C = 1/2\pi f X_c = 100\mu F$	1 1
Q.5	For any four types of energy losses in transformer	1/2+1/2+1/2+1/2
	3 Marks Questions	
Q.1	No effect on R, X_L becomes twice and X_C becomes half	1+1+1
Q.2		
Q.3	$\omega_r = \sqrt{\frac{1}{LC}}$ = 111 rad/sec $Q = \frac{1}{R}\sqrt{L/C}$ = 45	½ + 1 ½ + 1
Q.4	Three advantages of AC over DC voltage	1+1+1
	5 Marks Questions	
Q.1	a) Principle working of ac generator with the help of a labelled diagram b) (i) 4.5 A (ii) 375 Wb (iii) Zero	½ ½+1 1 1 1
Q.2	a) Ns = 10000 b) Ip = 5A c) Vs = 22 KV d) Is = 0.05A e) Ps = 1100	1 1 1 1 1
	Case study Based	
Q.1	(i) a) Increased power loss due to higher current flow (ii) b) 6.3 kW (iii) a) It allows for lower current, reducing resistive losses over long distances. (iv) a) 900 W OR c) The number of turns in the primary and secondary coils.	1 1 1 1

Competency Based Questions with Solutions

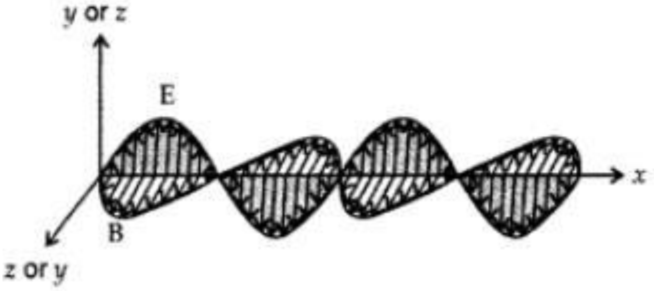
Electromagnetic Wave

	MCQ
Q.1	The diagram below shows a single EM wave of wavelength λ. For different values of x given as x = 0, λ/4, λ/2, 3λ/4 and λ, which of the following statements are correct.  I. Energy density is maximum at x = 0, λ/2 and λ II. Magnitude of instantaneous intensity is minimum at x = λ/4, 3λ/4 III. Energy density and the magnitude of instantaneous intensity have minimum values at positions where E and B are both zero. A. Only I is true B. Only II is true C. Only III is true D. All statements I, II & III are true Ans-D
Q.2	Study the following statements carefully. A. Electric and magnetic fields have zero average value in a plane em wave. B. For an em wave, the ratio k/ω is independent of wavelength. C. In an em wave, the E and B fields vary with the same frequency and are in opposite phase. D. Since E = cB, the energy associated with the electric field is much greater than that associated with the magnetic field. Identify the correct option. A. only A and B are correct B. only C and D are correct C. only A and C are correct D. only B and D are correct Ans-A

Q.3	Which of the following statement/s are incorrect? A. The displacement current flows in a dielectric of the capacitor when the potential difference across its plates is decreasing with time. B. The direction of propagation of electromagnetic waves is given by $\vec{E} \times \vec{B}$ C. The dimensions of $\varepsilon_0 \frac{d\varphi_E}{dt}$ are the same as that of electric voltage. D. Instantaneous energy flow rate is a constant for an electromagnetic wave. E. Light of uniform intensity shines perpendicularly on a totally absorbing surface. On decreasing the area of the surface, the intensity remains the same. A. Only statements A & B B. Only statements C & D C. Only statements D & E D. Only statements A, C & D Ans-B
Q.4	The diagrams below show the electric and magnetic field components of an electromagnetic wave at a certain time and location. Which of these electromagnetic waves are travelling towards you?  A. only the em wave in Fig I B. only the em wave in Fig I and II C. only the em wave in Fig II and III D. only the em wave in Fig II, III and IV Ans-D

Q.5	An electromagnetic wave going through vacuum is described by $E=E_o \sin(kx - \omega t)$; $B=B_o \sin(kx - \omega t)$. Then (a) $E_o k=B_o \omega$ (b) $E_oB_o=\omega k$ (c) $E_o \omega=B_o k$ (d) none of these Ans-A
Q.6	When is the conduction current the same as the displacement current? a)When the source is ac b)When the source is dc c) When the source is either an ac or a dc d) When the source is neither dc nor ac Ans-A
Q.7	An electromagnetic wave can be produced when the charge is a. moving in a circular orbit b. moving with a constant velocity c)falling in an electric field d)Both (a) and (c) Ans-D
Q.8	Which characteristic of an electromagnetic wave is affected by the medium through which it travels? a)Time period b) Velocity c) Wavelength d) Frequency Ans-B Reason: The frequency, wavelength, and time period of a wave can all change depending on the source of the wave) The velocity of an electromagnetic wave, on the other hand, is determined by the medium through which it travels. The speed of light is the velocity of a wave in a vacuum, which is considered to be 3×10^8m/s.
	Assertion & Reason
Q.1	Two statements are given below. One is labelled Assertion (A) and the other is labelled Reason (R). Read the statements carefully and choose the option that correctly describes statements A and R. Assertion(A): An oscillating electric charge loses energy. Reason(R): An oscillating electric charge radiates em waves. A. Both assertion and reason are true and reason is the correct explanation for assertion. B. Both assertion and reason are true but reason is not the correct explanation for assertion. C. Assertion is true but the reason is false. D. Assertion is false but the reason is true. Ans-A
Q.2	Assertion – A charge moving in a circular orbit can produce electromagnetic wave. Reason – The source of electromagnetic wave should be in accelerated motion. Ans- A

Q.3	Assertion – In electromagnetic waves electric field and magnetic field lines are perpendicular to each other. Reason – Electric field and magnetic field are self-sustaining Ans-B
Q.4	Assertion : The basic difference between various types of electromagnetic waves lies in their wavelength or frequencies. Reason : Electromagnetic waves travel through vacuum with the same speed. Ans-A
	2 Marks Questions
Q.1	(a) Given the direction of electric and magnetic fields, how is the direction of an em wave determined? (b) Suggest a pair of varying Electric (Ex or Ey or Ez) and magnetic field (Bx or By or Bz) vectors that would generate a plane electromagnetic wave travelling along –z direction. Ans-(a) The direction of the em wave is given by the cross product of electric and magnetic vectors (E x B) (1 mark) (b) Ey and Bx would generate an em wave along –z direction. (1 mark)
Q.2	In a spaceship orbiting around the Earth, two astronauts stationed 2 m apart are speaking to each other. The conversation is transmitted to Earth via electromagnetic waves. Given that the sound waves travel through the air between the two astronauts in exactly the same time as the em waves take to reach the Earth ground station. Calculate the distance of the spaceship from the ground station. Take speed of sound in the air between the two astronauts as 340 m/s. Ans-For the travel of sound waves between the two astronauts: 2 / 340 = t ….(1) For the travel of em waves from the spaceship to the Earth station: $d/(3 \times 10^8) = t$ ….(2) [0.5 mark for each of the equations for sound and em waves] Equating (1) and (2) and solving for d, $d \approx 1765$ km

Q.3	How is electromagnetic wave produced? Draw a sketch of a plane e.m. wave propagating along X-axis depicting the directions of the oscillating electric and magnetic fields. Ans-Electromagnetic waves are produced due to oscillating/accelerating charged particles. 
	3 Marks Questions
Q.1	Consider a radiation whose magnetic field component is given by $B = 10^{-3}\cos(4\times 10^{10}\pi x + 12\pi \times 10^{18}t)$ Wb m^{-2} .What will be the mass of a particle whose momentum is the same as that of the photon of this radiation and whose speed is 1000 times smaller than that of the photon? ($h = 6.626 \times 10^{-34}$ J s) Ans-The momentum (p) of a photon is given by the equation: p = E/c Where, E = energy of the photon c = speed of light The energy of a photon is related to its frequency (f) by the equation: E = hf Where: E = energy, h = Planck's constant, f = frequency Thus, p = hf/c The momentum of the particle is given by mv and as per the question we need mv = hf/c mc/1000 = hf/c $m = 1000hf/c^2$ Comparing the equation of B with B = B0 cos(2πx/λ + 2πft) We have, $f = 6 \times 10^{18}$ Hz $m = 1000 \times 6 \times 1018 \times h/(3 \times 10^8)^2$ $= 2/3 \times 10^5 \times 6.626 \times 10^{-34}$ = 4.42 × 10-29 kg

Q.2	An electromagnetic wave of frequency 1 GHz travels through an empty space along the z-direction. At a specific point in space, the electric field E attains a maximum value of 50 V/m. If the electric wave is polarized along x-axis, then, (a) explain and identify the plane in which the magnetic field B will lie. (b) express the electric and magnetic fields as a function of z and t. Ans-(a) Since E wave is polarized along x-direction and the em wave propagates along z-direction, the magnetic field vector has to be perpendicular to both E wave and the direction of propagation of the wave. So, B vector is aligned along y axis and lies in y-z plane. [1 mark for correct explanation and the direction] (b) The standard waveforms of E and B vector in an em wave are: E = Eo sin (kz - ωt) B = Bo sin (kz - ωt) Bo = Eo/c = 50/c $k = 2\pi/\lambda = 2\pi\ \nu/c = 2\pi \times 10^9/c$ $E = 50 \sin \left(\frac{2\pi \times 10^9 z - 2\pi \times 10^9 . t}{C}\right)$ $E = 50 \sin 2\pi \times 10^9 . (z/c - t)$ $B = (50/c).\sin [2\pi \times 10^9 . (z/c - t)]$ [1 mark for each correct final equation of E and B]
Q.3	In a plane em wave, the electric field oscillates sinusoidally at a frequency of 2 x 10 10 Hz and amplitude 48 V/m. What is the wavelength of the wave? What is the amplitude of the oscillating magnetic field? Ans: $\lambda = c/\nu = 1.5 \times 10^{-2}$ m $B_0 = E_0/c = 48/3 \times 10^8 = 1.6 \times 10^{-7}$ T
	5Marks Questions
Q1.	(i) Determine which region of the electromagnetic spectrum is: (a) appropriate for aircraft navigation radar systems, (b) created by firing high-speed electrons at a metal target. (c) absorbed by the ozone layer of the atmosphere. (ii) Why does a galvanometer briefly deflect while a capacitor is being charged or discharged? Compose the phrase required to explain this observation.

Ans-(i)(a) Microwaves

(b) X-rays

(c) UV rays

(ii) Conduction current (i_c) and displacement current (i_d) are added to create total current i

Hence, $i = i_c + i_d = ic + \varepsilon_0 \frac{d\varphi_E}{dt}$

This indicates that we have no displacement current (id = 0) and conduction current (ic) in the connecting wires outside the capacitor plates. On the other hand, (ic = 0), there is no conduction current and just displacement current inside the capacitor, hence i = id. It explains why there is a brief deflection in the galvanometer when a capacitor is being charged or discharged.

Case study Based

According to Maxwell's electromagnetic equations it has been proved that electric and magnetic field vectors are perpendicular to each other and also perpendicular to the direction of propagation as shown in the figure below. If E_X is the electric field along X axis, then BY will be the direction of magnetic field along Y axis and both which are perpendicular to the Z axis showing direction of propagation. The light waves are also the electromagnetic waves and may travel through vacuum also. So, we can find the velocity of a light traveling through the material medium having permittivity 'ε' and magnetic permeability 'μ' as $v = 1/\sqrt{\varepsilon\mu}$. In this way, we proved that velocity of light also depends on the electrical and magnetic properties of that medium through which it is traveling. The velocity of light which is a constant, having value as 3×10^8 m/s. The most technological importance of EM waves is that they are having strong capacity to take energy from one place to another place. The best examples are radio waves, TV signals which also carry energy from their broadcasting stations. Also, life is possible on the earth only because of the sunlight coming from the sun to the earth which also carry energy and it is nothing but the EM waves. Due to which EM waves are considered as the transverse waves.

(i) The ratio of permittivity of the medium to the permittivity of vacuum is called as______.

(a) Permeability (b) Permittivity of free space (c) Dielectric constant of the medium

(d) Electric intensity

(ii) Who showed that electromagnetic waves can be produced?

(a) Maxwell (b) Hertz (c) Ampere (d) Michelson and Morley

(iii) The pressure exerted by the electromagnetic wave is called as

(a) Light pressure (b) Electric pressure (c) Magnetic pressure (d) Radiation pressure

(iv) What is the relationship between magnitude of magnetic field and electric field in case of Electromagnetic waves from Maxwell's equations?

OR

(v) What is meant by permittivity and permeability of the medium?

Answer

(i). (c) dielectric constant of the medium

(ii). (b) Hertz

(iii). (d) radiation pressure

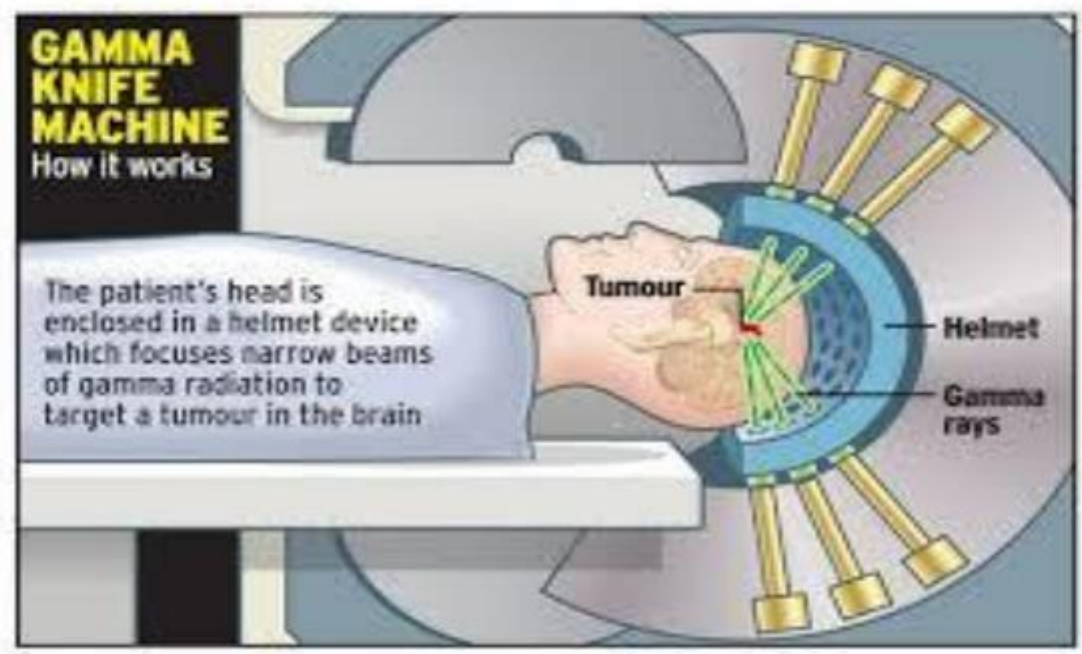
(iv). From Maxwells equqtions,the relationship between magnitude of electric field and magnetic field is given as $B_{\circ}=E_{\circ}/c$

(v). Permittivity of the medium is the ability of that medium to store electric potential energy in that medium. While permeability of the medium is the ability of the medium to allow the number of field lines through it

Q2 GAMMA RAYS IN TREATMENT OF CANCER

Gamma rays are used in radiotherapy to Treat cancer. They are used to spot tumors.

they kill the living cells and damage malignant tumor.



Q) what is the source of gamma rays?

a) radioactive decay of nucleus

b) accelerated motion of charges in conducting wire

c) hot bodies and molecule

d) klystron valve

2 Q) how is wavelength of gamma rays

a) low

b) high

c) infinite

d) zero

3 Q)choose the one with correct radiation order?

a) alpha>beta>gamma

b) beta>alpha>gamma

c) gamma>beta>alpha

d) gamma>alpha>beta

4 Q) what is other use of gamma rays?

a) used to change white topaz to blue topaz

b) used in aircraft navigation

c) used in kill microbes

d) checking fractures of bone

ANSWER KEY

1) a 3)c

2) b 4)a

RAY OPTICS

Competency-based Questions

SECTION-A (MCQ)

Q1.An object is moved towards a concave mirror at a constant speed, from infinity to its focus
Which of the following statements correctly describe the corresponding motion in the image formed by the concave mirror?

A. The image moves slower initially and faster later on, away from the mirror.

B. The image moves faster initially and slower later on, towards the mirror.

C. The image moves at a constant speed, faster than the object, away from the mirror.

D. The image moves at a constant speed, slower than the object, towards the mirror.

Q2.An incident light ray falls on a glass prism at an angle of 60o and emerges with an angle of 30o with its initial incident direction. If the angle of the prism is 30o, then which of the following is an INCORRECT statement?

A. Refractive index of the prism is √3.

B. The light undergoes minimum deviation through the prism (i.e., r1 = r2).

C. The emergent ray is perpendicular to the face from which it emerges.

D. Angle of refraction r1 at the incident face is same as angle of the prism

Q3.Which of the following actions will lead to an increase in the magnifying power of an astronomical telescope?

A. Increase in the length of the telescope tube.

B. Interchange the objective and the eyepiece of the telescope.

C. A small piece of paper on the objective of the telescope pointed towards the moon.

D.
Increase in the focal length of the objective and decrease in the focal length of the eye piece.

Q4.Two superimposing waves are of amplitudes a1 and a2 and intensities are I1 and I2 respectively. If the ratio I1:I2 is 1:16, what will be the ratio of their maximum to minimum intensities upon super-imposition?

A. 1/4 B. 4/1

C. 25/9

D. 9/25

Q5.Loud music being played on the TV in the adjacent room can be heard through the slightly open door of your study room. But you cannot see what is happening outside your room.

Why is it that you can hear the sounds but unable to see through the narrow opening of the d oor?

A. Sound waves can pass right through the walls, but light waves cannot.

B. The open door is a small slit for sound waves, but a large slit for light waves.

C.Light waves diffract efficiently through the single slit of the open doorway,but sound wave s cannotD.Light waves can travel only along straight lines whereas sound waves can travel al ong curved paths.

Q6.A 5% change in wavelength is observed in the light received from a distant star. What is t he speed of the moving star?

A. c B. 0.05 c C. 20.0 c D. 0.02 c

Q7. Which of the following statements DOES NOT correctly comply with Huygens '

Principle of constructing a secondary wavefront from a primary wavefront?

A. After some time interval, the new position of the wave front is the surface tangent to the secondary wavelets.

B. Secondary wavelets propagate outward through a medium with speeds characteristic o f 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 wave front are taken as point sources for the

production of spherical secondary waves, called wavelets.

Q8. In a glass prism of refractive index n, identify the condition for which an incident

light emerges out of the prism with a non-zero deviation.

A. Angle of prism is zero
B. Angle of incidence is equal to angle of emergence
C. . The n of the material of the prism is same as its surroundings
D. . Sum of angle of incidence and angle of emergence is equal to angle of prism

Q9. A real image of size p times the size of an object is formed by a concave mirror

of focal length f.

What is the object distance from the mirror?

A. (p+1)*f/p

B. (p-1)*f/p

C. p*f/(p+1)

D. p*f/(p-1)

Q10. Which of the following statements related to forming of interference patterns are correct?

I. The light-wave interference pattern exists in three dimensions.

II. There is a net energy flow from the slits to the screen in an interference pattern.

III. The light waves from the two slits overlap as they spread out and produce interference fringes on a screen placed opposite to the slits.

IV. Two different but identical powered white light bulbs placed side by side would fail to produce an interference pattern on the screen.

A. All are correct

B. Only I and II are correct

C. Only I, II and III are correct

D. Only II, III and IV are correct

SECTION-B (Assertion – Reason)

Q11 Read the statements given here carefully. Each statement is in reference to spherical mirrors. Here u, v and f denote the object distance, the image distance and the focal length of the spherical mirror respectively.

I. A graph plotted between u and v is a hyperbola and when u = f, v = Infinity.

II. A graph plotted between u and v is a straight line and when u = Infinity, v = f.

III. A graph plotted between (1/u) and (1/v) is a straight line with an intercept of each axis as (1/f).

IV. A graph plotted between (1/u) and (1/v) is a hyperbola with an intercept of each axis as f.

Select the correct option.

A. Statements I and III are correct

B. Statements II and IV are correct

C. Statements I and II are correct

D. Statements III and VI are correct

Q12When coherent light waves interfere to produce alternate bands of dark and bright interference bands, which of the following statement/s 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

Q13. Two statements are given below. One is labelled Assertion (A) and the other is labelled Reason (R). Read the statements carefully and choose the option that correctly describes statements A and R.

Assertion(A): A ray of light travelling from one media to another always changes its path.

Reason(R): The speed of light changes when it travels from one medium to another.

A. Both assertion and reason are true and reason is the correct explanation for assertion.

B. Both assertion and reason are true but reason is not the correct explanation of assertion.

C. Assertion is true but reason is false.

D. Assertion is false but reason is true..

Q14 Two statements are given below. One is labelled Assertion (A) and the other is labelled Reason (R). Read the statements carefully and choose the option that correctly describes statements A and R.

Assertion(A): The degree of convergence of a convex lens made of glass decreases when it is placed in water.

Reason(R): The relative refractive index of the glass with respect to water is less than that of glass with air.

A. Both assertion and reason are true and reason is the correct explanation for assertion.

B. Both assertion and reason are true but reason is not the correct explanation of assertion.

C. Assertion is true but reason is false.

D. Both assertion and reason are false.

Q15. Assertion : In optical fibre, the diameter of the core is kept small.

Reason : The small diameter of the core ensures that the fibre should have inside it an angle greater than critical angle needed for total internal reflection.

A. If both, Assertion and Reason are true and the Reason is the correct explanation of the Assertion.

B. If both, Assertion and Reason are true but Reason is not a correct explanation of the Assertion.

C. If Assertion is true but the Reason is false.

D. If both, Assertion and Reason are false.

SECTION-C (2 Marks)

Q16.An object is placed on the optical bench at a distance of 40 cm from the convex mirror o f focal length 10 cm. A plane mirror is placed in between the object and the convex mirror su ch that it covers the lower half of the convex mirror. Find the distance from the object where t he plane mirror be placed, so that no parallax is observed between the two images formed by the two mirrors. 2

Q.17A beam of yellow light falls with a certain angle of incidence at the interface of the two media and experiences an angle of refraction of 90o. Red and blue light beams then replace th e yellow light successively, keeping all other conditions same. One of the two colours, red or blue, undergoes total internal reflection. (a) Identify the colour of light that undergoesTIR. Give reason for your choice. (b) Also give reason why the other colour doesn't undergoTIR. 2

Q.18A thin convex and a thin concave lens are placed along the same axis on an opt ical bench. A parallel beam of light falls on the convex lens. The distance d between the two l ens is adjusted by moving the concave lens so that the light emerging out of the concave lens is parallel.

(a) Draw a suitable ray diagram to represent the flow of light through the lens system.

(b)State the condition that ensures that the emergent beam is parallel. If the focal length (conv ex) = 20 cm and focal length (concave) = 8 cm, find d. 2

Q.19 Lens Q when placed in contact with a converging lens P of focal length = 20 cm makes a combination that behaves as a converging lens system of focal length 30 cm. Lens Q when placed in contact with another lens R makes a combination that behaves as a diverging lens system of focal length 10 cm. Identify the nature of lens Q and R and dete rmine their focal lengths.
2

Q.20 An object placed at a distance of x from the first focus of a convex lens forms a real im age at a distance of y from its second focus. Show that the product xy is equal to the square of the focal length f of the lens

SECTION- D(3 Marks)

Q21. A plano concave lens forms a virtual image at a distance of 5 cm in front of the

lens of an object placed in front of it.The image formed is 1/2 times the size of the object. If the speed of light in the Plano concave lens is 2/3 times the speed of light in air, then find

(a) the refractive index of the lens.

(b) the radius of curvature of the curved surface of the lens. 3

Q22. A small piece of paper is stuck on the surface of the glass sphere of radius 10 cm

and refractive index 1.5. The paper is viewed from diametrically opposite side.

a. Represent the image formation using a ray diagram.

b. Determine the image position. 3

Q23. A thin convex lens of focal length 10 cm and refractive index n1 = 1.5 is immersed in a medium of refractive index n2. In each of the following instances, determine whether the lens behaves as a converging lens, plane glass or a diverging lens. Also find the focal length of the lens in each case.

(a) n2 = 1.2

(b) n2 = 1.5

(c) n2 = 2. 3

Q24.Beam of yellow light falls with a certain angle of incidence at the interface of the two m edia and experiences an angle of refraction of 90o. Red and blue light beams then replace the yellow light successively, keeping all other conditions same. One of the two colours, red or blue, undergoes total internal reflection. (a) Identify the colour of light that undergoes TIR. Give reason for your choice. (b) Also give reason why the other colour doesn't undergoTIR. 3

Q25.A combination of multiple convex lens kept in contact with each other has an equivalent focal length of 0.02 m. An object is placed at a distance of 0.03 m from the combination lens system. If one of the component lens of focal length 0.1 m is removed from the combination, by what distance is the image of the object shifted from its initial position? 3

SECTION-E (5 Marks)

Q26. (i) What are the two main considerations for designing the objective and eyepiecelenses of an astronomical telescope ? Obtain the expression for magnifying power of the telescope when the final

image is formed at infinity.(ii) A ray of light is incident at an angle of 45° at one face of an

equilateral triangular prism and passes symmetrically through the prism. Calculate :

(1) the angle of deviation produced by the prism

(2) the refractive index of the material of the prism. 5

Q27 a) Draw the labeled ray diagram for the formation of image by a compound microscope. Derive the expression for the total magnification of a compound microscope.

(b) A tank is filled with water to a height of 12.5 cm. The apparent depth of a needle lying at the bottom of a tank is measured to be 9.4 cm. What is the refractive index of water? If a liquid of refractive index 1.63 upto the same height replaces water, by what distance would the microscope have to be moved to focus the needle again. 5

SECTION-F (4 Marks)

Q28. Strontium titanate is a rare oxide a natural mineral found in Siberia. It is used as a substitute for diamond because its refractive index and critical angle are 2 41 and 24 5 , respectively, which are approximately equal to the refractive index and critical angle of diamond. It has all the properties of diamond. Even an expert jeweller is unable to differentiate between diamond and strontium titanate. A ray of light is incident normally on one face of an equilateral triangular prism ABC made of strontium titanate.

Answer the following questions based on the above:

(a) Define critical angle. 1

(b) Write the relation between refractive index and critical angle 1

(c) Briefly explain two applications of total internal reflection. 2

Q29. Diffraction of light is bending of light around the corners of an object whose size is comparable with the wavelength of light. Diffraction actually defines the 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.

Answer the following questions based on the above:

(a) How will the width of central maximum be affected if the wavelength of light is increased? 1

(b) Under what condition is the first minimum obtained? 1

(c) Write two points of difference between interference and diffraction patterns. 2

OR

(c) Two students are separated by a 7 m partition wall in a room 10 m high. If both light and sound waves can bend around obstacles, how is it that the students are unable to see each other even though they can converse easily? 2

ANSWERS

Q1. A. The image moves slower initially and faster later on, away from the mirror.

Q2. B. The light undergoes minimum deviation through the prism (i.e., r1 = r2).

Q3. D. Increase in the focal length of the objective and decrease in the focal length

of the eye piece.

Q4. C. 25/9

Q5. B. The open door is a small slit for sound waves, but a large slit for light waves.

Q6. B. 0.05 c

Q7. C. A secondary wavefront is always a plane wavefront irrespective of whether

the primary wavefront is planar or spherical.

Q8. B. Angle of incidence is equal to angle of emergence

Q9. **A. (p+1)*f/p**

Q10. A. All are correct

Q11. A. Statements I and III are correct

Q12. C. Statement II and III only

Q13. D. Assertion is false but reason is true..

Q14. A. Both assertion and reason are true and reason is the correct explanation

For assertion.

Q15. B.If both, Assertion and Reason are true but Reason is not a correct explanation of the Assertion.

Q.16 Using mirror formula for the convex mirror, $1/f = 1/v + 1/u$ $1/10 = 1/v + 1/(-40)$

Solving for v, v = 8 cm

[0.5 mark for the correct value of image distance]

For no parallax, the position of the image formed by plane mirror should

coincide with position of the image formed by the convex mirror.

[0.5 mark for identifying the condition of parallax] Hence,

Total distance between object and image formed by convex mirror

= 40 + 8 = 48 cm

Plane mirror has to be placed at 48/2 = 24 cm from the object. [1 mark for the

correct final result] 2

Q.17 (a) Blue colour undergoes TIR.

As n is proportional to $1/\lambda$ and $\sin c = 1/n$

Since $\lambda b < \lambda y$, $nb > ny$

So Critical angle Cb < Cy

In the present situation, since at the given angle of incidence i, the yellow light

has angle of refraction = 90, at the same angle of incidence i, the blue light will

undergo total internal reflection since Cb < Cy .

[0.5 mark for the correct colour identification] [1 mark for the correct reasoning]

(b) Red colour does not undergo TIR. It passes through the interface with angle

of refraction < 90.

As n is proportional to $1/\lambda$ and $\sin c = 1/n$ Since $\lambda r > \lambda y$, $nr < ny$,

So critical angle Cr > Cy

In the present situation, since at the given angle i, the yellow light has angle of

refraction = 90, at the same angle of incidence i, the red light simply passes

through into the rarer medium at an angle of refraction < 90.

[0.5 mark for the correct colour identification] [1 mark for the correct reasoning]

Q.18 (a)

(b) Parallel beam that enters the convex lens converges at its focus after refraction. If the emergent beam from the concave lens is to be parallel, then the rays coming from convex lens must virtually meet at the focus of concave lens. [1 mark for the correct reasoning]

Distance d = fcx - fcv = 20 – 8 = 12 cm [1 mark for the correct result] 2

Q.19 P & Q combination:

Calculating f2= -60 cm

[1 mark for the correct result of focal length of lens Q]

That is, Lens Q is a diverging lens.

[0.5 mark for correct identification of lens Q]

Q & R combination:

Calculating f2 = -12 cm

[1 mark for the correct result of focal length of lens R] That is, Lens R is also a diverging lens.

Q20. Using lens formula,

[1 mark for correct formula and substitution] f(x + 2f + y) = xy + fy + fx + f2

Transposing and solving xy = f2

[1 mark for correct proof]

Q21. (a) Refractive index = c/v

n = c /(2/3c) =1.5

(b) v = - 5.0 cm

m = v/u = hi/ho (0.5 marks)

-5/u = (1/2ho)/ho

u = - 5 × 2 = -10 cm (0.5 marks)

1/f = 1/v - 1/u (0.5 marks)

1/f = -1/5 + 1/10 = -1/10

f = - 10 cm (0.5 marks)

By lens maker formula

1/f = (n - 1)(1/R1 - 1/R2) (0.5 marks)

-1/10 = (1.5 - 1)(1/R1 - 1/-∞)

R1=-5 cm

Q22. [1 mark for the correct ray diagram depicting the location of the image]

b. Using,

Here,

u = -20 cm, R = -10 cm, n1 = 1.5, n2 = 1

[1 mark for correct formula and identify correct values with signs]

Upon substituting and calculating

1/v = -1/40

v = -40 cm

Image is formed 20 cm behind the glass ball.

[1 mark for the correct final value]

Q23. Use lens maker's formula and derive relation 3

Q24. Blue colour undergoes TIR.

As n is proportional to $1/\lambda$ and sin c = 1/n

Since $\lambda b < \lambda y$, nb > ny

So Critical angle Cb < Cy

In the present situation, since at the given angle of incidence i, the yellow light has angle of refraction = 90, at the same angle of incidence i, the blue light will undergo total internal reflection since Cb < Cy .

[0.5 mark for the correct colour identification] [1 mark for the correct reasoning]

(b) Red colour does not undergo TIR. It passes through the interface with angle of refraction < 90.

As n is proportional to $1/\lambda$ and sin c = 1/n Since $\lambda r > \lambda y$, nr < ny ,

So critical angle Cr > Cy

In the present situation, since at the given angle i, the yellow light has angle of refraction = 90, at the same angle of incidence i, the red light simply passes through into the rarer medium at an angle of refraction < 90.

[0.5 mark for the correct colour identification] [1 mark for the correct reasoning]

Q25. Initially,

$1/v1 - 1/u = 1/F$

$1/v1 - 1/(-3) = 1/2$

So initially the image is formed at v1 = +6 cm

[1 mark for finding the initial position of the image]

For the combination lens system,

$1/F = 1/f1 + 1/f2 + 1/f3 +\cdots. = 1/f1 + 1/F'$, here f1 is the focal length of the lens that 3

is removed from the combination,

$1/F' = 1/F - 1/f1 = 1/2 - 1/10$

F' = 2.5 cm.

This is focal length of the remaining combination after the removal of one lens.

[1 mark for finding the focal length of the combination after the removal of the lens]

$1/v2 - 1/u = 1/F'$ = $1/v2 - 1/(-3) = 1/2.5$

v2 = + 15 cm

So the final image of the object is shifted away from the lens system by a

distance of 9 cm. [0.5 mark for finding the image position in the new combination]

[0.5 mark for the correct shift in the position of the image]

Q26.) Two main considerations for designing objective and eye piece 1

Obtaining expression for magnifying power of telescope 2

(ii) Calculating

(1) Angle of deviation 1 (2) Refractive index 1

Two main considerations

Objective should have

1. Larger diameter 2. Larger focal length

Eye piece should have

1. Smaller diameter 2. Smaller focal length

Magnifying power of telescope

Magnifying power is the ratio of the angle β subtended at the eye by the

final images to the angle α which the object subtends at the lens or eye

(ii) i+e = D+A

Q27. (a) Figure

Magnifying power

(b) Finding aμw

Finding apparent depth

Q28.a) definition

b) write formula c) any two applications of TIR

Q29. (a) □o □ □

□o will increase with increase in wavelength.

(b)to write formula (c) Differences

Interference Pattern

(i) All the maxima are equally spaced.

(ii)The dark fringe is having zero intensity.

(iii) All the maxima are of the same intensity.

(iv)Alternatively:-

-It is obtained by the superposition of
two waves originating from two
sources/slits.

Diffraction Pattern

(i) Width of Central bright maxima
is twice the width of the other
maxima.

(ii) The dark fringe is not
Completely dark.

(iii) There is a sharp decrease in the

Competency based questions with solutions
Wave Optics

MCQ

1. For coherent sources, what is essential?
   A) colour difference B) Constant phase difference (C) Different frequencies D) same Amplitudes

2. The energy in the phenomenon of interference is
   (A) Conserved, gets redistributed (B) is equal at every point C) Distroid in the regions

   of Dark fringes. D) none of These.

3. In Young's Double Slit experiment, for which colour the fringe width is the least?
   A) Red B) Green C) Blue D) Yellow

4. Which of the following statements is true in young's Experiment when separation between the slits is gradually increased
   A). fringe width increases B) fringe width decreases C) fringe width remains same. D) none of these

5. when exposed to sunlight, thin films of oil on water often exhibits brilliant Colours due to the phenomenon of

A) interference B) diffraction C) dispersion D) polarization

6. for a parallel beam of monochromatic light of wavelength λ, diffraction is produced by a single slit whose width is a . If D is the distance of screen from the slit, the width of the central maxima will be
   A) Dλ/a. B) Da/λ. C) 2Dλ/a. D) 2Dλ/a

7. The width of a central fringe of a single slit diffraction pattern is 6.8mm on a screen at a distance 2m. If light source has wavelength 6800A° then the shit width is :
   A) 0.2mm B) 0.4 mm C) 0.8mm D) 0.1mm

8. In a young's double slit experiment, the fringe width. is found to be 0.4mm. If the whole apparatus is immersed in water of refractive index 4/3 without disturbing the arrangement, the new fringe width will be
   A) 540 microns B) 0.53mm C) 0.4mm D) 0.3mm
9. In a single shit diffraction experiment, the width of the stilt is halved. The width of central maximum in the pattern become
   A) halt B) Double C) Four times D) one fourth
10. A diffraction pattern is obtained by using a beam of red light. What will happen, if the red light is replaced by the blue light?
    A) Band disappear B) Bands becomes broader c) no change will take place D) diffraction bands become narrow

Answer

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

Assertion and reason

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

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

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

(c) If the Assertion is correct but Reason is incorrect.

(d) If both the Assertion and Reason are incorrect.

1. Assertion : The phase difference between any two points on wavefront is zero.
   Reason: All the points on a wavefront are at the same distance from the source and thus oscillate in the same phase.

2. Assertion : In Young's Double Slit experiment all the fringes are of equal width.
   Reason: The fringe width depends upon wavelength of light used, distance of screen from slits and the separation of slits.

3. Assertion : to observe diffraction of light , the size of obstacle should be of the order of 10^{7} m.
   Reason: 10^{7} m is the order of wavelength of visible light.

4. Assertion : colourful pattern is seen on the thin layers of oil drops.
   Reason: white light consists of many colours.

5. Assertion : noise is heard/seen on radio/television during lightning.
   Reason: Electromagnetic waves due to lightning interfere with the radio/TV signals

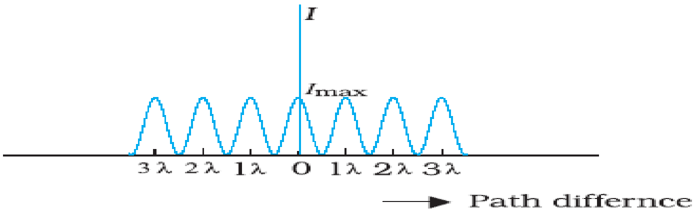
Answers

Qn	1	2	3	4	5
Ans	A	a	d	B	a

Two marks Questions

1. What type of wave front will emerge from a point source and a distant source of light?
   Answer: Spherical and plane

2. Sketch the variation of intensity of the interference pattern in Young's double slit experiment. How the angular separation of interference fringes change in Young does's double slit experiment, if the distance between the slits is increased?



   Ans- Decreases

3. In Young's double slit experiment, slits are separated by 0.28 mm and the screen is 1.4 m away. Distance between central and 4th bright fringe is 1.2 cm. calculate wavelength of light used.
   Ans: $y = 4D\lambda/d = 0.012$, $\lambda = 6\times10^{-7}$ m.

4. Red light of wavelength 6500 A falls on a slit 0.5 mm wide. What is the distance between two dark bands on each side of the central bright fringe of diffraction pattern on a screen 1.8 m away?
   Ans: $2D\lambda/a = 4.7$mm

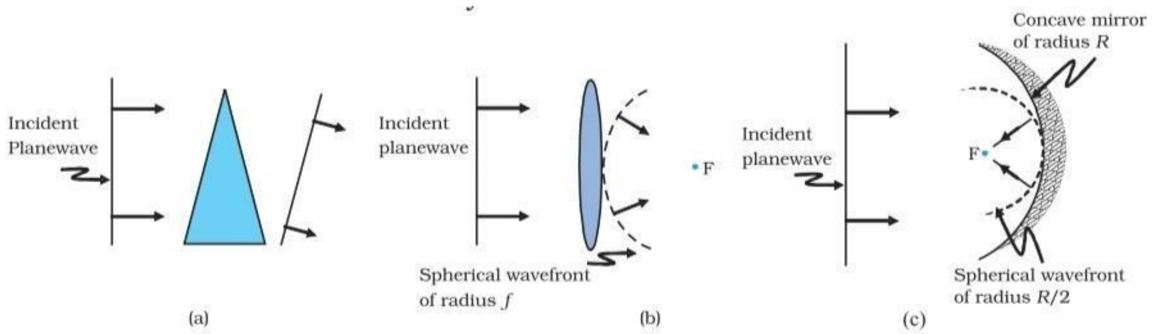
5. Give two differences between interference and diffraction of light.
   Ans: (i) The interference pattern has a number of equally spaced bright and dark bands. The diffraction pattern has a central bright maximum which is twice as wide as the other maxima. The intensity falls as we go to successive maxima away from the centre, on either side.

   (ii) We calculate the interference pattern by superposing two waves originating from the two narrow slits. The diffraction pattern is a superposition of a continuous family of waves originating from each point on a single slit.

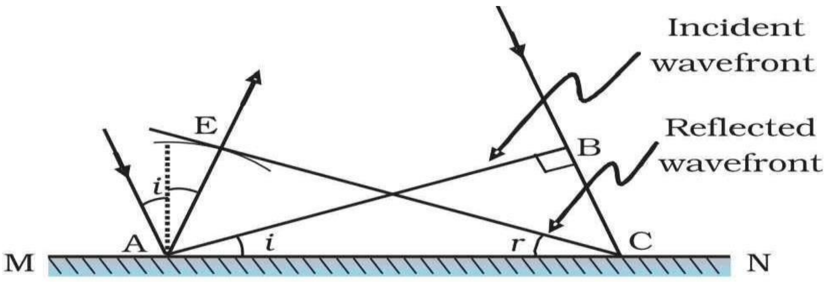
Three marks Questions

1. Draw the refracted/reflected wave front when a plane wavefront fall on a
a. Glass prism
b. Convex Lens
c. Concave mirror

Answer



2. Use Huygen's principles to explain reflection of a plane wavefront. Hence prove laws of reflection.
   Answer:

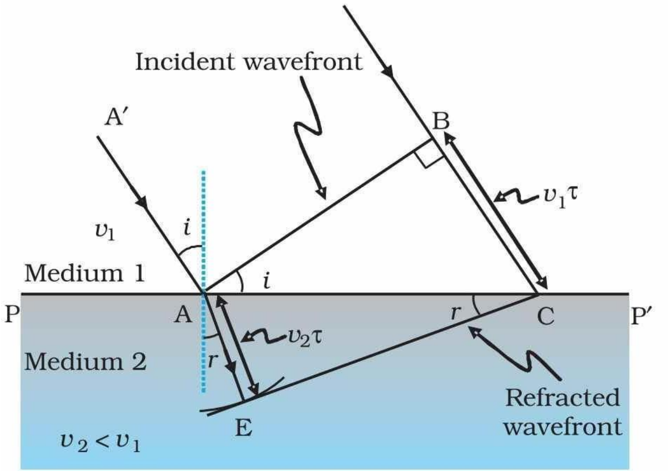


Consider a plane wave AB incident at an angle i on a reflecting surface MN. If v represents the speed of the wave in the medium and if τ represents the time taken by the wavefront to advance from the point B to C then the distance BC = vτ

In order the construct the reflected wavefront we draw a sphere of radius vτ from the point A as shown in Figure. Let CE represent the tangent plane drawn from the point C to this sphere. Obviously AE = BC = vτ

If we now consider the triangles EAC and BAC we will find that they are congruent and therefore, the angles i and r would be equal. This is the law of reflection.

3. Use Huygen's principles to explain refraction of a plane wavefront from a rarer to denser medium. Hence prove Snell's law.
Answer



Let PP′ represent the surface separating medium 1 and medium 2. Let v1 and v2 represent the speed of light in medium 1 and medium 2, respectively.

v2<v1

We assume a plane wavefront AB propagating in the direction A′A incident on the interface at an angle i. Let τ be the time taken by the wavefront to travel the distance BC. Thus, BC = v_1.τ

In order to determine the shape of the refracted wavefront, we draw a sphere of radius v2.τ from the point A in the second medium (the speed of the wave in the second medium is v2). Let CE represent a tangent plane drawn from the point C on to the sphere. Then, AE = v2.τ and CE would represent the refracted wavefront.

If we now consider the triangles ABC and AEC, we obtain

$$\sin i = \frac{BC}{AC} = \frac{v_1 \tau}{AC}$$

and

$$\sin r = \frac{AE}{AC} = \frac{v_2 \tau}{AC}$$

where i and r are the angles of incidence and refraction, respectively. Thus we get

$$\frac{\sin i}{\sin r} = \frac{v_1}{v_2}$$

But refractive index n=c/v hence n2/n1=v1/v2

Hence sini/sinr = n2/n1

4. What is the shape of the wavefront in each of the following cases:
   (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 the wavefront of light from a distant star intercepted by the Earth.

   Answer: a) spherical

   b) plane

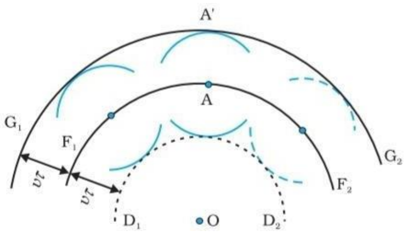
   c) plane

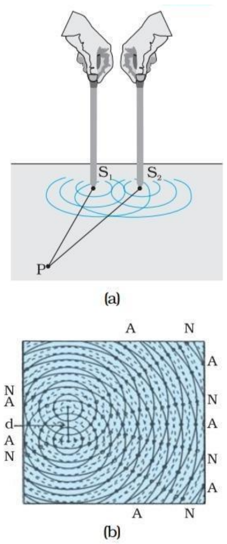
5. Define a wavefront. State Huygen's principles for propagating wave of light. Show geometrical construction of propagation of a spherical wavefront.
   Answer :

   A wavefront is defined as a surface of constant phase.

   According to Huygens principle, each point of the wavefront is the source of a secondary disturbance and the wavelets emanating from these points spread out in all directions with the speed of the wave. These wavelets emanating from the wavefront are usually referred to as secondary wavelets and if we draw a common tangent to all these spheres, we obtain the new position of the wavefront at a later time.

   Geometrical construction of propagation of a spherical wavefront:





(a)

(b)

Five marks Questions

1. Explain coherent sources of light. Find condition for constructive and destructive interference of light. Explain sustained interference.
Answer :

Consider two needles S1 and S2 moving periodically up and down in an identical fashion in a trough of water.

They produce two water waves, and at a particular point, the phase difference between the displacements produced by each of the waves does not change with time; when this happens the two sources are said to be coherent.

For any arbitrary point P let the phase difference between the two displacements be ϕ. Thus, if the displacement produced by S1 is given by

$y1 = a \cos \omega t$

and, the displacement produced by S2 would be

$y2 = a \cos (\omega t + \phi)$

and the resultant displacement will be given by

$y = y1 + y2$

$= a [\cos \omega t + \cos (\omega t + \phi)]$

$= 2 a \cos (\phi/2) \cos (\omega t + \phi/2)$

The amplitude of the resultant displacement is $2a \cos (\phi/2)$ and

therefore the intensity at that point will be

$I = 4 I_0 \cos^2(\phi/2)$

If $\phi = 0, \pm 2\pi, \pm 4\pi$,… which corresponds constructive interference leading to maximum intensity. On the other hand, if $\phi = \pm \pi, \pm 3\pi, \pm 5\pi$ …. we will have destructive interference leading to zero intensity.

Now if the two sources are coherent (i.e., if the two needles are going

up and down regularly) then the phase difference ϕ at any point will not

change with time and we will have a stable interference pattern; i.e., the

positions of maxima and minima will not change with time. However, if

the two needles do not maintain a constant phase difference, then the

interference pattern will also change with time and, if the phase difference

changes very rapidly with time, the positions of maxima and minima will

also vary rapidly with time and we will see a "time-averaged" intensity

distribution.

2. a) Write the necessary conditions to obtain sustained interference fringes. Also write the expression for the fringe width.
(b) In Young's double slit experiment, plot a graph showing the variation of fringe width versus the distance of the screen from the plane of the slits keeping other parameters same.

(c) What is the effect on the fringe width if the distance between the slits is reduced keeping other parameters same?

Answer:

(a) Conditions for sustained interference:

(i) The interfering sources must be coherent i.e., sources must have same frequency and constant initial phase.

(ii) Interfering waves must have same or nearly same amplitude, so that there may be contrast between maxima and minima.

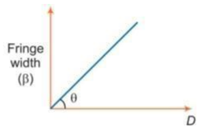
Fringe width = Dλ/d

where D = distance between slits and screen.

d = separation between slits.

λ = wavelength of light used.

(b)



(c) Effect: From relation Dλ/d

If distance d between the slits is reduced, the size of fringe width will increase.

Case study Based

1. Case Based Question:
According to superposition principle, the resultant displacement produced due the number of waves at a particular point is the vector sum of displacement produced by each wave at that point. The two sources of light are said to be coherent only when the phase difference between the light waves produced by them is zero or constant. The point at which two waves are in phase, the resultant intensity produced at that point will be larger and amplitude also maximum. Such points are the points where constructive interference takes place. While there are some points where two light waves are not in phase with each other and crest of one wave coincides with the trough of other and vice versa due to which resultant intensity at that point is minimum and amplitude also get decreased. Such points are the points where destructive interference takes place. When light is passed around the sharp edges of an obstacle it gets bent and may enter into the geometrical shadow of that obstacle such a phenomenon of light is called diffraction.

Questions:

Q 1.) For coherent sources of light, the phase difference between the two waves must be____

a) one b) 180° c) either zero or constant d) 90°

Q 2.) If the phase difference is 0, +2π, +4π then the interference should be

a) constructive interference b) destructive interference

c) both a and b d) none of these

3.) For destructive interference

a) path difference is (n +1/2) times wavelength

b) phase difference is π, -3π, +5π

c) path difference is integral multiple of wavelengths

d) both a and b

Q 4.) The interference and diffraction of light explains which nature of light?

Answer key:

Q 1.) c) either zero or constant

Q 2.) a) constructive interference

Q 3.) d) both a and b

Q 4.) The phenomenon of interference of light and diffraction of light explains the wave

nature light.

Case Based Question: Qn no 2

According to Huygens principle, each point of the wavefront is the source of a secondary disturbance and the wavelets emanating from these points spread out in all directions with the speed of the wave. These wavelets emanating from the wavefront are usually referred to as secondary wavelets and if we draw a common tangent to all these spheres, we obtain the new position of the wavefront at a later time.

Based on the above paragraph, answer following questions

i) the wavefront due to source situated at infinity are

a) spherical. b) cylindrical. c) plane. d) all types of wavefronts

ii) if a wave is refracted into a denser medium, which of the following is true

a) wavelength, frequency and speed decrease
b) wavelength increases, speed decreases and frequency remains constant
c) wavelength and speed decrease while frequency remains same
d) none these

iii) According to Huygens principle, the amplitude of secondary wavelets is

a) equal in both forward and the backward directions
b) maximum in forward direction and zero in backwards
c) large in forward direction and small backwards
d) none of these

iv) which of the followings can not be explained by wave theory of light

a) reflection b) refraction c) diffraction d) polarization

Answer -i) c. ii) c. iii) b. iv) d

COMPETANCY BASED QUESTIONS

DUAL NATURE OF MATTER AND RADIATION

- **MCQ**

1- In which of the following, emission of electrons does not take place:-

a. Thermionic emission b. X-rays emission
c. Photoelectric emission d. Secondary emission

Answer: b

2- Photons of energies 1eV and 2eV are successively incident on a metallic surface of work function 0.5eV.
The ratio of kinetic energy of most energetic photoelectrons in the two cases will be:-

a. 1:2 b.1:1 c. 1:3 d.1:4.

Answer: c

3- Photons are deflected by:-

a. electric field only b. magnetic field only
c. electromagnetic field d. None of these

Answer: d

4- What happens to the kinetic energy of the emitted electrons when the light is incident on a metal
Surface:-

a. It varies with the frequency of light b. It varies with the light intensity
c. It varies with the speed of light d. It varies irregularly

Answer: a

5- The photoelectric effect is based on the law of conservation of:-

a. Energy b. Momentum
c. Mass d. Angular momentum

Answer: a

6- 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: a

7- 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: b

8- An electron, an alpha particle, a deutron and a proton have the same KE. Which one has shortest de Broglie wavelength:-

a. α particle b. electron c. proton d. deutron.

Answer: b

- **ASSERTION - REASON**

Select the most appropriate answer from the options given below:

a) Both A and R are true and R is the correct explanation of A
b) Both A and R are true but R is not the correct explanation of A.

c) A is true but R is false.
d) A is false and R is also false.

1- A: Every metal has a definite work function. Still all photoelectrons do not come out with the same energy if incident radiation is monochromatic.

R: Work function is the minimum energy required for the electron in the highest level of the conduction band to get out of the metal. Not all electrons in the metal belong to this level rather they occupy a continuous band of levels.

Answer: a) Both A and R are true and R is the correct explanation of A

2- A: Work function of aluminum is 4.2 eV. Emission of electrons will be possible by two photons, each of 2.5eV energy, striking the electron of aluminum.
R: Energy of a photon can be less than the work function of the metal, for photoelectron emission.

Answer: d) A is false and R is also false

3- A: On increasing the intensity of light, the number of photoelectrons emitted is more.
R: Photoelectric current is independent of intensity but increases with increasing frequency of incident radiation.

Answer: c) A is true but R is false

4- A: There is almost no time-lag between the incidence of light and the emission of photoelectrons.
R: A photon transfers almost all its energy to a single electron on metal surface.

Answer: a) Both A and R are true and R is the correct explanation of A

5- A: Wave nature of particles is not visible in daily life.
R: In daily life, mass of particles is very high so their de Broglie wavelength is very small.

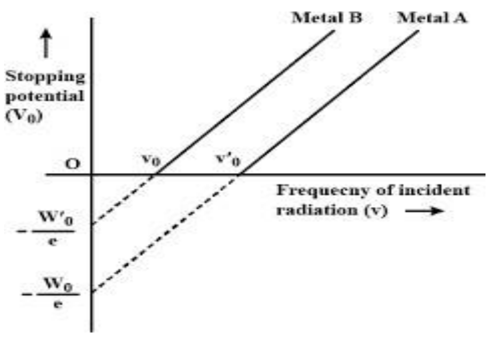
Answer: a) Both A and R are true and R is the correct explanation of A

- **2 MARK QUESTIONS**

1- Electrons are emitted from a photosensitive surface when it is illuminated by green light but electron emission does not take place by yellow light. Will the electrons be emitted when the surface is illuminated by (i) red light, (ii) blue light?
Justify your answer.

Answer: (i) Since photoelectrons are not emitted by yellow light, so electrons will not be emitted by red Light as frequency of red is less than yellow light.
(ii) Since green light is able to emit electrons so blue light will emit electrons with large velocity as the frequency of blue light is more than green light.

2- The graph shows variation of stopping potential Vo verses frequency of incident radiation ϑ for two photosensitive metals A and B.



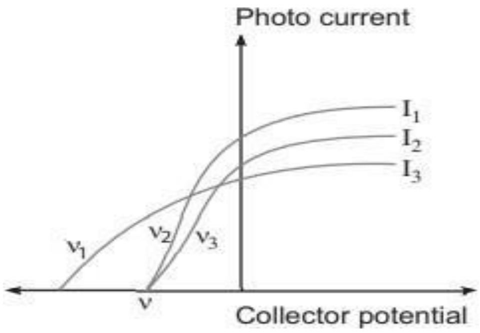
(i) Which of the two metals has higher threshold frequency and why?
(ii) What does intercept on -ve Y-axis represent?

Answer:

(i) the threshold frequency of Metal A is greater than the Metal B,
(ii) Intercept on potential axis = $-\phi_0/e$

3- 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 (I_1 and I_2) have the same frequency ν and the third has frequency $\nu_1 > \nu$.

Answer: The graph is as follows:



- **3 MARK QUESTIONS**

1- Light of wavelength 2000 Å falls on a metal surface of work function 4.2 eV.
(a) What is the kinetic energy (in eV) of the fastest electrons emitted from the surface?
(b) What will be the change in the energy of the emitted electrons if the intensity of light with same wavelength is doubled?
(c) If the same light falls on another surface of work function 6.5 eV, what will be the energy of emitted electrons?

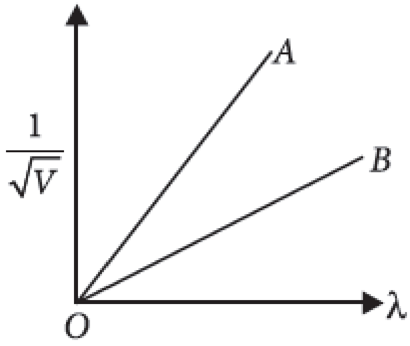
Ans- λ = 2000 Å = (2000×10^{-10}) m, W_0 = 4.2eV, h = 6.63×10^{-34}JS

a) Using Einstein's photoelectric equation
K. E. = (6.2 – 4.2) eV = 2.0 eV

b) The energy of the emitted electrons does not depend upon intensity of incident light; hence the energy remains unchanged.

c) For this surface, electrons will not be emitted as the energy of incident light (6.2 eV) is less than the work function (6.5 eV) of the surface.

2- Define the terms cut-off voltage. Figure shows a plot of $1/\sqrt{V}$, where V is the accelerating potential, Vs. The de Broglie wavelength λ in the case of two particles having same charge 'q' but different masses m_1 and m_2.



Which line (A or B) represents a particle of larger mass? Justify your answer.

Answer: Cut-off voltage is the negative voltage required to stop the photoelectron so that photocurrent becomes zero.

$$\lambda_A = \frac{h}{\sqrt{2m_1 qV_A}}$$

$$\lambda_B = \frac{h}{\sqrt{2m_2 qV_B}}$$

$$\therefore \quad \frac{\lambda_A}{\lambda_B} = \sqrt{\frac{2m_2 qV_B}{2m_1 qV_A}} = \sqrt{\frac{m_2 V_B}{m_1 V_A}}$$

$$\because \quad \frac{\lambda_A}{\sqrt{V_A}} = \frac{\lambda_B}{\sqrt{V_B}}$$

Therefore m1 < m2.

3- An electron and a photon have the same wavelength 1 nm, find following:

(i) Their momenta
(ii) Energy of photon
(iii)Kinetic energy of electron

$$p = \frac{h}{\lambda} = \frac{6.6 \times 10^{-34}}{1 \times 10^{-9}} = 6.6 \times 10^{-25} \text{ kg m s}^{-1}$$

Momentum of electron

$$p = \frac{6.6 \times 10^{-34}}{1 \times 10^{-9}} = 6.6 \times 10^{-25} \text{ kg m s}^{-1}$$

(ii) Energy of photon

$$E = \frac{hc}{\lambda} = \frac{6.6 \times 10^{-34} \times 3 \times 10^{8}}{1 \times 10^{-9}} = 1.98 \times 10^{-16} \text{ J}$$

(iii) Kinetic energy of electron

$$E_e = \frac{p^2}{2m} = \frac{(6.6 \times 10^{-25})^2}{2 \times 9.1 \times 10^{-31}} = 2.39 \times 10^{-19} \text{ J}$$

- **5 MARK QUESTIONS**

1-(i) Draw properly labelled graphs to show the following concerning photo electric emission:

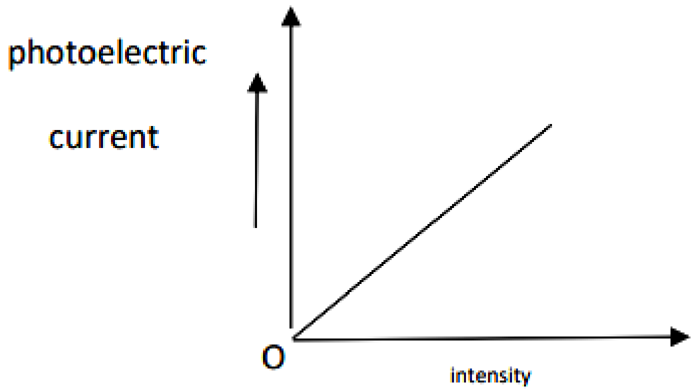
a) Variation of photo electric current with the intensity of incident radiation.
b) Variation of photo electric current with accelerating potential for varying intensity.
c) Variation of stopping potential with frequency of incident radiation for two metals having different threshold frequencies.

(ii) A proton and an alpha particle are accelerated through the same potential. Which one of the two has (a) greater value of de Broglie wavelength associated with it and

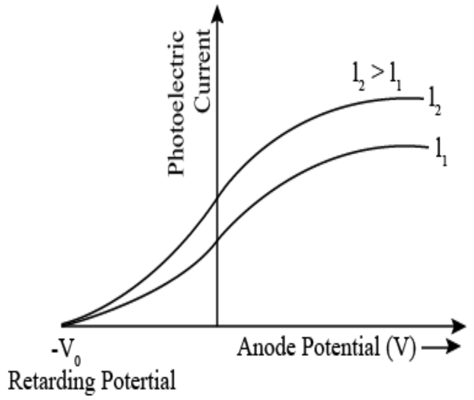
(b) less kinetic energy? Give reasons to justify your answer.

Answer:

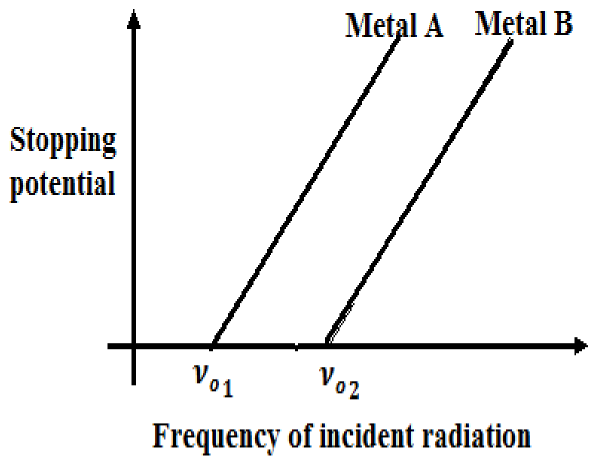
(i) **a)**



b)



c)



(ii) a)

de Broglie wavelength

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mqV}}$$

For same V, $\lambda \alpha \frac{1}{\sqrt{mq}}$

$$\frac{\lambda_p}{\lambda_\alpha} = \sqrt{\frac{m_\alpha q_\alpha}{m_p q_p}} = \sqrt{\frac{4m_p}{m_p} \cdot \frac{2e}{e}}$$

$$= \sqrt{8} = 2\sqrt{2}$$

Clearly, $\lambda_p > \lambda_\alpha$.

Hence, proton has a greater de-Broglie wavelength.

b)

Kinetic energy, $K = qV$

For same V, $K \alpha q$

$$\frac{K_p}{K_\alpha} = \frac{q_p}{q_\alpha} = \frac{e}{2e} = \frac{1}{2}$$

Clearly, $K_p < K_\alpha$.

Hence, proton has less kinetic energy.

- **CASE BASED QUESTIONS**

Q1. We know that metals have free electrons which contribute towards conduction of electricity and heat. The electrons cannot normally escape from the metal surface. Why? When an electron escapes from the metal surface, it is quite likely to be quickly absorbed back as the metal becomes positive. One can thus understand that it is captive within the metal even though it can freely move within the metal. A certain minimum (external) energy is required to be given to an electron for it to escape a given metal surface. This is known as the work function for that metal. It is denoted by and is measured in electron volt eV. One eV is the energy gained by an electron when it is accelerated by a potential difference of 1 Volt.

1) Does the size of the atom effects the value of work function?

i) Yes ii) No iii)Sometimes iv) remain same

2) From which type of metal, electron emission would be easier?

i) Caesium ii) Potassium iii)Sodium iv) Calcium

3) The work function would depend upon the following

i) material of the metal ii)temperature
iii) the nature of its surface iv)All of them

4) Work function of platinum is the highest (5.65eV) and is least for Cesium (2.1eV). If energy, equal to the work function is required by electrons to escape, which of the two will emit electron with higher kinetic energy for same radiation?

i) Caesium ii) Platinum iii) same for both iv) Can't be calculated

Answers: 1) option i 2) option i 3) optioniv 4) i

Q 2. Studies, that followed, showed that different metals emit electrons when irradiated by different electromagnetic radiations. For example, alkali metals (sodium, caesium, potassium) emit electrons with X–rays ultraviolet light and also with visible light, except red and orange light. Heavy metals, like zinc, cadmium, magnesium, emit electrons only when ultraviolet radiations fall on .

1) Why do we not observe the phenomenon of photoelectric effect with non-metals?

i) For non metals the work function is high

ii) Work function is low

iii) Work function can't be calculated

iv) For non metals, threshold frequency is low

2) 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

3) What is the effect of increase in intensity on photoelectric current?

i)Photoelectric current increases ii) Decreases
iii) No change iv) Varies with the square of intensity

4) Alkali metals like Li, Na, K and Cs show photo electric effect with visible light but metals like Zn, Cd and Mg respond to ultraviolet light. Why?

i) Frequency of visible light is more than that for ultraviolet light

ii) Frequency of visible light is less than that for ultraviolet light

iii) Frequency of visible light is same for ultraviolet light

iv) Stopping potential for visible light is more than that for ultraviolet light

Answers: 1) option i 2) option iv 3) option i 5) ii

CHAPTER: ATOMS AND NUCLEI

MCQ (1 Marks)

1. In Bohr's model of an atom which of the following is an integral multiple of $h/2\pi$?
   (a) Kinetic energy
   (b) Radius of an atom
   (c) Potential energy
   (d) Angular momentum
   Answer: (d) Angular momentum
2. The ratio between Bohr radii is
   (a) 1:2:3
   (b) 2:4:6
   (c) 1:4:9
   (d) 1:3:5
   Answer: (c) 1:4:9
3. In terms of Rydberg constant R, the wave number of the first Balmer line is
   (a) 5R/36
   (b) 3R
   (c) R
   (d) 8R/9
   Answer: (a) 5R/36
4. The transition of the electron n= 4,5,6 ...... to n=3 corresponds to
   (a) Lyman series
   (b) Balmer series
   (c) Paschen series
   (d) Brackett series
   Answer: (c) Paschen series
5. The quantity which is not conserved in a nuclear reaction is
   (a) Momentum
   (b) Mass
   (c) Charge
   (d) None of these
   Answer: (b) Mass
6. Ratio of the radii of the nuclei with mass numbers 8 and 27
   (a) 2/3
   (b) 8/27
   (c) 27/8
   (d) 3/2
   Answer: (a) 2/3
7. The curve of the binding energy per nucleon as a function of an atomic mass number has a sharp peak for helium nucleus. This implies that helium nucleus is
   (a) Radioactive
   (b) Unstable
   (c) Easily fissionable
   (d) More stable nucleus than its neighbours.
   Answer: (d) More stable nucleus than its neighbours.
8. The ratio of the volume of an atom to the volume of its nucleus is of the order of
   (a) 10^{15}
   (b) 10^{10}

(c) 10^{5}
(d) 10

Answer: (a) 10^{15}

9. Nuclear fusion is possible only at very high temperatures because at such temperatures :
   (a) Atoms are ionized
   (b) Atoms are disintegrated
   (c) Nuclei are disintegrated
   (d) Nuclei are so much energized that they are able to overcome the mutual repulsion.
   Answer: (d) nuclei are so much energized that they are able to overcome the mutual repulsion.
10. The sun obtains its radiant energy from:
   (a) Fissions process
   (b) Fusion process
   (c) Disintegration
   (d) Photoelectric process
   Answer: (b) fusion process

ASSERTION-REASON

In the following questions, a statement of Assertion (A) is given followed by a corresponding statement of Reason (R). Of the following statements, choose the correct one for each question:

(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) Both A and R are false.

1. A: The radii of first orbit in hydrogen and helium atoms are same.

   R: Radius of orbit does not depend upon Z.

   Ans: (d)

2. A: The energy in different states of an atom can only be an integral multiple of hυ where h is Planck constant and υ is the frequency of radiation.

   R: Bohr's theory gives no information about the wave nature of electron.

   Ans: (b)

3. A: Bohr had to postulate that the electrons in stationary orbits around the nucleus do not radiate.

   R: According to classical physics, all moving electrons radiate.

   Ans: (b)

4. A: Balmer series lies in the visible region of the electromagnetic spectrum.

   R: $1/\lambda = R(1/2^2 - 1/n^2)$ where n = 3, 4, 5, ...

   Ans: (a)

5. A: Distance of closest approach of an α-particle to the nucleus is always greater than the actual size of the nucleus.

   R: Nuclear forces are very strong as compared to the electrostatic forces.

   Ans: (a)

SHORT ANSWER QUESTIONS (2 MARKS)

1. What is the angular momentum of an electron in Bohr's hydrogen atom whose energy is -3.4 eV?

Ans. The energy of electron in n^{th} Bohr orbit of hydrogen atom is given by

$E = -\frac{13.6}{n^2}$ eV

$-3.4 = -\frac{13.6}{n^2}$

$\Rightarrow n^2 = 4$

$\Rightarrow n = 2$

Angular momentum of an electron in n^{th} orbit, $L = nh/2\pi$

Putting n = 2, we get $L = 2h/2\pi = h/\pi$

2. Write two important inferences drawn from Rutherford’s alpha scattering experiments.

Ans. The two important conclusions are:

(i) The entire positive charge (and almost the entire mass) of the atom is confined at the centre called nucleus.

(ii) The size of the nucleus is about 10^{-4} times the atomic size.

3. Draw a labelled diagram of Geiger and Marsden experiment on a-particle scattering. Explain how does it help to find the size of a nucleus.

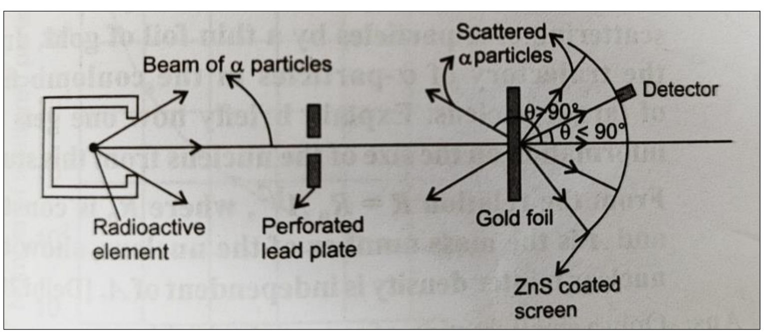
Ans. In this experiment, the energised a-particles were bombarded on gold foil, K.E. of a-particle is changed into P.E. of a-particle and a gold nucleus, due to nuclear repulsion. During this scattering process, mechanical energy of the system remains constant.

$(K.E.)_{initial} = (P.E.)_{final}$

$K_\alpha = \frac{1}{4\pi\epsilon0} . \frac{(2e)(Ze)}{r_0}$) or $r_0 = \frac{1}{4\pi\epsilon0} . \frac{2Ze^2}{k_\alpha}$

By knowing r_0 the size of the nucleus can be ascertained.

Figure



4. State Bohr's postulate of hydrogen atom which successfully explains the emission lines in the spectrum of hydrogen atom.

Use Rydberg formula to determine the wavelength of H_α line.

[Given: Rydberg constant $R = 1.09 \times 10^7\ m^{-1}$]

Ans. According to the Bohr's third postulate, an electron might make a transition from one of its specified non-radiating orbits to another of lower energy. When it does so, a photon is emitted having energy equal to the energy difference between the initial and final states. The frequency of the emitted photon is given by

$$h\upsilon = E_i - E_f$$

where E_i and E_f energies of initial and final states ($E_i > E_f$)

Wavelength of H_α line is given by

$1/\lambda = 1.09 \times 10^7 \, [1/(2^2) - 1/(3^2)]$

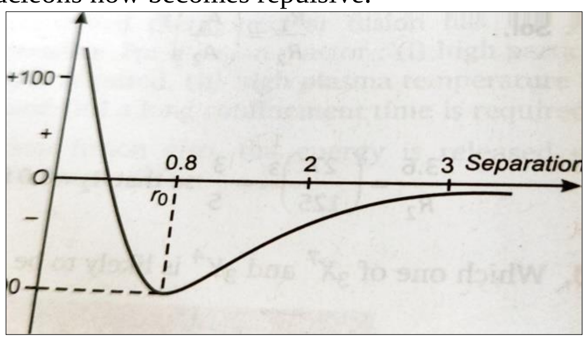
$\lambda = 6990A$

5. 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 graph.

Ans. The graph is shown in the figure. From the graph, it is clear that

(i) As the separation (r) between the nucleons decreases, the potential energy becomes more negative and becomes minimum at about r_0 = 0.8 fermi. Thus, for separation r ≥ 0.8 fermi, the force is attractive between nucleons (nuclear force is effective in this region).

(ii) When separation r becomes less than r_0 the potential energy increases sharply and becomes positive, i.e., the force between nucleons now becomes repulsive.



LONG ANSWER QUESTIONS (3 MARKS)

6. State the processes taking place in the following situations:

(i) When a slow neutron goes sufficiently close to a U^{235} nucleus.

(ii) When a neutron goes sufficiently close to a proton.

(iii) What will be the similarities and dissimilarities between the two processes?

Ans. (i) Fission of U^{235}

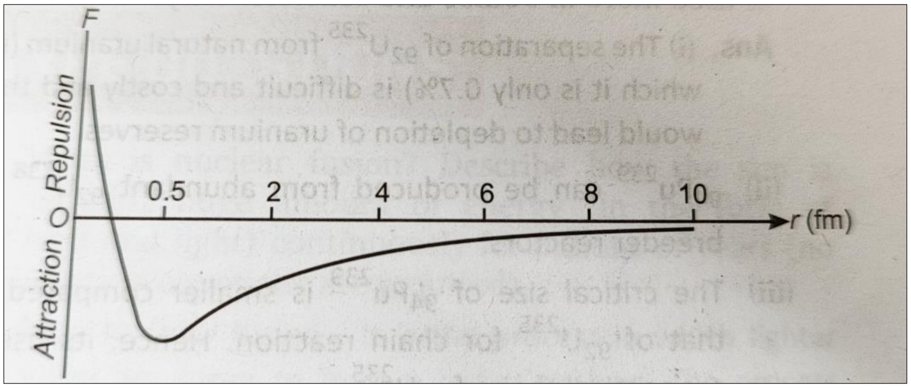
(ii) Fusion process to form deuteron.

(iii) **Similarity**: Energy is liberated.

Dissimilarities: In fission process heavy nucleus splits up into light nuclei, while in fusion process, heavy nucleus is formed.

7. Draw a graph between the separation between nucleons and the nuclear force and mention important conclusions of this plot.

The graph between separation r and nuclear force F is shown in figure



From the graph, it is clear that

(i) The nuclear force does not follow the inverse square law.

(ii) Beyond r = 10fm, the nuclear force becomes negligible small. 10gmsbom

(iii) For r > 0.5m the nuclear force is attractive and is maximum (stronger) at r about 0.8 fm.

(iv) When the separation r between nucleons becomes less than 0.5 fm, nuclear force becomes repulsive. This force of repulsion is different from Coulomb's repulsion.

8. If λ_1 and λ_2 are the wavelengths of the first member of Lyman and Paschen series respectively, then determine the ratio λ_1/λ_2.

Ans.

$1/\lambda_1 = R\,[1/(1^2) - 1/(2^2)]$ For Lyman series, $n_i = 2$, $n_f = 1$]

$1/\lambda_1 = 3/4\,R$ ... (i)

[In Paschen series for first member, $n_i = 4$, $n_f = 3$]

Similarly,

$1/\lambda_2 = R\,[1/(3^2) - 1/(4^2)]$

$1/\lambda_2 = (7R)/144$ ... (ii)

Dividing eqn. (ii) by (i), we get

$\lambda_1/\lambda_2 = 7/144 \times 4/3 = 7/108$

9. The total energy of an electron in the first excited state of the hydrogen atom is about - 3.4 eV.

(i) What is the kinetic energy of the electron in this state?

(ii) What is the potential energy of the electron in this state?

(iii) Which of the answers above would change if the choice of the zero of potential energy is changed?

Sol. Total energy E = - 3.4 eV

(i) Kinetic energy in this state

$K = -E = -(-3.4\text{eV}) = 3.4\text{eV}$

(ii) Potential energy in this state

$U = 2E = 2(-3.4\text{eV}) = -6.8\text{eV}$

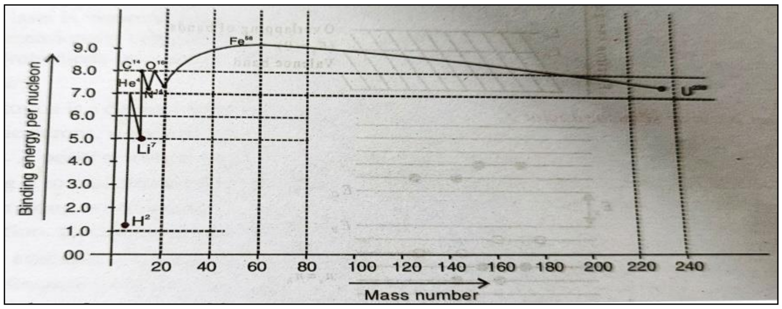
(iii) Potential energy is taken zero at infinity. If the choice of zero potential energy is changed then kinetic energy will remain unchanged but total energy will change.

LONG ANSWER QUESTIONS (5 MARKS)

1. (a) Draw the graph to show variation of binding energy per nucleon with mass number of different atomic nuclei. Briefly State, how nuclear fusion and fission can be explained on the basis of this graph.

(b) Calculate binding energy/nucleon of Ca nucleus. 20

(a)



1. Lighted nuclei combined to form a heavier nucleus in order to attain higher value of B.E./A (Nuclear fusion)

2. A heavier nucleus may split into lighter nuclei to attain higher value of B.E./A (Nuclear fission)

(b) Number of protons = 20

Number of neutrons = 40 - 20= 20

Expected mass of the nucleus

$m = 20 (m_p + m_n)$

$= 20 (1.007825 + 1.008665)$ u

$= 40.3298$ u

Actual mass is $m' = 39.962589$ u

Mass defect, $\Delta m = m - m'$

$= 40.3298 - 39.962589$

$= 0.367211$ u

Total B.E. = 0.367211 x 931 MeV = 341.873441 MeV

B.E./nucleon = 341.873441/40 = 8.547 MeV/nucleon

2. Using Bohr's postulates of the atomic model, derive the expression for radius of nth electron orbit. Hence obtain the expression for Bohr's radius.

Ans. According to Bohr's first postulate, electron moves around the nucleus in circular orbit, nucleus being stationary. The centripetal force for circular motion is provided by the positively charged nucleus and negatively charged electron, i.e., for motion in nth orbit

$$\frac{m\upsilon_n^2}{r_n} = \frac{1}{4\pi\epsilon_0}.\frac{(Ze).(e)}{r_n^2} \qquad \ldots\ldots(i)$$

Where m = mass of electron,

e = charge of electron,

Z = atomic number of nucleus,

υ_n = velocity of electron in nth orbit.

r_n = radius of nth orbit

Bohr's quantum condition states that the electron can revolve only in those orbits for which its angular momentum is an integral multiple of h / 2π i.e.

$m\upsilon_n r_n = nh/2\pi$ ....(ii)

Squaring Eq. (ii) and dividing by Eq. (i)

$m^2\upsilon_n^2 r_n^2/m\upsilon_n^2 . r_n = n^2h^2/4\pi^2 . 4\pi\epsilon_0 r_n^2/z^2e^2$

$mr_n = \epsilon_0 n^2h^2/\pi Z^2e^2$

$r_n = \epsilon_0 n^2h^2/\pi m Z^2e^2$ ....(iii)

This is the expression for radius of nth orbit. Taking z = 1for hydrogen and n = 1 for Bohr's orbit, we get radius of Bohr's orbit

$\mathbf{r_1 = \epsilon_0 h^2/\pi me^2}$

CASE BASED QUESTIONS (4 MARKS EACH)

1. In 1912, Neils Bohr studied the spectrum of hydrogen in Rutherford Laboratory and concluded that the limitations of Rutherford's atomic model cannot be explained using classical mechanics and electromagnetism. He proposed the first quantum model of the atom by combining concepts of classical and quantum mechanics. He explained the structure of atom and its stability.

(i) In terms of Bohr radius r_0 what is the radius of second Bohr orbit of hydrogen atom?

(a) $4r_0$ (b) $8r_0$ (c) $\sqrt{2}r_0$ (d) $2r_0$

Ans: (a) as r α n^2

(ii) The kinetic energy of electron in the first excited state is 3.4 eV. Calculate its potential energy in this state is

(a) -3.4 eV (b) 6.8 eV (c) -6.8 eV (d) 3.4 eV

Ans: (c) P.E. = -2K.E.

(iii) The ionisation energy of electron in a hydrogen atom is 13.6 eV. What is the energy required to remove electron from the second excited state is

(a) -13.6 eV (b) 1.51 eV (c) -1.51 eV (d) -3.4 eV

Ans: (c)

(iv) The largest wavelength in the UV region of hydrogen spectrum is 122 nm. What is the smallest wavelength in the infrared region of the hydrogen spectrum?

(a) 802 nm (b) 823 nm (c) 1882 nm (d) 1648 nm

Ans: (b)

Or

(iv) In Rutherford's atomic model, the electrons

(a) experience no force in the innermost orbit.

(b) always experience a net force,

(c) experience equal force in all orbits.

(d) experience maximum force in the outermost orbit.

Ans: (b)

2. The alpha particle scattering experiment by Rutherford made him conclude that most of the space within the atom is empty. The entire positive charge and most of the mass of the atom is concentrated in its central core. The angle of scattering of a-particle is dependent on how close to the nucleus, did it approach. An alpha particle approaching a nucleus slows down and stops at a certain distance and rebounds back. The angle of scattering keeps on decreasing due to weaker nuclear repulsive force on them.

(i) The number of a-particles per unit area that scatter at angle 0, varies as,

(α) $N(\theta) \alpha 1/\sin^2 (\theta/2)$

(b) $N(\theta) \alpha 1/\sin^4 (\theta/2)$

(c) $N(\theta) \alpha \sin^2 (\theta/2)$

(d) $N(\theta) \alpha \sin^4 (\theta/2)$

Ans: (b)

(ii) The least distance at which an alpha particle stops before reaching a nucleus is called

(a) distance of scattering

(b) distance of rebounding

(c) distance of closest approach

(d) nuclear radius

Ans: (c)

(iii) The alpha particles are emitted in this experiment by

(a) charged helium

(b) electric cells

(c) gold foil of 0.1 μm thickness

(d) radioactive source in lead

Ans: (a)

(iv) The perpendicular distance of velocity vector of approaching a-particle from centre of target nucleus is

(a) scattering distance

(b) impact pacometer

(c) trajectory

(d) distance of closest approach

Ans: (a)

Or

(iv) The electrons revolve around the nucleus in

(a) orbits

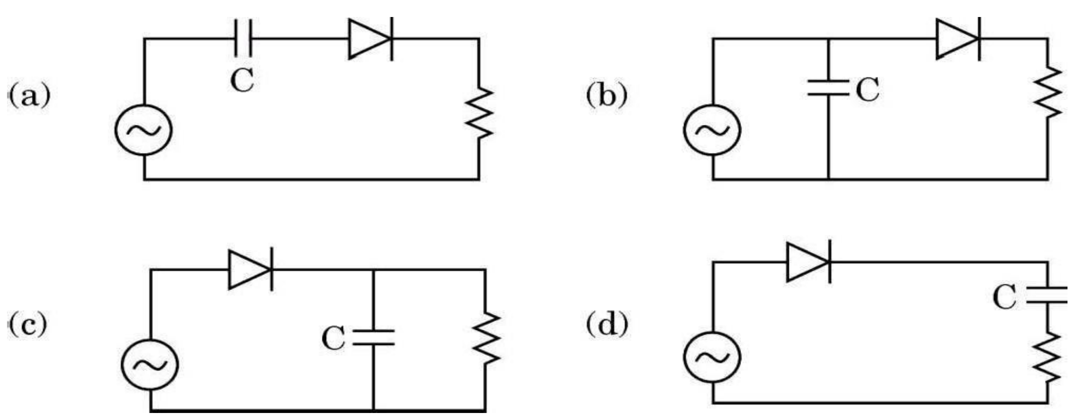
(b) form of electron clouds

(c) Both (a) and (b)

(d) None of these.

Ans: (a)

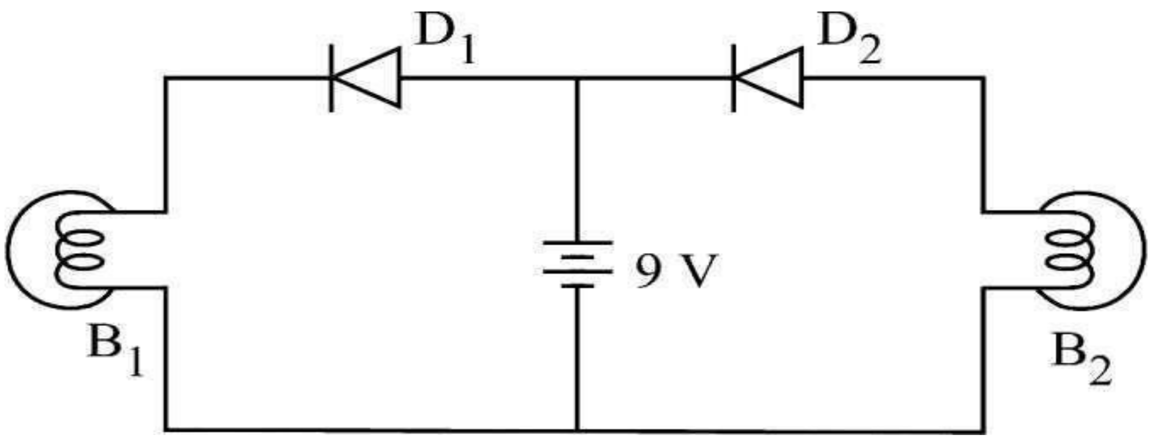
ELECTRONIC DEVICES

Que	MCQ
1.	**When intrinsic silicon semiconductor is doped with Al atom, then it :** **(A) decreases the number of holes in the conduction band.** **(B) increases the number of holes in the valence band.** **(C) increases the energy gap value.** **(D) increases the number of electrons in the valence band.**
2	**An n-type semiconducting Si is obtained by doping intrinsic Si with :** **(A) Al** **(B) B** **(C) P** **(D) In**
3.	**When a p-n junction diode is subjected to reverse biasing :** **(A) the barrier height decreases and the depletion region widens.** **(B) the barrier height increases and the depletion region widens.** **(C) the barrier height decreases and the depletion region shrinks.** **(D) the barrier height increases and the depletion region shrinks.**
4.	**Ge is doped with As. Due to doping,** **(A) the structure of Ge lattice is distorted.** **(B) the number of conduction electrons increases.** **(C) the number of holes increases.** **(D) the number of conduction electrons decreases.**
5.	**In which of the following diagrams is the capacitors C connected correctly to provide smoothoutput of a half-wave rectifier?** 

6.	The energy band gap is maximum in (a) metals (b) superconductors (c) insulators (d) semiconductors
7.	The formation of depletion region in a p-n junction diode is due to (a) movement of dopant atoms (b) diffusion of both electrons and holes (c) drift of electrons only (d) drift of holes only
8.	In an extrinsic semiconductor, the number density of holes is 4 x 10^{20} m^{-3}•If the numberdensity of intrinsic carriers is 1.2 x 10^{15} m^{-3}, the number density of electrons in it is (a) 1.8 x 10^{9} m^{-3} (b) 2.4 x 10^{10} m^{-3} (c) 3.6 x 10^{9} m^{-3} (d) 3.2 x 10^{10} m^{-3}
9.	A semiconductor device is connected in series with a battery, an ammeter and a resistor. A current flows in the circuit. If the polarity of the battery is reversed, the current in the circuit almost becomes zero. The device is (a) intrinsic semiconductor b) n-type semiconductor (c) p-type semiconductor d) p-n junction diode
10.	.When an impurity is doped into an intrinsic semiconductor, the conductivity of the semiconductor (a) Increases (b) decreases (c) remains the same (d) becomes zero
	ASSERTION-REASON TYPE QUESTION
	Questions number 11 to 14 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 ofthe Assertion (A).** **(B) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correctexplanation of the Assertion (A).** **(C) Assertion (A) is true, but Reason (R) is false.** **(D) Both Assertion (A) and Reason (R) are false.**
11.	**Assertion (A): Silicon is preferred over germanium for making semiconductor devices.Reason (R): The energy gap in germanium is more than the energy gap in silicon.**
12.	**Assertion (A) : The diffusion current in a p-n junction is from the p-side to the n-side** **Reason (R) :The diffusion current in a p-n junction is greater than the drift current when thejunction is in forward biased**
13.	**Assertion (A) : In n-type semiconductor number of density of electron is greaterthan the number density of holes but the crystal maintains an overall charge neutrality.** **Reason (R) : The charge of electrons donated by donor atoms is just equal andopposite to that of the ionised donor.**

14.	**Assertion (A) : The temperature coefficient of resistance is positive for metals and negative for p type semiconductors.** **Reason (R) : The charge carriers in metal are negatively charged, whereas majority charge carriers in p-type semiconductors are positively charged.**
	SHORT ANSWER OF TWO MARKS
15	**Explain the roles of diffusion current and drift current in the formation of the depletion layer in a p-n junction diode.**
16	**Explain the property of a p-n junction which makes it suitable for rectifying alternating voltages. Differentiate between a half-wave and a full-wave rectifier.**
17	**Differentiate between intrinsic and extrinsic semiconductors.**
18	**Draw the circuit arrangement for studying the V - I characteristics of a p-n junction diode in forward bias and reverse bias. Show the plot of V - I characteristic of a silicon diode.**
	SHORT ANSWER OF THREE MARKS
19	**With the help of a circuit diagram, explain the working of a p-n junction diode as a full wave rectifier. Draw its input and output waveforms.**
20	**(a) Explain the characteristics of a p-n junction diode that makes it suitable for its use as a rectifier.** **(b) With the help of a circuit diagram, explain the working of a full wave rectifier.**
21	**Explain the following giving reasons:** **(a) A doped semiconductor is electrically neutral.** **(b) In a p-n junction under equilibrium, there is no net current .** **(c) In a diode, the reverse current is practically not depend on the applied voltage.**
22	**With the help of a circuit diagram, explain the working of a p-n junction diode as a half wave rectifier. Draw its input and output waveforms.**
	LONG ANSWER OF FIVE MARKS
23	**(i) Briefly describe the classification of solids into metals, insulators and semi- conductors on the basis of energy level diagrams.** **(ii) In a silicon diode, the current increases from 10 mA to 20 mA when the voltage changes from 0 6V to 0 7V. Calculate the dynamic resistance of the diode.**
	CASE STUDY BASED **Questions number 24 and 25 are case study-based questions. Read the following paragraphs and answer the questions that follow.**
24	**The process of converting ac into dc is called rectification and the device used is called a rectifier. When ac signal is fed to a junction diode during positive half cycle, the diode is forward biased and current flows through it. During the negative half cycle, the diode is** reverse biased **and it does not conduct. Thus the ac signal is rectified. The p-n junction diodes can be used as half-wave and full-wave rectifiers.**

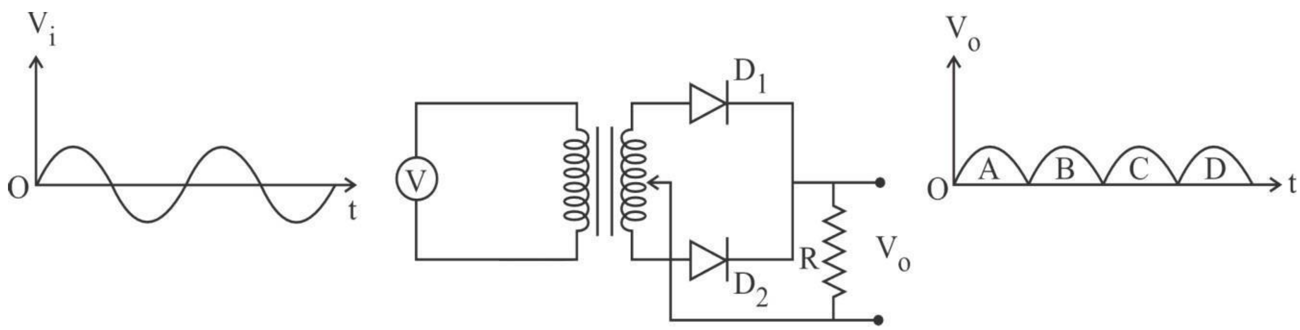
(i) Which bulb/bulbs will glow in the given circuit?



(A) B_1 only **(B)** B_2 only

(C) Both B_1 and B_2 **(D)** Neither B_1 nor B_2

(ii) A) A full-wave rectifier circuit is shown in the figure. The contribution in output waveform from junction diode D_1 is :



(A) A, D **(B)** A, C

(C) B, D **(D)** B, C

OR

(b) The output in a half-wave rectifier is :

(A) unidirectional without ripple (B) steady and continuous

(C) Unidirectional with ripple (D) steady but discontinuous

(iii) In a p-n junction diode, the majority charge carriers on p-side and on n-side are, respectively:

(A) electrons, electrons (B) electrons, holes
(C) holes, holes (D) holes, electrons

(iv) If the frequency of the half-wave rectifier is 50 Hz, the frequency of full-wave rectifier is :

(A) 25 Hz (B) 50 Hz
(C) 100 Hz (D) 200 Hz

25. Consider a thin p-type silicon (p-Si) semiconductor wafer. By adding precisely, a small quantity of pentavalent impurity, part of the p-Si wafer can be converted into n-Si. There areseveral processes by which a semiconductor can be formed. The wafer now contains p-regionand n- region and a metallurgical junction between p-, and n- region. Two important processes occur during the formation of a p-n junction: diffusion and drift. We know that in an n-type semiconductor, the concentration of electrons (number of electrons per unit volume) is more compared to the concentration of holes. Similarly, in a p-type semiconductor, the concentration of holes is more than the concentration of electrons. Duringthe formation of p-n junction, and due to the concentration gradient across p-, and n-sides, holes diffuse from p- side to n-side (p → n) and electrons diffuse from n-side to p-side (n → p).This motion of charge carries gives rise to diffusion current across the junction.

1) How can a p-type semiconductor be converted into n- type semiconductor?
a) adding pentavalent impurity
b) adding trivalent impurity
c) not possible
d) heavy doping

2) At absolute zero, silicon (Si) acts as

(a) non-metal (b) metal (c) insulator (d) none of these

3) Which of the following is true about p type semiconductor?
a) concentration of electrons is less than that of holes.
b) concentration of electrons is more than that of holes.c)concentration of electrons equal to that of holes. d)None of these

4). Which of the following is the reason about diffusion current?
a) diffusion of holes from p to n b) diffusion of electrons from n to p
c) both (a) and (b) d) None of these

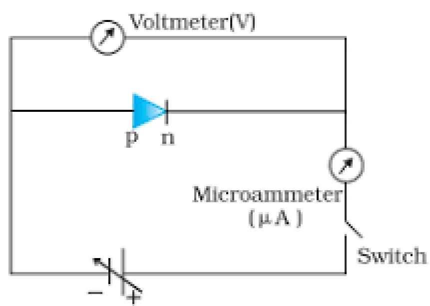
	MARKING SCHEME
1.	(B) increase the number of holes in the valence bond
2.	(C) P
3.	(B) The barrier height increases and the depletion region widens.
4.	(B)The number of conduction electrons increases.
5.	(C)
6.	(C)
7.	(B)
8.	(C)
9.	(D)
10.	(A)
11.	(C)
12.	(B)
13.	(A)
14.	(A)
15	Diffusion and drift current play important role in the formation of a depletion layer in p-njunction diode. During the formation of p-n junction ,and due to the concentration gradient across p-,and n-sides, holes diffuse from p-side to n-side (p →n) and electrons diffuse from n-side to p- side(n→p).When an electron diffuses from (n→p), it leaves behind an ionized donor(positive charge) on n-side which is immobile. Similarly, when a hole diffuses from (p→n) due to the concentration gradient, it leaves behind an ionised acceptor (negative charge) which is immobile. This space–charge region on either side of the junction together is known as depletion region. As a result, an electric field is developed across the junction. Due to this field, an electron on p-side of the junction moves to n-side and a hole on n-side of the junctionmoves to p-side. The motion of charge carriers due to the electric field is called drift .Initially,diffusion current is large and drift current is small. As the diffusion process continues, the electric field strength & hence drift current increases. This process continues till diffusion & drift current becomes equal.
16	The p-n junction diode has asymmetric current/voltage characteristics, which allows currentto flow in only one direction. This property of the p-n junction diode allows it to convert alternating current into direct current. DIFFERENCE BETWEEN HALF WAVE AND FULL WAVE RECTIFIERHALF WAVE RECTIFIER FULL WAVE RECTIFIER

1. Only half cycle of AC is rectified 2. Requires only one diode 3. The output frequency is equalto input supply frequency. (F) 4. The electric current through the load isnot continuous	1. Both cycles of AC are rectified 2. Requires two diodes. 3. The output frequency is double of theinput supply frequency. (2F) 4. A continuous electric current flow

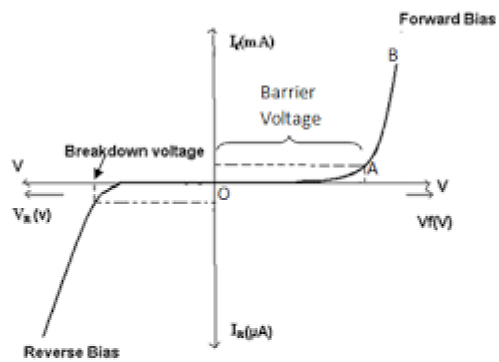
17 (a) Difference between intrinsic and extrinsic semiconductor

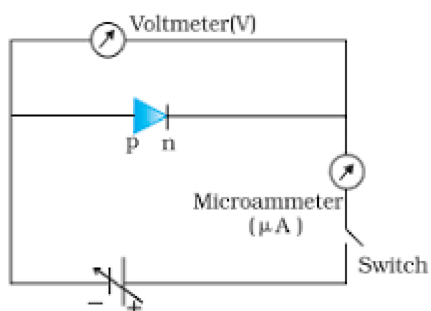
Intrinsic semiconductor	Extrinsic semiconductor
1. Pure semiconductor. 2. Low conductivity at room temperature. 3. $n_e = n_h$	1. Semiconductor is Doped with impurities.2.High conductivity at room temperature 3.n_e is not equal to n_h

18 Circuit diagram for forward and reverse biased p-n junction diodeV-I characteristic (Forward and Reverse bias)



Reverse Bias





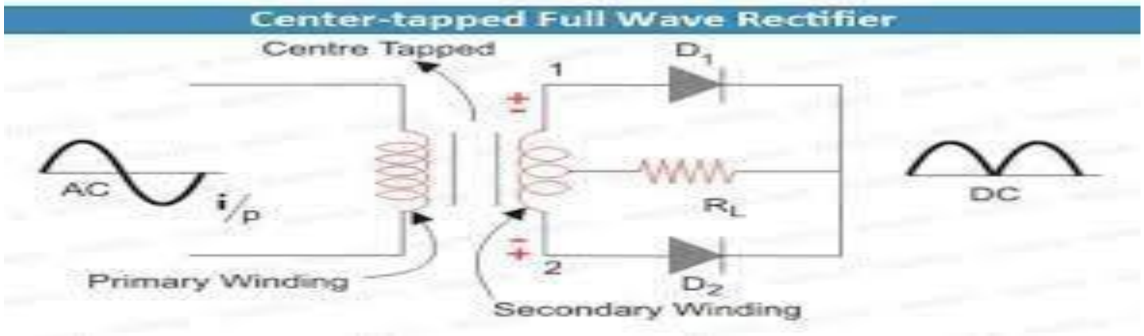
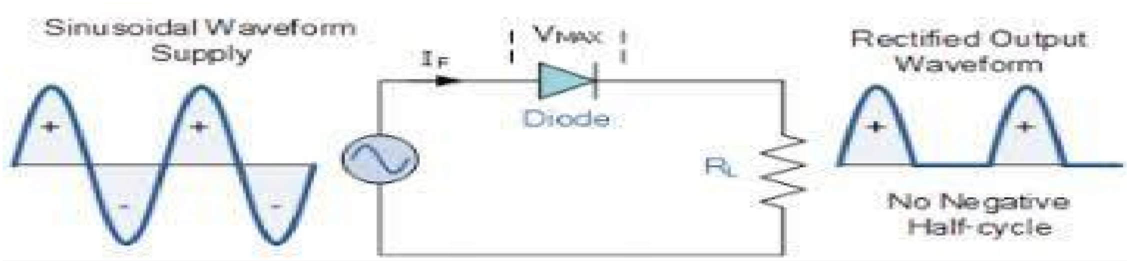
Reverse Bias

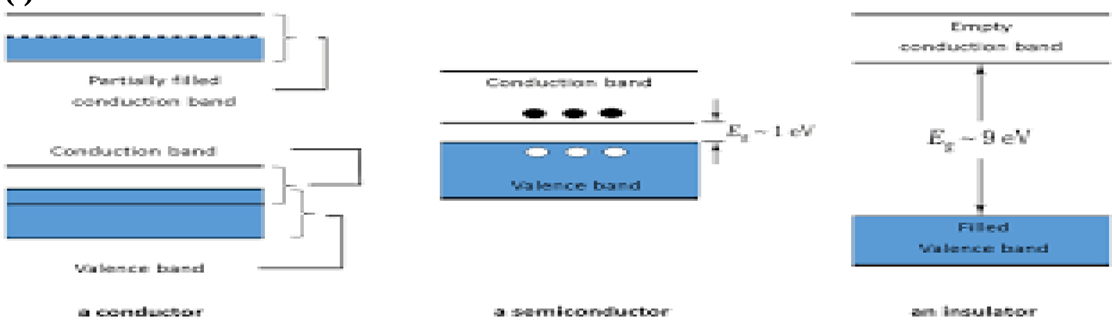
19 <u>Explaining working of full wave rectifier</u> 2

<u>Drawing input and output wave forms</u> <u>1</u>

When input voltage at A with respect to the centre tap at any instant is positive, at that instant voltage at B, being out of phase will be negative, during the positive half cycle diode D1 gets forward biased and conducts while diode ,D2 gets reverse biased and does not conduct. Hence during positive half cycle an output current and output voltage across RL isobtained.

During second half of the cycle when voltage at A becomes negative with respect to centre tap, the voltage at B would be positive hence D1 would not conduct but D2 ,would be givingan output current and output voltage. We get output voltage in both positive and negative half cycles.

	
20	(a) Characteristics of p-n junction diode that makes it suitable for rectification (p-n junction diode allows current to pass only when it is forward biased) (b) Circuit diagram (c) Explanation of working of full wave rectifier
21	Explanation of (a), (b) and(c) 1+1+1 (a) Charge of additional charge carriers is just equal and opposite to thatof the ionised cores in the lattice. (b)Under equilibrium, the diffusion current is equal to the drift current. (c) Reverse current is limited due to concentration of minority charge carriers on either side of the junction.
22	Explaining working of half wave rectifier 2 Drawing input and output wave forms 1 A halfwave rectifier circuit consists of three main components as follows: • A diode • A transformer • A resistive load let us understand how a half-wave rectifier transforms AC into DC.  1. A high AC voltage is applied to the primary side of the step-down transformer. The obtained secondary low voltage is applied to the diode. 2. The diode is forward biased during the positive half cycle of the AC voltage and reverse biased during the negative half cycle. 3. The final output voltage waveform is as shown in the figure below:

	LONG ANSWER OF FIVE MARKS
23	**(i)**  **For Eg> 3eV material is insulator** **For Eg < 3eV material is semiconductor** **For Eg=0 or overlapping of conduction and valence band material is conductor.** **(ii) r_d = V/I** **r_d = 10 ohm**
	CASE STUDY BASED
24	**i) (A) B_1 only** **(ii) (B) A, C OR (C) unidirectional with ripple** **(iii) (D) holes,** **electrons(iv) (C)** **100 Hz**
25	**i) A** **ii) c** **iii) a** **iv) c**

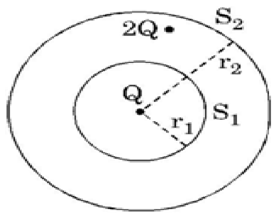
CHAPTERWISE MINIMUM LEARNING LEVEL QUESTIONS

(I) - ELECTROSTATICS AND CURRENT ELECTRICITY

1. A 4Ω resistance wire is bent in form of circle. Find equivalent resistance across diametrically opposite end? 2

2. Why does the resistivity of semi-conductors and insulators decrease with the rise is temperature? 2

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



4. Derive relation between electric field and potential gradient. 2

5. Consider a uniform electric field E = 3 x 103 î N/C. What is the flux of this field through a square of 10cm on a side whose plane is parallel to the YZ plane? 2

6. Two metallic wires of the same materials have the same length but cross sectional area is in the ratio of 1:2. They are connected in series compare the drift velocities of electrons in the two wires. What will happen to drift velocity if they are connected in parallel. 2

Or

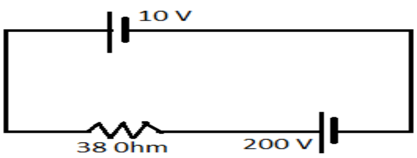
Define is dielectric strength? Write the value of dielectric strength for air?

7. An infinite line charge produces a field of 9×10^4 N/C at a distance of 2 cm. calculate linear charge density? 2

8. What do you mean by internal resistance of a cell, mention two factors on which it depends? 2

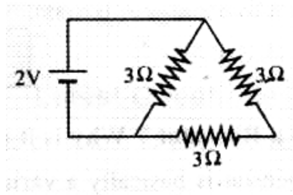
9. Depict the orientation of the electric dipole in (a) stable, (b) unstable equilibrium in a uniform electric field. 2

10. A 10 V battery of negligible internal resistance is connected across a 200 V battery and a resistor of 38 ohm as shown in figure, Find the value of current in circuit. 2



11. A 4μF capacitor is charged by a 200V supply. The supply is then disconnected and the charged capacitor is connected to another uncharged 2μF capacitor. How much electrostatic energy of the system is lost in the process of attaining the steady situation? 3

12. Find current in circuit. 3

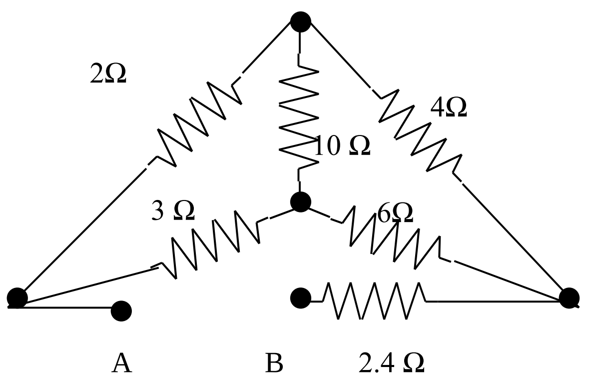


13. Derive expression for electric field intensity produced by electric dipole on equatorial line. 3

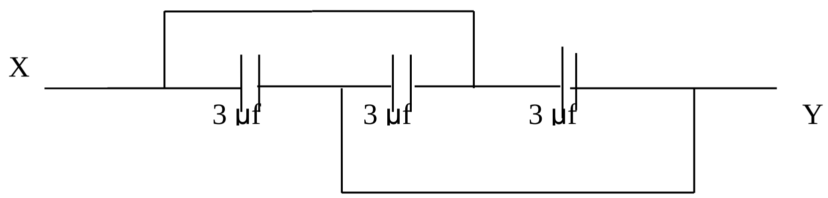
14. Write kirchhoffs law and mention basic laws on which it is based. 3

15. Define equipotential surfaces and write any two properties. 3

16. find equivalent resistance between A and B 3



17. (i) What is the capacitance? Write its SI unit. (ii) Find the total capacitance between X and Y of in the circuit shown. 3



18. Using Gauss's law, obtain the expression for electric field intensity at a point due to an infinitely large, plane sheet of charge of charge density C/m^2 . 3

19. Two wires of the same material having lengths in the ratio 1:2 and diameter 2:3 are connected in series with an accumulator. Compute the ratio of p.d across the two wires 3

20. Derive an expression for capacitance of a parallel plate capacitor with partially filled dielectric slab of dielectric constant K and thickness t but of same areas that of the plates is inserted between the plates. (d = separation between the plates) 3

21. i)Write Gauss's law in electrostatics. Derive an expression for potential at a point P lies 5

on the axial line of dipole.

(ii) A metal sphere 30cm in radius is positively charged with 2 μC. Find the potential (a) at the centre of the sphere. (b) on the surface of the sphere.

22. Define drift velocity and using it derive ohm's law. 5

23. Write Wheatstone bridge Principle Derive condition for balanced Wheastone bridge. How null point gets affected on interchanging position of galvanometer and battery in balanced whetstone bridge. 5

24. Derive formula for torque experienced by electric dipole in uniform electric field. 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 torque & P.E. on the dipole 5

25. Derive expression for electric field produced by uniformly charged spherical shell and sketch graph of electric field Vs distance for spherical shell. 5

SOLUTIONS AND ANSWERS

Que no	Key ideas of Solution
1.	R α l so each half have resistance of 2 ohm. In parallel combination $1/R=1/R_1+1/R_2$ R = 1 Ohm
2.	Temperature dependence of resistivity of semi-conductors and insulators is given by P = Po $e^{E/2KT}$, where K is Boltzmann constant, and E is energy gap. Therefore, resistivity of semiconductors and insulators decrease with rise in temperature.
3.	$Ø_1/Ø_2$ =Q/3Q =1/3 No effect on flux emitting through S_1
4.	Derivation of E = - $\frac{dV}{dR}$
5.	Φ = E. dA = 3 x 10^3.(10 x 10^{-2}) ^{2} Φ = 30 Nm^2C^{-1}
6.	In series combination current is same so ratio of drift velocities is 2:1 (I= $neAv_d$) In parallel combination $\frac{I_1}{I_2}=\frac{R_2}{R_1}=\frac{1}{2}$ So v_{d1}/v_{d2}=1:1
7.	E =2λ /4πε_0 r $9x10^4 = 9x10^{9} x 2\lambda/2x10^{-2}$ $\lambda = 10^{-7}$C/m
8.	It is resistance offered by electrolyte of cell. Internal resistance depends on electrolyte of cll

9. (a) Stable equilibrium $\Theta = 0^0$; p is parallel to E
(b) Unstable equilibrium $\Theta = 180^0$; p is antiparallel to E

10. -38 I- 200+10=0

38 I =190

I =2 amp

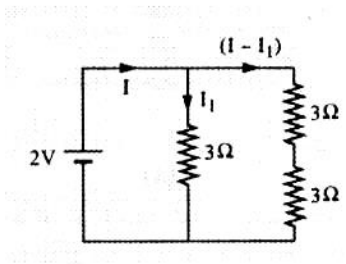
11. $E_1 = 1/2\ C_1 V_1^2 = 8X10^{-2}$ J

$V = \frac{q1+q2}{c1+c2}$ =400/3 volt

$E_2 = (C_1+C_2)V^2/2 = 5.33X10^{-2}$ J

Energy lost = $E_1 - E_2$ =0.0267 J

12. Clearly in the shown equivalent circuit, $R_{eq} = \frac{3\times6}{3+6} = \frac{18}{9} = 2\Omega$



$\therefore Current I = \frac{V}{R_{eq}} = \frac{2}{2} = 1A$

13. Derivation

14. Kirchhoffs 1st law

The algebraic sum of the currents meeting at a junction is zero.

Σ I =0

Kirchhoffs 2nd Law

The algebraic sum of the changes of potential (potential rise and drop) across the elements of a circuit in a closed loop is zero.

Σ IR =Σ E

Kirchhoffs 1st law is based on conservation of Charge.

Kirchhoffs 2nd law is based on conservation of Energy.

15. Equipotential surface is a surface obtained by joining all the points in an electric field having same electric potential.
Properties of equipotential surface are given below,
(i) Electric field is always perpendicular to the equipotential surface at every point.
(ii) Work done on moving a charge on an equipotential surface is zero.

16. 2/4 =3/6 so no current in 10 ohm resistance

R_1=2+4 =6Ω

R_2 =3+6 =9Ω

In parallel combination

$1/R=1/R_1+1/R_2$

R =18/5 Ω

17. Capacitance is ratio of charge given to body to rise in its potential . unit Farad

All capacitors are in parallel

So C =3+3+3 = 9μF

18. Derivation

19. R = ρl/A = $4\rho l/\pi d^2$
RA/RB = 9/8
VA/VB = IARA/IBRB
= 9/8

20. Diagram & Correct derivation [$C = \varepsilon_0 A/ (d-t+t/k)$]

21. Correct statement of Gauss's law.

Expression for electric potential at axial point $V_p = kp/r^2$ where $k = 1/4\pi\varepsilon_0$

(ii) (a) V = 60 kV (b) V = 80 kV

22. Definition

Derivation

23. Wheatstone bridge Principle

Proof of P/Q=R/S

No change in balancd point situation

24. Derivation of Ʈ = pESinϴ

Torque = $4x10^9$ x $5x10^4Sin30^0$ Nm

$=10^{14}$ Nm

U = -pECosϴ

= - $4x10^9$ x $5x10^4Cos30^0$ J = $-\sqrt{3}X10^{14}$ J

25. Derivation

Graph

2-Marks Questions

1. Charge q is uniformly distributed on a disc of radius a.If the disc is rotated with a frequency ν,then find the magnetic field induced at the centre of the disc.

Ans.

Uniform charged disc

Surface charged density $\sigma = q/\pi a^2$

$dq = \sigma 2\pi x\, dx = q/\pi a^2 . 2\pi x\, dx = 2qxdx/a^2$

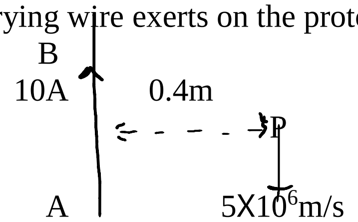
$dI = dq.\nu = 2q\, \nu\, xdx/ a^2$

$dB = \mu 0/4\pi .\ 2\pi dI/x = \mu 0/2x\ .dI == \mu 0/2x\ .2\ q\nu xdx/ a^2 = \mu 0 q\nu\ dx/ a^2$

integrate dB we will get

$B == \mu 0 q\nu /a$

2. A long straight wire AB carries a current of 10 A. A proton P travels at $5\times 10^6 ms^{-1}$ parallel to the wire 0.4 m from it and in a direction opposite to the current as shown in the figure. Calculate the force which the magnetic field due to the current carrying wire exerts on the proton. Also specify its direction



Ans.

Due to infinite wire $B = \mu_0\ i/2\pi\ a$

At a distance of 0.4 m from wire $B = \mu_0\ i/2\pi\ a$

$B = 5\times 10^{-6} T$

On a charged particle $F = qvB\sin\Theta = 4\times 10^{-18}$ N

3. A circular coil of 'N' turns and diameter 'd' carries a current 'I'. It is unwound and rewound to make another coil of diameter '2d', current 'I' remains the same. Calculate the ratio of the magnetic moments of the new coil and the original coil.

Ans.

Since the total length of the wire used remains the same,

$N.\pi\ d = N'.\pi\ 2d$

$N' = N/2$

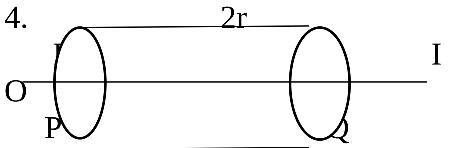
Hence the ratio of the magnetic moments=$M'/M = IN'A'/INA$

$= N'A'/NA$

$= N'd^2/Nd^2$

$= 2$

4.



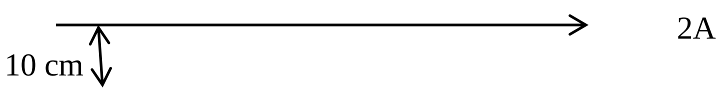
Two identical circular loops P and Q, each of radius r and carrying equal currents are kept in the parallel planes having a common axis passing through O. The direction of current in P is clockwise and Q is anti -clockwise as seen from O which is equidistant from the loops P and Q. Find the magnitude of net magnetic field at O

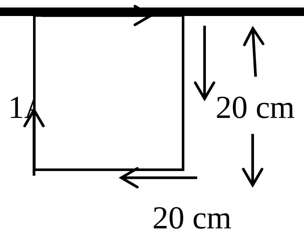
Ans.

Bp$= \mu_0 Ir^2/2(r^2+r^2)^{3/2} = \mu_0 I/4\sqrt{2}r =$ $\mathbf{B_Q}$

$B = Bp + B_Q = \mu_0 I/2^{3/2} r$

4. A square loop of side 20 cm carrying current of 1 A kept near an infinite long straight wire carrying a current of 2 A in the same plane as shown in the figure. Find the force due to parallel currents.





Ans.

F= $\mu_0 I_1 I_2 L/2\pi d$

(I_1=1A, I2=2A,d=o.1m, L=0.2m

=5.33 x 10^{-7} N (attractive and towards the wire)

6.

A straight wire carrying a current of 12 A is bent into a semi- circular arc of radius 2 cm as shown in figure. What is the
magnetic field **B** at o due to

(a) Straight segments

(b) The semi-circular arc?

Ans.

(a) Zero(as both current element and distance r is parallel)

B== ½ (μ_0I/2r)

=1.9 x 10^{-4}T

7. An ammeter of resistance 0.6 Ω can measure current upto 1.0 A. Calculate

(i) The shunt resistance required to enable the ammeter to measure current upto 5.0 A

(ii) The combined resistance of the ammeter and the shunt.

Ans:

(*i*) Shunt Resistance, $S = \frac{R_A i_g}{i - i_g} = \frac{0.6 \times 1}{4} = 0.15\ \Omega$

(*ii*) Total Resistance, $\frac{1}{R_{total}} = \frac{1}{0.6} + \frac{1}{0.15} = \frac{25}{3}$

$$R_{total} = \frac{3}{25}\ \Omega = \mathbf{0.12\ \Omega}$$

8. A circular loop of 100 turn carries a current of .5 A.If the radius of the loop is 10cm , Find the magnetic field at the centre

Ans. B=C

=$4\pi\times10^{-7}\times100\times1/2\times0.1$

=6.28×10^{-4} T

9. A long solenoid consists of 20 turns per cm.What current is necessary to produce a magnetic field of 20 mT inside the solenoid?

Ans.

I=B/ μ_0n=$20\times10^{-3}/4\pi\times10^{-7}\times20\times10^{2}$=8 A

10. In what way is the behaviour of a diamagnetic material different from that of a paramagnetic, when kept in an external magnetic field?

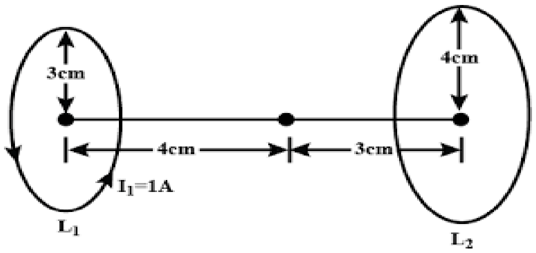
Ans.

The affinity of the paramagnetic material towards an external magnetic field is much higher than a diamagnetic material.

The magnetic field lines pass through the paramagnetic material while the magnetic field lines move away from the diamagnetic material

3-Marks Questions

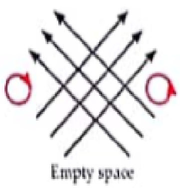
1.Two coaxial circular loops L_1 and L_2 of radii 3cm and 4cm are placed as shown. What should be the magnitude and direction of the current in the loop L_2 so that the net magnetic field at the point O be zero?

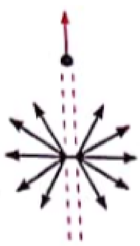


Ans.
Magnetic field produced by both are equal in nature but in opposite direction
$\mu_0 I_1 a_1^2/2(a_1^2 + x_1^2)^{3/2} = \mu_0 I_2 a_2^2/2(a_2^2 + x_2^2)^{3/2}$
I_2 =0.56 A
2.i) Which of the following substances are diamagnetic :
Bi, Na, Al , Cu, Ca, and Ni
ii) Does a bar magnet exert a torque on itself due to its own field ?Justify your answer.
iii)The susceptibility of a magnetic material is 0.9853, identify the type of magnetic material.
Ans.
i. Bi and Cu are diamagnetic substances
ii. A bar magnet does not exert a torque on itself due to its own field. This so because there is no force or torque on an element due to its own field.
iii. Given susceptibility χ = 0.9853 since susceptibility χ given is +ve and less than unity i.e. χ magnetic material is paramagnetic material.
3.Distinguish between diamagnetic and ferromagnetic substances in respect of (i)intensity of magnetisation (ii)behaviour in a non uniform magnetic field (iii)susceptibility.
Ans.

)	diamagnetic	ferromagnetic
Intensity of magnetisation	Negative and very small	Positive and very large
Behaviour in non-uniform magnetic field	Attracted toward a region of weaker magnetic	Attracted toward a region of stronger magnetic field.
Susceptibility	Negative and small 0<X<∈∈ small quantity	Positive and large X of the order of hundreds & thousands.

4.The figures given below show magnetic field lines wrongly (**thick lines shown in the figure**). Point out what is wrong with them:



(a)

(b)

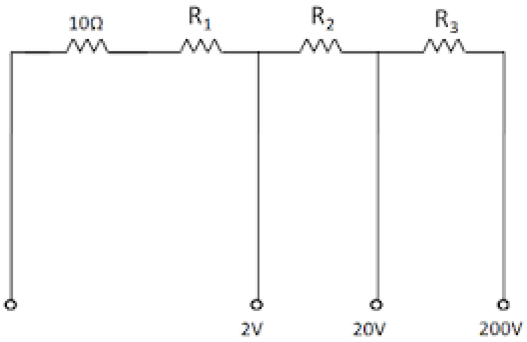
(c)
Ans.

a) Wrong, because magnetic field lines do not cross one another.
b) Wrong, because magnetic lines of force never emanate from a single point as shown. The field lines shown represent electric field of a single positive charge.
c) Wrong, magnetic field lines between two poles cannot be precisely straight at the ends. Some deviation of lines is inevitable, otherwise, Ampere's law is violated. This is true also for electric field lines.

5. **(a)**State the condition under which a charged particle moving with velocity v goes undeflected in a magnetic field B.
(b) An electron, after being accelerated through a potential difference of 10^4 V, enter a uniform magnetic field of 0.04 T, perpendicular to its direction of motion. Calculate the radius of curvature of its trajectory
Ans.
a)For F =0 ,sinΘ=nπ
So.magnetic field will be parallel or antiparallel to the velocity of charged particle.

b)For a charged particle moving in a constant magnetic field and v perpendicular to magnetic field
$mv^2/r = qvB$
r=p/qB …………..(i)
K.E of electron=ev
$P^2/2m=ev$
$P=\sqrt{2mev}$ ………(ii)
From (i) and (ii)
$r = 8.4\text{x}10^{-3}$m

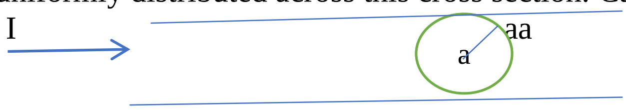
6.A multirange voltmeter can be constructed by using a galvanometer circuit as shown in the figure. We want to construct a voltmeter that can measure 2 V, 20 V and 200 V using a galvanometer of resistance 10 Ω and that produces maximum deflection for current of 1 mA. Find the value of R1, R2 and R3 that have to be used.



Ans. $2=I_GG+R_1\ I_G$
R_1=19KΩ
$20= I_G(10+R_1+R_2)$
R_2=18 KΩ

$200=I_G(10+R_1+R_2\ +R_3)$
R_3=180 KΩ

7.Figure shows a long straight wire of a circular cross section (radius a) carrying steady current I. The current I is uniformly distributed across this cross section. Calculate the magnetic field in the region r <a and r > a.

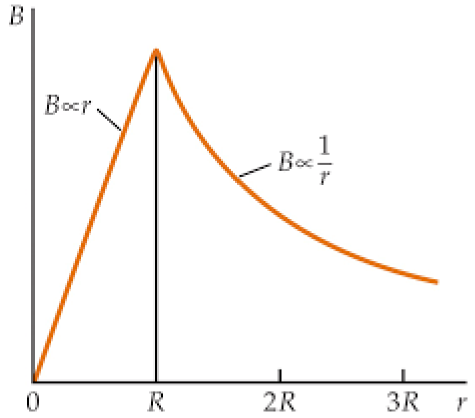


Also the variation of magnetic field(B) with distance(r).
Ans. Case-1 (r<a)
$B.L=\mu_0 Ie$
$B.2\pi r = \mu_0 I(\pi r^2/\pi a^2)$
$B. = \mu_0 I(r/2\pi a^2)$

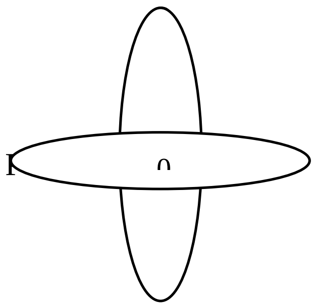
Case-2 (r>a)

B=$\mu_0 I/2\pi d$ (B α 1/r)

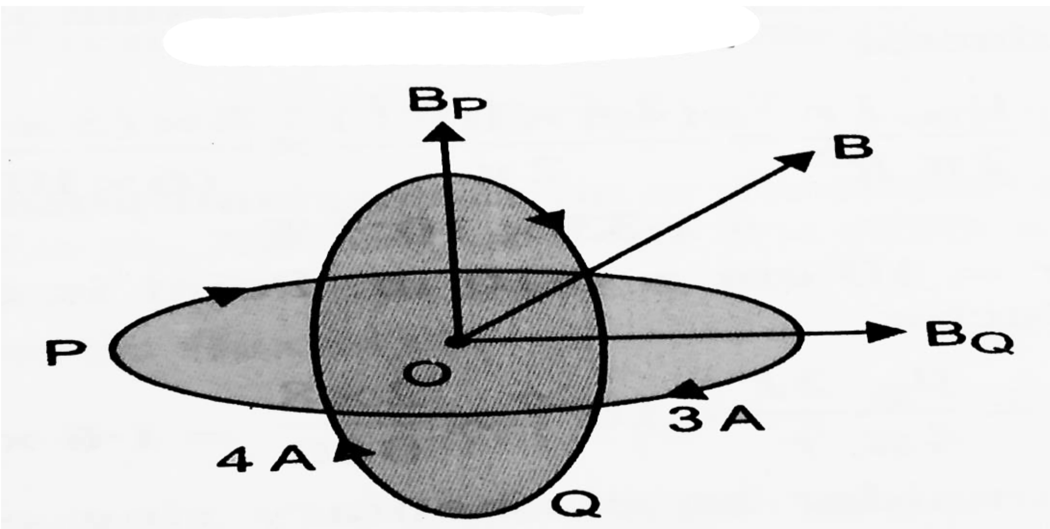
Graph:



8.Two identical loops P and Q each of radius 5 cm are lying perpendicular planes such that they have a common centre as shown in the figure. Find the magnitude and direction of the net magnetic field at the common centre of the two coils, if they carry currents equal to 3A and 4A, respectively.



Ans.



Bp=$\mu_0 I/2d$

Bq=$\mu_0 I/2d$

Bnet=$\sqrt{(Bp^2+Bq^2)}$

B = $2\pi \times 10^{-5}$T

and
tanθ =Bp/Bq
=¾

9.A wire AB is carrying a steady current of 12 A and is lying on the table. Another wire CD carrying 5 A current is held directly above AB at a height of 1 mm. Find the mass per unit length of the wire CD, so that it remains suspended at its position when left free. Give the direction of the current flowing in CD with respect to that in AB. (take g = 10 m/s^2)

Ans.

Anti-parallel currents offers repulsive force.

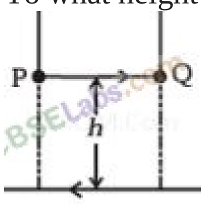
$F/L = \mu_0 I_1 I_2 / 2\pi d$

$Mg/L = \mu_0 I_1 I_2 / 2\pi d$

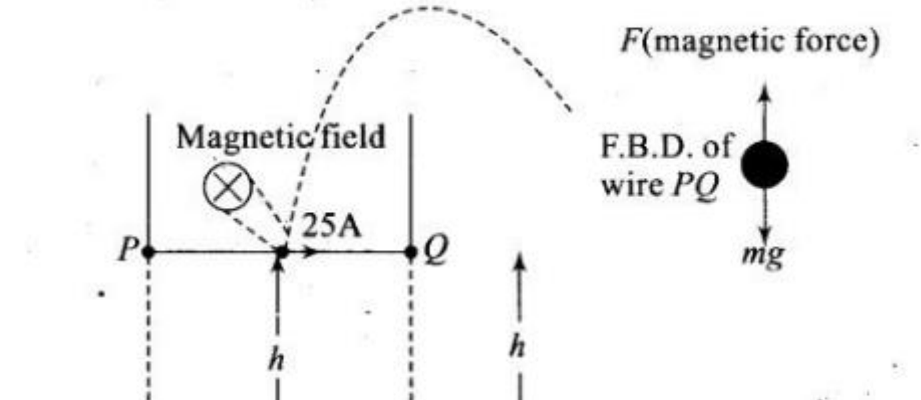
M= 1.2 x 10^{-3}kg/m and

current in CD should be opposite to that of AB

10.A long straight wire carrying current of 25 A rests on a table as shown in figure. Another wire PQ of length 1 m, mass 2.5 g carries the same current but in the opposite direction. The wire PQ is free to slide up and down. To what height will PQ rise?



Ans. The force applied on PQ by a long straight wire carrying current of 25 A which rests on a table. And the forces which other are repulsive if two straight wires are placed parallel to each other carrying current in opposite direction. Now if the wire PQ is in equilibrium then that repulsive force on PQ must balance its weight.



The magnetic field produced by a long straight wire carrying current of 25 A rests on a table on small wire.

$$B = \frac{\mu_0 I}{2\pi h}$$

The magnetic force on small conductor is

$$F = BIl \sin\theta = BIl$$

Force applied on PQ balance the weight of small current carrying wire,

$$F = mg = \frac{\mu_0 I^2 l}{2\pi h}$$

$$h = \frac{\mu_0 I^2 l}{2\pi mg} = \frac{4\pi \times 10^{-7} \times (25)^2 \times 1}{2\pi \times 2.5 \times 10^{-3} \times 9.8} = 51 \times 10^{-4} \text{m}$$

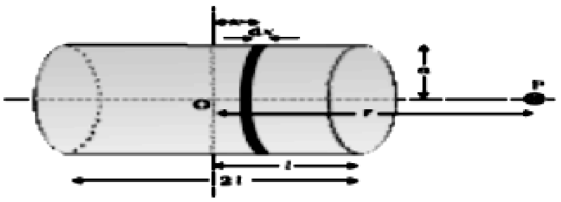
$$h = 0.51 \text{ cm}$$

5-Marks Questions

1.a)Show that a current carrying solenoid behaves as a small bar magnet.

b) A steady current of 2A flows through a circular coil having 5 turns of radius 7 cm. The coil lies in X-Y plane with its centre at the origin. Find the magnitude and direction of the magnetic dipole moment of the coil

Let 'r' be radius of solenoid of length 2l.



To calculate magnetic field at a point on axis of solenoid, consider a small eleme of thickness 'dx' of solenoid at a distance 'x' from 'o'.

Number of turns in this element = n.dx

If current 'i' flows through element 'ndx' the magnitude of magnetic field at P du to this element is

$$dB = \frac{\mu_0}{4\pi} \frac{2\pi (n\,dx) i\, a^2}{[(r-x)^2 + a^2]^{3/2}}$$

If point 'p' is at large distance from 'o' i.e r >> l and r >> a then $[(r - x)^2 + a^2] = r^2$

$$dB = \frac{\mu_0}{4\pi} \frac{2\pi (n\,dx) i\, a^2}{[r^2]^{3/2}} = dB = \frac{\mu_0}{4\pi} \frac{2\pi (n\,dx) i\, a^2}{[r]^3}$$

The total magnetic field at 'p' due to the current 'i' in solenoid is

$$B = \int_{-l}^{l} dB = \int_{-l}^{l} \frac{\mu_0}{4\pi} \frac{2\pi ni\, a^2 dx}{[r]^3} = \frac{\mu_0}{4\pi} \frac{2\pi ni\, a^2}{[r]^3} [x]_{-l}^{l}$$

$$B = \frac{\mu_0}{4\pi} \frac{2\pi ni\, a^2}{[r]^3} [l + l]$$

$$= \frac{\mu_0}{4\pi} \frac{2\, i\, n\, \pi\, a^2 .2l}{[r]^3}$$

$$B = \frac{\mu_0}{4\pi} \frac{2\, i\, n\ A\, .2l}{[r]^3} = \frac{\mu_0}{4\pi} \frac{2\ (n\, .2l)iA}{[r]^3}$$

$$B = \frac{\mu_0}{4\pi} \frac{2\, N\, i\ A}{[r]^3}$$ (N = No of turns of solenoid = n x 2l)

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

This equation gives the magnitude of magnetic field at a point on axis of a solenoid.

This equation is similar to the expression for magnetic field on axis of a short bar magnet. Hence a solenoid carrying current behaves as a bar magnet.

(b)

$$M = NI \times \pi a^2$$

$$= 5 \times 2 \times \pi \times 49 \times 10^{-4} = 0.154 Am^2$$

M will be parallel to Z axis

2.(a)A galvanometer of resistance G is converted into a voltmeter to measure upto V volts by connecting a resistance R_1 in series with the coil. If a resistance R_2 is connected in series with it, then it can measure upto V/2 volts. Find the resistance, in terms of R_1 and R_2, required to be connected to convert it into a voltmeter that can read upto 2 V. Also find the resistance G of the galvanometer in terms of R_1 and R_2.

b) Answer the following:
(i) Why is it necessary to introduce a cylindrical soft iron core inside the coil of a galvanometer?
(ii) Increasing the current sensitivity of a galvanometer may not necessarily increase its voltage sensitivity. Explain, giving reason.

Ans. (a) Let Ig be the current through galvanometer at full deflection To measure -
V volts, $V = I_g (G + R_1)$ ...(i)
V/2 volts $V/2 = I_g(G + R_2)$.......(ii)
2 V volts, $2V = I_g(G + R_3)$ ...(iii)
To measure for conversion of range dividing (i) by (ii),
$2 = G+R_1/G+R_2$
$G = R_1 - 2R_2$
Putting the value of G in (i), we have
$I_G = V/R_1 - 2R_2 + R_1$
$I_G = V/2R_1 - 2R_2$
Substituting the value of G and I_G in equation (iii), we have $2V = V/R_1 - 2R_2(R_1 - 2R_2 + R_3)$
$4R_1 - 4R_2 = R_1 - 2R_2 + R_3$
$R_3 = 3R_1 - 2R_2$

(b) (i) The cylindrical, soft iron core makes the field radial and increases the strength of the magnetic field, i.e. the magnitude of the torque.
(ii) Sensitivity of galvanometer :
Current sensitivity: It is defined as the deflection of coil per unit current flowing in it.
Sensitivity, $S_I = \phi / I = NAB / K$ = ...(ii)
Voltage sensitivity: It is defined as the deflection of coil per unit potential difference across its ends
i.e., . $S_V = \phi / V = NAB / R_g K$...(iii)
whereRg is resistance of galvanometer. Clearly for greater sensitivity number of turns N, area A and magnetic field strength B should be large and torsional rigidity C of suspension should be small.

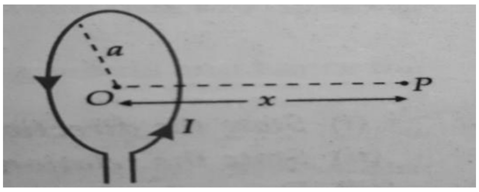
Dividing (iii) by (ii)

$S_V/S_I=1/G$

$S_V=(1/G)S_I$

Clearly the voltage sensitivity depends on current sensitivity and the resistance of galvanometer. If we increase current sensitivity then it is not certain that voltage sensitivity will be increased. Thus, the increase of current sensitivity does not imply the increase of voltage sensitivity.

3.A student records the following data for the magnitudes(B) of the magnetic field at axial points at different distances x from the centre of the circular coil of radius 'a' carrying a current I. Verify that these observations are in good agreement with the expected theoretical variation of B with x.



x →	x = 0	x =a	x =2a	x =3a
B →	B_0	$0.25\sqrt{2}B_0$	$0.039\sqrt{5}Bo$	$0.010\sqrt{10}Bo$

Ans.

$B=\mu_0 I/2(a^2+x^2)^{3/2}$, a- Radius of the coil and x- is position on x-axis.Substitute the value and verify it.

4.**(i)** State the underlying principle of working of a moving coil galvanometer.

(ii) Write two reasons why a galvanometer cannot be used as such to measure current in a given circuit.

(iii) Name any two factors on which the current sensitivity of a galvanometer depends.

Ans. Moving coil galvanometer works on the principle of a torque experienced by a current carrying coil placed in a magnetic field, whose magnitude is a function of current passing through the coil.

(ii) The galvanometer cannot be used to measure the value of the current in a given circuit due to the following two reasons:

(a) Galvanometer is a very sensitive device. It gives a full scale deflection for a small value of current.

(b) The galvanometer has to be connected in series for measuring currents and as it has a large resistance, this will change the value of the current in the circuit.

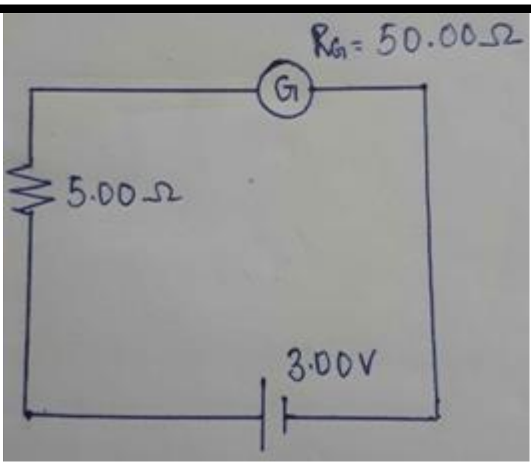
(iii)

$$\text{Current sensitivity, } I_s = \frac{\alpha}{I} = \frac{NBA}{K}.$$

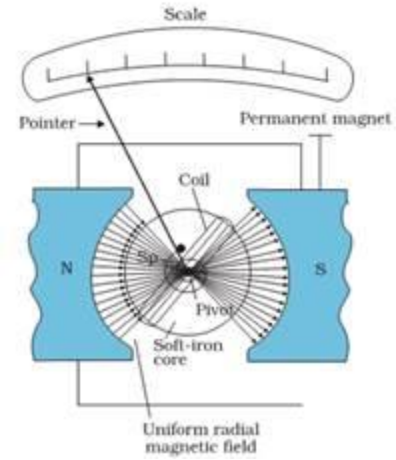
It depends on the number of turns N of the coil, torsion constant and the area A of the coil.

5.(a) Draw a labelled diagram of a moving coil galvanometer. Prove that in a radial magnetic field, the deflection of the coil is directly proportional to the current flowing in the coil.

(b) The galvanometer shown below has a resistance (R_G) of 50.00 Ω. Now, this galvanometer is converted to an ammeter with the help of a shunt resistance (r_S) of 0.05 Ω. Calculate the current passing through the galvanometer in both the cases.



Ans.



θ is the angle made by the normal to the plane of coil with B

τ = NIAB —-(1)

This is called as deflecting torque

As the coil deflected the spring is twisted and a restoring torque per unit twist then the restoring torque for the deflecting & is given by

τ' = k ϕ —-(2)

In equilibrium

Deflecting Torgue=Restoring Torgue

NIAB = Kϕ

I = $\frac{K\phi}{NAB}\phi$

I = Gϕ where G = $\frac{K}{NAB}$ (galvanometer constant)

=> $I \propto \phi$

Thus deflection of the coil is directly proportional to the current flowing in the coil.

(b)

Explanation: R_G = 50.00 Ω; r_S = 0.05 Ω; V = 3.00 V; R = 5.00 Ω

First case ➔ Current (I) = V(RG+R)

= 3(50+5)

= 355

= 0.0545 A

Second case ➔ Resistance = (rS×RG)(rS+RG)

= (0.05×50.00)(0.05+50.00)

= 0.0499 = 0.05 Ω

Total resistance = 5 + 0.05 = 5.05 Ω

Therefore, current = 35.05

= 0.594 A

(III) - ELECTROMAGNETIC INDUCTION AND ALTERNATING CURRENT

TWO- MARKS QUESTION

Q.N. 1Define the term self-inductance .Write its SI unit . Give 2 factors on which self-inductance of air core coil depends.

Q.N.2.How does the mutual inductance of a pair of coils change when: (a) The distance between the coils is increased? (b) The number of turns in each coil is decreased?

Q.N.3 State Lenz's law. Give one example to illustrate this law. The Lenz's law is a consequence of the principle of conservation of energy. Justify this statement.

Q.N.4 An Alternating voltage is applied to a pure inductor of inductance L. Show that the current lags behind the voltage by a phase π/2.

Q.N.5 How the reactance of inductor and capacitor varies according to frequency.

Q.N.6 Explain the energy losses in a transformer. How are they minimized?

Q.N.7 What is power dissipated by an ideal inductor in ac circuit? Explain.

Q.N.8 If the rate of change of current is 4A per sec.induces an emf of 20mv. In a solenoid what is the self inductance of the solenoid.

Q.N.9 The mutual inductance of two coils is 2H. The current in one coil is changed uniformly from zero to 0.5 A in 100 ms. Find the:

1] change in magnetic flux through the other coil

2] emf induced in the other coil during the change.

Q.N.10 An a.c. source of 100 V r.m.s , 50 Hz is connected across a 2 ohms resistor and 2 mH inductor in series calculate the currentand phase of the current in the circuit.

THREE- MARKS QUESTION

Q.N.1 Distinguish between self induction and mutual induction.

Q.N. 2 A capacitor of 100µF and a coil of resistance 50 Ohms and inductance 0.5H are connected in series with a 110 V -50 Hz source. Calculate the rms value of current in the circuit.

Q.N.3 An a.c. voltage is applied across a pure capacitor of capacitance . Find an expression for the current flowing in the circuit and show mathematically that the current flowing through it leads the applied voltage by a phase angle of 90 degree . Also draw (a) phasor diagram (b) graphs of i and versus t for the circuit.

Q.N.4 A series circuit is connected to an a.c. source having voltage $V=v_0 \sin\omega t$. Using phasor diagram, derive expressions for impedance, instantaneous current and its phase relationship to the applied voltage. Also draw graphs of and versus t for the circuit. (b) A 50 mH inductor, a capacitor of capacitance 20 µF and 10 Ω resistor are connected in series across 220 V a.c. source of variable frequency. Calculate: i. Current amplitude at resonance. ii. Maximum power dissipation

Q.N.5 An A.C. source v=200sinωt.is connected across a resistance of 10Ω.findthe average and rms value of current

Q.N.6 Aresister of 50 ohm, an inductor of 20 H and a capacitor of 5 micro farad are connected in series to a 230v ,50Hz.find impedance of the circuit.

Q.N.7 An inductor of 200mH,capacitor of 500micro farad,resistance of 10 ohm are connected in series with a100v a.c.source calculate

1. frequency at which power factor is unity

2.Q- Factor.

Q.N.8 a. draw the graph showing variation of inductive reactance and capacitative reactance with frequency .
b. can the voltage drop across inductor or capacitor in a series circuit be greater than applied voltage of a.c. source.

Q.N.9 define self inductance and give its S.I unit .derive an expression of self induction of an air core solenoid.

Q.N. 10 A..5m long solenoid of 10turn per cm has area of cross section $1cm^2$. Calculate the voltage induced across its end if the current in the solenoid change from 1A to 2A IN 0.1 Sec.

FIVE MARKS QUESTIONS

Q.N. 1 An electric lamp is designed to operate at 110 V dc and 11 A current. If the lamp is operated on 220 V

50 Hz ac source with a coil in series, then find the inductance of the coil.
Draw a labelled diagram of a step-up transformer and describe its working principle. Explain any three causes for energy losses in a real transformer.
A step-up transformer converts a low voltage into high voltage. Does it violate the principle of conservation of energy ? Explain.
Q.N.2(i) Explain with the help of a labelled diagram, the principle and working of an ac generator and obtain expression for the emf generated in the coil. (ii)Draw a schematic diagram showing the nature of the alternating emf generated by the rotating coil in the magnetic field during one cycle.
Q.N.3 A. a toroidalsolenoid with an air core has an average radius of 15 cm area of cross section $12cm^2$and 1200 turn. obtain the self inductance of the toroid.
b. a second coilof 300turn is wound closely on the toroid above if current in primary coil is increased from zero to 2A in 0.05 sec. obtained the induced emf in second coil.
Q.N.4 a. define efficiency of a transformer
b. state any two factor that reduced the efficiency of a transformer.
c. calculate the current drawn by the primary of a 90% efficient transformer which steos down the 220v to 22v ,if the output resistance is 440 ohm.

SOLUTIONS

TWO-MARK QUESTIONS

Q.N.1 It is the induced emf produced in a coil if rate of change of current is unity. its s.i .unit is Henry .two factors on which it depend
1. no of turn.
2. area of loop.
Q.N. 2 a. decreases
b. increases.
Q.N.3. the induced emf produced in faraday law is always in such a way that it opposes all the factors by which it can be produced. The direction of current produced in a coil due to the motion of a magnet towards it. Due to the opposition the mechanical energy is converted into electrical energy.
Q.N. 4 We know that $e=e_0\sin wt$
And $e=L di/dt$
Now on integrate it w.r.t. time and get the result.
$I=i_0\sin(wt+\pi/2)$.
It state that current is π/2 lag behind voltage.
Q.N. 5 $X_L=2\pi fL$ for inductor.
So it is directely proportional to frequency.
$X_C=1/2\pi fc$. For capacitor .so it is inversely proportional to frequency.
Q.N.6 Losses in transformer
1.flux loss
2.eddy current loss
3.hysteresis loss
For minimize it
1.use thin metal sheet between the two coils
2.polished the plate
3. use soft iron
Q.N.7 In ideal inductor the phase difference between voltage and current is π/2.so power loss is zero.
P=VICOSΘ.
Q.N.8 L=e/rate of change of current
So L =.02/4=.005H.
Q.N.9 . 1. CHANGE IN FLUX=$L(I_2-I_1)$=2(.5-0)=1 WEBER
2. e=Ldi/dt=10 v.
Q.N.10 i=V/Z=100/2.09=47.8
TANΘ=X_L/R=.2π/2=.314.

THREE-MARKS QUESTIONS

Q.N.1 Slf induction 1. It is the phenomenon of production of induced emf in a coil when a changing current is passing through it.
2. self induction depend upon shape size and no of turn.larger no. of turn larger area self induction is large.

Mutual induction 1. It is the phenomenon of production of induced emf in one coil due to change in current in second coil.
2. it is depend upon no of turn of both coil and shape.
Q.N. 2 Here C=100μF = 100 x 10-6 F = 10-4F R=50 Ohms L= 0.5 H Erms= 110 V Frequency ν= 50Hz.
XL =wL = 2πνL = 2 x 3.14 x 50 x 0.5 = 157 Ohms.
Xc= 1/wc= 1 / 2πνc= 1/ 2 x3.14 x 50 x 10-4 = 31.85 Ohms.
Impedence of the circuit Z2=R2 + (XL- Xc) 2 Z2= 502 + (157 – 31.85)2
Z= 134.77 Ohms Rms current Irms= Erms / Z = 110 / 134. 77 = 0. 816 A
Q.N. 3 We have the applied voltage $v=v_0 sinwt$.
$Q=cv=cv_0 sinwt$
$I=dq/dt=cwv_0 coswt$.
It gives that $i=i_0 sin(wt+\pi/2)$
hat is current leads voltage by π/2.

a.

i

voltage

b. Draw the sinusoidal graph.

Q.N. 4 draw the phaser diagram .
And using pathagorous theorem Find $Z=(R^2+(X_L-X_C)^2)^{1/2}$.

b.at resonance Z=R
SO I=V/Z=220/10=22

II.P=V2/R=220×220/10=4840
Q.N. 5. $v_0=200$
$I_0=200/10=20$
$I_{rms}=i_0/\sqrt{2}=20/\sqrt{2}=14.18$
$I_{av}=2i_o/\pi=2\times20/3.14=12.73$
Q.N.6. $X_L=2\pi fL=2\times3.14\times50\times.020=6.28$
$X_c=1/2\pi fc=1/2\times3.14\times50\times5\times10^{-6}=636.94$
$Z=(R^2+(X_L-X_C)^2)^{1/2}=(50^2+630.66^2)^{1/2}=632.57$
Q.N.7. 1. $f=1/2\pi\sqrt{LC}=15.9$
2. $Q=1/R\sqrt{L/C}=2$
Q.N.8.a. $X_L$directely proportional to frequency
X_C is inversely proportional to frequency.
b. yes.
Q.N. 9.it is the induced emf produced in the coil if rate of change of current is unity.
Its s.i unit is Henry..
we know that ø=Li
and also ø=μoNi×NA/l
equating these two equation
L=μoN2A/l
Qq.n.10. n=10 turn per cm =1000turn per meter.

l=0.5m
$A=1cm^2=10^{-4}m^2$
di=2-1=1
dt=0.1 sec
$v=Ldi/dt=4\pi\times10^{-7}\times(1000)^2\times10^{-4}\times0.5\times1/0.1$
=0.628mv.

FIVE-MARK QUESTIONS

Q.N. 1 $R=V/I=110/11=10\Omega$.
$Z=V/I=220/11=20\Omega$.
$Z^2=R^2+X_L^2$
$20^2=10^2+X_L^2$
$X_L^2=400-100=300$
$X_L=10\sqrt{3}=2\pi fL$
$L=10\sqrt{3}/2\times3.14\times50=0.05H$.
draw the diagram of step up transformer'
Write its working that
$V_s/V_p=N_S/N_P$
$N_S>N_P$
SO $V_S>V_P$.

1. FLUX LOSS
2. 2.EDDY CURRENT LOSS
3. HYSTERESIS LOSS

The energy is conserved in step up transformer.
Q.N. 2 Draw the diagram of a.c.generator.
We know that $ø=NBA\cos\omega t$
$E=-dø/dt=e_0\sin\omega t$.
Draw the graph of sin wave.
Q.N.3. a. $B=\mu_o Ni/2\pi r$
$Ø=NBA=\mu_o N^2Ia/2\pi r$
$L=ø/i=\mu_o N^2A=2\pi r=4\pi\times10^{-7}\times1200^2\times12\times10^{-4}/2\pi\times0.15=2.3Mh$.
B. $N_1=1200, N_2=300, dt=0.05s, di=2-0-2A$.
$E=Mdi/dt=\mu_o N_1N_2A/ldi/dt=4\pi\times10^{-7}1200\times300\times12\times10^{-4}\times2/2\pi\times0.15=0.023v$.
Q.N.4 a. $efficiency=V_O/V_I\times100$
B. 1. Flux
2. production of eddy current
C. $i_o=V_O/R_O=22/440=0.05A$.
$P_O=V_O\times I_O=22\times0.05=1.1W$
$P_i=100/90\times P_O=100/90\times1.1=11/9$
$I_P=P_{in}/v_p=11/9\times220=0.005A$

(IV) - ELECTROMAGNETIC WAVES AND RAY OPTICS

SECTION A: 2-Mark Questions

Q1) What are electromagnetic waves? List two properties of electromagnetic waves.
Q2)Draw a simple diagram to show the electromagnetic spectrum and label any three types of EM waves.
Q3)Define the term "wavelength." How is it related to the frequency of EM waves?
Q4)State the law of reflection and draw a simple ray diagram to illustrate it.
Q5)State and explain Snell's Law with a simple ray diagram.
Q6)Explain the difference between transverse and longitudinal waves with an example.
Q7)An Air bubble in a jar of water shines brightly .Why?
Q8)Draw a ray diagram to show the refraction of light through a convex lens.
Q9)What is the intensity of an electromagnetic wave, and how does it relate to amplitude?
Q10)State the mirror formula and list the terms involved.

SECTION B: 3-Mark Questions

Q11)Describe the properties of electromagnetic waves and how they propagate.
Q12)Derive the relationship between speed, wavelength, and frequency of an EM wave.
Q13)Explain how a concave mirror forms images. Draw diagrams for two different object positions.
Q14)Explain the term "critical angle" and derive the relation for it in terms of refractive indices.
Q15)A beam of white light on passing throught a hollow prism gives no spectrum .Why?
Q16)What is dispersion of light? Explain with a diagram showing the spectrum through a prism.
Q17)Explain why the light travels faster in air than in water.
Q18)Describe any three applications of X-rays
Q19)Explain how radio waves are produced and mention one application
Q20)Derive the relation between object distance (u), image distance (v), and focal length (f) for a convex mirror.

SECTION C: 5-Mark Questions

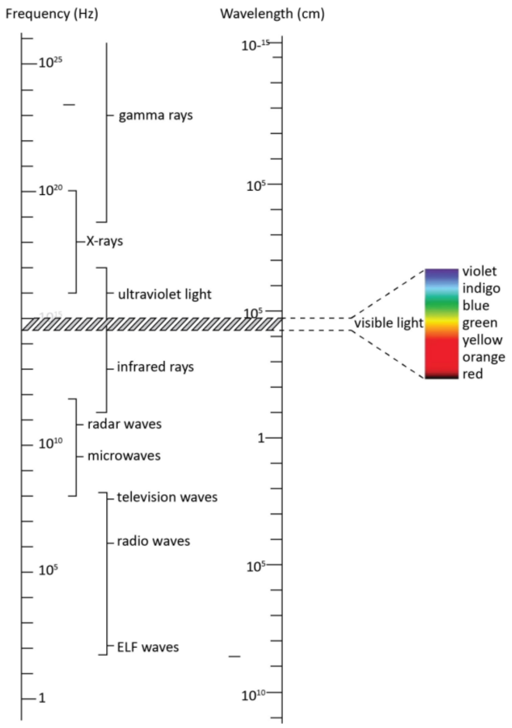
Q21) Derive the mirror formula for a concave mirror. Illustrate with a ray diagram.
Q22)Explain Huygens' Principle and use it to derive the laws of reflection.
Q23)With the help of a labeled diagram, explain the working of a simple microscope. Derive the formula for its magnifying power.
Q24)Explain the principle of total internal reflection and its applications in optical fibers and diamond cutting.

(Answers)

1)Electromagnetic waves are waves that propagate through space by oscillating electric and magnetic fields perpendicular to each other and the direction of propagation.

- **Two properties:**
  1. Electromagnetic waves do not require a medium to propagate; they can travel through a vacuum.
  2. They travel at the speed of light, approximately 3×108 m/s3×108m/s in a vacuum.

2)

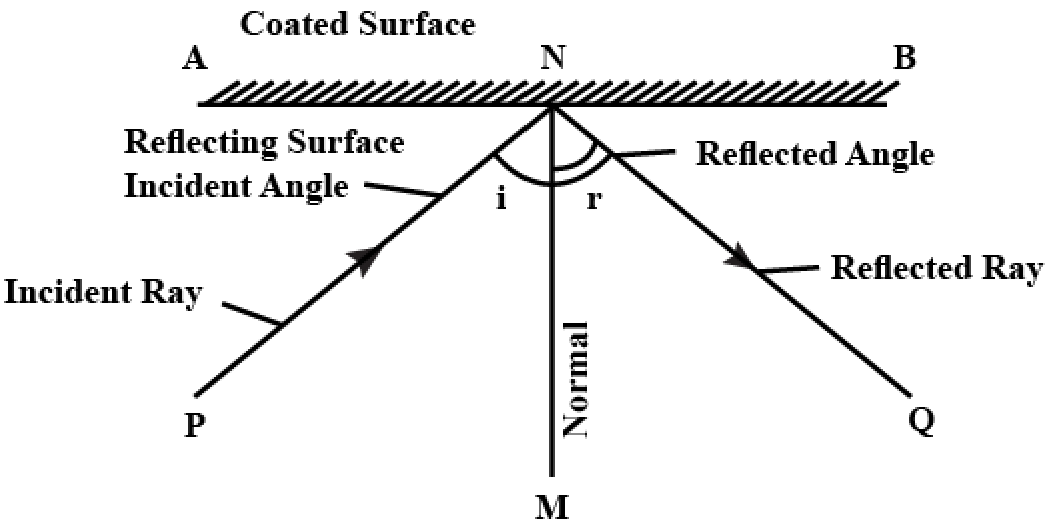


- Label three types: **Radio Waves, Visible Light, and Gamma Rays.**

3)**Wavelength** is the distance between two consecutive peaks (or troughs) in a wave.

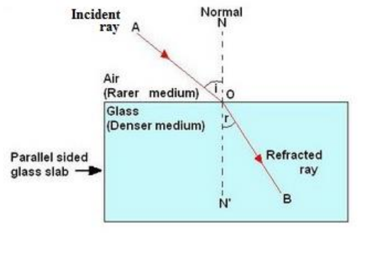
- **Relationship:** Wavelength (λ) and frequency (f) are related by the formula:$c=\lambda\times f$ where c is the speed of light. As frequency increases, wavelength decreases.

4)



The law of reflection states that the angle of incidence is equal to the angle of reflection (i=r).

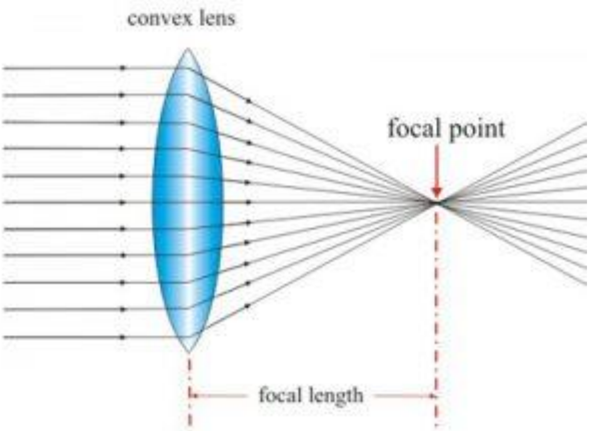
5)**Snell's Law** states that the ratio of the sine of the angle of incidence to the sine of the angle of refraction is constant for a given pair of media. Mathematically:
$\sin i/\sin r=n2/n1$
where n1 and n2 are the refractive indices of the two media.



6)**Transverse waves**: Particles vibrate perpendicular to the direction of wave propagation (e.g., electromagnetic waves).
Longitudinal waves: Particles vibrate parallel to the direction of wave propagation (e.g., sound waves).

7)The air bubble acts as a spherical lens and reflects and refracts light, making it appear bright due to the focusing effect and total internal reflection occurring at the water-air interface.

8)



9)The **intensity** of an electromagnetic wave is the power per unit area carried by the wave. It is proportional to the square of the amplitude of the wave ($I \propto A^2$).

10)where ff is the focal length, vv is the image distance, and uu is the object distance.

Mirror Formula

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

$$m = \frac{-v}{u}$$

11)Electromagnetic waves:

1. Are transverse waves with oscillating electric and magnetic fields perpendicular to each other and to the direction of propagation.
2. Do not require a medium and can propagate through a vacuum.
3. Travel at the speed of light in a vacuum.
   They propagate as self-sustaining oscillations of electric and magnetic fields, generating each other as they travel.

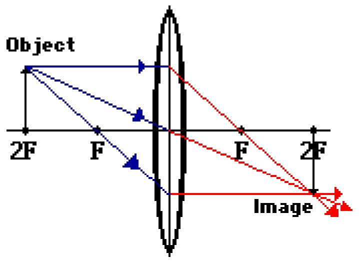
12)For an electromagnetic wave, the relationship between speed (c), frequency (f), and wavelength (λ) is:

$c = \lambda \times f$

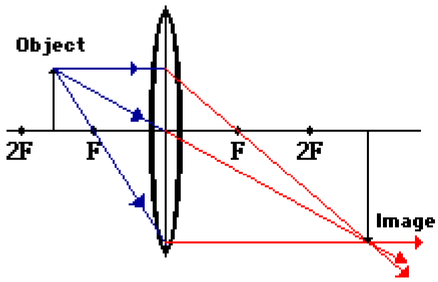
This relationship shows that if the frequency increases, the wavelength decreases, as c is constant in a given medium.

13)A concave mirror can form:

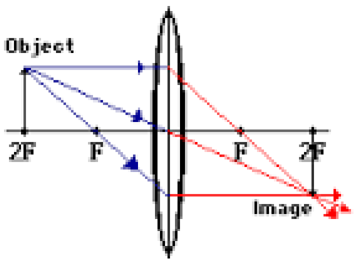
1. **Real, inverted images** when the object is beyond the focal point.
2. **Virtual, upright images** when the object is within the focal point.



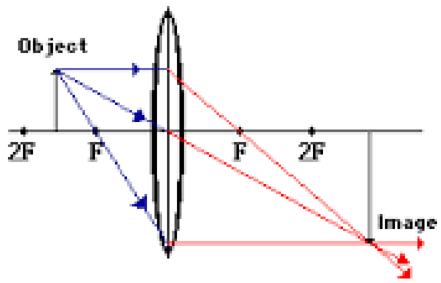
Ray Diagram for Object Located at 2F



Ray Diagram for Object Located Between F and 2F



Ray Diagram for Object Located at 2F



Ray Diagram for Object Located Between F and 2F

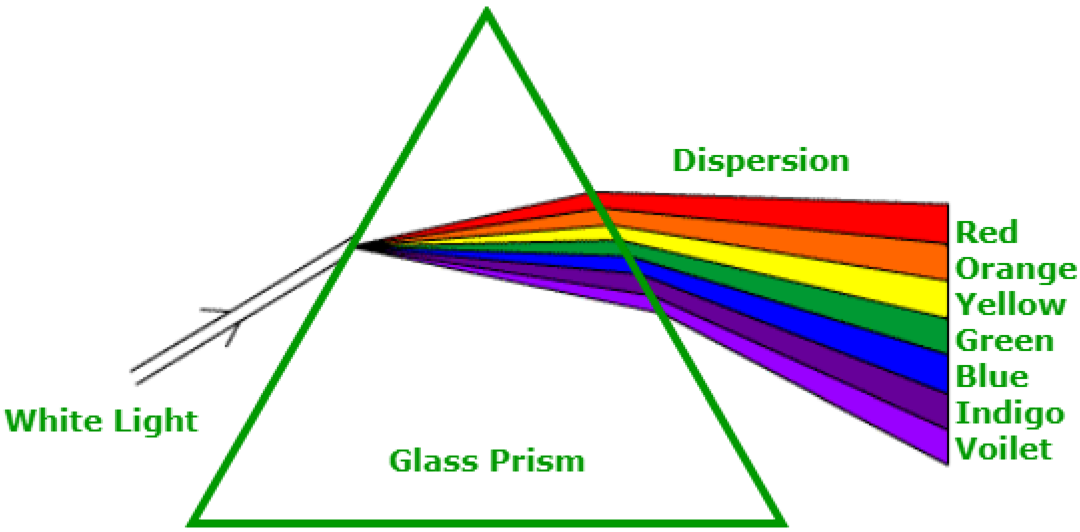
14)The **critical angle** is the angle of incidence in the denser medium at which the angle of refraction in the rarer medium is 90°.
Relation:

$\sin c = n_2/n_1$

where n1 is the refractive index of the denser medium, and n2 is that of the rarer medium.

15)A hollow prism has no refractive material inside to cause dispersion. Without refraction, no separation of colors (spectrum) occurs.

16)**Dispersion** is the splitting of white light into its component colors due to varying refractive indices for different wavelengths.



17)Light travels faster in air than in water because water has a higher refractive index than air, slowing down light as it enters the denser medium.

18) **Medical Imaging:** Used to view bones and internal organs.

Security Scanning: Used in airports to check luggage contents.

Material Analysis: Used in crystallography to study atomic structures.

19)Radio waves are produced by oscillating electric charges, typically using antennas.

- **Application:** Radio waves are used in broadcasting for communication.

20) For a convex mirror, the mirror formula is:

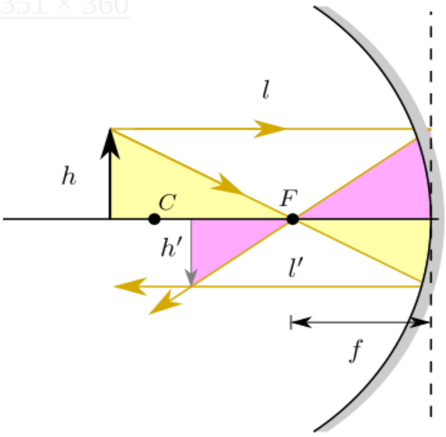
Mirror Formula

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

$$m = \frac{-v}{u}$$

Using ray diagrams and geometry, this relationship is derived by considering similar triangles formed by the object, image, and focal point.

351 × 360



21)(Include derivation as explained above in the previous response)

22)Huygens' Principle states that every point on a wavefront acts as a source of secondary wavelets. The new wavefront is formed by the envelope of these wavelets.

For reflection:

- When a plane wavefront strikes a reflective surface at an angle, each point on the wavefront emits secondary wavelets.

- These wavelets reflect off the surface at the same angle (angle of reflection = angle of incidence).

- The reflected wavefront is the envelope of all these reflected wavelets, and it forms at the same angle as the incident wavefront but in the opposite direction.

This process explains the law of reflection:

angle of incidence = angle of reflection

23)Explain the principle of the microscope and derive M=1+D/f)

—Principle of the Microscope

The microscope works on the principle of magnification, where a system of lenses (usually two) is used to form a magnified image of an object. The two main lenses are:

1. **Objective lens**: Forms a real, magnified image of the object.

2. **Eyepiece lens**: Magnifies the image formed by the objective lens

The microscope magnifies the object by creating a virtual image that appears larger than the actual object, making it easier to observe fine details

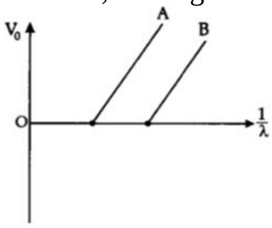
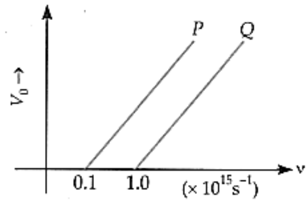
24)(Describe TIR, and explain its applications in optical fibers and diamonds with diagrams

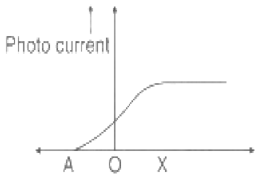
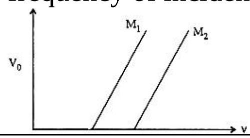
(V) - WAVE OPTICS

	Questions	Marks
1	What are coherent sources? How does the width of interference fringes in Young's experiment change when 1. the distance between the slits and screen is decreased? 2. frequency of the source is increased?	**[2]**
2	Draw the intensity pattern for single slit diffraction and double slit interference. Hence, state two differences between interference and diffraction patterns.	**[2]**
3	Define the term wavefront? What are the assumptions on which Huygens' principle is based? Describe Huygens' geometrical construction for the propagation of wavefronts in a medium.	**[2]**
4	What will be the effect on the interference fringes in Young's double - slit experiment when, 3. the width of the source slit is increased? 4. the monochromatic sources is replaced by another monochromatic source of shorter wavelength? 5. monochromatic source is replaced by a source of white light?	**[2]**
5	State two conditions for sustained interference of light. Draw the variation of intensity with a position, in the interference pattern of Young's double - slit experiment.	**[2]**
6	Using Huygen's principle, for a plane wavefront incident on a plane reflecting surface, draw the reflected wavefront. Hence prove laws of reflection.	**[3]**
7	A plane wavefront is incident on a surface separating two media of refractive indices n_1 and n_2 ($> n_1$). With the help of a suitable diagram, explain its propagation from the rarer to denser medium. Hence, verify Snell's law.	**[3]**
8	Two narrow slits are illuminated by a single monochromatic source. Name the pattern obtained on the screen. One of the slits is now completely covered. What is the name of the pattern now obtained on the screen? Draw intensity pattern obtained in the two cases. Also, write two differences between the patterns obtained in the above two cases.	**[3]**
9	Briefly explain how bright and dark fringes are formed on the screen in Young's double slit experiment. Hence, derive the expression for the fringe width.	**[3]**
10	Monochromatic light of wavelength 600 nm is incident from air on a water surface. The refractive index of water is 1.33. Find the (i) wavelength, (ii) frequency and (iii) speed, of reflected and refracted light.	**[3]**
11	6. Sketch the refracted wavefront for the incident plane wavefront of light from a distant object passing through a convex lens. 7. Using Huygens' principle, verify the laws of refraction when light from a denser medium is incident on a rarer medium. 8. For yellow light of wavelength 590 nm incident on a glass slab, the refractive index of glass is 1.5. Estimate the speed and wavelength of yellow light inside the glass slab.	**[5]**
12	9. State the essential conditions for diffraction of light. 10. Explain the diffraction of light due to a narrow single slit and the formation of pattern of fringes on the screen. 11. Find the relation for the width of central maxima in terms of wavelengthλ ,the width of slit a, and separation between slit and screen D.	**[5]**

	12. If the width of the slit is made double the original width, how does it affect the size and intensity of the central band?	

(VI) - Dual Nature of Matter and Radiation

	Questions	Marks
1	Obtain an expression for the threshold frequency for photoelectric emission in terms of the work function of the metal.	**[2]**
2	Write three characteristic features in photoelectric effect which cannot be explained on the basis of the wave theory of light, but can be explained only using Einstein's equation.	**[2]**
3	13. Write two main observations of photoelectric effect experiment which could only be explained by Einstein's photoelectric equation. 14. Draw a graph showing variation of photocurrent with the anode potential of a photocell.	**[2]**
4	Figure shows the stopping potential (V_0) for the photo electron versus $\frac{1}{\lambda}$ graph, for two metals A and B, λ being the wavelength of incident light.  1. How is the value of Planck's constant determined from the graph? 2. If the distance between the light source and the surface of metal A is increased, how will the stopping potential for the electrons emitted from it be effected? Justify your answer.	**[2]**
5	If photoelectrons are to be emitted from a potassium surface with a speed of 6×10^{6}ms $^{-1}$, what frequency of radiation must be used? (Threshold frequency for potassium is 4.22×10^{14} Hz, h = 6.6×10^{-34} Js and m_e = 9.1×10^{-31} kg).	**[2]**
6	A metal has a work function of 2.0 eV and is illuminated by monochromatic light of wavelength 500 nm. Calculate 1. the threshold wavelength. 2. the maximum energy of photoelectrons. 3. the stopping potential.	**[3]**
7	A beam of monochromatic radiation is incident on a photosensitive surface. Answer the following questions giving reasons. 1. Do the emitted photoelectrons have the same kinetic energy? 2. Does the kinetic energy of the emitted electrons depend on the intensity of incident radiation? 3. On what factors does the number of emitted photoelectrons depend?	**[3]**
8	An electron and a proton are accelerated through the same potential. Which one of the two has (i) greater value of de - Broglie wavelength associated with it and (ii) less momentum? Justify your answer.	**[3]**
9	Figure shows the variation of stopping potential V_0 with the frequency ν of the incident radiation for two photosensitive metals P and Q. 1. Explain which metal has a smaller threshold wavelengths.  2. Explain, giving reason, which metals emits photo electrons having smaller kinetic	**[3]**

	energy, for the same wavelength of incident radiation. 3. If the distance between the light source and metal P is doubled, how will the stopping potential change?	
10	1. An electron and a proton are accelerated through the same potential. Which one of the two has a. greater value of de - Broglie wavelength associated with it, and b. lesser momentum? Justify your answer in each case. 2. How is the momentum of a particle related with its de - Broglie wavelength? Show the variation on a graph.	**[3]**
11	The following graph shows the variation of photocurrent for a photosensitive metal:  1. Identify the variable X on the horizontal axis. 2. What does point A on the horizontal axis represent? 3. Draw this graph for three different values of frequencies of incident radiation v_1 , v_2 and v_3 ($v_1 > v_2 > v_3$) or same intensity 4. Draw this graph for three different values of intensities of incident radiation I_1 , I_2 and I_3 ($I_1 > I_2 > I_3$) having the same frequency.	**[5]**
12	1. Write three observed features of photoelectric effect which cannot be explained by wave theory of light. Explain how Einstein's photoelectric equation is used to describe these features satisfactorily 2. Figure shows a plot of stopping potential (V_0) with frequency (v) of incident radiation for two photosensitive materials M_1 and M_2 . Explain a. Why the slope of both the lines is same? b. For which material emitted electrons have greater kinetic energy for the same frequency of incident radiation?  	**[5]**

(VII)- MLL CLASS XII ATOMS, NUCLEI AND SEMICONDUCTOR DEVICES

2 MARKS

1. What is meant by ionisation energy? write its value for hydrogen atom.
Solution: Ionisation energy is the minimum amount of energy which is to be supplied to an atom in its ground state so that it gets converted into an ion i.e. the minimum energy required to shift an electron from n = 1 to n = infinity. The value of ionisation energy for hydrogen is 13.6 eV.

2. Calculate the ratio of radii and Nuclear density of elements having mass number in ratio 24:81
Solution: $R1/R2 = (A1/A2)^{1/3} = (24/81)^{1/3} = (8/27)^{1/3} = 2:3$
Nuclear Density is independent of mass number therefore ratio = 1:1

3. What do you mean by distance of closest approach and Impact Parameter?
Solution:
The distance of charged particle from the centre of the nucleus were the total kinetic energy of the charge particle get convertedinto potential energy is called distance of closest approach
Impact Parameter is the perpendicular distance between initial velocity vector of Alpha particle and line of nucleus

4.How much mass has to be converted into energy to produced electric power of 500 MW for one hour?
Solution:
Given, $P = 500\ MW = 5 \times 10^8\ W$, $t = 1\ h = 3600\ s$
Energy produced $E = P \times t = 5 \times 10^8 \times 3600 = 18 \times 10^{11}\ J$
As $E = \Delta mc2$ $\quad \Delta m = E/c2 = 18 \times 10^{11}\ J / 9\times 10^{16} J = 2\times 10^{-5}\ kg$

5. State the relation between size of nucleus and mass number and prove that the nuclear density is independent of mass number.
Solution: radius of nucleus $R = R_0 A^{1/3}$;where R_0 is constant and A is mass number

$$\text{Volume } V = \frac{4}{3}\pi R^3 = \frac{4}{3}\pi R_0^3 A$$

If m be the average mass of one nucleon , nuclear density = mass of nucleus / volume

$$= mA / \frac{4}{3}\pi R_0^3 A$$

= constant

6. A heavy nucleus P of mass number 240 and binding energy 7.6 MeV per nucleon splits into two nuclei Q and R of mass number 110 and 130 and binding energy per nucleon 8.5 MeV and 8.4 MeV respectively calculate the energy released in the fission.
Solution:According to the question
P(210)= Q(110) + R(130) + E
E= 110 x 8.5 + 130 × 8.4 - 240 x 7.6
E =935+ 1092 - 1824 $\qquad$ E = 203 MeV

7. Define the two important processes that takes place during formation of PN junction
Solution: Diffusion and Drift are two important processes that takes place during formation of PN junction.

The motion of free electrons and holes due to their concentration gradient is called diffusion. The motion of free electron and holes due to electric field developed across PN junction is called drift.

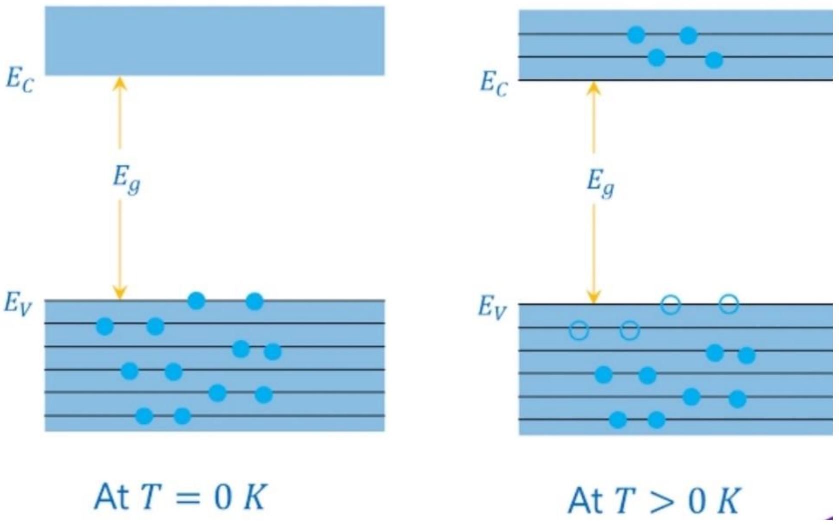
8.Define energy band gap and break down voltage.

Energy gap: The difference in lowest energy level of conduction band and highest energy level of valance band is called forbidden gap or energy band gap.

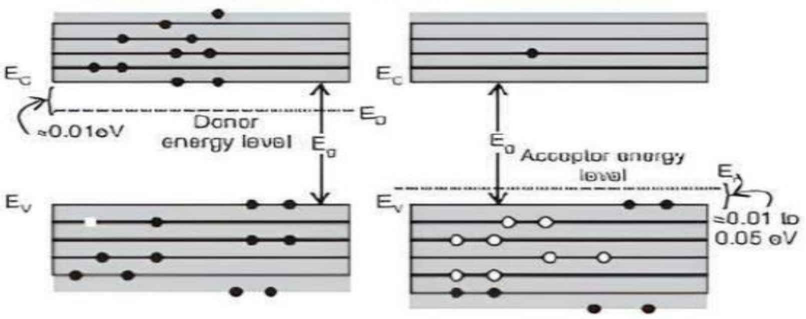
Break down voltage: the reverse bias voltage at which reverse bias current increases abruptly called breakdown voltage.

9.Draw energy band diagram for intrinsic semiconductors at T=0K and at T>0K

Solution:



10. Draw energy band diagram for n type and P type semiconductors.



Solution

3 MARKS

1. The total energy of an electron in the first excited state of the H- atom is -3.4eV.

(A)What is the kinetic energy and potential energy of the electron in this state?

(B)Which of the answers above would change if the choice of zero potential energy change?

Solution: (A)K.E. = - Total Energy = 3.4eV P.E. = 2× total energy = -6.8 eV

(B) The P.E. and consequently Total energy will change.

2.Calculate the ratio of i) radii ii) velocity of electron in second and third orbit in H atom.

Solution: since radius of nth orbit = $n^2 a_0$

where a_0 is radius of smallest orbit $0.53A^0$ thus $r_2/r_3 = 4/9$

Velocity in nth orbit = $\frac{1}{n}(c/137)$ or $\frac{2.18}{n}$ x 10^6m/s

Thus $v_2/v_3 = 3/2$

3.The ground state energy of hydrogen atom is –13.6 eV. What is the kinetic and potential energies of the electron in the ground and second excited state?
[CBSE (AI) 2010, 2011, Bhubaneshwar

Solution: In ground state : KE = - total energy = 13.6eV
PE = 2× total energy = - 27.2eV
In second excited state (n=3), total energy = -13.6eV/ n2 = -13.6 /9 = -1.51eV
KE = 1.51eV
PE = - 3.02 eV

4.Calculate the de Broglie wavelength of electron in the second excited state of the H-atom.

Solution: second excited state(n=3) by de Broglie hypothesis $n\lambda = 2\pi r$
$n\lambda = 2\pi \times n^2 a_o$
$\lambda = 2 \times 3.14 \times n \times 0.53\ A^o = 3.328 \times 3 = 10\ A^o$

5.Calculate the wavelength of Radiation emitted when electron in H atom jump from second excited State to ground state.

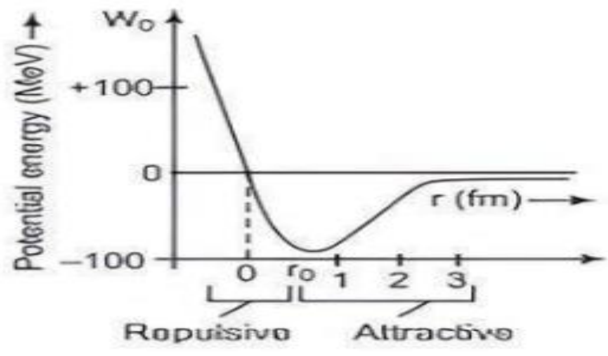
Solution: energy of electron in second excited State (n=3) = -13.6eV / n2
= -13.6eV / 9 =-1.51eV
Energy of electron in ground state (n=1) = -13.6eV
Energy of photon emitted = Ei - Ef = - 1.51 - (-13.6) = 12.09 eV
Wavelength = $12375A^o$/ Ein eV = $1024A^o$

6.Find the ratio of smallest wavelengths of Radiation present in the Lyman series to that in Balmer series.

Solution:)In Lyman series $1/\lambda = R(1/1^2 - 1/n^2)$
Thus for smallest wavelength n= infinity $1/\lambda = R(1 - 0) = R$
smallest wavelength =1/R

Now for Balmer series $1/\lambda = R(1/2^2 - 1/n^2)$
For smallest wavelength n= infinity $1/\lambda = R(1/2^2 - 0) = R/4$
smallest wavelength =4/R
Therefore required Ratio = 1:4

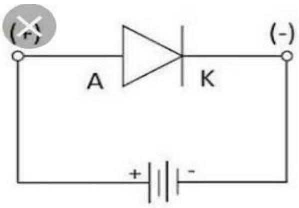
7.Draw the graph to show the variation of nuclear potential energy vs separation between two nucleons. State the properties of nuclear forces.



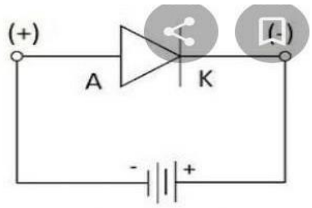
Solution:Graph

Properties of nuclear forces:
i) Strong Attractive ii) independent of charge and mass iii)short ranged

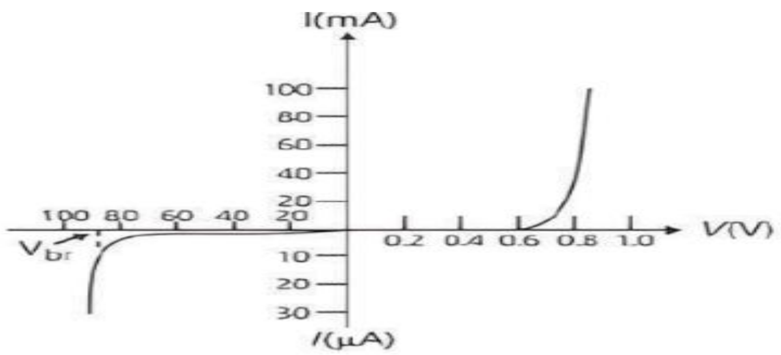
8.Draw circuit diagrams to show a pn junction diode under forward bias and under reverse bias.Draw V-I characteristics of PN junction under forward bias and reverse bias.
Solution:



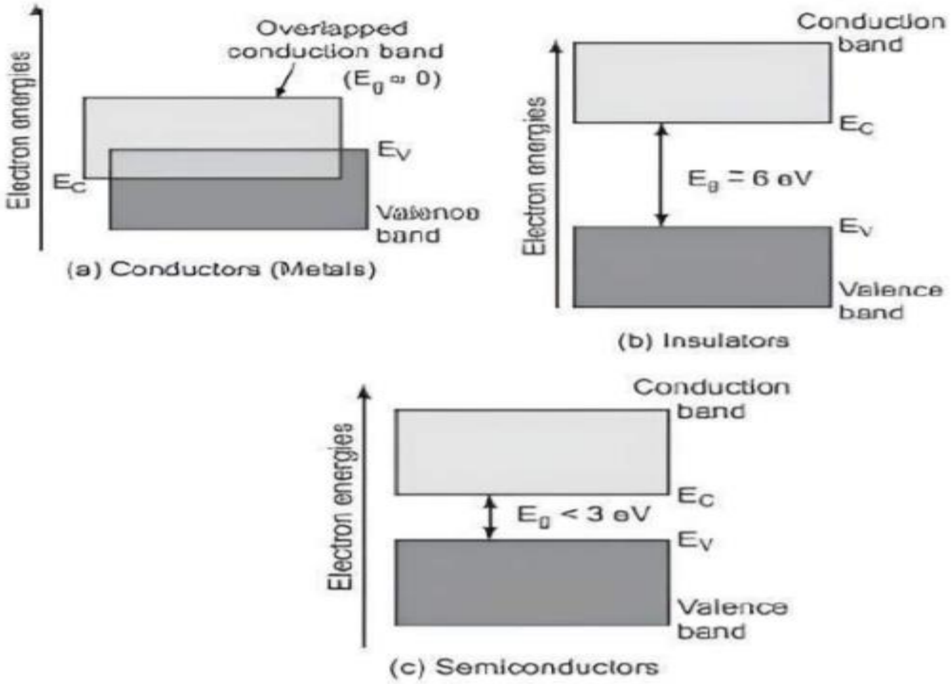
Forward biased Connection



Reverse biased Connection



9. Differentiate between metals, insulators and semiconductors on the basis of energy band

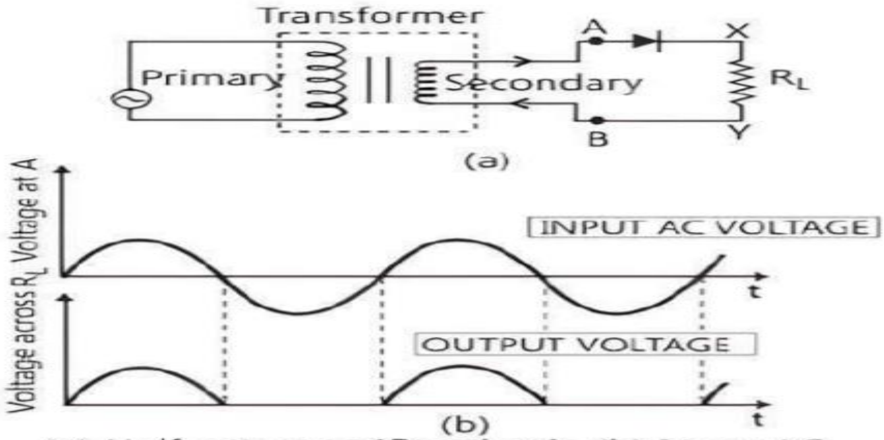


diagrams.

Solution: In metals due to overlapping between conduction band and valence band large number of free electrons are available for conduction, hence metals are good conductors of electricity.
In insulators the forbidden energy gap is very large greater than 3eV therefore no electron from valance bond is able to jump to conduction band this is why their resistivity is very high.

In semiconductors the energy gap is less than 3eV, therefore at room temperature some electrons are able to jump from valance band to conduction band hence their conductivity is less than metals but greater than insulators

10. Draw a circuit diagram and explain the working of half wave rectifier.



(a) Half-wave rectifier circuit. (b) Input AC voltage and output voltage waveforms of rectifier circuit.

Solution:
In the first half cycle the diode is under forward bias so it conducts and we get output while in second half cycle the diode is under reverse bias so it does not conduct as shown in the figure. Therefore half wave rectifier converts only half of the AC voltage into DC

5 MARKS

1.(a) state the postulates of Bohr model of hydrogen atom and derive the expression for radius, velocity and energy of electron in nth orbit.
(b)find the ratio of the longest and the shortest wavelength among the spectral lines of Balmer series in the spectrum of hydrogen atom.
Solution:

(a)Postulates Of bohr atomic model
1. Electron in an atom could revolve about nucleus in certain fixed orbits, called stationary orbits, without emitting radiation.
2. Electrons revolve only in those orbits in which its angular momentum is equal to integral multiple of h/2

$L = mv_n r_n = n(h/2\pi) \quad n = 1,2,3\ldots$

3. An electron can make a transition from higher energy orbit to lower energy orbit by emitting a photon whose energy is equal to the energy difference between initial and final orbits. $h\nu = E_1 - E_2$

derivation:

according tobohr's second postulate $mv_n r_n = n(h/2\pi) \quad n = 1,2,3\ldots \quad \ldots..(i)$

and centripetal force is provided by Colombian force

$$mv_n^2/r_n = (1/4\pi\varepsilon_0)\, e \times e / r_n^2$$

i.e. $mv_n^2r_n=(e^2/4\pi\varepsilon_0)$ ....(ii)

ii/ i

$$\mathbf{v_n = (1/n)(e^2/2\varepsilon_0 h)}$$

putting the value of velocity in (i)

$$\mathbf{r_n = n^2(\varepsilon_0 h^2 / \pi me^2)}$$

Now total energy of electron in H atom

En= $-(1/8\pi\varepsilon_0)\, e^2 / r_n$

$$\mathbf{E_n = - (1/n^2)(me^4/8\varepsilon_0^2h^2)}$$

$$\mathbf{E_{n}= - 13.6eV / n^2}$$

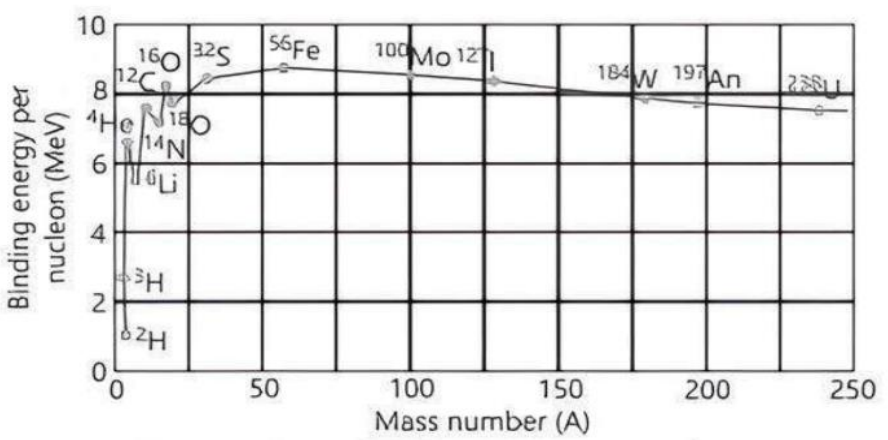
(b)In Balmer series $1/\lambda = R(1/2^2 - 1/n^2)$

Thus for largest wavelength n= 3 $= R(1/4 - 1/9)$
$= R(5/36)$
largest wavelength =36/5R

Similarly for smallest wavelength n=infinity $1/\lambda = R(1/2^2 - 0) = R/4$
smallest wavelength =4/R

Thereforerequired Ratio = 9:5

2. (A)Draw the graph showing the variation of binding energy per nucleon with mass number write two inferences which can be drawn from this graph.
(B)explain the releaseof energy in nuclear fission and fusion and the basis of this graph. Solution



Inferences

i) the binding energy per nucleon is almost constant i.e. independent of mass number for nuclei of middle mass number (30<A< 170) and have a maximum of 8.75 MeV for Fe-56

ii) Ebn is lower for both light nuclei andheavy nuclei.

Conclusions:

i) The nuclear force is attractive and sufficiently strong to produce binding energy of few MeVper nucleon ii) the constant of binding energy in the middle range shows that the nuclear force is short ranged.

(B) In nuclear fission a heavy nucleus splits into comparatively lighter nuclei. The binding energy of fragments is greater than the binding energy of parent nuclei. This difference in binding per nucleon is released as energy.

In nuclear fusion lighter nuclei fuse to form comparatively heavy nuclei. The binding energy of the product is greater than the binding energy of reactants. This difference in binding energy per nucleon is released as energy.

3. Distinguish between nuclear fission and fusion. Show how both these processes energy is released. Calculate the energy release in MeV in the deuterium-tritium fusion reaction 1H2 + 1H3 → 2He4 + n using the data mass of1H2= 2.014102 u, mass of 1H3 = 3.016949 u, mass of 2He4 = 4.002603 u, mass of neutron = 1.008665 u, u = 931.5 MeV

Solution:

Nuclear Fission: When the nucleus of an atom splits into lighter nuclei through a nuclear reaction the process is termed nuclear fission. When each atom split, a tremendous amount of energy is released. Fission reactions do not occur in nature. Little energy is needed to split an atom in a fission reaction. Atomic bomb and nuclear reactors work on the principle of nuclear fission

Nuclear Fusion: In Nuclear fusion two or more light nuclei fuse to form a heavier nucleus. The energy released during nuclear fusion is several times greater than the energy released during nuclear fusion. naturally Fusion reactions occur in stars and the sun. High energy (T = 10^7K)is needed to fuse two or more atoms together in a fusion reaction. Hydrogen bomb works on the principle of a nuclear fusion bomb.

In both reactions there is a mass defect which is converted into energy.

Now energy released in the reaction

Q = [mass(1H2) + mass(1H3) – mass(2He4) – mass of neutron] x c2

= [2.014102 + 3.016049 -4.002603-1.008665] x 931.5 MeV = 0.018883 x 931.5 MeV

= 17.58 MeV

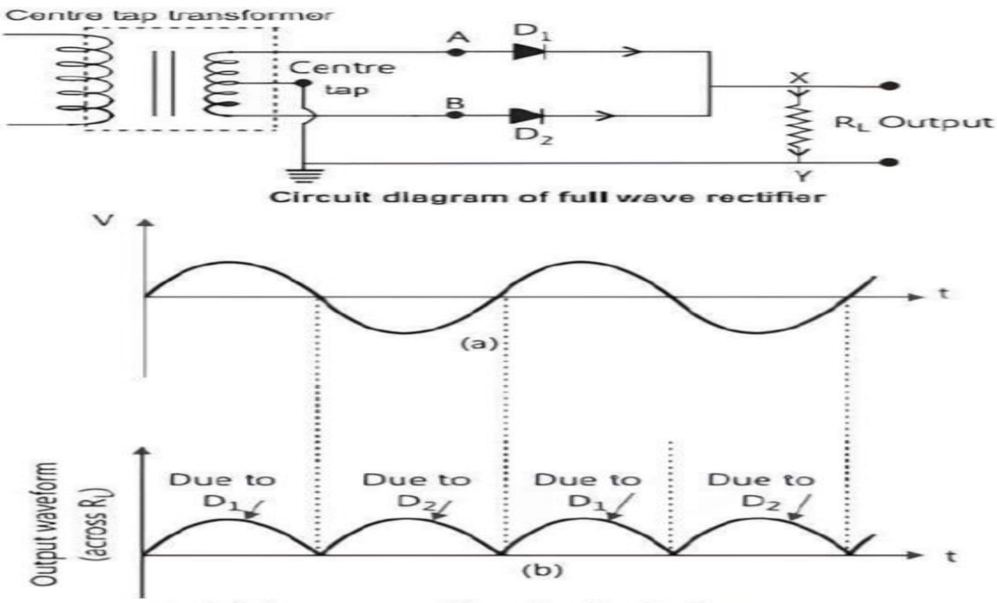
4.(A) Write the property of the junction diode which makes it suitable for rectification of AC voltage.

(B)Draw a circuit diagram and explain the working of full wave rectifier.

(C)If an AC voltage of frequency 50 hertz is applied as input, what will be the pulse frequency of output of a half wave rectifier and a full wave rectifier?

Solution:

(A) A pn junction diode offers low resistance under forward bias and high resistance under Reverse wires and hence it conducts under Forward bias only.



(a) A full-wave rectifier circuit; (b) Output wave form across the load R_L connected in the full-wave rectifier circuit.

(B)

In the first half cycle D1 is under forward bias while D2 is under reverse bias therefore we get output only due to D1. In second half cycle D1 is under reverse wires and D2 is under forward therefore we get output due to D2. In this way full wave rectifier converts whole part of AC into DC as shown in the figure.

(C)Frequency of output of half wave rectifier will be same as frequency of input voltage i.e. 50 hertz

Frequency of output of full wave rectifier will be twice of frequency of input voltage i.e. 100 hertz.

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PREVIOUS YEAR QUESTIONS

CHAPTER 1 : ELECTRIC CHARGES AND FIELDS

SECTION A (Mcqs and Assertion and Reason)

1. Two identical small conducting balls B1 and B2 are given -7 pc and + 4pc charges respectively . They are brought in contact with a third identical ball B3 and then separated . If the final charge on each ball is – 2pc , the initial charge on b3 was
   (a) – 2pc (CBSE 2024)
   (b) – 3pc
   (c) – 5pc
   (d) – 15pc

   Ans (b) – 3pc.

2. A point charge situated at a distance r from a short dipole on the axis , experiences a force F . If the distance of the charge is 2r , the force on the charge will be
   (a) F/16 (CBSE 2023)
   (b) F/8
   (c) F/4
   (d) F/2

   Ans (b)

3. A negatively charged object X is repelled by another charged object Y. However an object Z is attracted to object Y . Which of the following is the most possiblity for the object Z ? (CBSE 2022)
   (a) Positively charged only.
   (b) Negatively charged only.
   (c) Neutral or positively charged .
   (d) Neutral or negatively charged.

   Ans – ©

4. In an experiment three microscopic latex spheres are sprayed into a chamber and became charged with charges + 3e , +5e and – 3e respectively . All the three spheres came in contact simultaneously for a moment and got separated . Which one of the following are possible values for the final charges on the spheres (CBSE 2022)
   (a) + 5e , - 4e , + 5e.
   (b) + 6e , + 6e , - 7e.
   (c) – 4e , +3.5e, +5.5e.
   (d) + 5e , - 8e , + 7e.

   Ans – (b).

5. An object has charge of 1 C and gains 5×10^{18} electrons . The net charge on the object becomes – (CBSE 2022)
   (a) – 0.80 C
   (b) + 0.80 C
   (c) + 1.80 C
   (d) + 0.20 C

   Ans – (d).

Questions number 6 to 8 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 and Reason are true and Reason is the correct explanation of Assertion.

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

6. Assertion: The electric field is a conservative field.
Reason: Line integral of electric field around a closed path is non zero.
(CBSE COMP 2023)
Ans – (c)

7. Assertion : In a non uniform electric field , a dipole will have translatory as well as rotatory motion.
Reason : In a non uniform electric field a dipole experiences a force as well as torque.
(CBSE SAMPLE PAPER 2020-21)
Ans (a)

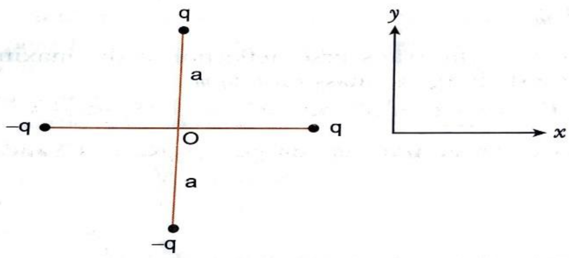
8. Assertion : An electric dipole is in stable equilibrium when placed in a uniform electric field with its dipole moment is in a direction opposite to the field .
Reason : No torque acts on an electric dipole when its dipole moment is in a direction opposite to the field.

CBSE COMPETENCY FOCUSSED PRACTICE QUESTIONS VOL 1)
Ans – (e)

9. Assertion: Work done in moving a charge around a closed path in an electric field is always zero.
Reason : Electrostatic force is a conservative force .
(CBSE 2023).
Ans (a)

SHORT ANSWER TYPE QUESTIONS (2 MARKS)

10. Two identical dipoles are arranged in X-Y plane as shown in the figure . Find the magnitude and direction of net electric field at the origin.
(CBSE 2023)



$\overrightarrow{E1} = \frac{kq}{a^2}(-\hat{j}-\hat{j}) = \frac{kq}{a^2}(-2\hat{j})$

$E2 = \frac{kq}{a^2}(-\hat{\imath}-i) = \frac{kq}{a^2}(-2\hat{\imath})$

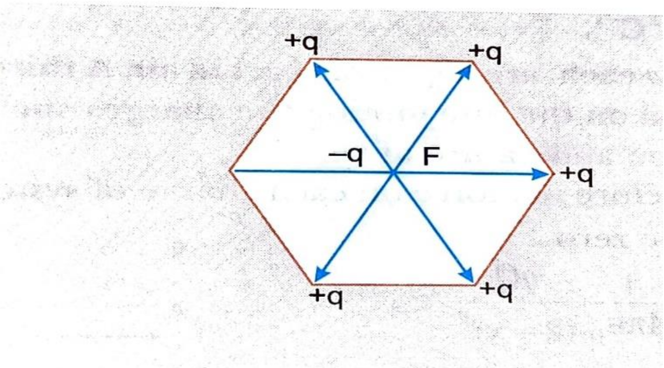
Net electric field at O = $\sqrt{\left(\frac{2kq}{a^2}\right)^2 + (2kq/a^2\ )\text{^}2}$

$= 2\sqrt{2}\ kq/a^2$ N/C

Tan α= E1/E2
= 1
A= 45 ^{0} to its – x axis.

11. Five point charges each of charge + q are placed on the five vertices of a regular hexagon of side ‘l’ . Find the magnitude of the resultant force on a charge – q placed at the centre of the hexagon .

(CBSE 2019 (55/3/1))

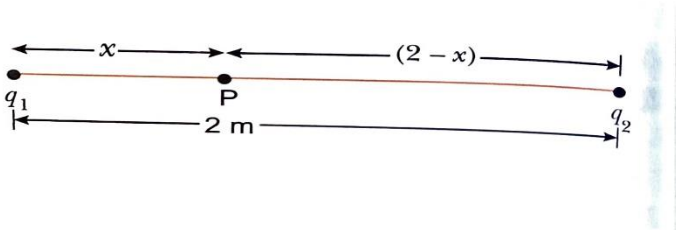


Ans – The forces due to the charges placed diagonally opposite at the vertices of the hexagon , on the charge – q cancel in pairs . Hence net force is due to one charge only.

$$F = \frac{1}{4\pi\varepsilon0}\frac{q^2}{l^2}$$

12. Two point charges q1 = + 1 μC and q2 = + 4 μC are placed 2 m apart in air . At what distance from q1 along the line joining the two charges, will the net electric field be zero ?

(CBSE 2020(55/3/1))



The electric field at P due to q1

$E1 = \frac{kq1}{x^2}$

The electric field at point p due to q2

$E2 = \frac{kq2}{(2-x)^2}$

At point P , net electric field is zero

E1 = E2

$\frac{kq1}{x^2} = \frac{kq2}{(2-x)^2}$

X = 2/3 m.

SHORT ANSWER QUESTIONS (3 Marks).

13. Two charged conducting spheres of radii a and b are connected to each other by a wire . Find the ratio of the electric field at their surfaces.

(CBSE 2023 (55/2/1))

Ans V1 = V2

$\frac{kq1}{a} = \frac{kq2}{b}$

q1/q2 = a/b

$E1 = \frac{kq1}{a^2}$ $E2 = \frac{kq2}{b^2}$

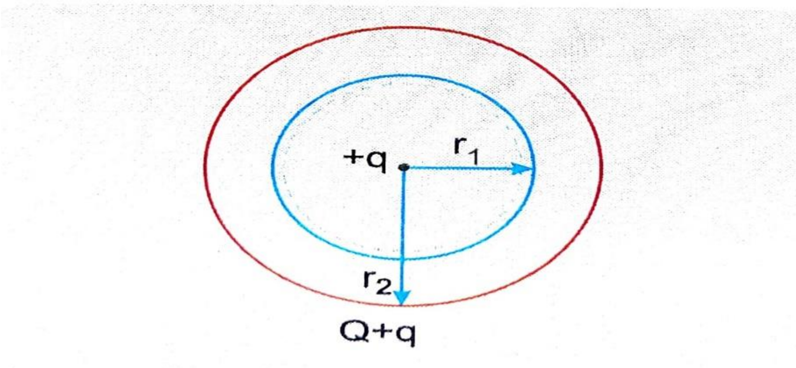
E1/E2 = b/a.

14. A conducting shell of inner radius r1 and outer radius r2 has a charge Q .

(a) A charge q is placed at the centre of the shell . Find out the surface charge density on the inner and outer surfaces of the shell .

(b) Is the electric field inside a cavity (with no charge) zero ; independent of the fact whether the shell is spherical or not ? Explain.

(CBSE 2019)



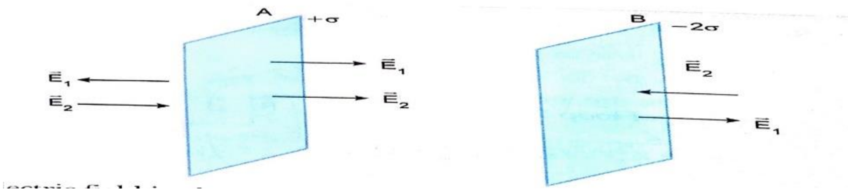
Ans (a) the surface charge density on inner surface of the shell is $\sigma_1 = -\frac{q}{4\pi r r1^2}$

the surface charge density on outer surface of the shell is $\sigma_2 = \frac{Q+q}{4\pi r r2^2}$

(b) if a Gaussian surface is considered inside the shell , net flux is zero since $q_{net} = 0$. According to Gauss's law , it is independent of shape and size of the shell.

15. Two large charged plane sheets of charge densities σ and – 2 σ C/m^2 are arranged vertically with a separation of d between . Deduce expression for the electric field at points (i) to the left of the first sheet . (ii) to the right of the second sheet and (iii) between the two sheets.

(CBSE 2019)



Ans (i) Electric field in the region left of the first sheet

$E_I = E1 + E2$

$= \sigma/\epsilon_0 - \sigma/2\epsilon_0 = \sigma/2\epsilon_0$ towards right.

~~(ii)~~ Electric field in the region right of the second sheet

$E_{II} = \sigma/2\epsilon_0 - \sigma/\epsilon_0$

$= \sigma/2\epsilon_0$ towards left

(iii) Electric field between the two sheets

$E_{III} = E1 + E2$

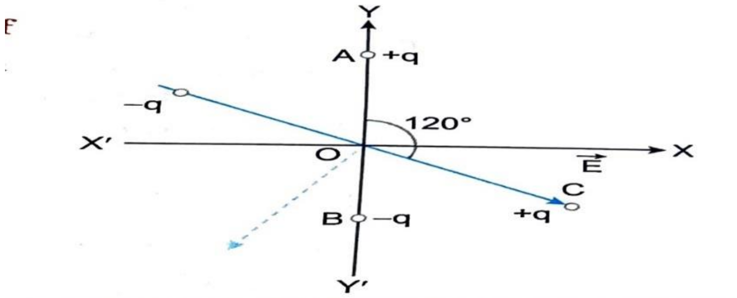
$=3\ \sigma/2\epsilon_0$ towards right.

16. Two small identical electric dipoles AB and CD , each of dipole moment p are kept at an angle of 120^0 to each other in an external electric field E pointing along the X axis as shown in the figure .Find the

(a) Dipole moment of the arrangement .

(b) Magnitude and direction of the net torque acting on it.

(CBSE 2020).



Ans (a) Dipole moment of dipole AB = p$\hat{j}$

Dipole moment of dipole CD = p cos 30^0 $\hat{\imath}$ - p cos 60^0 $\hat{j}$

= p $\sqrt{3}$ /2 $\hat{\imath}$ – p/2 $\hat{j}$

Net dipole moment = p$\hat{j}$ + p $\sqrt{3}$ /2 $\hat{\imath}$ – p/2 $\hat{j}$

= p $\sqrt{3}$ /2 $\hat{\imath}$ + p/2 $\hat{j}$

Magnitude of dipole moment = $\sqrt{\frac{3}{4}p^2 + p^2/4}$

= p.

Tan θ = $1/\sqrt{3}$

Torque acting on dipole AB = p$\hat{j}$ X E $\hat{\imath}$

= pE $\widehat{-k}$

Torque on dipole CD =(p $\sqrt{3}$ /2 $\hat{\imath}$ – p/2 $\hat{j}$) X E $\hat{\imath}$

= pE/2 $\hat{k}$

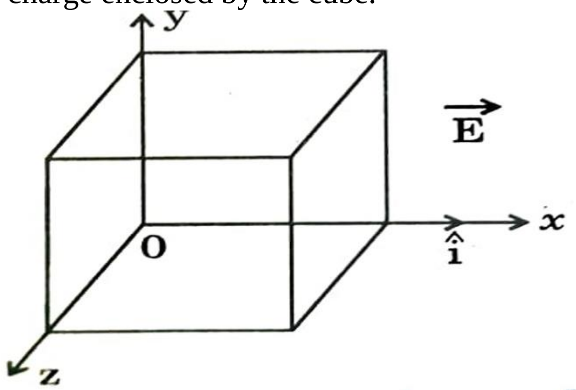
Net torque = torque on AB + torque on CD

= -pE/2 $\hat{k}$

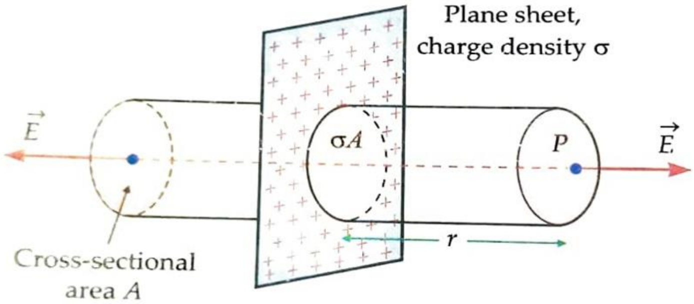
LONG ANSWER QUESTIO (5 MARKS)

17. (i) Using Gauss's law , show that the electric field $\vec{E}$ at a point due to a uniformly charged infinite plane sheet is given by $\vec{E}$ = $\frac{\sigma}{2\epsilon 0}$ $\hat{n}$ where symbols have their usual meanings.

(ii) Electric field $\vec{E}$ = ($5x^2$ + 2) $\hat{\imath}$
Where E is in N/C and x is in meters.
A cube of side 10 cm is placed in the region as shown in figure.
Calculate (1) the electric flux through the cube , and
(2) the net charge enclosed by the cube. CBSE 2024



Ans (i) By symmetry electric field points outward normal to the sheet. Also it must have same magnitude and opposite direction at P and P' equidistant from the sheet on opposite sides. A cylindrical Gaussian surface is chosen of cross sectional area A and length 2r.



The flux through the end faces = 2EA
Charge enclosed by the Gaussian Surface is q = σA
According to Gauss Theorem
$\Phi = q/\epsilon_0$
$2EA = \sigma A/ \epsilon_0$
$E = \sigma/2 \epsilon_0$
$\vec{E} = \frac{\sigma}{2\epsilon 0} \hat{n}$ where $\hat{n}$ is unit vector normal to the plane and outward to it.
(ii) For right face E = 5 x 0.01 + 2
= 2.05 N/C
Area of the face = .01 m^2
Flux through right face $\Phi 1 = 2.05 \times 10^{-2}$ Nm^2 /C
Similarly flux through left face $\Phi 2 = - 2 \times 10^{-2}$ Nm^2 /C
Net flux through the cube = $\Phi 1 + \Phi 2$
$= 5 \times 10^{-4}$ Nm^2 /C
Charge enclosed $q = \epsilon_0 \Phi_{net}$
$= 8.85 \times 10^{-12} \times 5 \times 10^{-4}$
$= 44.25 \times 10^{-16}$ C.

CASE BASED QUESTIONS (4 MARK).

18. FARADAY CAGE

A Faraday cage or Faraday shield is an enclosure made of a conducting material . The fields within a conductor cancel out with any external fields, so the electric field within the enclosure is zero. These Faraday cages act as big hollow conductors you can put things in to shield them from electrical fields. Any electrical shocks the cage receives , pass harmlessly around the outside of the cage.

(CBSE SQP 2020-21)

1. Which of the following material can be used to make a Faraday cage ?
   (a) Plastic
   (b) Glass
   (c) Copper
   (d) Wood.

   Ans c - copper

2. Example of a real world Faraday cage is
   (a) Car
   (b) Plastic box
   (c) Lightning rod
   (d) Metal rod.

Ans a - car

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.

Ans c – zero.

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

Ans c -q

OR

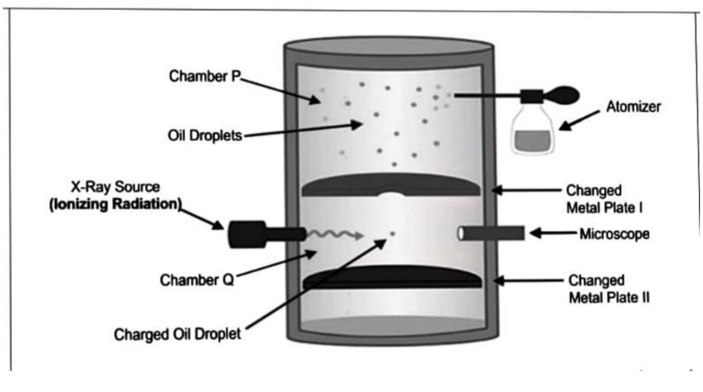
A point charge 2C is placed at centre of Faraday cage in the shape of cube with surface of 9 cm edge. The number of electric field lines passing through the cube normally will be –

(a) 1.9×10^5 Nm^2 / C entering the surface.
(b) 1.9×10^5 Nm^2 / C leaving the surface.
(c) 2.01×10^5 Nm^2 / C leaving the surface.
(d) 2.01×10^5 Nm^2 / C entering the surface.

Ans b 1.9×10^5 Nm^2 / C leaving the surface.

19. The figure below represents the set up of Millikan's oil drop experiment which was used by Millikan to determine the charge on an electron. Tiny droplets of oila in the form of mist are sprayed into the chamber P. Some of these droplets pass through the small hole in the metal plate I and are ionized by X – rays in chamber Q.
If its is observed that an ionized oil droplet having a mass 3.2×10^{-14} Kg and carrying a charge of $– 6.4 \times 10^{-19}$ C , remains stationary between the metal plates I and II when a potential difference 'V' is applied between the plates , then
   (a) What is the direction of the applied electric field in chamber Q ? Give reason .
   (b) What is the potential difference 'V" applied between the meatl plates , if the plates are separated by a distance of 1 cm ?

(Assume there is negligible drag force experienced by the oil droplet and take $g = 10\ m/s^2$)



(CBSE COMPETENCY FOCUSSED PRACTICE QUESTIONS VOL 1)

Ans (a) The applied electric field in the chamber Q is in the downward direction , from metal plate I to metal plate II. The charged oil droplet will experience a downward pull due to gravity . For the droplet to be stationary an equivalent upward force should act on the oil droplet. This is possible only when the metal plate I acquires a positive charge and the metal plate II acquires a negative charge.

(b) When the charged oil droplet is stationary

$qE = mg \qquad E = V/d$

$6.4 \times 10^{-19} \times V / 10^{-2} = 3.2 \times 10^{-14} \times 10$

V = 5000 V.

20. Dipoles , whether electric or magnetic , are characterized by theor dipole moments , which are vector quantities . Two equal and opposite charges separated by a small distance constitute an electric dipole , while a current carrying loop behaves as a magnetic dipole . Electric dipoles create electric fields around them. Electric dipoles experience a torque when placed in an external electric field .

(CBSE COMP 2024)

(i) Two identical electric dipoles, each consisting of charges – q and +q separated by distance d , are arranged in X-Y plane such that their negative charges lie at the origin and positive charge lie at points (d,0) and (0,d) respectively . The net dipole moment of the system is

(a) -qd ($\hat{\imath} + \hat{\jmath}$)
(b) qd ($\hat{\imath} + \hat{\jmath}$)
(c) qd ($\hat{\imath} - \hat{\jmath}$)
(d) qd (- $\hat{\imath} + \hat{\jmath}$)

Ans (b) qd ($\hat{\imath} + \hat{\jmath}$)

(ii) E1 and E2 are magnitudes of electric field due to a dipole , consisting of charges -q and +q by distance 2a , at points r (>>a) (1) on its axis , and (2) on equitoeial plane , respectively . Then E1/E2 is

(a) ¼ (b) ½ (c) 2 (d) 4

Ans © 2

(iii)An electric dipole of dipole moment 5×10^{-8} Cm is placed in a region where an electric field of magnitude 1×10^{3} N/C acts at a given instant . At that instant the electric field is inclined at an angle of 30^{0} To the dipole moment . The magnitude of torque acting on the dipole , at that instant is

(a) 2.5×10^{-5} Nm
(b) 5×10^{-5} Nm
(c) 1×10^{-4} Nm
(d) 2×10^{-6} Nm.

Ans (a) 2.5×10^{-5} Nm

CHAPTER 2: ELECTROSTATIC POTENTIAL AND CAPACITANCE

MULTIPLE CHOICE QUESTIONS (MCQ)

Q.1 Ten capacitors, each of capacitance 1 µF, are connected in parallel to a source of 100 V. The total energy stored in the system is equal to : (2024) 55/1/1

(A) 10^{-2} J (B) 10^{-3} J (C) $0\cdot5 \times 10^{-3}$ J (D) $5\cdot0 \times 10^{-2}$ J

Ans (D) $5\cdot0 \times 10^{-2}$ J

Q.2 A proton is taken from point P_1 to point P_2 , both located in an electric field. The potentials at points P_1 and P_2 are - 5 V and + 5 V respectively. Assuming that kinetic energies of the proton at points P_1 and P_2 are zero, the work done on the proton is : (2024) 55/3/1

(A) $-1\cdot6 \times 10^{-18}$ J (B) $1\cdot6 \times 10^{-18}$J (C) Zero (D) 0.8×10^{-18}J

Ans (B) $1\cdot6 \times 10^{-18}$J

Q.3 Two charges $+q$ each are kept ' $2a$ ' distance apart. A third charge $-2q$ is placed midway between them. The potential energy of the system is - (2024) 55/4/1

(A) $\frac{q^2}{8\pi\epsilon_0 a}$ (B) $-\frac{6q^2}{8\pi\epsilon_0 a}$ (C) $\frac{-7q^2}{8\pi\epsilon_0 a}$ (D) $\frac{9q^2}{8\pi\epsilon_0 a}$

Ans (C) $\frac{-7q^2}{8\pi\epsilon_0 a}$

Q.4 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 (2022) 55/2/1

(A) $\frac{1}{x^2}$ (B) $\frac{1}{x^3}$ (C) $\frac{1}{x^4}$ (D) $\frac{1}{x^{1/2}}$

Ans (A) $\frac{1}{x^2}$

Q.5 The capacitors, each of 4 μF are to be connected in such a way that the effective capacitance of the combination is 6 μF. This can be achieved by connecting

(A) All three in parallel

(B) All three in series

(C) Two of them connected in series and the combination in parallel to the third.

(D) Two of them connected in parallel and the combination in series to the third.

(2023) 55/5/1

Ans (C) Two of them connected in series and the combination in parallel to the third

ASSERTION AND REASON

Questions number 6 to 9 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).

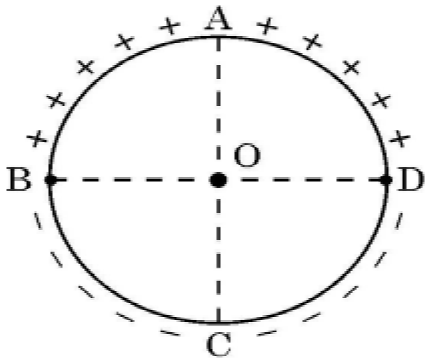
(B) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A).

(C) Assertion (A) is true, but Reason (R) is false.

(D) Assertion (A) is false and Reason (R) is also false.

Q6 Assertion (A) : Equal amount of positive and negative charges are distributed uniformly on two halves of a thin circular ring as shown in figure. The resultant electric field at the centre O of the ring is along OC.

Reason (R) : It is so because the net potential at 0 is not zero. (2024) 55/5/1



Ans (C) Assertion (A) is true but Reason (R) is false.

Q.7 Assertion (A): Electric field is always normal to equipotential surfaces and along the direction of decreasing order of potential
Reason (R) : Negative gradient of electric potential is electric field

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Ans (B) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A).

Q.8 Assertion (A) : An electron has a higher potential energy when it is at a location associated with a negative value of potential and has a lower potential energy when at a location associated with a positive potential
Reason (R) : Electrons move from a region of higher potential to a region of lower potential.

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Ans (C) Assertion (A) is true but Reason (R) is false

Q.9 Assertion (A): The direction of the electric field is always perpendicular to the equipotential surface. Reason (R): Work is done by the electric force in moving a charge between any two points on an equipotential surface is zero.

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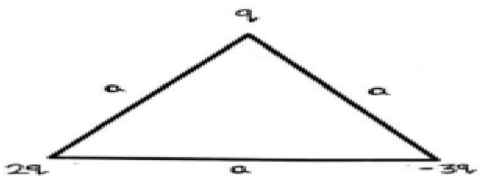
Ans (A) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).

TWO MARKS QUESTIONS

Q.10 Obtain an expression for electrostatic potential energy of a system of three charges q, 2q and 3q placed at the vertices of an equilateral triangle of side a (2023) 55/4/1

Ans



OR a similar diagram with different order of charges

$$U = \frac{1}{4\pi \epsilon_0} \cdot \frac{q_1 q_2}{r}$$

$$U = \frac{1}{4\pi \epsilon_0}\left[\frac{2q^2}{a} - \frac{6q^2}{a} - \frac{3q^2}{a}\right]$$

$$U = \frac{1}{4\pi \epsilon_0}\frac{\left(-7q^2\right)}{a}$$

Q.11 Two point charges + q and q are located at points (3a, 0) and (0, 4a) respectively in x-y plane. A third charge Q is kept at the origin. Find the value of Q, in terms of q and a, so that the electrostatic potential energy of the system is zero. (2023) 55/3/1

Ans Potential energy of the system $= K\left[\frac{Q(-q)}{4a} + \frac{Qq}{3a} - \frac{q^2}{5a}\right]$

Potential energy of the system = 0

$$\Rightarrow K\left[\frac{-Qq}{4a} + \frac{Qq}{3a} - \frac{q^2}{5a}\right] = 0$$

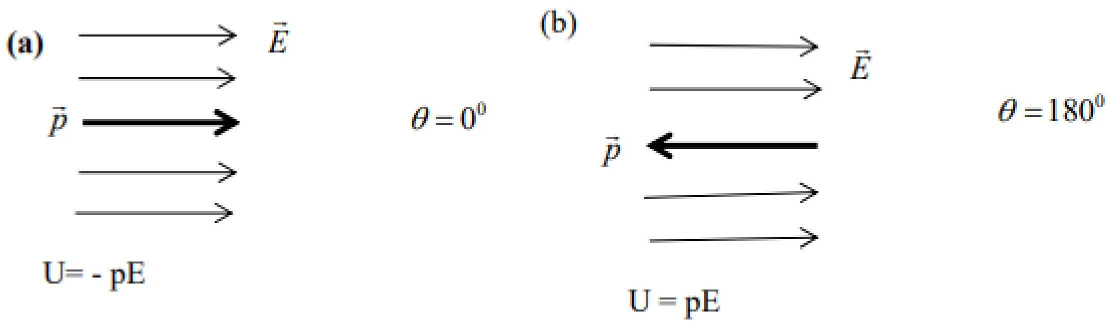
$$\Rightarrow \frac{-Q}{4} + \frac{Q}{3} - \frac{q}{5} = 0$$

$$\Rightarrow +\frac{Q}{12} - \frac{q}{5} = 0$$

$$\Rightarrow Q = +\ \frac{12q}{5}$$

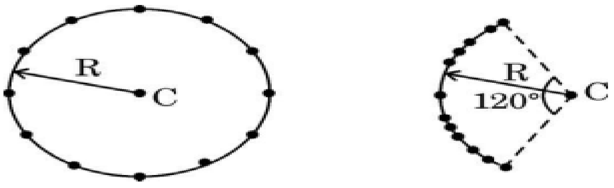
Q.12 Depict the orientation of an electric dipole in (a) stable and (b) unstable equilibrium in an external uniform electric field.
Write the potential energy of the dipole in each case. (2023) 55/5/1

Ans



THREE MARKS QUESTIONS

Q.13 (a) Twelve negative charges of same magnitude are equally spaced and fixed on the circumference of a circle of radius R as shown in Fig. (i). Relative to potential being zero at infinity, find the electric potential and electric field at the centre C of the circle.
(b) If the charges are unequally spaced and fixed on an arc of 12^0 of radius R as shown in Fig. (ii), find electric potential at the centre C. (2023) 55/1/1



(i) (ii)

Ans (a) Electric potential due to point charge V= kq /R
Value of each charge = - q , Total charge = -12q
Total potential V = $\frac{k(-12)q}{R} = \frac{-12kq}{R} = \frac{-12q}{4\pi\epsilon_0 R}$
By symmetry the resultant of all electric field vectors becomes zero. So electric field is zero.
(b) (b) Electric potential is a scalar quantity and does not depend on placement of charges
potential V = $\frac{k(-12)q}{R} = \frac{-12kq}{R} = \frac{-12q}{4\pi\epsilon_0 R}$

Q.14 Two point charges of 10 mC and 20 mC are located at points (– 4 cm, 0, 0) and (5 cm, 0, 0) respectively, in a region with electric field $E = A/r^2$, where $A = 2 \times 10^{-6}$ $NC^{-1} m^2$ and $\vec{r}$ is the position vector of the point under consideration. Calculate the electrostatic potential energy of the system.

(2024) 55/S/1

Ans

$$U = \frac{kq_1q_2}{r_{12}} + q_1V_1 + q_2V_2$$

$$\frac{kq_1q_2}{r_{12}} = \frac{9\times10^9\times10\times10^{-6}\times20\times10^{-6}}{9\times10^{-2}} = 20J$$

$$q_1V_1 = q_1\frac{A}{r_1} = \frac{10\times10^{-6}\times2\times10^6}{4\times10^{-2}} = 500J$$

$$q_2V_2 = q_2\frac{A}{r_2} = \frac{20\times10^{-6}\times2\times10^6}{5\times10^{-2}} = 800J$$

$$U = (20+500+800)J$$

$$U = 1320J$$

Q.15 Three point charges 1μC, -1μC and 2μC are kept at the vertices A, B and C respectively of an equilateral triangle of side 1 m. A_1 , B_1 and C_1 are the midpoints of the sides AB, BC and CA respectively. Calculate the net amount of work done in displacing the charge from A to A_1 , from B to B_1 and from C to C_1 . (2023) 55/C/1

Ans Initial electrostatic potential energy of the system

$$U_i = \frac{k}{r}[1\times(-1)+(-1)\times2+(1)\times(2)]\times10^{-12}$$

$$= \frac{9\times10^9}{1}[-1-2+2]\times10^{-12}$$

$$= -9\times10^{-3}J$$

Now $A_1B_1 = B_1C_1 = A_1C_1 = \frac{1}{2}$ m

Final electrostatic potential energy of the system

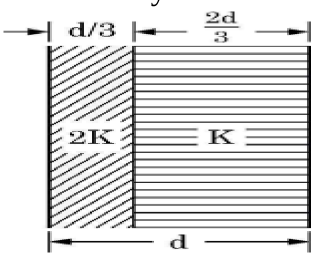
$$U_f = \frac{-9\times10^{-9}}{1/2} = -18\times10^{-3}J$$

Amount of work done W= U_f - U_i

W= $-18\times10^{-3} + 9\times10^{-3} = -9\times10^{-3}J$

Q.16 (a) A dielectric slab is inserted between the plates of a parallel plate capacitor. The electric field between the plates decreases. Explain.

(b) Two slabs of dielectric constants 2K and K fill the space between the plates of a parallel plate capacitor of plate area A and plate separation d as shown in figure. Find an expression for capacitance of the system.



(2023) 55/5/1

Ans (a) Within the dielectric slab, induced electric field due to polarization, decreases the electric field E = E0/ K

(b)

Capacitance of left portion, $C_1 = \frac{6K \epsilon_0 A}{d}$

Capacitance of right portion, $C_2 = \frac{3K \epsilon_0 A}{2d}$

As the capacitors are in series

$$\frac{1}{C_{eqi}} = \frac{1}{C_1} + \frac{1}{C_2}$$

$$\frac{1}{C_{eqi}} = \frac{d}{6K \epsilon_O A} + \frac{2d}{3K \epsilon_O A} = \frac{5d}{6KA \epsilon_O}$$

$$C_{eqi} = \frac{6KA \epsilon_O}{5d}$$

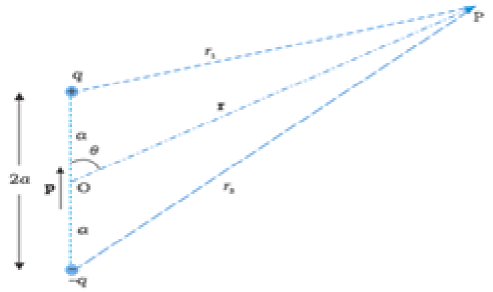
LONG ANSWER QUESTIONS 5 MARKS QUESTIONS

Q.17 (i) Obtain an expression for the electric potential due to a small dipole of dipole moment $\overrightarrow{p}$, at a point r from its centre, for much larger distances compared to the size of the dipole.

(ii) Three point charges q, 2q and nq are placed at the vertices of an equilateral triangle. If the potential energy of the system is zero, find the value of n. (2024) 55/2/1

Ans

(i)



Potential due to the dipole is the sum of potentials due to charges q and -q

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

By geometry

$$r_1^2 = r^2 + a^2 - 2ar\cos\theta$$

$$r_2^2 = r^2 + a^2 + 2ar\cos\theta$$

For r >> a, retaining terms only up to first order in a/r

$$r_1^2 = r^2\left(1 - \frac{2a\cos\theta}{r} + \frac{a^2}{r^2}\right)$$

$$\cong r^2\left(1 - \frac{2a\cos\theta}{r}\right)$$

Similarly

$$r_2^2 \cong r^2\left(1 + \frac{2a\cos\theta}{r}\right)$$

Using the binomial theorem and retaining terms up to the first order in a/r

$$\frac{1}{r_1} \cong \frac{1}{r}\left(1 - \frac{2a\cos\theta}{r}\right)^{-1/2}$$

$$\cong \frac{1}{r}\left(1 + \frac{a\cos\theta}{r}\right) \quad \text{-------------------------------------(2)}$$

$$\frac{1}{r_2} \cong \frac{1}{r}\left(\frac{1 + 2a\cos\theta}{r}\right)^{-1/2} \quad \text{-------------------------------(3)}$$

$$\cong \frac{1}{r}\left(1 - \frac{a\cos\theta}{r}\right)$$

Using eqn. (1) (2), (3) and p = 2qa

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

$$= \frac{p\cos\theta}{4\pi\varepsilon_0 r^2}$$

(ii) Consider the side of equilateral triangle as 'a'

Potential energy $= U = \frac{kq_1q_2}{a} + \frac{kq_2q_3}{a} + \frac{kq_1q_3}{a}$

According to question

$$U = \frac{k(q)(2q)}{a} + \frac{k(2q)(nq)}{a} + \frac{k(q)(n\,q)}{a} = 0$$

$$= \frac{2q^2}{a} + \frac{2nq^2}{a} + \frac{n\,q^2}{a} = 0$$

$$2 + 2n + n = 0$$

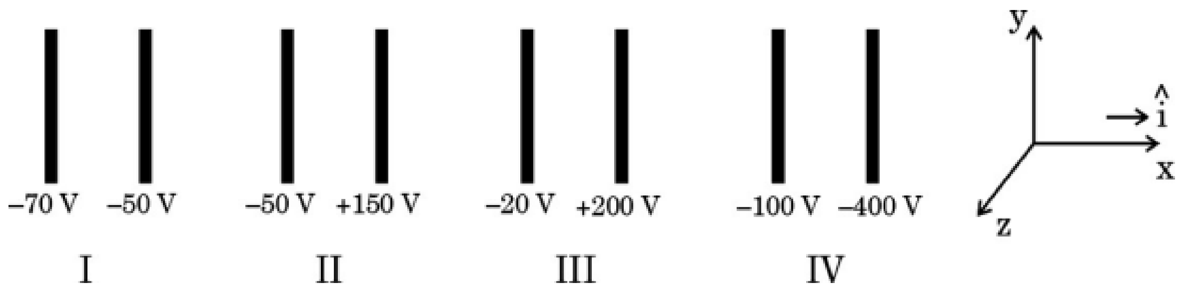
$$3n = -2$$

$$n = -\frac{2}{3}$$

CASE BASED QUESTIONS

Q.18 The figure shows four pairs of parallel identical conducting plates, separated by the same distance 2.0 cm and arranged perpendicular to x-axis. The electric potential of each plate is mentioned. The electric field between a pair of plates is uniform and normal to the plates.

(2024) 55/3/1



(i) For which pair of the plates is the electric field $\vec{E}$ along $\hat{\imath}$? 1

(A) I (B) II (C) III (D) IV

(ii) An electron is released midway between the plates of pair IV. It will : 1

(A) move along $\hat{\imath}$ at constant speed (B) move along - $\hat{\imath}$ at constant speed

(C) accelerate along $\hat{\imath}$ (D) accelerate along - $\hat{\imath}$

(iii) Let V_0 be the potential at the left plate of any set, taken to be at x = 0 m. Then potential V at any point ($0 \leq x \leq 2$ cm) between the plates of that set can be expressed as : 1

(A) $V = V_0 + \alpha x$ (B) $V = V_0 + \alpha x^2$

(C) $V = V_0 + \alpha x^{1/2}$ (D) $V = V_0 + \alpha x^{3/2}$

where α is a constant, positive or negative

(iv) (a) Let E_1 , E_2 , E_3 and E_4 be the magnitudes of the electric field between the pairs of plates, I, II, III and IV respectively. Then : 1

(A) $E_1 > E_2 > E_3 > E_4$ (B) $E_3 > E_4 > E_1 > E_2$

(C) $E_4 > E_3 > E_2 > E_1$ (D) $E_2 > E_3 > E_4 > E_1$

OR

(b) An electron is projected from the right plate of set I directly towards its left plate. It just comes to rest at the plate. The speed with which it was projected is about : (Take (e/m) =1.76 10^{11} C/kg) 1

(A) 1.3 X10^5 m/s (B) 2.6 X 10^6 m/s (C) 6.5 X 10^5 m/s (D) 5.2X10^7 m/s

Ans (i) (D) IV

(ii) (D) accelerate along - $\hat{\imath}$

(iii) (A) V= V0 + αx

(iv) (a) (C) $E_4 > E_3 > E_2 > E_1$

OR

(b) (B) 2.6× 10^6 m/s

Q.19 Dielectrics play an important role in design of capacitors. The molecules of a dielectric may be polar or non-polar. When a dielectric slab is placed in an external electric field, opposite charges appear on the two surfaces of the slab perpendicular to electric field. Due to this an electric field is established inside the dielectric.

The capacitance of a capacitor is determined by the dielectric constant of the material that fills the space between the plates. Consequently, the energy storage capacity of a capacitor is also affected. Like resistors, capacitors can also be arranged in series and/or parallel.

(2024) 55/5/1

(i) Which of the following is a polar molecule

(A) O_2 (B) H_2 (c) N_2 (D) HCl

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

(A) A polar dielectric has a net dipole moment in absence of an external electric field which gets modified due to the induced dipoles.

(B) The net dipole moments of induced dipoles is along the direction of the applied electric field.
(C) Dielectrics contain free charges.
(D) The electric field produced due to induced surface charges inside a dielectric is along the external electric field.

(iii) When a dielectric slab is inserted between the plates of an isolated charged capacitor, the energy stored in it:
(A) increases and the electric field inside it also increases.
(B) decreases and the electric field also decreases.
(C) decreases and the electric field increases.
(D) increases and the electric field decreases.

(iv) (a) An air-filled capacitor with plate area A and plate separation d has capacitance C_O A slab of dielectric constant K, area A and thickness (d/5) is inserted between the plates. The capacitance of the capacitor will become
(A) $\left[\frac{4K}{5K+1}\right]C_o$ (B) $\left[\frac{K+5}{4}\right]C_o$ (C) $\left[\frac{5K}{4K+1}\right]C_o$ (D) $\left[\frac{K+4}{5K}\right]C_o$

OR

(iv) (b) Two capacitors of capacitances 2 C_O and 6 C_O are first connected in series and then in parallel across the same battery. The ratio of energies stored in series combination to that in parallel is
(A)1/4 (B) 1/6 (C) 2/15 (D) 3/16

Ans (i) (D) HCl
(ii) (B) The net dipole moments of induced dipoles is along the direction of the applied electric field.
(iii) (B) decreases and the electric field also decreases
(iv) a (C) $\left[\frac{5K}{4K+1}\right]C_o$

OR

(iv) b (D) 3/16

Q.20. The electric potential at a point in an electric field is the work done in bringing a unit positive charge from infinity to this point. If the potential difference between any two points at a surface is zero, the surface is called an equipotential surface. The shape of an equipotential surface can give direction of electric field at a point on it. It may be a closed surface or an open surface, depending on the charges creating the electric field.

(2024) 55(B)-S

(i) The shape of equipotential surface due to an isolated point charge is : 1
(A) ellipsoidal, with charge at its one foci (B) plane surface not passing through point charge (C) spherical with charge at its centre (D) cylindrical with charge at its axis

(ii) The equipotential surfaces in a uniform electric field acting along + Z direction are : 1
(A) planes parallel to the XY plane (B) concentric spherical surfaces
(C) planes parallel to the YZ plane (D) planes parallel tothe XZ plane

(iii) Which of the following statements is not true for equipotential surfaces ? 1
(A) Potentials at two equipotential surfaces are different.
(B) No work is done in moving a charge on an equipotential surface.
(C) Equipotential surfaces always enclose some volume.
(D) Two equipotential surfaces do not intersect each other.

(iv) (a) The angle between the electric field at a point and outward normal at that point on an equipotential surface is : 1

(A) 90° (B) 45° (C) 30° (D) 0°

OR

(iv) (b) A and B are two equipotential surfaces around a point charge Q. Surface A is closer to the charge than surface B. If a test charge is released between them, it will : 1

(A) remain stationary

(B) move from A to B

(C) move from B to A

(D) move around Q in a circular path between the equipotential surfaces A and B

Ans (i) (C) Spherical with charge at its centre

(ii) (A) Planes parallel to the XY plane

(iii) (C) Equipotential surfaces always enclose some volume

(iv) (a) (D) 0^0

OR (b) (B) move from A to B

CBSE PREVIOUS YEARS BOARD QUESTIONS
CHAPTER - CURRENT ELECTRICITY
MULTIPLE CHOICE QUESTIONS -

1. 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?

A: (a) Current is constant along a conductor.

2. A current passes through a wire of non-uniform cross-section. Which of the following quantities are independent of the cross-section?
(a) The charge crossing
(b) Drift velocity
(c) Current density
(d) Free-electron density

A: (d) Free-electron density.

3. The relaxation time in conductors
(a) increases with the increases of temperature
(b) decreases with the increases of temperature
(c) it does not depend upon temperature
(d) all of sudden changes at 400 K

A: (b) decreases with the increases of temperature

4. Emf of a cell is

(a) the maximum potential difference between the terminalsof a cell when no current is drawn from the cell.
(b) the force required to push the electrons in the circuit.
(c) the potential difference between the positive andnegative terminal of a cell in a closed circuit.
(d) less than terminal potential difference of the cell

A: (a) the maximum potential difference between the terminalsof a cell when no current is drawn from the cell.

5. A cell of internal resistance r is connected to an external resistance R. The current will be maximum in R, if
(a) R = r (b) R < r (c) R > r (d) R = r/2

A: (a) R = r

ASSERTION AND REASON QUESTIONS – 1 MARKS(4)

1. Assertion: When a current is established in a wire, the free electrons drift in the direction opposite to the current and so the number of free electrons in the wire continuously decrease.

Reason: Charge is a non-conserved quantity.

A: d) Assertion and Reason both are incorrect.

2. Assertion: Current is a vector quantity.
Reason: Current has magnitude but not direction.

A: d) Assertion and Reason both are incorrect.

3. Assertion: The electric bulb glows immediately when switch is on.

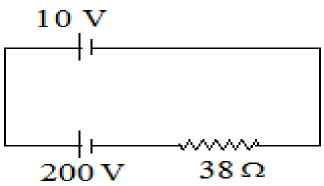
Reason: The drift velocity of electrons in a metallic wire is very high.

A: c) Assertion is true but Reason is false.

4. Assertion: If potential difference between two points is zero and resistance between those two points is zero, current may flow between the points.
Reason: Kirchhoff's first law is based on the law of conservation of charge.
A: a)Assertion and Reason both are correct and R is the correct explanation of A.

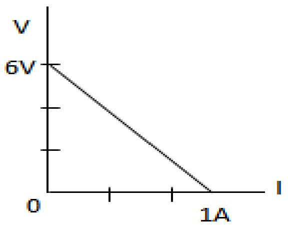
2 MARKS QUESTIONS(3)

1. A 10 V battery of negligible internal resistance is connected across a 200 V battery and a resistance of 38 Ω. Find the value of the current in circuit.



A: $I = \frac{E}{r+R} = \frac{200-10}{0+38} = 5A$

2. The plot of the variation of potential difference across a combination of three identical cells in series, versus current is as shown below. What is the emf of each cell?



A: Let E be emf of each cell and r be the total internal resistance of circuit. The equation of terminal potential difference $V = 3E - Ir$ …………(1)
At V = 6V, I = 0. Therefore from eq (1), $6 = 3E - 0 \Rightarrow E = 2V$

3. A wire of 15 Ω resistance is gradually stretched to double its original length. It is then cut into two equal parts. These parts are then connected in parallel across a 3 volt battery. Find the current drawn from the battery.

A: When the length of the wire is doubled, the area of cross section becomes half.

New resistance $R' = \rho \frac{2l}{\left(\frac{A}{2}\right)} = 4\rho \frac{l}{A} = 4R = 60\Omega$

Resistance of each half part is 30Ω.

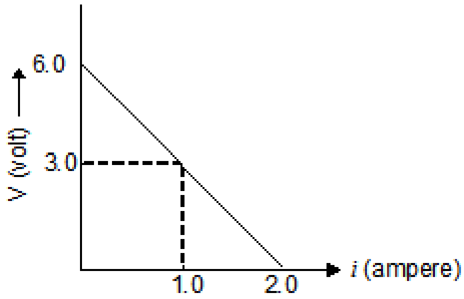
When both parts are connected in parallel, Equivalent resistance = $\frac{30}{2} = 15\Omega$

Current drawn from battery, $I = \frac{V}{R_{eq}} = \frac{3}{15} = 0.2A$

3 MARKS QUESTIONS(5)

4. The following graph shows the variation of terminal potential difference *V*, across a combination of three cells in series to a resistor, versus the current, *I*.
(i) Calculate the emf of each cell. (ii) For what current *I* will the power dissipation of the

circuit be maximum?



A: (i) Let E be emf of each cell and r be the total internal resistance of circuit. The equation of terminal potential difference $V = 3E - Ir$ ………..(1)

At V = 6V, I = 0. Therefore from eq (1), $6 = 3E - 0 \Rightarrow E = 2V$

(ii) At V = 0V, I = 2A. Therefore from eq (1), $0 = 6 - 2r \Rightarrow r = 3\Omega$

(iii) For maximum power dissipation, external resistance (R) = Internal resistance (r)

$$\text{Current, I} = \frac{3E}{r+R} = \frac{6}{3+3} = 1A$$

5. A conductor of length 'l' is connected to a dc source of potential 'V'. If the length of the conductor is doubled by gradually stretching it, keeping 'V' constant, how will (i) drift speed of electrons and (ii) resistance of the conductor be affected? Justify your answer.

A: (i) $v_d = \frac{eV\tau}{mL} \propto \frac{1}{L}$

Thus, the length is doubled, the drift velocity becomes half.

(ii) $R = \rho \frac{l}{A}$

When the length of the conductor is doubled, the area of cross section becomes half.

New resistance $R' = \rho \frac{2l}{\left(\frac{A}{2}\right)} = 4\rho \frac{l}{A} = 4R$

Thus, the length is doubled, resistance becomes four times.

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

A: Mobility of an ion is defined as the drift velocity per unit electric field.

$$\mu = \frac{v_d}{E} = \frac{e}{m}\tau .$$ Its unit is m^2 /Vs.

When temperature increases, covalent bonds of neighbouring atoms break and charge carriers become free, so resistivity of semi-conductor decreases with rise of temperature.

7. Two conducting wires X and Y of same diameter but different materials are joined in series across a battery. If the number density of electrons in X is twice that in Y, find the ratio of drift velocity of electrons in the two wires.

A: In series current is same $I_X = I_Y$.

For same diameter, cross-sectional area is same.

$$\therefore n_x eAv_x = n_y eAv_y \Rightarrow \frac{v_x}{v_y} = \frac{n_y}{n_x} = \frac{1}{2}$$

8. A conductor of length L is connected to a dc source of emf V. If this conductor is replaced by another conductor of same material and same area of cross-section but of length 3L, how will the drift velocity change?

A: $v_d = \frac{eV\tau}{mL} \propto \frac{1}{L}$

When the length is made 3L, the drift velocity becomes one third

5 MARKS QUESTIONS

9. (a) State Kirchhoff's rules.

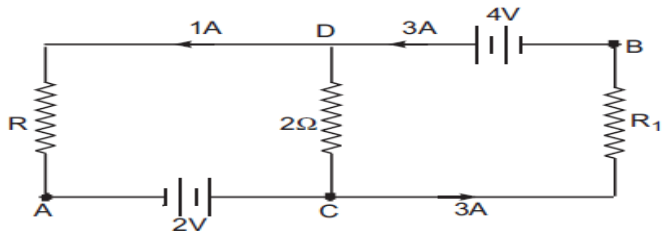
(b) In the given circuit, assuming point A to be at zero potential, use Kirchhoff's rules to determine the potential at point B.

A: (a) Kirchhoff's Rules:

(i) The algebraic sum of currents meeting at any junction is zero, i.e. $\sum I = 0$

(ii) The algebraic sum of potential differences across circuit elements of a closed circuit is zero,i.e.,

$\sum V = 0$

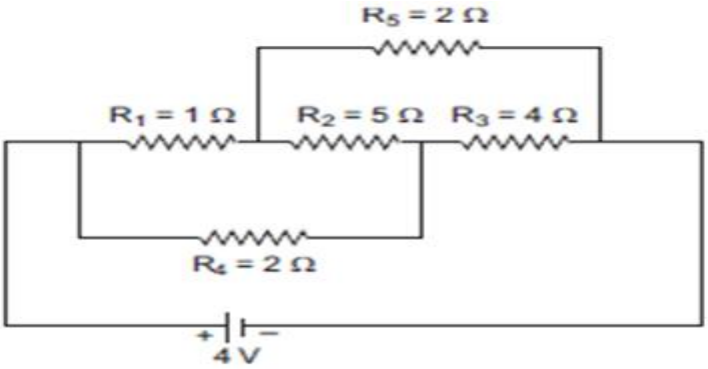


(b) By KCL, current in DC branch I = 3-1 = 2A

Applying KVL along path ACDB, $V_A + 2 + 2X2 - 4 = V_B \Rightarrow V_B = V_A + 2 = 0 + 2 = 2V$

10. (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?

(b)Calculate the current drawn from the battery in the given network.

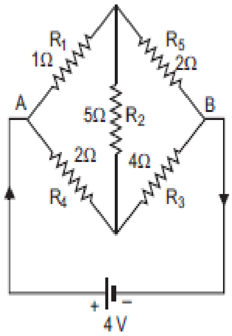


A: (a) A: Drift velocity is defined as the average velocity with which the free electrons get drifted towards the positive end of the conductor under the influence of an external electric field applied. It is given by $v_d = \frac{eV\tau}{mL}$

When V is doubled and L is halved, the drift velocity becomes 4 times.

(b)The equivalent circuit is shown in fig.

The five resistors form a balanced Wheatstone's bridge. Since $\frac{R_1}{R_5} = \frac{R_4}{R_3}$



So, R_2 is ineffective.
The effective resistance of R_1 and R_5 in series,
$R' = R_1 + R_5 = 1 + 2 = 3\ \Omega$
The effective resistance of R_4 and R_3 in series is
$R'' = R_4 + R_3 = 2 + 4 = 6\ \Omega$
R' and R" are in parallel. Therefore the Equivalent resistance of network between A and B,

$$R_{AB} = \frac{R' R''}{R' + R''} = 2\Omega$$

Current drawn from battery, $I = \frac{E}{R_{AB}''} = \frac{4}{2} = 2A$

CASE STUDY BASED QUESTIONS – 4 MARKS(3)

1. When the electric cell (source of EMF) is in a closed circuit, the current flows through the circuit. There is a fall of potential across the the internal resistance of the cell. The terminal potential difference between the two electrodes of the cell becomes less than the EMF of the cell by an amount equal to to potential drop across the internal resistance of the cell. Thus, in a closed circuit The terminal potential difference of a cell is always less than the the EMF of the cell.

Q.i EMF of a cell is independent of:
(A) size of the electrodes
(B) quantity of electrolyte present in the cell
(C) distance between the electrodes
(D) all of these

A: (d)

Q.ii three cells of EMF, 2.0 V,2.5 V and 3.0 V are connected in series. Their internal resistances are 0.20 Ω, 0.20Ω and 0.15Ω respectively. The battery is connected to an external resistor of 6.5 Ω wire a very low resistance ammeter, what would be the reading of ammeter?

(A) 1.1Ω
(B) 1Ω
(C) 2 Ω
(D) 2.1 Ω

A: (a)

Q.iii A cell of emf E and internal resistance r is connected in series with an external resistance nr. Then ratio of terminal potential difference to emf is:

(A) 1/n
(B) 1/(n+1)
(C) n/(n+1)
(D) (n+1)/n

A: (c)

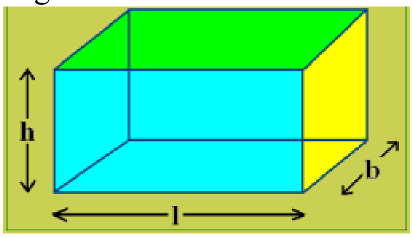
Q.iv In an experiment a student measures terminal potential difference (TPD) of a cell. When the same cell is connected to an external resistance of 5 Ω then the TPD is 2 V and when the same is repeated for an external resistance of 10 Ω then the TPD is 2.4 V. What is the EMF and internal resistance of cell?

(A)2.5 V,3Ω
(B) 3 V,3.5Ω
(C) 3 V,2.5Ω
(D) 2.5 V,3Ω
A: (c)
2. It is worth noting that electric field inside a charged conductor is zero, but it is non zero inside a current carrying conductor and is given by E=V/L where V is the potential difference across the conductor and L is the length of the conductor.Electric field outside the conductor is zero.The small value of drift velocity produces a large number of electric current,due to the presence of extremely large of free electrons in a conductor.The propagation of current is almost at the speed of light and involves electromagnetic process.It is due to this reason that electric bulb glows immediately when switch is on.
1.Which of the following quantity remains constant along the metallic conductor of non-uniform cross section when a constant potential difference is applied?

(a)Drift velocity
(b) Current
(c) Electric field
(d)Current density.

A: (b)

2.Find the current density across the cuboid shaped conductor when electric current I flows across its height 'h':



(A)i/lh
(B) i/bh
(C) i/bl
(D) i/lbh

A: (c)

3.In absence of applied potential, the electric current flowing through a metallic wire is zero because

(A)the electrons remains stationary
(B) the electrons are drifted in a random direction with a speed of 10-12 cm/sec.
(C) the electrons move in random direction with a speed of the order close to that of velocity of light
(D) the electrons and ions move in opposite direction.

A: (c)

4. At room temperature copper has free electron density of 8.4x 1028 m-3. The electron drift speed in copper conductor of 5.4 A will be-

(A) 4m/s
(B) 0.4m/s
(C) 4cm/s
(D)0.4mm/s

A: (d)

5. Current is flowing from a conductor of non uniform cross section area. If a2> a1, then Which of the quantity is same across both ends:
(A)Current
(B) drift velocity
(C)current density
(D) current and current density

A: (a)
3. Whenever an electric current is passed through a conductor, it becomes hot after some time. The phenomenon of the production of heat in a resistor by the flow of an electric current through it is called heating effect of current or Joule heating. Thus, the electrical energy supplied by the source of emf is converted into heat. In purely resistive circuit, the energy expended by the source entirely appears as heat. But if the circuit has an active element like a motor, then a part of energy supplied by the source goes to do useful work and the rest appears as heat. Joule's law of heating forms the basis of various electrical appliances such as electric bulb, electric furnace, electric press etc.

(i) Which of the following is correct statement?
(a) Heat produced in a conductor is independent of the current flowing.
(b) Heat produced in a conductor varies inversely as the current flowing.
(c) Heat produced in a conductor varies directly as the square of the current flowing.
(d) Heat produced in a conductor varies inversely as the square of the current flowing.

A: (c)
(ii) If the coil of a heater is cut to half, what would happen to heat produced?

(a) Doubled
(b) Halved
(c) Remains same
(d) Becomes four times.

A: (b)

(iii) A 25 W and 100 W are joined in series and connected to the mains. Which bulb will glow brighter?
(a) 100 W
(b) 25 W
(c) Both bulbs will glow brighter
(d) None will glow brighter

A: (b)

(iv) A rigid container with thermally insulated wall contains a coil of resistance 100 Ω, carrying 1 A. Change in its internal energy after 5 min will be

(a) 0 Kj

(b) 10 kJ
(c)20 kJ
(d) 30 kJ

A: (d)

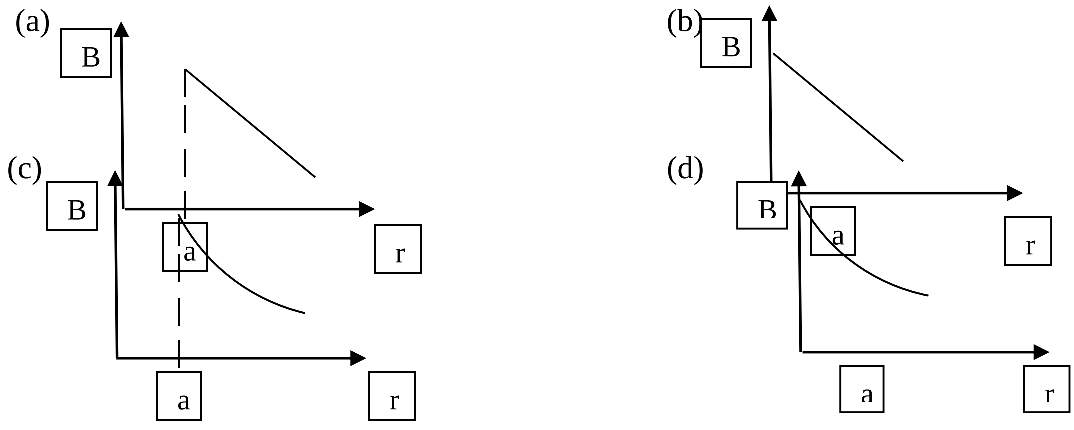
(v) The heat emitted by a bulb of 100 W in 1 min is
(a) 100 J
(b) 1000 J
(c) 600 J
(d) 6000 J

A: (d)

PREVIOUS YEAR ASKED QUESTIONS IN CBSE BOARD EXAMINATIONS
CHAPTERS: (1) MOVING CHARGES AND MAGNETISM
(2) MAGNETISM AND MATTER

MULTIPLE CHOICE QUESTIONS

1. A long straight wire of circular cross – section of radius ‘a’ carries a steady current ‘I’. The current is uniformly distributed across its cross – section. The ratio of magnitudes of magnetic fields $\overrightarrow{B_1}$ at a point distant ‘a/2’ and $\overrightarrow{B_2}$ at distance ‘2a’ is (CBSE OD 2023)
   (a) ½ (b) 1 (c) 2 (d) 4
2. Which of the following graphs correctly represents the variation of the magnitude of the magnetic field outside a straight infinite current carrying wire of radius ‘a’, as a function of distance ‘r’ from the centre of the wire? (CBSE OD 2023)



3. An electron enters a uniform magnetic field with the speed ‘v’. It describes a circular path and comes out of the field. The final speed of the electron is (CBSE F 2023)
   (a) Zero (b) v (c) v/2 (d) 2v
4. A particle of mass m and charge q moving with a uniform velocity $\vec{v} = v_{0x}\hat{\imath} + v_{0y}\hat{\jmath}$ enters in region with magnetic a field$\vec{B} = B_0\hat{\jmath}$. After sometime, an electric field $\vec{E} = E_0\hat{\jmath}$ is also swithed on in the region. The resulting path described by the particlewill be (CBSE OD 2023)
   (a) a circle in x-z plane (b) a parabola in x-y plane
   (c) a helix with constant pitch (d) a helix with increasing pitch
5. Two long parallel wires kept 2m apart carry 3A current each, in the same direction. The force per unit length on one wire due to the other is (CBSE D 2023)

(a) $4.5 \times 10^{-5} Nm^{-1}, attractive$ (b) $4.5 \times 10^{-7} Nm^{-1}, repulsive$

(c) $9 \times 10^{-7} Nm^{-1}, repulsive$ (d) $9 \times 10^{-7} Nm^{-1}, attractive$

6. Beams of electrons and protons move parallel to each other in the same direction. They (CBSE OD 2023)
   (a) attract each other (b) repel each other
   (c) neither attract nor repel (d) attract or repel, it depends upon speeds of beams
7. A small bar, when placed near a magnet, is repelled by it. This is because the bar is made of (CBSE C 2023)
   (a) iron (b) copper (c) aluminium (d) nickel
8. Which of the following has its permeability less than that of free space (CBSE D 2023)
   (a) Copper (b) Aluminium (c) Copper chloride (d) Nickel

ASSERTION –REASON QUESTIONS

For Questions 9 to 12, 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 and Reason are true and Reason is the correct explanation of Assertion.
(B) If both Assertion and Reason are true but Reason is not the correct explanation of Assertion.
(C) If Assertion is true but Reason is false.
(D) If both Assertion and Reason are false.

9. Assertion: The magnetic field produced by a current carrying solenoid is independent of its length and cross sectional area.
   Reason: The magnetic field inside the solenoid is uniform. CBSE 2023C
10. Assertion: The deflecting torque acting on a current carrying loop is zero when its plane is perpendicular to the direction of magnetic field.
    Reason: The deflecting torque acting on a loop of magnetic moment $\vec{m}$ in a magnetic field $\vec{B}$ is given by the dot product of $\vec{m}$ and $\vec{B}$. CBSE D 2023
11. Assertion: When radius of a circular loop carrying a steady current is doubled, its magnetic moment becomes four times.
    Reason: The magnetic moment of a circular loop carrying a steady current is proportional to the area of the loop. CBSE OD 2023
12. Assertion: Diamagnetic substances exhibit magnetism. CBSE OD 2023
    Reason: Diamagnetic substances do not have permanent magnetic dipole moment.

TWO- MARKS QUESTIONS

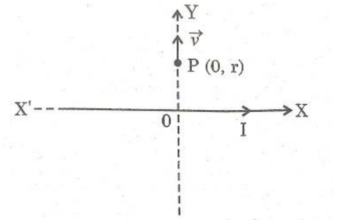
13. A long wire with a small current element of length 1cm is placed at the origin and carries a current of 10A along the X-axis. Find out the magnitude and direction of the magnetic field due to the element on the Y-axis at a distance 0.5m from it CBSE (OD) 2019
14. A galvanometer of resistance 16Ω shows full scale deflection for a current of 4 mA. How will you convert it into a voltmeter to measure a voltage up to 3V? CBSE (OD) 2020
15. A wire of length ‘l’ is in the form of circular loop A of one turn. This loop is reshaped into loop B of three turns. Find the ratio of the magnetic field at the centre of loop A and loop B for the same current through them. CBSE (OD) 2023
16. Why is the magnetic field radial in a moving coil galvanometer? Explain how it is achieved. CBSE (OD) 2015C, 2023
17. An α-particle and a proton of the same kinetic energy 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 radii of the circular paths describes by them. CBSE (D) 19

THREE MARKS QUESTIONS

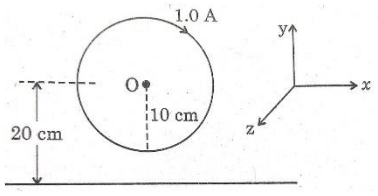
18. What are ferromagnetic materials? Explain ferromagnetism with the help of suitable diagrams, using concept of magnetic domain. CBSE (OD) 2024

19. An infinite straight conductor is kept along X'X axis and carries a current I. A charge q at point P(0,r) starts moving with velocity $\vec{v} = v_0\hat{j}$ as shown in the figure. Find the direction and magnitude of force initially experienced by the charge. CBSE (OD) 2024

20. A circular loop of radius 10 cm carrying current of 1.0 A lies in x-y plane. A long straight



wire lies in the same plane parallel to x-axis at a distance of 20 cm as shown in figure. Find



the direction and value of current that has to be maintained in the wire so that the net magnetic field at O is zero. CBSE (OD) 2024

21. (a) State Boit-Sawart law and express it in vector form.

(b) Deduce the expression for the magnetic field at a point on the axis of a current carrying circular loop of radius 'R', distance 'x'from the centre. Hence write the magnetic field at the centre of a loop.

CBSE 18C, OD 15, 19,20,23

22. Explain how a galvanometer can be converted into an ammeter of a given range. Derive an expression for shunt resistance and current for full scale deflection. Find the effective resistance of the ammeter. CBSE OD 19

23. (a) A particle of charge q and mass m moving with velocity $\vec{v}$ is subjected to a uniform magnetic field $\vec{B}$ perpendicular to its velocity.
Show that the particle describes a circular path. Obtain the expression for the radius of the circular path of the particle.

(b) Explain, how path will be affected if the velocity $\vec{v}$ makes an angle θ $(\neq 90°)$ with the direction of the magnetic field. CBSE 19C

24. (a) It is not advisable to use a galvanometer as such to measure current correctly. Why?

(b) Why should the value of resistance connected in parallel to a galvanometer be low?

(c) Is the reading shown by an ammeter in a circuit less than or more than the actual value of current flowing in the circuit? Why? CBSE 23 C

25. An ammeter of resistance 0.8Ω can measure current up to 1.0 A. (i) What must be the shunt resistance to enable the ammeter to measure the current up to 5.0 A? (ii) What is the combined resistance of the ammeter and the shunt? CBSE D 2013; OD 2020

FIVE MARKS QUESTIONS

26. (a) With the help of a diagram, explain the principle and working of a moving coil galvanometer.

(b) What is importance of radial a magnetic field and how is it produced?

(c) Why is it necessary to introduce a cylindrical soft iron core inside the coil of galvanometer?

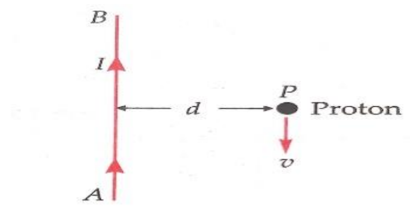
(d) "Increasing the current sensitivity of a galvanometer may not increase its voltage sensitivity". Justify this statement. CBSE D 06, 13C, OD 15, 16, 20C, 23

27. (a) Derive

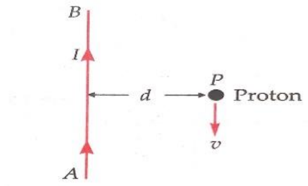
expression for the force between two long parallel current carrying conductors.

(b) Use this expression to define SI unit of current.

(c) A straight wire AB carries a current I. A proton P travel with a speed v, parallel to the wire, at a distance d from it in a direction opposite to the current as shown in the figure. What is the



the force experienced by the proton and what is its direction? CBSE D 23; OD 10, 20



28. (a) Derive a mathematical expression for the force acting on a current carrying straight conductor kept in a magnetic field. State the rule used to determine the direction of this force. Under what condition is this force (i) minimum and (ii) maximum?

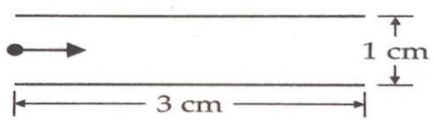
(b) Two long parallel straight wire A and B are 2.5 cm apart in air. They carry 5.0 A and 2.5 A currents respectively in opposite directions. Calculate the magnitude of the force exerted by wire A on a 10 cm length of wire B. CBSE OD 23

CASE BASED QUESTIONS

In following question read the paragraph and answer the questions that follow.

A beam of electrons moving horizontally with a velocity of $3 \times 10^7\ m/s$ enters a region between two plates as shown in the figure. A suitable potential difference is applied across the plates such that the electron beam just strikes the edge of the lower plate. [CBSE OD 23]

(i) Time taken by an electron to strike the edge is



(A) $10^5\ s$ (B) $10^{-2} s$ (C) $10^{-7} s$ (D) $10^{-9} s$

(ii) What is the shape of the path followed by the electron?

(A) Straight line (B) Parabola (C) Circle (D) Ellipse

(iii) Direction of the electric field is

(A) Upward (B) Downward (C) Out of the page (D) Into the page

(iv) (a) The direction of the magnetic field which should be created in the space between the plates so that the electrons beam goes straight (undeviated), is

(A) Upward (B) Downward (C) Out of the page (D) Into the page

OR

(b) The strength of magnetic field for the above purpose will be

(A) $1.9 \times 10^{-3} T$ (B) $1.9 \times 10^{-5} T$ (C) $3 \times 10^5 T$ (D) $3 \times 10^{-5} T$

ANSWERS OF QUESTIONS ASKED IN BOARD EXAMINATIONS

1. MOVING CHARGES AND MAGNETISM

2. MAGNETISM AND MATTER

MULTIPLE CHOICE QUESTIONS

1 (b) 1 — 1

Field inside the conductor $B_1 = \frac{\mu_0 Ir}{2\pi a^2} = \frac{\mu_0 I}{2\pi a^2}\left(\frac{a}{2}\right) = \frac{\mu_0 I}{4\pi a}$

Field outside the conductor $B_2 = \frac{\mu_0 I}{2\pi r} = \frac{\mu_0 I}{2\pi 2a} = \frac{\mu_0 I}{4\pi a} = B_1$

2 (c) — 1

Magnetic field outside the conductor $B = \frac{\mu_0 I}{2\pi r}$ $i.e.\ \ B\ proportional\ \frac{1}{r}$

3 (b) v — 1

There is no component of magnetic force in direction of motion i.e. magnetic force is always perpendicular to ‘v’.

4 (d) Helix with increasing pitch. — 1

Due to non-zero velocity component in the direction of magnetic field path becomes helical. Since electric field is in the direction of magnetic field therefore pitch increase with time.

5 (d) $9 \times 10^{-7}\ Nm^{-1}, attractive$ — 1

Magnetic force between parallel currents

$$\frac{F}{l} = 2 \times 10^{-7}\frac{I_1 I_2}{d} = 2 \times 10^{-7}\frac{3 \times 3}{2} = 9 \times 10^{-7} Nm^{-1}$$

6 (b) repel each other — 1

Opposite currents repel each other.

7 (b) Copper. — 1

Because copper is a diamagnetic material and it is feebly repelled by a magnet.

8. (a) Copper. — 1

Because copper is a diamagnetic material and it has small negative magnetic susceptibility and permeability less than that of free space.

ASSERTION –REASON — 1

9. (b) Both the assertion and reason are true but the reason is not a correct explanation of the assertion. — 1

10 (c) Assertion is true but reason is false. — 1

Deflecting torque is the cross product of $\vec{m}\ and\ \vec{B}$.

$$\vec{m}\ is\ always\ in\ the\ direction\ of\ normal\ to\ the\ plane\ of\ loop\ so\quad \tau = mBsin0^0 = 0$$

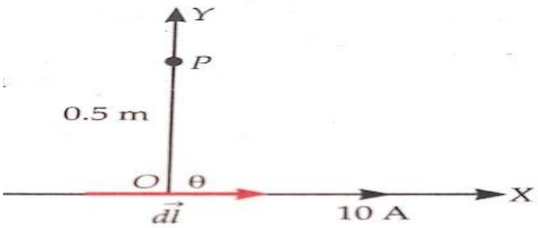
11. (a) Both the assertion and reason are true and the reason is the correct explanation of the assertion. — 1

$m = IA = I\pi r^2$ When radius is doubled $m' = I\pi(2r)^2 = 4m$

12 (b) Both the assertion and reason are true but the reason is not a correct explanation of the assertion. — 1

TWO- MARKS QUESTIONS

13 Here I = 10 A, dl = 1 cm = 0.01 m, r = 0.5 m, $\theta = 90^0$



Magnetic field at point P,

$$B = \frac{\mu_0}{4\pi} \cdot \frac{Idl sin\theta}{r^2} = \frac{10^{-7} \times 10 \times 0.01 \times sin90^0}{(0.5)^2} = 4 \times 10^{-8} T$$

14 Here $R_G = 16\Omega, \ I_G = 4\,mA, \ Desired\ range\ V = 3V$

Let required series resistance is R, then

$R + R_G = \frac{V}{I_G}$ So $R = \frac{V}{I_G} - R_G = \frac{3}{0.004} - 16 = 734\Omega$

15 Length of wire is l

Then for loop A $l = 2\pi r_A \ \ so \ \ r_A = \frac{l}{2\pi}$

Now magnetic field at the centre of loop A

$B_A = \frac{\mu_0 N_A I}{2 r_A} = \frac{\mu_0 \times 1 \times I}{2(l/2\pi)} = \frac{\mu_0 \pi I}{l}$

When same wire is bent into 3-turn coil then for coil B,

$l = 3 \times 2\pi r_B \quad or \quad r_B = \frac{l}{6\pi}$

Then magnetic field at the centre

$B_B = \frac{\mu_0 N_B I}{2 r_B} = \frac{\mu_0 \times 3 \times I}{2(l/6\pi)} = \frac{9\mu_0 \pi I}{l}$

Thus $\frac{B_A}{B_B} = \frac{1}{9}$

16 If deflection of the galvanometer coil is $\emptyset$

Then $k\emptyset = NIABsin\theta$

Because of the presence of factor sin θ, the deflection $\emptyset$ of the galvanometer coil is not quite proportional to the current I, so the instrument is not linear one. To make its scale linear, the field is made radial. Then $\theta = 90^\circ$ so that

$$\emptyset = \left(\frac{NBA}{k}\right) I \qquad or \qquad I \propto \emptyset$$

A radial magnetic field can be achieved by placing a soft iron cylindrical core between the concave magnetic poles.

17 Radius of path of the charge $r = \frac{mv}{qB}$

Momentum of the particle $p = mv = \sqrt{2mK}$ $\quad K = kinetic\ energy$

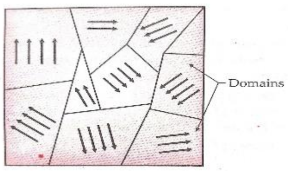
Then radius $r = \frac{\sqrt{2mK}}{qB}$

$$K_\alpha = K_p \qquad q_\alpha = 2e \ \ and \ \ q_p = e$$

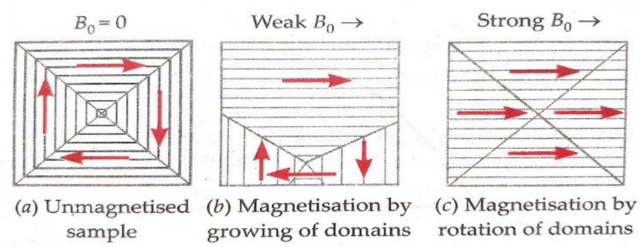
$\frac{r_\alpha}{r_p} = \frac{\sqrt{m_\alpha} e}{\sqrt{m_p} 2e} = \frac{1}{1}$

THREE MARK QUESTIONS

18 Ferromagnetism: Ferromagnetic materials are those materials which get strongly magnetised in an external magnetic field. They strongly attracted by magnets. Elements Fe, Ni, Co and some alloys are ferromagnetic materials. Ferromagnetic materials have very high permeability. Individual atoms of these materials possess large magnetic



moment.



(a) Unmagnetised sample (b) Magnetisation by growing of domains (c) Magnetisation by rotation of domains

The magnetic moments of neighbouring atoms interact and align themselves spontaneously in a common direction over microscopic regions called domains. Each domain has a typical size of about 1 mm and contains about 10^{11} atoms. In the absence of any external magnetic field, these domains are randomly oriented so that the net magnetic moment is zero.

When a ferromagnetic material is placed in a magnetic field, all domains align themselves along the direction of the field leading to strong magnetisation in the direction of the field.

19 At P, direction of magnetic field due to current is perpendicular and out of the paper (Right hand thumb rule).

$\vec{B} = B_0\hat{k} \qquad where\ B_0 = \frac{\mu_0}{2\pi}\frac{I}{r}$

Now using Fleming's left hand rule, the direction of force is along positive X.

$\vec{F} = qv_0\hat{j} \times B_0\hat{k} = qv_0B_0\hat{\imath}$

20 Magnetic field at the centre of circular loop

$$B = \frac{\mu_0}{2}\frac{I}{r} = 2 \times 10^{-7} \times \frac{1.0}{2 \times 0.1} = 10^{-6}\ T$$

Above field is perpendicular and inward to the paper.

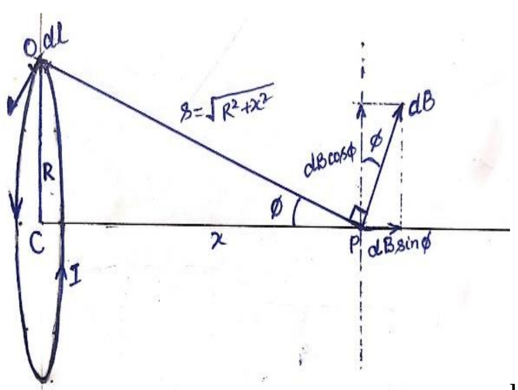
To neutralise the field of loop the magnetic field due to straight wire should be perpendicular and outward.

$B_{wire} = \frac{\mu_0}{2\pi}\frac{I_{wire}}{r} \qquad or \quad I_{wire} = B_{wire}\frac{2\pi}{\mu_0}r = 10^{-6} \times \frac{1}{2\times10^{-7}} \times 0.2 = 1.0\ A$

According to right hand thumb rule this current should be from left to right.

21 (a) According Boit-Savart law, the magnetic field due to a current element $I\vec{dl}$ at the observation point whose position vectoer is $\vec{r}$ is given by

$d\vec{B} = \frac{\mu_0}{2\pi}\frac{I\vec{dl}\times\vec{r}}{r^3} \qquad \mu_0\ is\ magnetic\ permeability\ of\ free\ space$



b)Consider a current element $\vec{dl}$ at the top of the loop. It has an outward coming current. Top point is O, centre C of the loop and R is the radius of R.

If $\vec{s}$ be the position vector of point P then from Boit-Sawart law

$dB = \frac{\mu_0}{4\pi}\frac{Idlsin\theta}{s^2}$

Since $\vec{dl} \perp \vec{s}$,

$dB = \frac{\mu_0}{4\pi}\frac{Idl}{s^2}$ $\qquad$ $Here\ s = \sqrt{R^2 + x^2}$

Let $\emptyset$ be the angle between OP and CP. Then $\overrightarrow{dB}$ can be resolved in to two rectangular components

1. $dBsin\emptyset\ along\ the\ axis,$
2. $dBcos\emptyset\ perpendicular\ to\ the\ axis.$

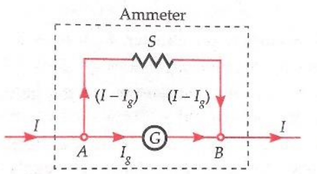
All perpendicular components are symmetrically distributed around the axis and overall cancelled out but all components along the axis add up to give resultant.

Therefore total magnetic field at the point P in the direction CP is

$B = \int dBsin\emptyset = \int \frac{\mu_0}{4\pi}\frac{Idl}{s^2}.\frac{R}{s}$

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

22 An ordinary galvanometer is a sensitive instrument. It gives full scale deflection with a small current of few microamperes. To measure large currents with it, a small resistance is connected in parallel with the galvanometer coil. This resistance is called SHUNT. Only a small part of the total current passes through the galvanometer coil.



Let $G = resistance\ of\ the\ galvanometer$

$I_g = the\ current\ with\ which\ galvanometer\ gives\ full\ scale\ deflection$

$I = the\ required\ current\ range\ of\ the\ ammeter$

$S = shunt\ resistance$

$I - I_g = current\ through\ the\ shunt.$

Potential difference across the gal. coil = Potential difference across the shunt

$I_g G = (I - I_g)S$

$S = \frac{I_g}{I - I_g}G$ $\qquad$ or $\qquad$ $I_g = \frac{S}{G+S} \times I$

The deflection in the galvanometer is directly proportional to I_g and hence to I. So scale can be graduated to read the value of current I.

The effective resistance of ammeter

$R_A = \frac{GS}{G+S}$

23 (a) Magnetic force acting on a moving charged particle is

$\vec{F} = q\vec{v} \times \vec{B}$ $\qquad$ or $\quad |\vec{F}| = qvBsin\theta$

$\theta = 90°, \quad so\ \ F = qvB$

Since force F is always perpendicular to the direction of velocity, therefore magnitude of velocity will remain constant and charges particle will describe a circle. The required centripetal force will be given by magnetic force.

So $qvB = \frac{mv^2}{r}$ $\qquad$ or $\quad r = \frac{mv}{qB}$

(b) The charged particle will follow the helical path with its parallel to the field. The component of initial velocity parallel to the magnetic field will make the particle move along the direction of the field while the component of the field perpendicular to the will compel it to follow a circular path. The net effect is the helical motion.

24 (a) A galvanometer has a high resistance. Its insertion will decrease the value of current in the circuit.

(b) A low value of resistance connected in the parallel with galvanometer will form an ammeter of small resistance.

(c) An ammeter has a small resistance so it introduces a resistance in the circuit. Thus an ammeter reads the current slightly less than the actual value of current.

25 The given ammeter can be regarded as the galvanometer.

$Therefore\ \ I_g = 1.0\ A, \qquad\qquad R_g = 0.80\Omega$

(i) Total current in the circuit, $I = 5.0\ A$

The required shunt resistance,

$R_s = \frac{I_g}{I - I_g} \times R_g = \frac{1.0}{5.0 - 1.0} \times 0.8 = 0.20\Omega$

(ii) The combined resistance R_A and the shunt is given by

$R_A = \frac{R_g \times R_s}{R_g + R_s} = \frac{0.8 \times 0.2}{0.8 + 0.2} = 0.16\Omega$

<u>FIVE MARKS QUESTIONS</u>

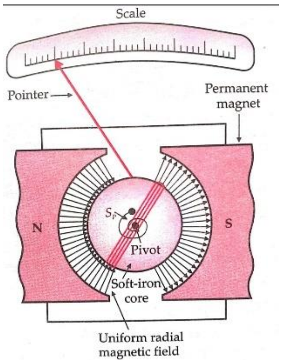
26 (a) Principle: A current carrying coil placed in a magnetic field experiences a current dependent torque, which tends to rotate the coil and produces angular deflection.

Working: A cylindrical soft iron core is mounted symmetrically between the concave poles of a magnet. This makes field lines radial. The plane of coil rotating in such a field remains parallel to the field in all orientations. Core increases the sensitivity of the galvanometer.

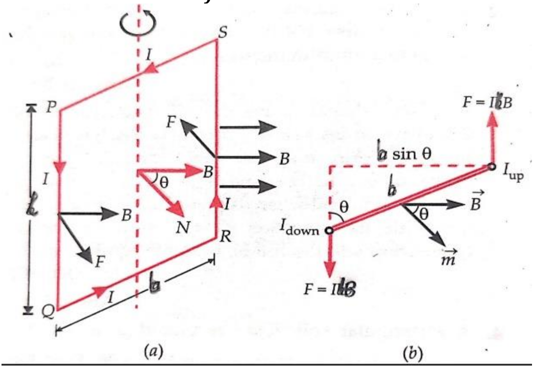
In figure,

$I = current\ in\ the\ coil$

l, b = sides of the rectangular coil



$N = number\ of\ turns\ in\ the\ coil$



The forces on the length sides form a couple and exert a torque given by

$\tau = force\ \times perpendicular\ distance\ between\ line\ of\ forces$

$= NIBl \times bsin90° = NIBA \qquad Here\ lb = A\ (area\ of\ coil)$

$\theta = 90°, as\ plane\ of\ the\ coil\ is\ parallel\ to\ the\ field$

The spring provided with the coil offers restoring torque against the deflection of coil under magnetic torque. Restoring torque is directly proportional to the angle of deflection.

$\tau_{rest} \propto \alpha \quad or \quad \tau_{rest} = k\alpha \quad where\ \ k = torsion\ constant\ of\ spring$

In equilibrium $\tau_{rest} = \tau$

Or $\qquad k\alpha = NIBA$

Or $\qquad \alpha = \frac{NBA}{k} I$

Or $\alpha \propto I$

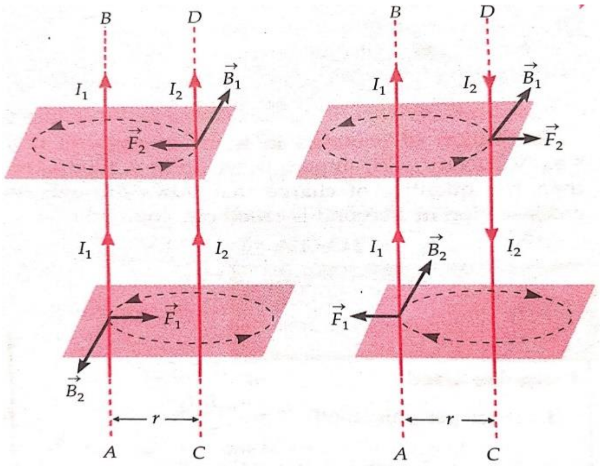
Using this linearity we can measure current.

(b) In the radial field the plane of coil is always parallel to the direction of field, independent of orientation. This provides linearity between angle of deflection and current in the coil.

(c) Cylindrical soft iron core has high permeability and it intensifies the magnetic field and hence increases the sensitivity of galvanometer.

(d) By increasing number of turns in the coil current sensitivity can be increased but in doing so resistance of the coil gets increased in the same proportion. So voltage sensitivity remains unchanged because voltage sensitivity is inversely proportional to resistance.

27



In the figure AB and CD are carrying currents $I_1 and\ I_2 respectively$. Separation between them is r. Wire AB experiences force due to magnetic field produced by CD and vice-versa.

Magnetic field due to current I_1 at any point on wire CD is

$B_1 = \frac{\mu_0 I_1}{2\pi r}$ This field is perpendicular to the wire CD and points into the plane of paper.

Then force acting on length l of the wire CD

$F_2 = I_2 l B_1 sin 90° = I_2 l \frac{\mu_0 I_1}{2\pi r}$

Force per unit length

$\frac{F_2}{l} = \frac{\mu_0 I_1 I_2}{2\pi r}$ (Towards AB)

Similarly, an equal force is exerted on the wire AB by bthe field of wire CD.

Thus when the currents in two wires are in the same direction, the force between them are attractive.

$\vec{F}_1 = -\vec{F}_2$

When currents in the two parallel wires flow in opposite directions, the force between the two wires are repulsive.

(b) SI unit of current

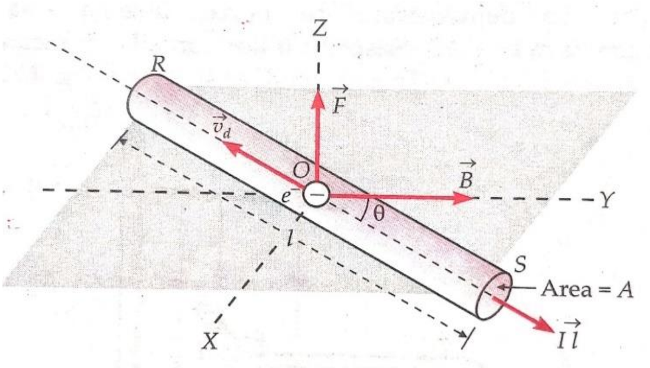
When $I_1 = I_2 = 1A\ and\ r = 1m,$ we get

$f = \frac{\mu_0}{2\pi} = 2 \times 10^{-7} Nm^{-1}$

One ampere is that steady current, which on flowing in each of the two parallel infinitely long conductors of negligible cross section placed in vacuum at a distance of 1m *from each other, produces between them a*

$force\ of\ 2 \times 10^{-7}\ newton\ per\ metre\ of\ their\ length.$
(c) Strength of field due to current I at the point P is,
$B = \frac{\mu_0 I}{2\pi d}$ $\quad$ $(Normal\ to\ the\ plane\ of\ paper)$
According to Fleming's left hand rule, force acts on the proton in the direction away from wire AB
$F = evBsin90° = ev\frac{\mu_0 I}{2\pi d} = \frac{\mu_0 I}{2\pi d}ev$

28 (a) Force on a current carrying conductor-



Suppose a straight conductor of cross section A, carrying current I is lying in the magnetic field at an angle θ with the magnetic field. Length l of the conductor is falling in the magnetic field.
Let drift velocity of electrons opposite to current is $\vec{v}_d$, then magnetic force on each electron is
$f = -e\vec{v}_d \times \vec{B}$
If n is the number of free electrons per unit volume, then total free electrons in the length l of the conductor is
$N = nAl$
Then total force on the conductor
$\vec{F} = N\vec{f} = nAl[-e\vec{v}_d \times \vec{B}] = neA[-l\vec{v}_d \times \vec{B}]$
$I\vec{l}$ Represents current element vector, so $\vec{l}\ and\ \vec{v}_d$ will have opposite directions.

Then $\quad -l\vec{v}_d = v_d\vec{l}$
So $\quad \vec{F} = enAv_d(\vec{l} \times \vec{B})$
$enAv_d = current, I$
$\vec{F} = I(\vec{l} \times \vec{B})$ $\qquad$ $or\ |\vec{F}| = IBlsin\theta$
(i) Magnitude of force will be minimum if $= 0°\ or\ 180°$, i.e current carrying conductor placed parallel to the direction of field experiences no force.
(ii) Force will be maximum if $\theta = 90°$
$F_{max} = IlB$
(c) $F = \frac{\mu_0 I_1 I_2}{2\pi r}l = \frac{2\times10^{-7}\times5\times2.5}{2.5\times10^{-2}} \times 0.10 = 10^{-5}$N

CASE STUDY BASED QUESTIONS

29 (i) (D)
Electron travels 3 cm along axis before striking the edge of the lower plate

$s_x = u_x t \quad or \ 3 \times 10^{-2} = 3 \times 10^7 \times t$
$t = 10^{-9} s$
(ii) (B) parabola
Because initial velocity is perpendicular to the force.
(iii) (A) Upward electric field
(iv) (C) Out of the page
OR
(iv) (A) $1.9 \times 10^{-3} T$
$eE = evB$
$B = \frac{E}{v} = \frac{ma_y}{e} \times \frac{1}{v} = \frac{9.1 \times 10^{-31} \times 10^{16}}{1.6 \times 10^{-19}} \times \frac{1}{3 \times 10^7} = 1.9 \times 10^{-3} T$

ELECTROMAGNETIC INDUCTION(PYQ)

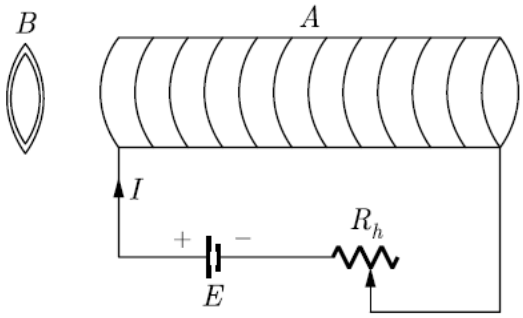
1) Lenz's law is associated with principle of conservationof (OD 2016, Comp 2015)
(a) charge
(b) mass
(c) energy
(d) momentum

2) A small piece of metal wire is dragged across the gap between the pole pieces of a magnet in 0.4 sec. If magnetic flux between the pole pieces is known to be 8 x 10^{-4}. then induced emf in the wire, is (QP 2009, OD 2014)
(a) 4 x 10^{-3} V
(b) 8 x 10^{-3} V
(c) 2 x 10^{-3} V

(d) 6×10^{-3} V

3) Faraday's laws are the consequence of the conservation of (FOREIGN 2013)
(a) charge (b) energy
(c) magnetic field (d) both (b) and (c)

4) An aluminum ring B faces an electromagnet A. The current through A can be altered. Then which of the following statements is correct:



(CBSE 2013)

(a) if I increases, A will repel B.
(b) if I decreases, A will repel B.
(c) if I increases, A will attract B.
(d) whether I increases or decreases B will not experience any force.

5) The Lenz's law gives (FOREIGN 2014)
(a) direction of induced E.M.F.
(b) magnitude of induced E.M.F.
(c) direction of induced current
(d) magnitude of induced current

ASSERTION AND REASON BASED QUESTIONS

6) Assertion : Lenz's law violates the principle of conservation of energy.

Reason : Induced emf always opposes the change in magnetic flux responsible for its production.

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

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

(c) Assertion is correct but Reason is incorrect.

(d) Assertion is incorrect but Reason is correct.

7) Assertion : Faraday's laws are consequence of conservation of energy.

Reason : In a purely resistive ac circuit, the current lags behind the emf in phase.

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

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

(c) Assertion is correct but Reason is incorrect.

(d) Assertion is incorrect but Reason is correct.

8) Assertion : An emf *E* is induced in a closed loop where magnetic flux is varied. The induced *E* is not

a conservative field.

Reason : The line integral *E.dl* around the closed loop is non-zero.

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

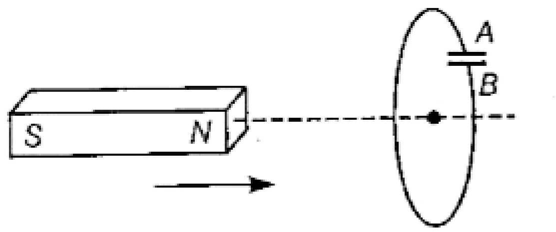
(b) Both Assertion and Reason are correct, but Reason is not the correct explanation of Assertion.

(c) Assertion is correct but Reason is incorrect.

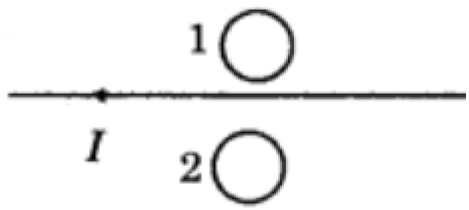
(d) Assertion is incorrect but Reason is correct.

2 MARKS QUESTIONS

9) In the given figure, a bar magnet is quickly moved towards a conducting loop having a capacitor. Predict the polarity of the plates A and B of the capacitor. (DELHI 2011)



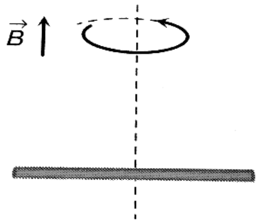
10) Predict the direction of induced current in metal rings 1 and 2 when current I in the wire is steadily decreasing? (CBSE 2017)



11) Write Lenz's law of electromagnetic induction. (2016,13)

3 MARKS QUESTIONS

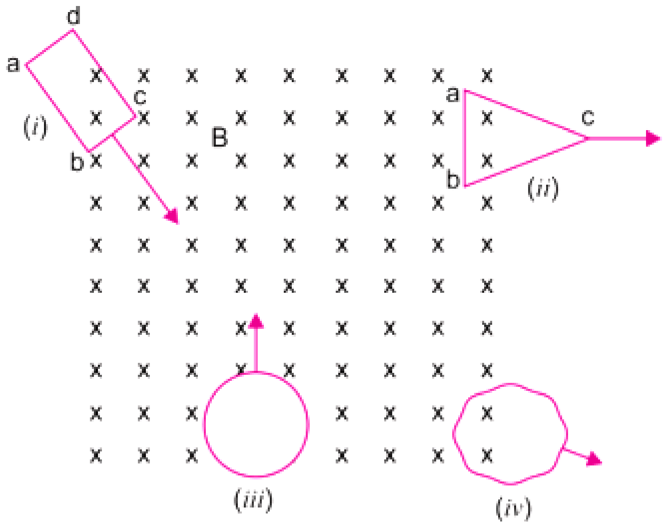
12) A conducting rod of length 2*l* is rotating with a constant angular speed ω about its perpendicular bisector as shown in the figure. A uniform magnetic field *B* exists parallel to the axis of rotation. The E.M.F. induced between two ends of the rod is (Foreign 2007, OD 2009)



13) A horizontal conducting rod 10 m long extending from east to west is falling with a speed 5.0 ms^{-1} at right angles to the horizontal component of the Earth's magnetic field, 0.3 x 10^{-4} Wb m^{-2}. Find the instantaneous value of the emf induced in the rod. (COMP . 2020)

14) There are two coils *A* and *B* separated by some distance. If a current of 2*A* flows through *A*, a magnetic flux of 10^{-2}Wb passes through *B* (no current through *B*). If no current passes through *A*and a current of 1 *A* passes through *B*, What is the flux through *A*? (DELHI 2020,12)

15) Figure shows planar loops of different shapes moving out of or into a region of magnetic field which is directed normal to the plane of loops downwards. Determine the direction of induced current in each loop using Lenz's law.
(DELHI 2013)



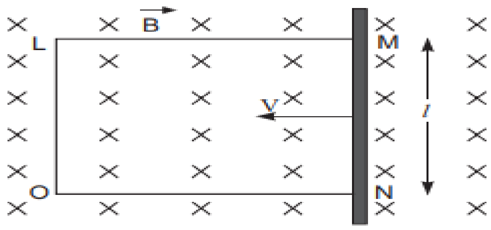
16) Calculate the self-inductance of a coil using the following data of obtained when an AC source of frequency $\frac{200}{\pi}$Hz and a DC source is applied across the coil (CBSE 2023)

AC Source		
S.No.	V (Volts)	I (A)
1	3.0	0.5
2	6.0	1.0
3	9.0	1.5

DC Source		
S.No.	V (Volts)	I (A)
1	4.0	1.0
2	6.0	1.5

3	8.0	2.0

17) 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 ms^{-1}, 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

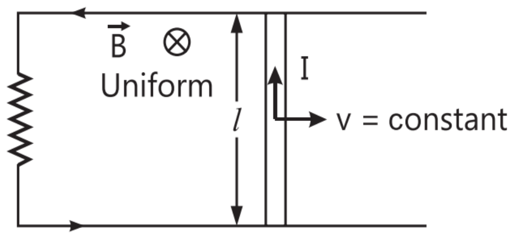


(CBSE 2013,21 SPQ 2004)

CASE BASED QUESTIONS

18) *CASE BASED*

The emf induced across the ends of a conductor due to its motion in a magnetic field is called motional emf. It is produced due to the magnetic Lorentz force acting on the free electrons of the conductor. For a circuit shown in figure, if a conductor of length l moves with velocity v in a magnetic field B perpendicular to both its length and the direction of the magnetic field, then all the induced parameters are possible in the circuit. Read the given passage carefully and give the answer of the following questions:

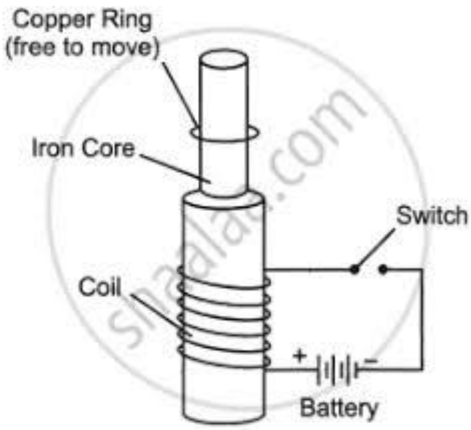


Q1. Direction of current induced in a wire moving in a magnetic field is found by which rule?
Q2. A conducting rod of length l is moving in a transverse magnetic field of strength B with velocity v. The resistance of the rod is R. What is the current in the rod?
Q3. A 0.1 m long conductor carrying a current of 50 A is held perpendicular to a magnetic field of 1.25 mT. What will be the required mechanical power to move the conductor with a speed of 1 ms-1 is?
Q4. A bicycle generator creates 1.5 V at 15 km/hr. What is the emf generated at 10 km/hr?
Q5. What is the dimensional formula for emf Ɛ in MKS system?

19) *CASE BASED*

Consider the experimental set up shown in the figure. This jumping ring experiment is an outstanding demonstration of some simple laws of Physics. A conducting non-magnetic ring is placed over the vertical core of a solenoid. When current is passed through the solenoid, the ring is thrown off.

(CBSE 2023)



Answer the following questions :
(i) Explain the reason of jumping of the ring when the switch is closed in the circuit.
(ii) What will happen if the terminals of the battery are reversed and the switch is closed? Explain.
(iii) Explain the two laws that help us understand this phenomenon.
OR
(b)Briefly explain various ways to increase the strength of magnetic field produced by a given solenoid.

5 MARKS QUESTIONS

20) (a) Explain the meaning of the term mutual inductance. Consider two concentric circular coils, one of radiusr1 and the other of radius r2 (r1 < r2) placed coaxially with centres coinciding with each other.Obtain the expression for the mutual inductance of the arrangement.

(b) A rectangular coil of area A, having number of turns N is rotated at 'f' revolution 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 2πf NBA.
(CBSE 2016)

21) (a) Derive the expression for the induced emf developed when a coil of N turns, and area of cross sectionA, is rotated at a constant angular speed ω in a uniform magnetic field.
(b) A wheel with 100 metallic spokes each 0.5 m long is rotated with speed of 120 rev/min in a plane normal to the horizontal component of the Earth's magnetic field. If the resultant magnetic field at that place is 4 x 10^{-4} T and the angle of dip at that place is 300, find the emf induced between the axle and the rim of the wheel (CBSE 2019)

ELECTROMAGNETIC INDUCTION (PYQ)

SOLUTIONS

1) (C) In each case whenever there is relative motion betweena coil and the magnet a force begins to act which opposes the relative motion therefore to maintain the relative motion, a mechanical work must be done. This work appears in the form of electric energy of coil. Thus lenz's law is based on principle of conservationof energy.
   Thus (c) is correct option.
2) (c) 2 x 10-3 V
3) (b) Faraday's laws involve conversion of mechanical energy into electrical energy. Thus they are in accordance with the law of conservation of energy. Thus (b) is correct option.
4) (a) when circuit is closed, increasing current in the coils of electromagnet *A* produces time varying magnetic flux which magnetised it. We also know from Lenz's law that when time varying magnetic flux links with a nearby ring, then direction of induced

current (or E.M.F.) in the ring will be such that it opposes the cause which produces it. Thus (a) is correct option.

5) (c) Lenz's law gives the direction of the induced current in electromagnetic induction. According to this law, the direction of induced current is such that it opposes the cause which produces it.
Thus (c) is correct option.

6) Lenz's law (that the direction of induced emf is always such as to oppose the change that cause it) is direct consequence of the law of conservation of energy. Thus (a) is correct option.

7) In purely resistive circuit, the current and emf are in the same phase. Thus (c) is correct option.

8)

According to Faraday's law of electromagnetic induction

$$\int \vec{E} \cdot d\vec{\ell} = -\frac{d\phi}{dt}$$

So, (E) is non-conservative field as in conservative field line integral over a closed loop is zero.

Thus (a) is correct option.

9) As the magnet moves towards the coil, flux linked with the coil, increases, hence according to the Lenz.s law, it will oppose the change. Here the North pole is approaching towards the loop, so the induced current in the face of loop viewed from left side will flow in such a way that it will behave like North pole. South pole is developed in the loop when viewed from right hand side of the loop. The flow of induced current is clockwise hence . A acquires positive polarity and B acquires negative polarity.

10) Using Lenz's law we can predict the direction of induced current opposes the cause of increasing of magnetic flux. So, induced current will be clockwise in ring 1 and anticlockwise in ring 2.

11) Lenz's Law states that the direction of induced current in a circuit is such that it opposes the cause or the change which produces it. i.e., it opposes the change in magnetic flux.

12)

Correct Answer - D

Potential difference between

$$O \text{ and } A is V_0 - V_A = \frac{1}{2} B l^2 \omega$$

$$O \text{ and } B is V_0 - V_B = \frac{1}{2} B l^2 \omega$$

$$\text{so } V_A - V_E = 0$$

13)

= 15 x 10^{-4} V

$l = 10$ m, u = 5 m/s, B = 0.3×10^{-4} Wb/m^2

$e = \text{Blv}$

$= 0.3 \times 10^{-4} \times 10 \times 5$

14)

Applying the mutual inductance of coil A with respect to coil B $M_{21} = \frac{N_2\phi_2}{I_1}$

Therefore, we have

mutual inductance $= \frac{10^{-2}}{2} = 5mH$

Again applying this formula for other case

$N_1\phi_1 = M_{12}I_2 = 5mH \times 1A = 5mWb.$

15) (a) In Fig. (i) the rectangular loop abcd and in Fig. (iii) circular loop are entering the magnetic field, so the flux linked with them increases; The direction of induced currents in these coils, will be such as to oppose the increase of magnetic flux; hence the magnetic field due to current induced will be upward, i.e., currents induced will flow anticlockwise.

In Fig. (ii), the triangular loop abc and infig. (iv) The zig-zag shaped loop are emerging from the magnetic field, therefore magnetic flux linked with these loops decreases. The currents induced in them will tend to increase the magnetic field in downward direction, so the currents will flow clockwise. Thus in fig. (i) Current flows anticlockwise, In fig. (ii) Current flows clockwise, In fig. (iii) Current flows anticlockwise, In fig. (iv) Current flows clockwise.

16)

(ii) When an D.C. source is applied,

$$R = \frac{V}{1} = \frac{4}{1} = \frac{6.0}{1.5} = \frac{8.0}{2.0} = 4\,\Omega$$

When AC source 3 V is applied,

$$I = \frac{3}{\sqrt{4^2 + \omega^2 L^2}}$$

$$0.5 = \frac{3}{\sqrt{16 + (2\pi f L)^2}}$$

$$\sqrt{16 + \left(\frac{2\pi \times 200\,L}{\pi}\right)^2} = 6$$

Squaring both sides, we get

$$16 + 160000 L_2 = 6^2$$

$$160000\,L^2 = 36 - 16$$

$$L^2 = \frac{20}{160000} = \frac{1}{8000} = 0.000125$$

$$L^2 = 125 \times 10^{-6}$$

$$L = 11.2 \times 10^{-3}\,H$$

17)

Induced emf in a moving rod in a magnetic field is given by

$\varepsilon = -Blv$

Since the rod is moving to the left so

$\varepsilon = +Blv$

$= 0.5 \times 0.2 \times 10$

$= 1v$

Current in the rod $I = \varepsilon/R = 1/5 = 0.2A$

18) CASE BASED

1. Direction of current induced in a wire moving in a magnetic field is found by using Fleming's right hand rule.

2. Induced emf $\varepsilon = Blv$

Current in the rod, $I = \frac{\varepsilon}{R} = \frac{Blv}{R}$

3. Here, $l = 0.1$ m, $v = 1$ m s^{-1}

$I = 50$ A, $B = 1.25$ mT $= 1.25 \times 10^{-3}$ T

The induced emf is $\varepsilon = Blv$

The mechanical power is

$P = \varepsilon I = BlvI = 1.25 \times 10^{-3} \times 0.1 \times 1 \times 50$

$= 6.25 \times 10^{-3}$ W $= 6.25$ mW

4. emf induced, $\varepsilon = Blv$

Here, $\vec{B}$, $\vec{l}$ and $\vec{v}$ are mutually perpendicular

For given B and l, $\varepsilon \propto v$.

$$\therefore \quad \frac{\varepsilon_1}{\varepsilon_2} = \frac{v_1}{v_2}$$

Here, $\varepsilon_1 = 1.5V$, $v_1 = 15$ km/hr $= 15 \times \frac{5}{18}$ ms^{-1}

$v_2 = 10$ km/hr $= 10 \times \frac{5}{18}$ m s^{-1}, $\varepsilon_2 = ?$

$$\therefore \quad \frac{1.5}{\varepsilon_2} = \frac{15 \times \frac{5}{18}}{10 \times \frac{5}{18}} = \frac{3}{2} \quad \Rightarrow \quad \varepsilon_2 = 1\text{ V}$$

5. $\varepsilon = \frac{[W]}{q} = \frac{[ML^2T^{-2}]}{[AT]} = [ML^2T^{-3}A^{-1}]$

19) CASE BASED

(i) When the switch is closed, a current flows through the solenoid and an emf is induced in the ring. An induced current flows in the ring.

Lenz's Law states that an induced current always flows in the opposite direction of that which produced it. In other words, the emf induced by the solenoid creates a current in the ring that flows in the opposite direction of the solenoid's current. These opposite currents repel one another, so the ring jumps up being repelled by the solenoid.

(ii) When the battery is reversed, the directions of currents in both solenoid and ring change and the ultimately same phenomenon is observed.

(iii) The laws which explain the phenomenon:

l Faraday's law of electromagnetic induction: An emf is induced in a conductor when it is placed in a varying magnetic field.

l Lenz's law: Induced current flows in a direction such that the current opposes the change that induced it.

OR

(b) Various ways to increase the magnetic field produced by a solenoid:

 By placing a soft iron core.

 By increasing the number of turns per unit length.

 By increasing the strength of current.

20)

(i) Mutual Inductance is the property of a pair of coils due to which an emf induced in one of the coils due to the change in the current in the other coil.

Mathematically $e_2 = \frac{M di_1}{dt}$

$$\therefore \quad M = -\frac{e_2}{di_1 / dt}$$

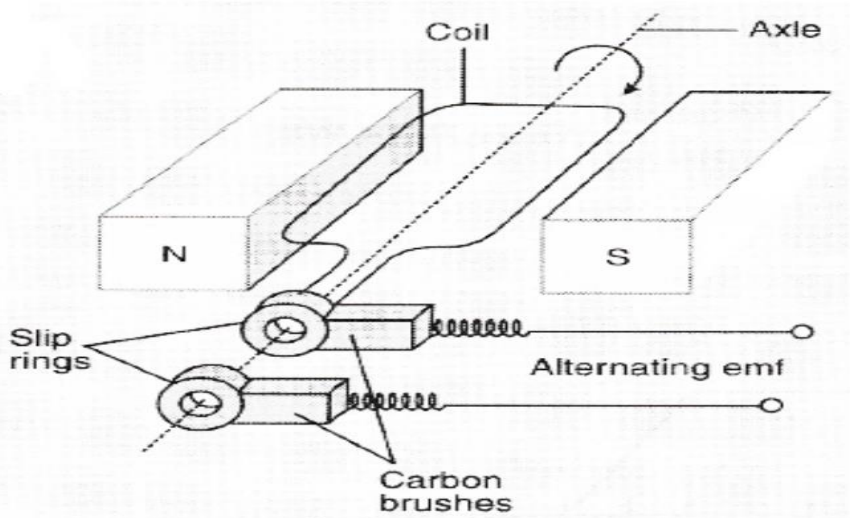
Let a current I_2 flow through the outer circular coil. Then

$$B_2 = \frac{\propto I_2}{2r_2}$$

$$\therefore \quad \phi_1 = \pi r^2 B_2 = \frac{\mu \pi r_1^2}{2r_2} I_2 = M_{12} I_2$$

Thus $M_{12} = \frac{\mu \pi r_1^2}{2r_2} I_2 = M_{21}$

(ii)



Flux at any time 't'.

$$\phi_B = BA\cos\theta = BA\cos\omega t$$

From Faraday's Law, induced emf

$$e = -N\frac{d\phi_B}{dt} = NBA\frac{d}{dt}(\cos\omega t)$$

Thus the instantaneous value of emf is

$$E = NBA\,\omega\sin\omega t$$

For maximum value of emf $\sin\omega t = \pm 1$

i.e., $e_0 = NBA\omega = 2\pi f NBA$

21)

(a) Flux linked with the coil at any instant of time is:

$\phi = \mathrm{NB}A\cos\omega t$

$\frac{d\phi}{dt} = NBA\omega(-\sin\omega t)\mathrm{S}$

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

$\varepsilon = \mathrm{NB}A\omega\sin\omega t$

$\varepsilon = \varepsilon_0\sin\omega t$ (Here $\varepsilon_0 = NBA\omega$)

(b) $l = 0.5$ m, v = 120rpm = 2rps

$\omega = 2\pi v = 4\pi$rad/s, $B = 4\times10^{-4}$ T, $\delta = 30^0$

$B_H = 4\times10^{-4}\times\frac{\sqrt{3}}{2}$

$B_H = 2\sqrt{3}\times10^{-4}$ T

$\varepsilon = \frac{1}{2}B\omega l^2$

$\varepsilon = \frac{1}{2}\times2\sqrt{3}\times10^{-4}\times4\pi\times(0.5)^2$

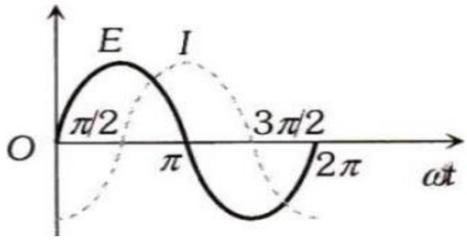
$\varepsilon = 5.4\times10^{-4}$volt

CHAPTER - ALTERNATIN CURRENT

PREVIOUS YEAR QUESTIONS

Multiple Choice Questions (1 Marks)

Q.1 The variation of the instantaneous current I(t) and the instantaneous emfE(t) in a circuit is as shown in the following fig. Which of the following statements is



(a) The voltage lags behind the current by π/2

(b) The voltage leads the current by π/2

(c) The voltage and the current are in phase

(d) The voltage leads the current by π

Q.2 If the equation of an electric current is I=0.6 sin It100πt , the
2017

(a) 50π (b) 50 (c) 100π (d) 100

Q.3 The unit of reactance is

(a) Ohm (b) Farad (c) Ampere (d) Mho

Q.4 The core of a transformer is laminated to reduce the effect of

(a) Flux leakage (b) copper loss (c) eddy current (d) hysteresis loss

Q.5 If φ is the phase difference between AC current and ... emf, then the value of power factor is
2022

(a) tan φ (b) $\cos^2\varphi$ (c) sin φ (d) cos φ

Answers 1.(b) 2. (b) 3.(a) 4.(c) 5.(d)

Assertion Reason Type Questions (1 Marks)

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

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

(c) Assertion is correct but Reason is incorrect.

(d) Assertion is incorrect but Reason is correct.

Q.6 Assertion :In series LCR circuit resonance can take place.
Reason : Resonance takes place if inductance and capacitive resistances are equal and opposite.
Q.7 Assertion : At resonance, LCR circuit have a minimum current.
Reason : At resonance, in LCR circuit, the current and e.m.f. are in phase with each other.
Q.8 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

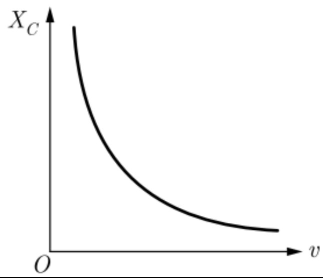
Answer : 1. (a) 2.(d) 3. (a)

Very Short Answer Type Questions (2 Marks)

Q.9 An alternating voltage of frequency *f* is applied across *LCR* circuit. Let *fr* be the resonance frequency for the circuit. Will the current in the circuit lag, lead or remain in phase with the applied voltage when
1. $f > fr$
2. $f < fr$
Explain your answer in each case.
Answer: In an *LCR* circuit, the phase angle φ is given by, $\tan\phi = \frac{X_L - X_C}{R} = \frac{2\pi fL - \frac{1}{2\pi fC}}{R}$

1. When $f > fr$, then $X_L > X_C$ and the circuit is inductive dominant circuit and tan φ is positive.
So the current will lag behind the applied voltage by a phase φ.
2. When $f < fr$, then $X_L < X_C$ and the circuit is capacitive dominant circuit, and tan φ is negative, so the current will lead the applied voltage by a phase φ.

The current will remain in phase if $f = fr$, then $X_L = X_C$ and the circuit is purely resistive and hence current and voltage are in phase.
Q.10 Prove that an ideal capacitor in an AC circuit does not dissipate power.
Answer: Since, average power consumption in an AC circuit is given by,
$$P_{av} = V_{rms} I_{rms} \cos\varphi$$
But in pure capacitive circuit, phase difference between voltage and current is,
$$\phi = \frac{\pi}{2}$$
$$P_{av} = V_{rms} \times I_{rms} \times \cos\frac{\pi}{2}$$
$$P_{av} = 0 \qquad \left(\text{since} \cos\frac{\pi}{2} = 0\right)$$
Thus, no power is consumed in pure capacitive AC circuit.
Q.11 Sketch a graph to show how the reactance of (1) a capacitor (2) an inductor varies as a function of frequency.
Answer:
(1) Capacitive reactance
$$X_C = \frac{1}{\omega C} = \frac{1}{2\pi\nu C}$$
$$X_C \propto \frac{1}{\nu}$$

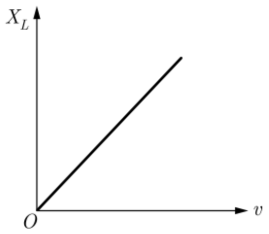


(2) Inductive reactance, $XL = \omega L$

$XL = 2\pi\nu L$

$XL \;\alpha\; \nu$

i.e. inductive reactance is directly proportional to frequency.



Short Answer Type Questions (3 Marks)

Q.12 In a series *L C R* circuit, obtain the conditions under which (i) the impedance of circuit is minimum and (ii) wattless current flows in the circuit.

Answer:

(i) The impedance of a series *L C R* circuit is given by $$Z = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}$$

Z will be minimum when $\omega L = 1/\ \omega C$ i.e., When the circuit is under resonance.

Hence, for this condition *Z* will be minimum and equal to *R*.

(ii) Average power dissipated through a series *L C R* circuit is given by

$P_{av} = E\,I \cos \varphi$

Where, *EV* = rms value of alternating voltage

I = value of alternating current

φ = phase difference between current and voltage

For wattless current, the power dissipated through the circuit should be zero

$$\cos\phi = 0$$

$$\cos\phi = \cos\frac{\pi}{2}$$

$$\phi = \frac{\pi}{2}$$

Hence, the condition for wattless current is that the phase difference between the current and the circuit is purely inductive or purely capacitive.

Q.13 State the principle of working of a transformer. Can a transformer be used to step-used to step-up or stepdown a DC voltage? Justify your answer.

Answer:

Working of a transformer is based on the principle of mutual induction. Transformer cannot step-up or step-down a DC voltage.

Reason: No change in magnetic flux.

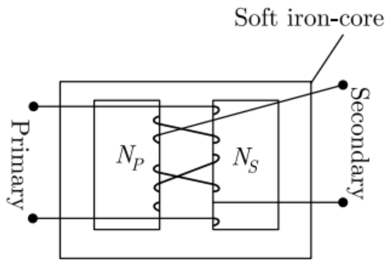
Explanation: When DC voltage source is applied across a primary coil of a transformer, the current in primary coil remains same, so there is no change in magnetic flux associated with it and hence no voltage is induced across the secondary coil.

Q.14 Show diagrammatically two different arrangements used for winding the primary and secondary coils in a transformer. Assuming the transformer to be an ideal one, write the expression for the ration of its:

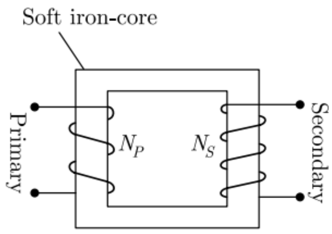
1. Output voltage to input voltage.
2. Output current to input current.

Mention two reasons for energy losses in an actual transformer.
Answer:

Arrangement of winding of primary and secondary coil in a transformer are shown in fig (a) and (b).



(a) Two coils on to of each other



(b) Two coils on separate limbs of the core

1. Ratio of output voltage to input voltage, $V_s / V_p = N_s / N_P$
2. Ratio of output current to input current, $I_s / I_p = N_p / N_s$

Reasons for energy losses in a transformer

1. Joule Heating Energy is lost due to heating of primary and secondary windings as heat(I^2Rt)
2. Flux Leakage Energy is lost due to coupling of primary and secondary coils not being perfect, i.e., whole of magnetic flux generated in primary coil is not linked with the secondary coil.

Q.15 A series *LCR* circuit is made by taking $R = 100\ \Omega$, $L = 2/\pi$ H, $C = 100/\pi\ \mu$F. The series combination is connected across an a.c. source of 220 V, 50 Hz. Calculate
(a) the impedance of the circuit,
(b) the peak value of the current flowing in the circuit.
Answer:

As per question, $R = 100\ \Omega$, $L = 2/\pi$ H

$$C = \frac{100}{\pi}\ \mu F = \frac{100}{\pi} \times 10^{-6}\ F = \frac{1}{\pi} \times 10^{-4}\ F$$

$V_{rms} = 220$ V and $\upsilon = 50$ Hz

(a) Inductive reactance, $X_L = \omega L = 2\pi\upsilon \times L$

$$= 2\pi \times 50 \times \frac{2}{\pi} = 200\ \Omega$$

Capacitive reactance, $X_C = \frac{1}{\omega C} = \frac{1}{2\pi\upsilon C}$

$$= \frac{1}{2\pi \times 50 \times \left(\frac{10^{-4}}{\pi}\right)} = 100\ \Omega$$

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

$$= \sqrt{(100)^2 + (200 - 100)^2} = 100\sqrt{2}\ \Omega$$

(b) Peak value of current, $I_0 = \sqrt{2}\ I_{rms}$

$$= \frac{\sqrt{2} \times V_{rms}}{Z} = \frac{\sqrt{2} \times 220}{100\sqrt{2}} = 2.2\ A$$

Long Answer Type Questions (5 Marks)

Q.16 State the working of AC generator with the help of a labelled diagram. The coil of an AC generator having *N* turns, each of area *A*, is rotated with a constant angular velocity *ω* Deduce the expression for the alternating emf generated in the coil. What is the source of energy generation in this device?

Answer:

A C Generator:

A dynamo or generator is a device which converts mechanical energy into electrical energy.

Principle:

It works on the principle of electromagnetic induction.When a coil rotates continuously in a magnetic field, the effective area of the coil linked normally with the magnetic field lines, changes continuously with time. This variation of magnetic flux with time results in the production of an alternating emf in the coil.

Construction:

It consists of the four main parts.

1. Field Maget It produces the magnetic field. In the case of a low power dynamo, the magnetic field is generated by a permanent magnet, while in the case of large power dynamo, the magnetic filed is produced by an electromagnet.

2. Armature It Consists of a large number of turns of insulated wire in the soft iron drum or ring. It can revolve an axle between the two poles of the field magnet. The drum or ring serves the two purposes: (i) It serves as a support to coils and (ii) It increases the magnetic filed due to air core being

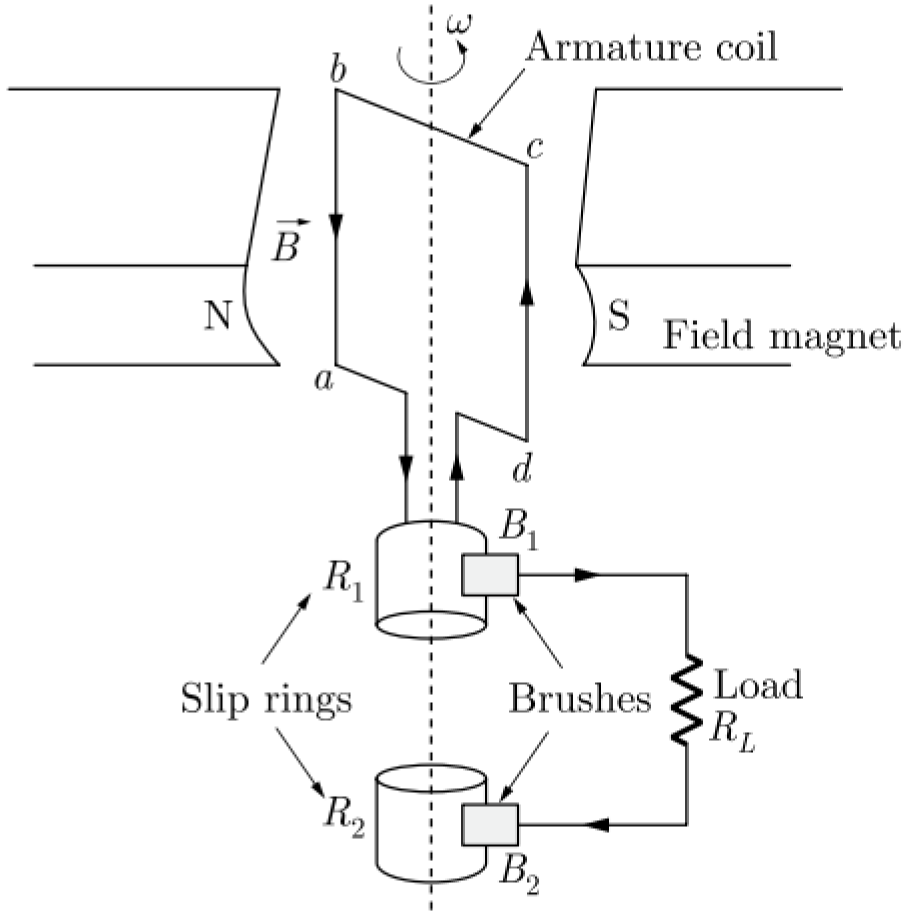
replaced by an iron core.
3. Slip Rings The slip rings *R*1 and *R*2 are the two metal rings to which the ends of armature coil are connected. These rings are fixed to the shaft which rotates the armature coil so that the rings also rotate along with the armature.
4. Brushes There are two flexible metal plates or carbon rods and which are fixed and constantly touch the revolving rings. The output current in external load *RL* is taken through these brushes.
Working
When the armature coil is rotated in the strong magnetic field, the magnetic flux linked with the coil changes and the current is induced in the coil, its direction being given by Fleming’s right hand rule. Considering the armature to be in vertical position and as it rotates in anticlockwise direction, the wire *ab* moves upward and *cd* downward, so that the direction of induced current is shown in fig. In the external circuit, the current is shown in fig. In the external circuit, the current flows along. The direction of current remains unchanged during the first half turn of armature. During the second half revolution, the wire *ab* moves downward and *cd* upward, so the direction of current is reversed and
in external circuit it flows along. Thus the direction of induced emf and current changes in the external circuit after each half revolution.

Expression for Induced emf
If *N* is number of turns in coil, *f* the frequency of rotation, *A* area of coil and *B* the magnetic induction,
then induced emf

$$\begin{aligned} e &= -\frac{d\phi}{dt} = -\frac{d}{dt}\{NBA(\cos 2\pi ft)\} \\ &= 2\pi NBA\, f \sin 2\pi\ ft \end{aligned}$$

Obviously, the emf produced is alternating and hence the current is also alternating.
Current produced by an AC generator cannot be measured by moving coil ammeter; because the average value of AC over full cycle is zero. The source of energy generation is the mechanical energy

or ration of armature coil.



Case Study Based Questions

Q.17 A transformer is an electrical device which is used for changing a.c. voltages. It is based on the phenomenon of mutual induction. It can be shown that $\frac{Es}{Ep} = \frac{Ip}{Is} = \frac{ns}{np}$ = K, where symbols have their standard meaning. For a step up transformer, K>1 and for a step down transformer, K<1. The numbers of turns in the primary and secondary coils of a transformer are 2000 and 50 respectively. The primary coil is connected to main of 120 V and secondary to a night bulb of 0.6 ohm. The efficiency of transformer is 80 %.

i) A transformer is used :

(a) to transform electric energy into mechanical energy.
(b) to obtain suitable DC voltage.
(c) to transform AC into DC.
(d) to obtain suitable AC voltage.

ii) Which quantity is increased in step-down transformer ?

(a) resistance
(b) power
(c) current
(d) charge

iii) In step-up transformer, relation between number of turns in primary(N_p) and number of turns in secondary(N_s) is

(a) $N_s > N_p$ (b) $N_p > N_s$

(c) $N_s = N_p$ (d) $N_p = 2 N_s$

iv) Voltage across the secondary of transformer is

(a) 120 V (b) 360 V

(c) 40 V (d) 3 V

v) Current in primary coil is

(a) 15 A (b) 5 / 3 A

(c) $\frac{5}{32}$ A (d) 0.6 A

.

Q.18 Series LCR circuits at resonance admit maximum current at particular frequencies. Therefore itis called acceptor circuit because at resonance, impedance of LCR circuit is minimum and it easily accepts that current out of the many currents whose frequency is equal to the resonant frequency. This circuit is used in radio and TV receivers to tune the desired frequency or filtered unwanted frequencies. The antenna of a radio or TV receives signals of tuning circuit of the receiver is changed by changing the the capacitance of the tuning circuit till the resonant frequency of the circuit becomes equal to the frequency of the desired broadcasting station. At this stage, the electrical resonance takes place. The amplitude of the current with the frequency of the signal from the desired station becomes maximum and hence it is received by the radio or TV receiver. The maximum current flows through for that a.c. voltage which has frequency equal to $f_r = \frac{1}{2\pi\sqrt{LC}}$ .If Q-value of circuit is large the signals of the other stations will be very weak. Quality factor determines the clarity of reception.Low quality factor means that bandwidth around the bandwidth around the resonance frequency is large and hence, tuning is not very accurate.

i) The current admitted by series LCR circuit corresponding to resonant frequency is

(a) maximum (b) minimum (c) zero (d) cannot be determined

ii) In a series LCR circuit L=8H, C=0.5μF and R=100Ω. The resonant frequency of the crcuit is

(a) 1000 / π Hz (b) 500 / π Hz (c) 250 / π Hz (d) 125 / π Hz

iii) At resonance, in a series LCR circuit, which relation does not hold

(a) $\omega = \frac{1}{LC}$ (b) $\omega = \frac{1}{\sqrt{LC}}$ (c) $L\omega = \frac{1}{C\omega}$ (d) $C\omega = \frac{1}{L\omega}$

iv) Nita switched on the radio set to listen to her favourite music but found the reception was not clear. Also there was there was overlapping of signals. So she adjusted the tuner. Name the phenomenon involved here :

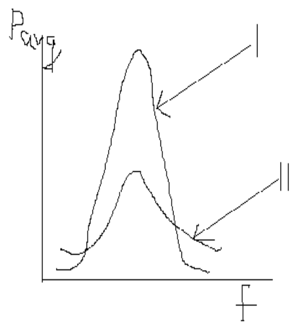
(a) reception (b) band width (c) ... tion

v) From the figure below, the curve with highest va...

(a) Curve I

(b) Curve II

(c) Both the curves



(d) None of them

Q.19 A thermal power plant produces electric power of 600 kW at 4000 V, which is to be transported to a place 20 km away from the power plant for consumers usage. It can be transported either directly with a cable of large current carrying capacity or by using a combination of step-up or step-down transformers at the two ends. The drawback of the direct transmission is the large energy dissipation. In the method using transformers, the dissipation is much smaller. In this method, a step-up transformer is used at the plant side so that the current is reduced to a smaller value. At the consumers end, a step-up transformer is used to supply power to the consumer at the specified lower voltage.

i) 11 kw of electric power can be transmitted to a distant station at (i) 220 V or (ii) 22000 V. Which of the two modes of transmission should be preferred ?

(a) 220 V (b) 22000 V (c) Both (d) none of the two

ii) Power is transmitted from a power house on high voltage because

(a) the rate of transmission is faster at high voltage
(b) it is more economical due to less power wastage
(c) the life of current carrying wire is prolonged
(d) a precaution against the theft of transmission line

iii) The core of a transformer is laminated so that

(a) the ratio of voltage in primary and secondary coils may be increased.
(b) the weight of the transformer may be reduced
(c) residual magnetism in the core may be reduced
(d) energy loss due to eddy currents may be reduced

iv) If the direct transmission method with a cable of resistance of 0.4 Ωkm^{-1} is used, the power dissipation in % during transmission is

(a) 20 (b) 30 (c) 40 (d) 50

v) What is increased in a step down transformer ?

(a) current (b) voltage (c) wattage (d) none

CASE STUDY QUESTIONS	i	Ii	iii	iv	v
17	d	C	a	d	a
18	a	C	a	c	a
19	b	B	d	b	a

PREVIOUS YEAR ASKED CBSE BOARD QUESTIONS
RAY OPTICS

MCQ(5)

Q1. A point object is placed in air at a distance of 4R on the principal axis of a convex spherical surface of radius of curvature R separating two mediums, air and glass. As the object is moved towards the surface, the image formed is : CBSE COMP. 2024
(A)always real (B)always real
(C)always virtual (D)first virtual and then real first real and then virtual

Q2. A small object lies at the bottom of a vessel filled with water (refractive index 4/3) up to a height H. When viewed from a point above the surface of water, the object appears raised by n percent of H. The value of n is : CBSE COMP. 2023

(a) 15 (b) 20
(c) 25 (d) 33

Q4. For a concave mirror of focal length 'f' the minimum distance between the object and its real image : CBSE 2023
(a) zero. (b) f
(c) 2f. (d) 4f

Q5. 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? CBSE 2023
(a) Energy carried (b) Speed
(c) Frequency (d) Wavelength

Q6. 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. CBSE 2023
(a) 1.4 (b) 1.5
(c) 1.6 (d) 1.8

Assertion Reason(3)

Q1. Assertion: Although the surfaces of a goggle lens are curved, it does not have any power.
Reason: In case of goggles, both the curved surfaces are curved on the same side and have equal radii of curvature. COMP2024

Q2. Assertion: Plane and convex mirrors cannot produce real images under any circumstance.
Reason: A virtual image cannot serve as an object to produce a real image.
CBSE2024

2Marks(5)

Q1. A point light source rests on the bottom of a bucket filled with a liquid of refractive index m = 1.25 up to height of 10 cm. Calculate : COMP2024
(a) the critical angle for liquid-air interface
(b) radius of circular light patch formed on the surface by light emerging from the source.

Q2. Monochromatic light of frequency $5{\cdot}0 \times 10^{14}$Hz passes from air into a medium of refractive index 1·5. Find the wavelength of the light
(i) reflected, and
(ii) refracted at the interface of the two media. CBSE 2024

Q3. A plano-convex lens of focal length 16 cm is made of a material of refractive index 1.4. Calculate the radius of the curved surface of the lens. CBSE2024

Q4. An object is placed 30 cm in front of a concave mirror of radius of curvature 40 cm. Find the (i) position of the image formed and (ii) magnification of the image. CBSE2024

Q5. Why is a reflecting telescope preferred over a refracting telescope? Justify your answer giving two reasons. CBSE 2023

Q6. The refractive indices of two media A and B are 2 and &$\sqrt{2}$ respectively. What is the critical angle for their interface? CBSE 2023

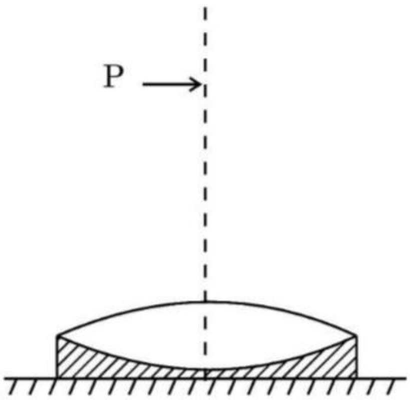
3Marks (5)

Q1. (a)A ray of light is incident on a surface separating air from a denser medium A of refractive index μ_1. It is then made incident on the parallel surface of another medium B of refractive index μ_2 at the same angle of incidence. If the angle of refraction in the two media are 30° and 35° respectively, then in which one of the two media (A or B) will light travel faster and why ?
CBSE COMP2024

5Marks(2)

Q1.(i)What are the two main considerations for designing the objective and eyepiece lenses of an astronomical telescope ? Obtain the expression for magnifying power of the telescope when the final image is formed at infinity.
(ii)A ray of light is incident at an angle of 45° at one face of an equilateral triangular prism and passes symmetrically through the prism. Calculate :
(1) the angle of deviation produced by the prism
(2) the refractive index of the material of the prism CBSE COMP2024

Q2. (I)Describe a simple activity to observe diffraction pattern due to a single slit.
(II)The figure below shows an equiconvex lens (of refractive index 1.50) in contact with a liquid layer on top of a plane mirror. A small needle with its tip on the principal axis is moved along the axis until its inverted image is found at the position of the needle. The distance of the needle from the lens is measured to be 45.0 cm. When the liquid is removed and the experiment is repeated, the new distance is 30.0 cm. Find the refractive index of the liquid. CBSE COMP2024



Q3. (i)A ray of light passes through a triangular prism. Show graphically, how the angle of deviation varies with the angle of incidence? Hence define the angle of minimum deviation.
(ii) A ray of light is incident normally on a refracting face of a prism of prism angle A and suffers a deviation of angle δ. Prove that the refractive index n of the material of the prism is given by $n = \frac{\sin(A+\delta)/2}{\sin A/2}$.
(iii) The refractive index of the material of a prism is $\sqrt{2}$. If the refracting angle of the prism is 60^O, find the
(1) Angle of minimum deviation, and
(2) Angle of incidence. CBSE2024

Q4.(i)Draw a labelled ray diagram of an astronomical telescope to show the image formation of a distant object by it in normal adjustment. What are the main considerations required in selecting the objective and eyepiece lenses so that the telescope has large magnifying power and high resolution?
(ii)A biconvex lens of focal length 20 cm is immersed in water, whose refractive index is 4/3. Find

the change, if any, in the nature and the focal length of the lens. Refractive index of the material of convex lens is 3/2. CBSE COMP2023

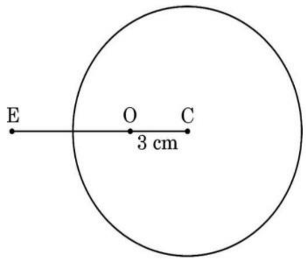
Q5.(i)Draw a ray diagram showing refraction of light through a prism of angle A and obtain the relation between, A and the angle of minimum deviation δ_m.

(ii)An equiconvex lens of radius of curvature R and made of glass of refractive index μ is cut into two identical plano-convex lenses. Find the focal length of the plano-convex lenses.

CBSE COMP 2023

Q6.(i) A spherical surface of radius of curvature R separates two media of refractive indices n_1 and n_2. A point object is placed in front of the surface at distance u in medium of refractive index n_1 and its image is formed by the surface at distance v, in the medium of refractive index n_2. Derive a relation between u and v.

(ii)A solid glass sphere of radius 6.0 cm has a small air bubble trapped at a distance 3.0 cm from its centre C as shown in the figure. The refractive index of the material of the sphere is 1.5. Find the apparent position of this bubble when seen through the surface of the sphere from an outside point E in air.



Q7.(i)Draw a ray diagram showing the formation of a real image of an object placed at a distance 'u' in front of a concave mirror of radius of curvature R'. Hence, obtain the relation for the image distance 'v' in terms of u and R.

(ii) A 1•8 m tall person stands in front of a convex lens of focal length 1 m, at a distance of 5 m. Find the position and height of the image formed. CBSE 2024

Q8. (i)Draw a ray diagram showing refraction of a ray of light through a triangular glass prism. Hence, obtain the relation for the refractive index (μ) in terms of angle of prism (A) and angle of minimum deviation (δ_m).

(ii) The radii of curvature of the two surfaces of a concave lens are 20 cm each. Find the refractive index of the material of the lens if its power is - 5.0 D.

case study based (5)

Q1. A lens is a transparent medium bounded by two surfaces, with one or both surfaces being spherical. The focal length of a lens is determined by the radii of curvature of its two surfaces and the refractive index of its medium with respect to that of the surrounding medium. The power of a lens is reciprocal of its focal length. If a number of lenses are kept in contact, the power of the combination is the algebraic sum of the powers of the individual lenses.

CBSE2024

(i)A double-convex lens, with each face having same radius of curvature R, is made of glass of refractive index n. Its power is:

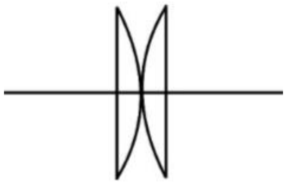
(A) 2(n- 1)/R (B) (2n -1)/R

(C) (n -1)/2R (D) (2n- 1)/2R

(ii) A double-convex lens of power P, with each face having same radius of curvature, is cut into two equal parts perpendicular to its principal axis. The power of one part of the lens will be:

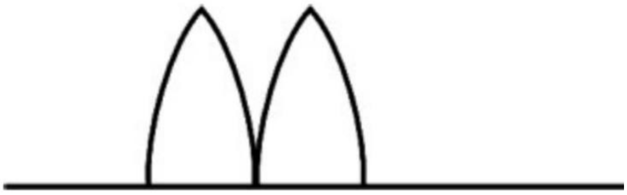
(A) 2P (B) P (C) 4P (D)P/2

(iii) The above two parts are kept in contact with each other as shown in the figure. The power of the combination will be:



(A)P/2 (B)P (C)2P (D)P/4

(iv) (a)A double-convex lens of power P, with each face having same radius of curvature, is cut along its principal axis. The two parts are arranged as shown in the figure. The power of the combination will be :



(A) Zero. (B)P (C) 2P (D)P/2

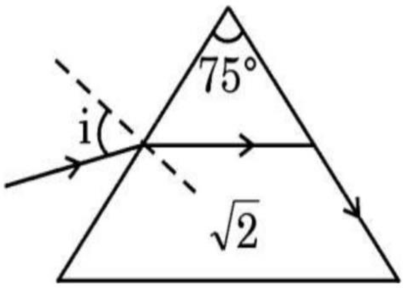
OR

(b)
Two convex lenses of focal lengths 60 cm and 20 cm are held coaxially in contact with each other. The power of the combination is:
(A) 6·6 D. (B) 15 D (C) 1/15D. (D)1/80D

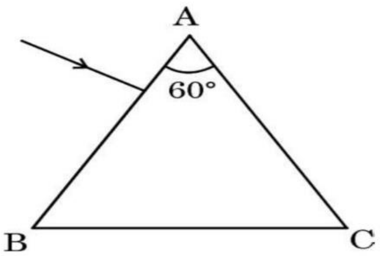
Q2. A prism is a solid transparent medium bounded by three rectangular faces with a triangular base and a top. A ray of light incident at angle i on one face of a prism suffers two refractions on passing through a prism. Hence it deviates through a certain angle £ from its original path. The angle of deviation becomes minimum ($\delta = \delta_m$) for a certain value of angle i. In such a condition, the refracted ray inside the prism becomes parallel to its base. An expression for refractive index μ of the material of the prism can be obtained in terms of angle A and angle δ_m.
CBSE COMP 2023
(A) Show in a figure the variation of angle δ with angle of incidence i.
(B) Show that for a prism of small angle A, the refractive index μ of its material can be written as $\delta = 1 + \delta_m/A$.
(C) A ray of light passes through an equilateral prism such that both the angle of incidence and the angle of emergence are equal to the angle of prism A. Find the refractive index of the material of the prism, in terms of A.

OR

A ray of light passes through a prism of angle 75^o, as shown in the figure. The refractive index of the material of the prism, with respect to its surrounding is &$\sqrt{2}$. Find the angle of incidence i.



Q3. Strontium titanate is a rare oxide a natural mineral found in Siberia. It is used as a substitute for diamond because its refractive index and critical angle are 2.41 and 24.5 degree£ , respectively, which are approximately equal to the refractive index and critical angle of diamond. It has all the properties of diamond. Even an expert jeweller is unable to differentiate between diamond and strontium titanate. A ray of light is incident normally on one face of an equilateral triangular prism ABC made of strontium titanate.



CBSE 2023

Answer the following questions based on the above:

(A)Trace the path of the ray showing its passage through the prism. 1

(B) Find the velocity of light through the prism. 1

(C)Briefly explain two applications of total internal reflection. 2

OR

Define total internal reflection of light. Give two conditions for it.

SOLUTIONS

MCQ (5) 1 Mark

Q1. (d)
Q2. (c)
Q3. (a)
Q4. (C)
Q5. (b)

Assertion Reason(2)

Q1.(A) Both assertion and reason are correct and reason is correct explanation of reason
Q2.(B) Both assertion and reason are correct but reason is not correct explanation of assertion

2 marks

Q1. Radius =16cm
Q2.To find the wavelength of light in different media, we can use the relationship between the speed

of light, frequency, and wavelength. The speed of light in a medium is given by the formula.
v=n/c
where *c* is the speed of light in vacuum (approximately 3.0×10^8 m/s) and *n* is the refractive index of the medium. The wavelength in a medium can be calculated using the formula:

λ=f/v

where *λ* is the wavelength, *v* is the speed of light in the medium, and *f* is the frequency of the light. Let's calculate the wavelengths for both reflected and refracted light.

Step by Step Solution:
Step 1
Identify the frequency of the light: *f*=5.0×10^14 Hz.

Step 2
Calculate the speed of light in the medium using the refractive index: *v=n/c* =2.0×10^8 m/s.

Step 3
Calculate the wavelength in the medium using the formula: *λ=f/v*==4.0×10^−7 m=400 nm.

Step 4
The wavelength of light in air (reflected) is the same as in vacuum: *λair=f/c*=6.0×10^−7 m=600 nm.

Step 5
Thus, the wavelengths are: (i) reflected: 600 nm and (ii) refracted: 400 nm.

Q3.

The radius of curvature of the curved surface should be

(a) $$\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\frac{1}{16} = (1.5 - 1)\left(\frac{1}{R} - \frac{1}{\infty}\right)$$

$$\Rightarrow \frac{1}{16} = 0.5 \times \frac{1}{R} \Rightarrow R = 8 \text{ cm}$$

Q4.

Solution

u = -30 cm, R = -40 cm

From the mirror equation,

$\frac{1}{v} + \frac{1}{u} = \frac{2}{R}$

$\Rightarrow \frac{1}{v} = \frac{2}{R} - \frac{1}{u}$

$= \frac{2}{-40} - \frac{1}{-30} = \frac{1}{-20} + \frac{1}{30}$

$= \frac{-30+20}{30 \times 20} = \frac{-10}{30 \times 20}$

$= -\frac{1}{60}$

or, v = -60 cm

So, the image will be formed at a distance of 60 cm in front of the mirror.

Then find the magnification also.

Q5.
(i) The reflecting telescopes are preferred over refracting type because of the following reasons:
(i) There is no chromatic aberration in case of reflecting telescopes as the objective is a mirror.
(ii) Spherical aberration is reduced in case of reflecting telescopes by using mirror objective in the form of a paraboloid.
Q6.

Explanation:

To find the critical angle between two media, we can use Snell's Law. The critical angle (θ_c) can be calculated using the formula:

$$\theta_c = \arcsin\left(\frac{n_2}{n_1}\right)$$

where n_1 is the refractive index of the first medium (A) and n_2 is the refractive index of the second medium (B). In this case, $n_1 = 2$ and $n_2 = \sqrt{2}$. We will calculate the critical angle step by step.

Step by Step Solution:

Step 1

Identify the refractive indices: n1 = 2 (medium A), n2 = √2 (medium B).

Step 2

Use the formula for critical angle: θc = arcsin(n2 / n1).

Step 3

Substitute the values: θc = arcsin(√2 / 2).

Step 4

Calculate θc: Since √2 / 2 = 0.7071, θc = arcsin(0.7071) ≈ 45°.

Final Answer:

The critical angle for the interface between media A and B is approximately 45°.

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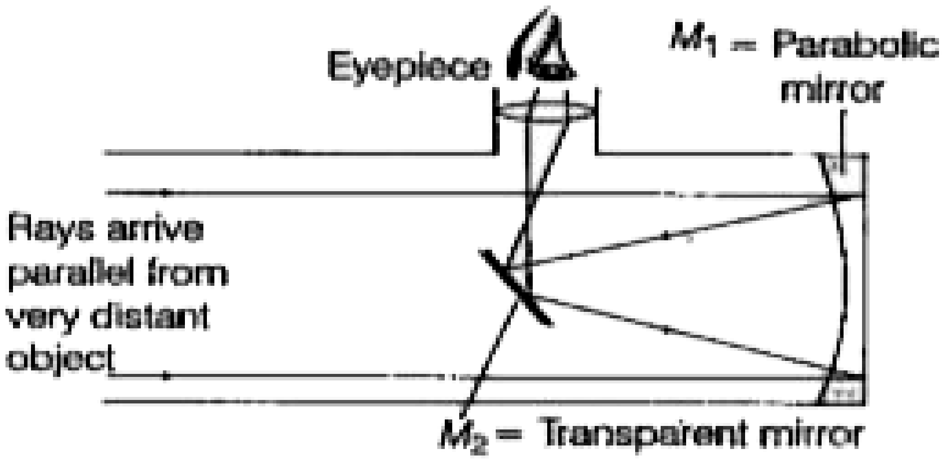
3 MARKS

Q1. To determine in which medium light travels faster, we need to compare the refractive indices of the two media. According to Snell's law,
$n1\sin\theta1=n2\sin\theta2$.
The speed of light in a medium is inversely proportional to the refractive index of the medium.
Therefore, the medium with the lower refractive index will have a higher speed of light.

5 Marks

Q1. (i)
(a) Main considerations for an astronomical telescope are
(i) resolvability (ii) light gathering power (iii) cost (iv) size
To achieve more resolvability, we use lens combination of higher resolving power.
Sometimes mirrors are used instead of lenses as their resolvability is much higher.
Light gathering power is increased by using a large objective. Cost and size are considerably reduced when we use mirrors instead of lenses.
Mirror objectives are easy to make, easy to support (as a mirror can be supported from backside while lens can be supported from edge only.)

Obstruction of rays of light can be overcome as shown,



(ii) Using the formula find the angle of deviation and refractive index

Q2. (II)

Solution

Step 1: Find the focal length of the concave lens of liquid.

Formula Used: $\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$

In the absence of liquid, for the combination of convex lens and plane mirror, inverted image will coincide with the object only when the object is placed at focus of convex lens. Same rule applies in the presence of the liquid between lens and the mirror. Hence the object or image distance given can be taken as focal length of the respective combinations.

When the liquid is used, the system acts as a combination of convex lens and a concave lens.

Therefore, the focal length of the combination is f (say) = 45 cm

When the liquid is removed, the image is formed at 30 cm.

Therefore, the focal length of convex lens, f_1 = 30 cm

Let the focal length of the concave lens of liquid be f_2.

For a pair of optical systems placed in contact, the equivalent focal length is given by,

$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$$

Putting the values, we get,

$$\frac{1}{45} = \frac{1}{30} + \frac{1}{f_2}$$

$$\frac{1}{f_2} = \frac{1}{45} - \frac{1}{30}$$
$$\frac{1}{f_2} = \frac{2-3}{90} = -\frac{1}{90}$$
$f_2 = -90$ cm

Step 2: Find the value of radius of curvature.

Hint: Lens maker's formula: $\frac{1}{f} = (n_{21} - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

Now, let the refractive index of the lens be n_1

and the radius of curvature of one surface be $R_1 = R$.

Then, the radius of curvature of the other surface is $R_2 = -R$

Using the lens maker,s formula,
$$\frac{1}{f_1} = (n_1 - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$
$$\frac{1}{30} = (1.5 - 1)\left(\frac{1}{R} - \frac{1}{-R}\right)$$
$$\frac{1}{30} = 0.5\left(\frac{2}{R}\right)$$
$$\frac{1}{30} = \frac{1}{R}$$
R = 30cm.

Step 3: Find the refractive index of the liquid.

Hint: Lens maker's formula.

Formula Used: $\frac{1}{f} = (n_{21} - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

Radius of curvature of the liquid lens, $R_1' = -30$ cm.

The other side of the liquid is plane, therefore, $R_2' = \infty$

Let n_2 be the refractive index of the liquid.

Using the lens maker's formula,
$$\frac{1}{f_2} = (n_2 - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$
$$-\frac{1}{90} = (n_2 - 1)\left(\frac{1}{-30} - \frac{1}{\infty}\right)$$
$$-\frac{1}{90} = -\frac{1}{30}(n_2 - 1)$$
$$n_2 - 1 = \frac{1}{3}$$
$n_2 = 1.33$

Hence, the refractive index of the liquid is 1.33.

Final Answer: n = 1.33

Q3. Correct Explanation and derivation
Q4. Correct Derivation
Q5. Correct Derivation
Q6. (i) correct Derivation
(ii)

(b) Given, refractive index, $n_2 = 1.5$, $n_1 = 1$(air)

Radius of curvature, R=20 cm

Object distance, u=-100 cm

To find, Image distance, v

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

$$\frac{1.5}{v} + \frac{1}{(100)} = \frac{1.5-1}{20} = \frac{1}{40}$$

$$\frac{1.5}{v} = \frac{1}{40} - \frac{1}{100} = \frac{5-2}{200} = \frac{3}{200}$$

$$v = \frac{200}{3} \times 1.5 = 100 \text{ cm}$$

The image is formed at 100 cm in denser medium.

CASE STUDY BASED

Q1. (i) A
(ii) D
(iii) D
(iv) c or A

Q2. Correct derivations

Q3. Correct explanation and conditions of TIR

PREVIOUS YEARS QUESTIONS OF EM WAVE AND WAVE OPTICS

MCQS

1. The electromagnetic radiations used to kill germs in water purifiers are called : CBSE 2023
(a) Infrared waves (b) X-rays (c) Gamma rays (d) Ultraviolet rays
2. The electromagnetic waves used in radar systems are : CBSE 2024
(a) Infrared waves (b) Ultraviolet rays (c) Microwaves (d) X-rays
3. Electromagnetic waves with wavelength 10 nm are called : CBSE 2023
(A) Infrared waves (B) Ultraviolet rays (C) Gamma rays (D) X-rays
4. In the process of charging of a capacitor, the current produced between the plates of the Capacitor : CBSE 20223

(a) $\mu_0 \frac{d\phi_E}{dt}$ (b) $\frac{1}{\mu_0} \frac{d\phi_E}{dt}$

(c) $\varepsilon_0 \frac{d\phi_E}{dt}$ (d) $\frac{1}{\varepsilon_0} \frac{d\phi_E}{dt}$

5. In four regions I, II, III and IV, the magnetic field is given by : I. $B_y = B_O \sin kz$ II. $B_y = B_O \cos kz$ III. $B_y = B_O \sin (kz-wt)$ IV. $B_y = B_O \sin kz + B_O \cos kz$. The electromagnetic wave will exist in the region : CBSE 2023
(A) IV (B) I (C) III (D) II
6. A plane wavefront is incident on a concave mirror of radius of curvature R. The radius of the refracted wavefront will be : CBSE 2024
(a) 2R (b) R (c) R/2 (d) R/4
7. Young's double -slit experiment, the fringe width is found to be β. If the entire apparatus is immersed in a liquid of refractive index μ , the new fringe width will be : CBSE 2024
(a). β (b) μβ (c) β/ μ (d) β / μ^2
8. In the wave picture of light, the intensity I of light is related to the amplitude A of the wave as :
(a) I α A (b) I α 1/A (c) I α A^2 (d) I α 2 A CBSE 2024

9. In a single-slit diffraction experiment, the width of the slit is halved. The width of the central maximum, in the diffraction pattern, will become :
(a) half (b) twice (c) four times (d) one-fourth CBSE 2023

ASSERTION REASON 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.
1. Assertion (A) : The phase difference between any two points on a wavefront is zero.
Reason (R) : All points on a wavefront are at the same distance from the source and thus oscillate in the same phase. CBSE 2023
2. Assertion (A): in Young's double -slit experiment interference pattern is not observed when two coherent sources are infinitely close to each other.
Reason (R) : The fringe width is proportional to the separation between the two sources. CBSE 2024
3. Assertion (A) : Displacement current goes through the gap between the plates of a capacitor when charges on the capacitor does not change .
Reason (R) : The displacement current arises in the region in which the electric field and hence the electric flux does not change with time.

SHORT ANSWER TYPE QUESTIONS 2 MARKS

1. Identify the part of electromagnetic spectrum which is :
(a) next to the lowest frequency end of the visible part of electromagnetic spectrum, and
(b) produced by bombarding a metal target by high energy electrons. Give one use of each of them. CBSE 2023

2.(a) What is a displacement current ? How is it different from a conduction current ?
(b) Write any two characteristics of an electromagnetic wave. Why are microwaves used in radar systems ? CBSE 2024

3. Use Huygens principle to show reflection /refraction of plane a wave by (i) concave mirror, and (ii) a convex lens. CBSE 2023

4. (a) Two waves each of amplitude 'a' and frequency 'ν' emanating from two coherent sources of light superpose at a point. If the phase difference between the two waves is φ , obtain an expression for the resultant intensity at that point. CBSE 2024

5. What is effect on interference pattern in Young's double -slit experiment when (i) the source slit is moved closer to the plane of the slits, and (ii) the separation between the two slits is increased ? Justify your answers. CBSE 2024

6. Using Huygens principle draw a ray diagram showing propagation of a plane wave refracting at a plane surface separating two media. Also verify Snell's law. CBSE 2023

SHORT ANSWER TYPE QUESTIONS 3 MARKS

1. (a) On what factors does the speed of an electromagnetic wave in a medium depend ? (b) How is an electromagnetic wave produced ? (c) Sketch a schematic diagram depicting the electric and magnetic fields for an electromagnetic wave propagating along z-axis. CBSE 2024

2. The electric field in an electromagnetic wave in vacuum is given by : E = (6·3 N/C) [cos (1·5 rad/m) y + ($4{\cdot}5*10^8$ rad/s) t] ^i (a) Find the wavelength and frequency of the wave.
(b) What is the amplitude of the magnetic field of the wave ?
(c) Write an expression for the magnetic field of this wave. CBSE 2024

3. Explain the following, giving proper reason :
(a) During charging of a capacitor, displacement current exists in the capacitor. But there is no displacement current when it gets fully charged.
(b) The frequency of microwaves in ovens matches with the resonant frequency of water molecules.
(c) Infrared waves are also known as heat waves. CBSE 2024

4. (a) The electric field of an electromagnetic wave passing through vacuum is represented as $E_x = E_o \sin(kz-wt)$. Identify the parameter which is related to the (i) wavelength, and (ii) the frequency of the wave in the above equation. CBSE 2023
(b) Write two properties of a medium that determine the velocity of light in that medium.

5. (i) In diffraction due to a single slit, the phase difference between light waves reaching a point on the screen is 5π . Explain whether a bright or a dark fringe will be formed at the point.
(ii) What should the width ‘a’ of each slit be to obtain eight maxima of double-slit patterns (slit separation d) within the central maximum of the single slit pattern ?
(iii) Draw the plot of intensity distribution in a diffraction pattern due to a single slit. CBSE 2024

6. (i) In which case is diffraction effect more dominant slit formed by 2 blades or slit formed by two fingers ?
(ii) Yellow light (= 6000 Å) illuminates a single slit of width 1×10^{-4} m. Calculate (i) the distance between two dark lines on either side of central maximum, in the diffraction pattern observed on a screen kept 1·5 m away from the slit, and (ii) the angular spread of the first minimum. CBSE 2023

7. (i) What will be the colour of the central bright fringe in Young’s double slit experiment if the monochromatic source is replaced by a source of white light ? Give reason for your answer.
(ii) In Young's double slit experiment, the slit is separated by 0.3 mm and the screen is placed 1.5 m away from the slits. The distance between the central bright fringe and the sixth bright fringe is found to be 1.8 cm. Find the wavelength of light used in the experiment. CBSE 2023

LONG ANSWER TYPE QUESTIONS 5 MARKS

1. (i) (1) Write two points of difference between an interference pattern and a diffraction pattern. (2) Name any two factors on which the fringe width in a Young’s double -slit experiment depends.

(ii) In Young's double -slit experiment, the two slits are separated by a distance equal to 100 times the wavelength of light that passes through the slits. Calculate : (1) the angular separation in radians between the central maximum and the adjacent maximum. (2) the distance between these two maxima on a screen 50 cm from the slits. CBSE 2023

2. (i)Give any two differences between the interference pattern obtained in Young s double-slit experiment and a diffraction pattern due to a single slit. CBSE 2023

(ii)Draw an intensity distribution graph in case of a double-slit interference pattern.

(iii) 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. Find the intensity of light at a point on the screen where the path difference is λ /6

3. (i) State Huygens principle. A plane wave is incident at an angle i on a reflecting surface. Construct the corresponding reflected wavefront. Using this diagram, prove that the angle of reflection is equal to the angle of incidence.

(ii) What are the coherent sources of light ? Can two independent sodium lamps act like coherent sources ? Explain.

(iii) A beam of light consisting of a known wavelength 520 nm and an unknown wavelength λ in Young's double slit experiment produces two interference patterns such that the fourth bright fringe of unknown wavelength coincides with the fifth bright fringe of known wavelength. Find the value of λ. CBSE 2024

CASE STUDY

1. Diffraction of light is bending of light around the corners of an object whose size is comparable with the wavelength of light. Diffraction actually defines the 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.

Answer the following questions based on the above :

(a) How will the width of central maximum be affected if the wavelength of light is increased ? 1

(b) Under what condition is the first minimum obtained ? 1

(c) Write two points of difference between interference and diffraction patterns. 2

OR

(c) Two students are separated by a 7 m partition wall in a room 10 m high. If both light and sound waves can bend around obstacles, how is it that the students are unable to see each other even though they can converse easily ? CBSE 2023

2. Diffraction and interference are closely related phenomena that occur together. Diffraction is the phenomenon of bending of light around the edges of the obstacle, while interference is the combination of waves that results in a new wave pattern. In order to get interference, there must be at least two waves that are diffracting. So while diffraction can occur without interference, interference cannot occur without diffraction. Two slits of width 2 um each in an opaque material are separated by a distance of 6 um. Monochromatic light of wavelength 450 nm is incident normally on the slits. One finds a combined interference and diffraction pattern on the screen.

(i) The number of peaks of the interference fringes formed within the central peak of the envelope of the diffraction pattern will be : 1

(A) 2 (B) 3(C) 4 (D) 6

(ii) The number of peaks of the interference formed if the slit width is doubled while keeping the distance between the slits same will be : 1

(A) 1 (B) 2(C) 3 (D) 4

(iii) if instead of 450 nm light ,another light of wavelength 680 nm is used, number of peaks of the interference formed in the central peak of the envelope of the diffraction pattern will be :

(A) 2 (B) 4 (C) 6 (D) 9

OR

Consider the diffraction of light by a single slit describe in this case study. The first minimum falls at an angle θ equal to:

(A) $\sin^{-1}(0.12)$ (B) $\sin^{-1}(0.225)$ (C) $\sin^{-1}(0.32)$ (D) $\sin^{-1}(0.45)$

(iv)the number of bright fringes formed due to interference on 1 m of the screen placed at 4/3 m away

from the slit is :
(A) 2 (B) 3 (C) 6 (D) 10 CBSE 2024

3. The British physicist Thomas Young explained the interference of light using the principle of superposition of waves. He observed the interference pattern on the screen, in his experimental set up known as Young's double slit experiment. The two slits S1 and S2 were illuminated by light from a slit S. The interference pattern consists of dark and bright bands of light. Such bands are called fringes. The distance between two consecutive bright and dark fringes is called fringe width.

(a) If the screen is moved closer to the plane of slits S1 and S2, then the fringe width :
(i) will decrease, but the intensity of bright fringe remains the same.
(ii) will increase, but the intensity of bright fringe decreases.
(iii) will decrease, but the intensity of bright fringe increases.
(iv) and the intensity both remain the same

(b) What will happen to the pattern on the screen, when the two slits S1 and S2 are replaced by two independent but identical sources ?
(i) The intensity of pattern will increase
(ii) The intensity of pattern will decrease
(iii) The number of fringes will become double
(iv) No pattern will be observed on the screen

(c) Two sources of light are said to be coherent, when both emit light waves of :
(i) same amplitude and have a varying phase difference.
(ii) same wavelength and a constant phase difference.
(iii) different wavelengths and same intensity.
(iv) different wavelengths and a constant phase difference.

(d) The fringe width in Young's double slit experiment is β . If the whole set-up is immersed in a liquid of refractive index μ , then the new fringe width will be :
(i) β (ii) $\beta\mu$ (iii) β/μ (iv) β/μ^2

(e) The total path difference between two waves meeting at points P1 and P2 on the screen are $3\lambda/2$ and 2λ respectively. Then :
(i) bright fringes are formed at both points.
(ii) dark fringes are formed at both points.
(iii) a bright fringe is formed at P1 and a dark fringe is formed at P2 .
(iv) a bright fringe is formed at P2 and a dark fringe is formed at P1 . CBSE 2022

PREVIOUS YEARS QUESTIONS OF EM WAVE AND WAVE OPTICS

ANSWERS AND SOLUTIONS
MCQS

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

Assertion reason

1. A 2. D 3. D

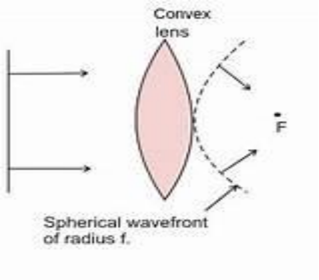
Short answer type

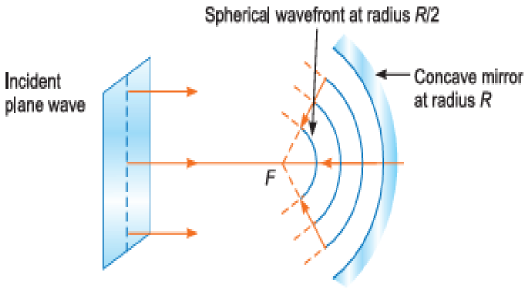
1(a) infra-red Uses remote control
(b) X ray uses medical diagnosis

2 (a) Current which is produced by changing electric flux is known as displacement current. While conduction current is produced by flow of free electron
(b) Two characteristics (i) it needs no medium (ii) transverse in nature

Microwave used in radar system because it has smaller wavelength so it can be transmitted in the desired condition.

3





4.

The resultant displacement will be given by

$$y = y_1 + y_2$$
$$= a \cos \omega t + a \cos(\omega t + \phi)$$
$$= a[\cos \omega t + \cos(\omega t + \phi)]$$
$$= 2a \cos(\phi/2) \cos(\omega t + \phi/2)$$

The amplitude of the resultant displacement is $2a \cos(\phi/2)$

The intensity of light is directly proportional to the square of amplitude of the wave. The resultant intensity will be given by

$$I = 4a^2 \cos^2 \frac{\phi}{2}$$

5. (i)

Let s be the size of the source-slit and S its distance from the plane of two slits. For interference fringes to be seen, the condition

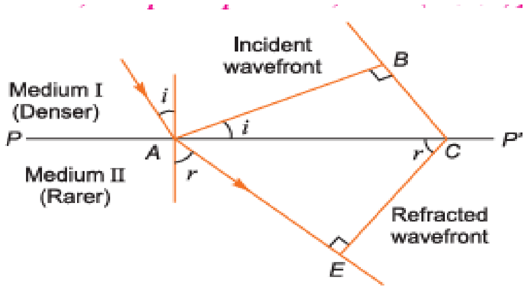
$$\frac{s}{S} < \frac{\lambda}{d}$$

should be satisfied; otherwise, interference patterns produced by different parts of the source overlap and no fringes are seen. Thus, as S decreases (i.e. the source slit is brough closer), the interference pattern gets less and less sharp, and when the source is brought too close for this condition to be valid, the fringes disappear.

(ii)fringe width decrease as separation between slit increase

6.

We assume a plane wavefront AB propagating in denser medium incident on the interface PP' at angle i as shown in Fig. Let t be the time taken by the wave front to travel a distance BC. If v_1 is the speed of the light in medium I.



So, $BC = v_1 t$

In order to find the shape of the refracted wavefront, we draw a sphere of radius $AE = v_2 t$, where v_2 is the speed of light in medium II (rarer medium). The tangent plane CE represents the refracted wavefront.

In ΔABC, $\sin i = \frac{BC}{AC} = \frac{v_1 t}{AC}$

and in ΔACE, $\sin r = \frac{AE}{AC} = \frac{v_2 t}{AC}$

$$\therefore \quad \frac{\sin i}{\sin r} = \frac{BC}{AE} = \frac{v_1 t}{v_2 t} = \frac{v_1}{v_2} \quad \ldots(i)$$

Let c be the speed of light in vacuum

So, $n_1 = \frac{c}{v_1}$ and $n_2 = \frac{c}{v_2}$

$$\frac{n_2}{n_1} = \frac{v_1}{v_2} \quad \ldots(ii)$$

From equations (i) and (ii), we have

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

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

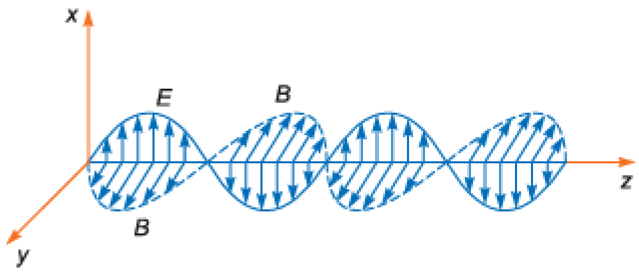
It is known as Snell's law.

Short answer type (3 marks)

1 (a) it depends upon permeability and permittivity of medium

(b) Electromagnetic wave is produced by accelerating/oscillating charge.

(c)



2.

(a) $k = \frac{2\pi}{\lambda}$

$$\lambda = \frac{2\pi}{K} = \frac{4\pi}{3}\,\text{m} = 4.18\,\text{m}$$

$$\omega = 2\pi\upsilon$$

$$\nu = \frac{\omega}{2\pi} = \frac{4.5\times10^8}{2\pi}\,\text{Hz}$$

$$\nu = \frac{9}{4\pi}\times10^8\,\text{Hz}$$

$$\nu = 7.16\times10^{-1}\,\text{Hz}$$

(b) $B_0 = \frac{E_0}{c}$

$$B_0 = \frac{6.3}{3\times10^8} = 2.1\times10^{-8}\,\text{T}$$

(c) $\vec{B} = 2.1\times10^{-8}[(\cos 1.5\,\text{rad/m})\,y + (4.5\times10^8\,\text{rad/s})\,t]\,\hat{k}\,\text{T}$

3 (a)After charging there is no change in electric flux, therefore there exist no displacement

current in charged capacitor
(b) Frequency of microwave matches with the resonant frequency of water molecules so that energy from wave is transferred to water molecules
(c) Infrared waves have wavelengths that set atoms and molecules into vibrational motion. Infrared waves set particles into vibration producing heat energy.

4. (a) k is related to wavelength , w is related to frequency
(b) it depends upon permeability and permittivity of medium

5.(a) bright fringe
(b) 4a

6.(i) 2 blades
(ii)(a) 18 mm (b).006 rad

7 (i) Central fringe will be white

(ii) 3.6 um

LONG QUESTION

1

(i) (1)

(a) The interference pattern has a number of equally spaced bright and dark bands while diffraction pattern has a central bright maximum which is twice as wide as the other maxima.

(b) Interference pattern is obtained by superposing two waves originating from two narrow slits, while diffraction pattern is a superposition of a continuous family of waves originating from each point on a single slit.

(c) The maxima in interference pattern is obtained at angle λ / a, while the first minima is obtained at same angle λ / a for diffraction pattern.

(d) In interference pattern the intensity of bright fringes remain same while in diffraction the intensity falls as we go to successive maxima away from the center on either side.

(any two)

(2) Factors affecting fringes width

Wave length (λ) / distance of screen from slits (D) / separation between slits (d).

(any two)

(ii) (1) $d \sin\theta = n\lambda$

$n=1$

$$\sin\theta = \frac{\lambda}{d}$$

For small angle $\sin\theta \approx \theta = \frac{\lambda}{100\lambda} = \frac{1}{100}$ radian.

(2) $\beta = \frac{\lambda D}{d} = \theta D$

$= \frac{1}{100} \times 50 \times 10^{-2}$

$= 50 \times 10^{-4} m$

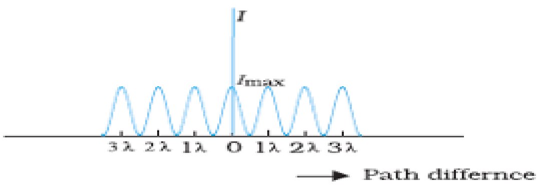
$= 5$ mm

2

(i)

	Interference	Diffraction
1	Bands are equally spaced	Bands are not equally spaced.
2	Intensity of bright bands is same.	Intensity of maxima decreases on either side of central maxima.
3	First maxima is at an angle λ / a	First minima is at an angle λ / a

(ii)



(iii) Path difference $(\Delta) = \lambda$

$$\phi = \frac{2\pi\Delta}{\lambda}$$

$$\phi = 2\pi$$

$$I = 4I_0 \cos^2 \frac{\phi}{2}$$

$$K = 4I_0 \cos^2 \pi \quad = 4I_0$$

$$\text{Path difference} = \frac{\lambda}{6}$$

$$\phi = \pi / 3$$

$$I = 4I_0 \cos^2 \frac{\pi}{6}$$

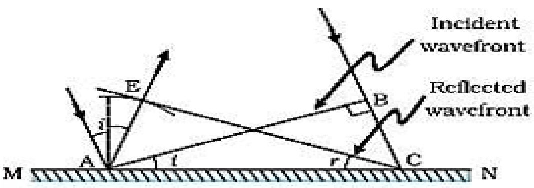
$$= 4I_0 \times \frac{3}{4}$$

$$= \frac{3}{4}\text{K}$$

3

(i) Each point of the wavefront is the source of a secondary disturbance and the wavelets emanating from these points spread out in all directions with the spread of the wave. Each point of the wavefront is the source of a

secondary disturbance and the wavelets emanating from these points spread out in all directions with the speed of the wave. These wavelets emanating from the wavefront are usually referred to as secondary wavelets and if we draw a common tangent to all these spheres, we obtain the new position of the wavefront at a later time.



ΔEAC is congruent to ΔBAC; so $\angle i = \angle r$

(ii) Two sources are said to be coherent if the phase difference between them does not change with time.

No, two independent sodium lamps cannot be coherent.

Two independent sodium lamps cannot be coherent as the phase between them does not remain constant with time.

(iii)

$$4\beta_2 = 5\beta_1$$

$$4 \times \frac{\lambda D}{d} = 5 \times \frac{\lambda_{known} D}{d}$$

$$\Rightarrow \lambda = \frac{5}{4} \times \lambda_{known}$$

$$= \frac{5}{4} \times 520$$

$$= 650 \text{ nm}$$

CASE BASED QUESTION

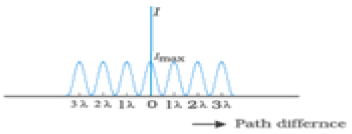
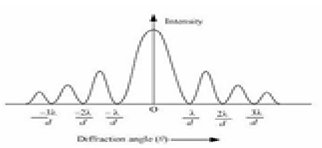
1

(a) $\beta_o \; \alpha \; \lambda$

β_o will increase with increase in wavelength.

(b) When path difference $a\theta = \lambda$ or at an angle ; $\theta \approx \lambda / a$

(c) Differences

Interference Pattern	Diffraction Pattern
(i) All the maxima are equally spaced. (ii)The dark fringe is having zero intensity. (iii) All the maxima are of the same intensity. (iv)  **Alternatively:-** -It is obtained by the superposition of two waves originating from two sources/slits.	(i) Width of Central bright maxima is twice the width of the other maxima. (ii) The dark fringe is not completely dark. (iii) There is a sharp decrease in the intensity of maxima after the central bright maxima. (iv)  It is obtained by the superposition of waves from points on a single slit.

Any two of the above differences.

OR

(c) The opening (slit) is 3m; which is of the order of the wavelength of sound waves whereas it is very large compare to the wavelength of light.
Hence, sound can bend around the obstacle while light cannot.

2
(i) (D) 6
(ii) (C) 3
(iii) (a) (C) 6

OR

(b) (B) $\sin^{-1}(0.225)$

(iv) (D) 10

3 a) (iii) b) (iv) c) (ii) d) (iii) e) (iv)

(Dual nature of radiation and Matter)

MCQ(1Marks)

Q1. The energy of a photon of wavelength λ is (2023)

(a) hcλ (b) hc/λ (c) λ/hc (d) h/c

Q2. Photons of energy 3.2 eV are incident on a photosensitive surface. If the stopping potential for the emitted electrons is 1.5 V, the work function for the surface is (CBSE 2023)

(a) 1.5 eV

(b) 1.7 eV

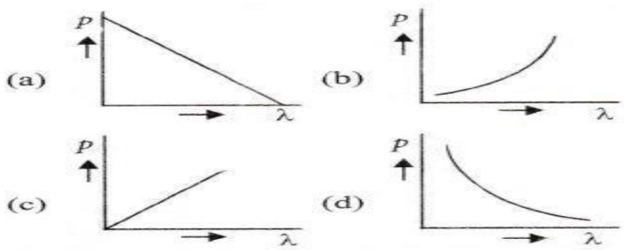
(c) 3.2 eV

(d) 4.7 ev

Q3. A proton and an alpha particle have the same kinetic energy. The ratio of de- Broglie wavelengths associated with the proton to that with the alpha particle is (CBSE 2023)

(a) 1 (b)2 (c) 2√2 (d) ½

Q4. Which of the following graphs correctly represents the variation of a particle momentum with its associated de-Broglie wavelength?



Q5:Which one of the following metals does not exhibit emission of electrons from its urface when irradiated by visible light? (CBSE 2023)

(a) Rubidium

(b) Sodium

(c) Cadmium

(d) Caesium

ASSERTION-REASON QUESTIONS

Directions (Q. Nos. 6-7) In the following questions, two statements are given- one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below:

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

(b) If both Assertion and Reason are correct but Reason is not the correct explanation of Assertion.

(c) If Assertion is correct but Reason is incorrect.

(d) If both Assertion and Reason are incorrect.

Q6: Assertion :The photoelectrons produced by a monochromatic light beam incident on a metal surface have a spread in their kinetic energies.

Reason :The energy of electrons emitted from inside the metal surface, is lost in collision with the other atoms in the metal. (CBSE SQP 2022-23)

Q7: Assertion: Electron has the smallest wavelength as compare to proton and a-particle (if they have same kinetic energy).

Reason: de-Broglie wavelength is inversely proportional to $\sqrt{mass}$.

2 MARKS QUESTIONS

Q8: (i) Name the factors on which photoelectric emission from a surface depends.

(ii) Define the term threshold frequency for a photosensitive material **(CBSE 2022)**

ANS: (i) The photoelectric emission depends on

(a) intensity of light

(b) potential applied

(c) frequency of incident radiation

(ii) For a given material, there exists a certain minimum frequency of the incident radiation below which no emissions of photoelectrons takes place. This frequency is called threshold frequency or cut-off frequency of that material.

Q9: Do all the electrons that absorb a photon come out as photoelectrons?

ANS: No, most electrons get scattered into the metal. Only a few come out of the surface of the metal.

Q10: Light of wavelength 3500 Å is incident on two metals A and B. Which metal will yield more photoelectrons if their work functions are 5 eV and 2 eV respectively?

ANS: Metal B will yield more photo electrons. work function of Metal B is lower than that of A for the same wavelength of light. Hence metal B will give more electrons.

Q11: A proton and an electron have same kinetic energy. Which one has greater de-Broglie wavelength and why?

ANS:

Kinetic energy of a particle $E = \frac{1}{2}mv^2$

or $mv = \sqrt{2mE}$

de-Broglie wavelength associated with the particle is $\lambda = \frac{h}{mv} = \frac{h}{\sqrt{2mE}}$

For a given value of E, $\lambda = \frac{1}{\sqrt{m}}$

Mass of electron < mass of proton

So, electron has greater de-Broglie wavelength.

Q12: How does a burglar alarm fixed in your entrance door of your house works?

ANS: In burglar alarms, a photocell is placed or fixed at the doorway. An invisible light like ultraviolet light is falling continuously on it. If any person enters through the door it interrupts the beam of ultraviolet light falling on the photocell due to which there will be sudden change in photoelectric current and hence the bell start ringing. So one can identify or get rectified when someone is coming to the doorsteps.

3 MARKS QUESTIONS

Q13:The photon emitted during the de-excitation from the 1st excited level to the ground state of hydrogen atom is used to irradiate a photo cathode of a photocell, in which stopping potential of 5V is used. Calculate the work function of the cathode used.

ANS:

Given : $n_1 = 2, \quad n_2 = 1, \quad V_0 = 5V, \quad eV_0 = 5eV,$
$(\phi_0) = ?$

Energy of photon (E) = (13.6) – (3.4) eV = 10.2 eV

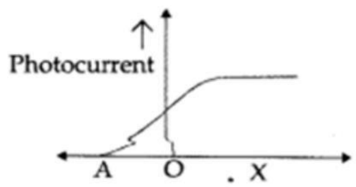
According to photoequation,

$$E = eV_0 + \phi_0$$

$$\phi_0 = E - (eV_0) = (10.2) - (5)$$

$$\therefore \quad \boldsymbol{\phi_0 = 5.2\ eV}$$

14: The given graph shows the variation of photocurrent for a photosensitive metal:



(a) Identify the variable X on the horizontal axis.

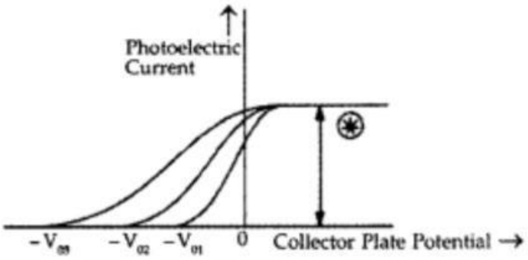
(b) What does the point A on the horizontal axis represent?

(c) Draw this graph for three different values of frequencies of incident radiation v1 v2 and v3 (v1 > v2 > v3) for same intensity.

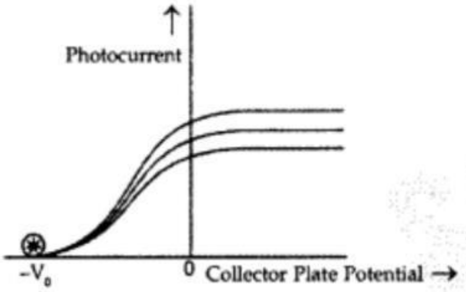
(d) Draw this graph for three different values of intensities of incident radiation I1 I2 and I3 (I1 > I2 >I3) having same frequency.

ANS:

(a) 'X' is a collector plate potential.
(b) 'A' represents the stopping potential.



(*d*) **Graph for different intensites :**



Q15: The momentum of photon of electromagnetic radiation is 3.3 X10-29 kg-m/s. Find out the frequency and wavelength of the wave associated with it.

ANS: Given, h = 6.63 10^{-34} J/s, c= 3 x10^8 m/s and p = 3.3 x 10 $^{-29}$- kg m/s

Momentum, p= hν c

or ν = pc/ h =3.3 x 10^{-29} x 3 x 108/6.63 x 10^{-34} = 1.5 x 10^{13} Hz ,λ = c ν = 3 x 10^8 X1.5 x 10^{13} = 2 x 10^{-5} m

Q16: The following table gives the values of work functions for a few sensitive metals. If each of these metals is exposed to radiations of wavelength 3300nm, which of these will not exit photoelectrons and why?

S. No.	Metal	Work function(eV)
1.	Na	1.92
2.	K	2.15
3.	Mo	4.17

ANS: Energy

$E=hc\lambda=(6.6\times10^{34}\times3\times10^{8})/(33\times10^{-8}J)$

$E=(6.20\times10^{-19})/(1.6\times10^{-19}\ eV)$

Energy $E=3.76\ eV$

As energy of incident radiations E<W hence no photoelectrons will be emitted .

Hence work function of Mo is (4.17eV) which is greater than the energy of the incident radiation (= 3.76 eV)

LONG ANSWER QUESTIONS

Q16: (i)Two monochromatic beams A and B of equal intensity I hit a screen. The number of photons hitting the screen by beam A is twice that by beam B. What inference can you make about their frequencies?

(ii)The work function of a metal is 2.31eV. Photoelectric emission occurs when light of frequency 6.4 x10^{14} Hz is incident on the metal surface. Calculate (a) energy of the incident radiation (b) the maximum kinetic energy of the emitted electrons (c) stopping potential of the surface

ANS: (i)Let n_A = number of photons falling per second of beam A n_B = number of photons falling per second of beam B

Energy of beam A=hνA, Energy of beam B=hνB Then according to the question,

Intensity I = n_A hν_A = n_Bh ν_B Or, n_A /n_B = ν_A/ ν_B

Or, ν_AB= 2 ν_A

Hence frequency of beam B is twice that of A.

(ii) (a) Energy of incident radiation, E= hν = 6.63x10^{-34} x6.4 x10^{14} J= 2.65 Ev

(b) Maximum kinetic energy, Kmax = (2.65- 2.31) eV= 0.342 eV

(c) Stopping potential Vo =Kmax/e

e=($\frac{0.342\ eV}{e}$)

e=0.342 V

Q17: Write Einsten's photoelectric equation. State clearly how this equation is obtained using the photon picture of electromagnetic radiation. Write the three salient features observed in photoelectric effect which can be explained using this equation.

ANS: hv=Φ_0 +K_{max}

This is Einstein's photoelectric equation. Photoelectric emission is the result of interaction of two particles—one a photon of incident radiation and other an electron of photo sensitive metal. The free electrons are bound within the metal due to restraining forces on the surface. The minimum energy required to liberate an electron from the metal surface is called work function Φ_0 of the metal. Each photon interacts with one electron. The energy hv of the incident photon is used up in two parts:

(a) a part of the energy of the photon is used in liberating the electron from the metal surface, which is equal to the work function φ0 of the metal and

(b) the remaining energy of the photon is used in imparting K.E. of the ejected electron. By the conservation of energy Energy of the inefficient photon = maximum K.E. of photoelectron + Work function

$$h\nu = \frac{1}{2}mv_{max}^2 + \phi_0$$

$$K_{max} = \frac{1}{2}mv_{max}^2 = h\nu - \phi_0$$
$$= h\nu - h\nu_0 = h(\nu - \nu_0)$$

Three salient features are :

Three salient features observed in photoelectric effect on the basis of Einstein's Photoelectric equation :

(*i*) **Threshold frequency.** For $KE_{max} \geq 0$.

$\Rightarrow \quad \nu \geq \nu_0 \qquad \ldots(i)$

i.e., the phenomenon of photoelectric effect takes place when incident frequency is greater or equal to a minimum frequency (threshold frequency) ν_0 fixed for given material.

(*ii*) **KE_{max} of photoelectron.** When incident frequency is greater than threshold frequency, then KE_{max} of photo electron is directly proportional to $(\nu - \nu_0)$ as

$$KE_{max} = h(\nu - \nu_0)$$

$$\Rightarrow \quad KE_{max} \propto (\nu - \nu_0)$$

iii) **Effect of intensity of incident light.** The number of photon incident per unit time per unit area increases with the increase of intensity of incident light. More number of photons facilitates ejection of more number of photoelectrons from metal surface leadint to further increase of photo current till its saturation value is reached.

PREVIOUS YEAR CBSE ASKED QUESTIONS
CHAPTER – ATOMS AND NUCLEI
Section A (MCQ)

1. Isotones are nuclides having :
(A) same number of neutrons but different number of protons (2019)
(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

2. Which of the following statements is correct for alpha particle scattering experiment?
(A) For angle of scattering $\theta \approx 0$, the impact parameter is small. (2024)
(B) For angle of scattering $\theta \approx \pi$, the impact parameter is large.
(C) The number of alpha particles undergoing head-on collision is small.
(D) The experiment provides an estimate of the upper limit to the size of target atom.

3. The impact parameter for an alpha particle approaching target nucleus is maximum when the scattering angle θ is (2023)

(A) 0∘
(B) 90∘
(C) 180∘
(D) 45∘

4. The curve of binding energy per nucleon as a function of an atomic mass number has a sharp peak for helium nucleus. This implies that helium nucleus is
(A) more stable nucleus than its neighbours (2023)
(B) Unstable
(C) easily fissionable
(D) radioactive

5. When two nuclei ($A \leq 10$) fuse together to form a heavier nucleus, the
(A) **binding energy per nucleon increases.** **(2020)**
(B) binding energy per nucleon decreases
(C) binding energy per nucleon does not change.
(D) total binding energy decreases.

(A/R QUESTIONS)

(A) If both assertion and reason are true and reason is the correct explanation of assertion

(B) If both assertion and reason are true but reason is not the correct explanation of assertion

(C) If assertion is true but reason is false
(D) If both assertion and reason are false

6. Assertion (A) : Nuclear fission reactions are responsible for energy generation in the Sun.
Reason (R) : Light nuclei fuse together in the nuclear fission reactions. (2024)

7. Assertion (A): Bohr's atomic model cannot be used to explain multiple electron species.
Reason (R): It does not take inter-electronic interactions in account. (SP 2022)

Section C

8.Write two important limitations of Rutherford nuclear model of the atom. (2017)

9. What is meant by ionization energy? Write its value for hydrogen atom. (2023)

10. The ground state energy of hydrogen atom is -13.6 eV. If an electron makes a transition from an energy level -1.51 eV to that of -3.4 eV. Calculate the wavelength of the spectral line emitted. (2023)

11.Define the term mass defect. How is it related to stability of the nucleus? (2023)

12. (a)Difference between nuclear fission and nuclear fusion. (Term-II 2021-22)

(b) Deuterium undergoes fusion as per the reaction.

$_1H^2 + _1H^2 = _2He^3 + _0n^1 + 3.27 MeV$

Find the duration for which an electric bulb of 500 W can be kept glowing by the fusion of 100 g of deuterium.

Section D

13.Explain briefly how Rutherford scattering of alpha particle by a target nucleus can provide information of the size of the nucleus. (2019)

14. Draw the energy level diagram for hydrogen atom. Mark the transitions corresponding to the series lying in the ultraviolet region, visible region and infrared region. (2023)

15. Calculate the de-Broglie wavelength associated with the electron in the 2nd excited state of hydrogen atom.The ground state energy of the hydrogen atom is 13.6 eV. (2020)

16.(a) How is the size of a nucleus found experimentally? (2023)

(b) Prove that the density of a nucleus is independent of its mass number.

17.Draw a plot showing the variation of potential energy of two nucleus as a function of distances between them. Identify the regions in which the force between the nucleusis

(i) attractive and

(ii) repulsive. Justify your answers. (2023)

Section- D

18. (a) Write two important limitations of Rutherford model which couid not explain the observed features of atomic spectra. How were these explained in Bohr`s model of hydrogen atom?

(b) Using Bohr's postulates, obtain the expression for the radius of the nth orbit in hydrogen atom. (2015)

ANSWERS

Section- A

1.(a) same number of neutrons but different number of protons

2.(c) The number of alpha particles undergoing head-on collision is small

3.(a) 0∘

4(a) The elements that lie high on binding energy versus mass number plot are tightly bound and hence are stable. As helium nucleus shows peak on this curve, which means that it is very stable.

5(a) When two lighter nuclei fuse to form a heavier nucleus, its binding energy per nucleon increases.

6.(d) Assertion (A) is incorrect because it attributes the Sun's energy generation to nuclear fission, which is incorrect. Reason (R) is incorrect because it describes nuclear fusion, not fission

7(a) Yes, both the assertion and reason are correct, and the reason is the correct explanation for the assertion.

Section- B

8. Two limitations of Rutherford nuclear model of the atom –

(i) Rutherford's model cannot explain the stability of an atom.

(ii) It can not explain the characteristic line spectra of atoms of different elements.

9. Ionization energy is the minimum amount of energy needed to remove an electron from an atom's ground state and free it.
The ionization energy of a hydrogen atom is 13.6 electron volts (eV).

10. **Solution**

When energy is -1.51 eV then n = 3.

When energy is -3.4 eV then n = 2.

$\therefore \quad \frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{3^2}\right)$

$\frac{1}{\lambda} = 1.1\times10^7 \left(\frac{1}{4} - \frac{1}{9}\right)$

$= 1.1\times10^7 \left(\frac{5}{36}\right)$

$\lambda = 36/5\times1.1\times10^{-7}$

$\lambda = 6.545\times10^{-7}$ $\qquad \lambda = 6545$ A°

Thus, it belongs to the Balmer series.

11. Mass defect is the difference between the mass of an atom and the sum of the masses of its protons and neutrons. Larger the value of mass defect, greater the nuclear binding energy and more stable the nucleus.

12.(a)

Nuclear Fission	**Nuclear Fusion**
A fission reaction is splitting up of a large atom or a molecule into two or more smaller ones.	**Fusion is the process of combination of two or more lighter atoms or molecules into larger ones.**
Fission reaction doesn't occur normally in nature.	**Fusion reaction process occurs in the stars, like in the sun, etc.**
Neutrons are the link particles of this process.	**Protons are the link particles of this process.**

(b) given, m = 100 g., P = 500W
Here two deuterium nuclei produce 3.27 MeV energy
$= 5.232 \times 10^{-13}$ J
Energy per nuclei $= 5.232 \times 10^{-13}$ J/2
$= 2.616 \times 10^{-13}$ J
Number of deuterium atoms in 100 g = 6.023×1

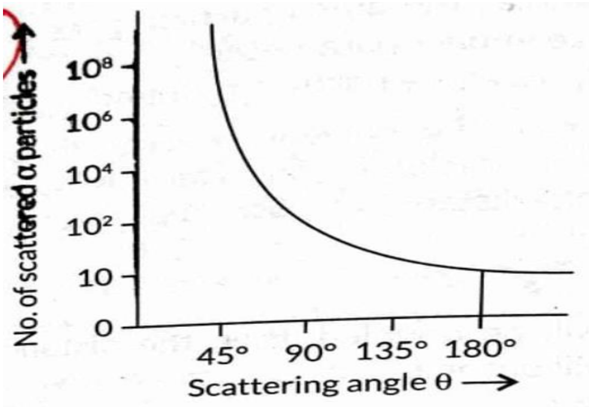
$0^{23}\times100/2 = 3.011\times10^{25}$ atoms
Thus, total energy $= 3.011\times10^{25} \times 2.616 \times 10^{-13}$
$= 7.88 \times10^{12}$ j
Power = Energy/ Time
Thus, time for which the bulb glows = 7.88×10^{12} j / 500

$= 1.58 \times 10^{10}$ s

$= 1.58 \times 10^{10} / 365 \times 24 \times 60 \times 60 = 500$ years

. **Section- C**

13.



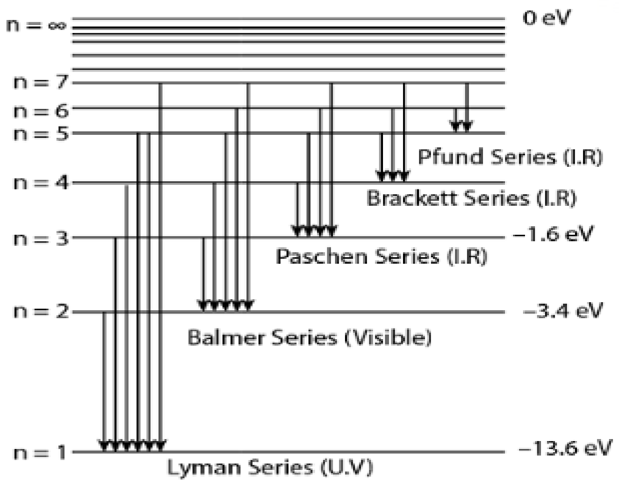
A very small fraction of α- particles are scattered at $\theta > 90^0$ because the size of nucleus is very small nearly 1/8000 times the size of atom. So a few α-particles experience at strong repulsive force and turn back.

Conclusions:

I. Entire positive charge and most of the mass of the atom is concentrated in the nucleus with the electrons some distance away.

II. Size of the nucleus is about 10^{-15} m to 10^{-14} m, while size of the atom is 10^{-10} m, so the electrons are at distance 10^{4} m to 10^{5} m from the nucleus and being large empty space in the atom, most α particles go through the empty space

14.



.

15.

de-Broglie wavelength, $\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mK}}$, where K is the kinetic energy.

Now, energy of electron,

$$K = \frac{13.6z^2}{n^2} = \frac{13.6}{3^2} = 1.51 \text{ eV} = 2.41 \times 10^{-19} \text{ J}$$

$$\therefore \quad \lambda = \frac{h}{\sqrt{2mK}} = \frac{6.63\times10^{-34}}{\sqrt{2\times9\times10^{-31}\times2.41\times10^{-19}}}$$

$= 1 \times 10^{-9}$ m = 1 nm

16.(a) The size of a nucleus can be determined experimentally using a technique called scattering (usually alpha particles) is directed at a thin target of a particular element. As the beam particles interact with the target nuclei, they are scattered in different directions. By measuring the scattering angles, scientists can deduced the size of the target nucleus.

An observation made by Rutherford about size of nucleus from his scattering experiment is that very few α-particles (1 in 8000) suffers deflection of 180^o. This shows that size of nucleus is very small, nearly 1/8000 times the size of atom.

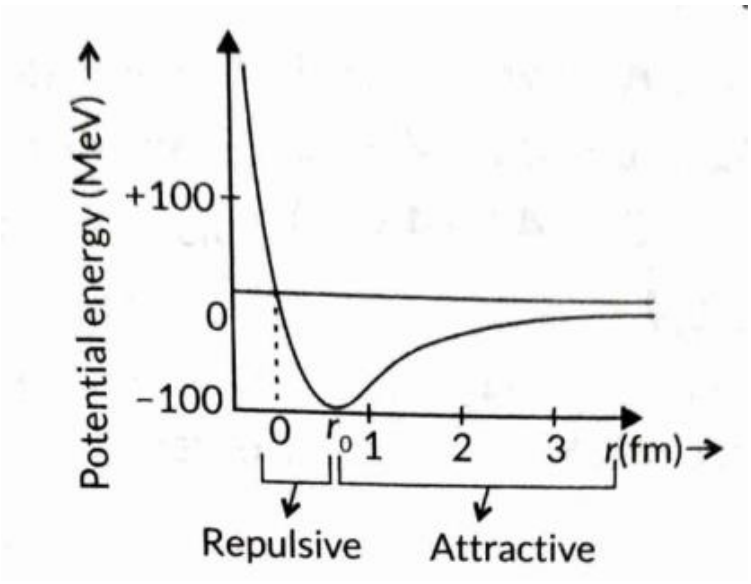
The relationship between the nuclear radius and the mass number of a nucleus can be described by $R=R_0A^{1/3}$

Where R_0 is a constant and A is the mass number . Nuclear radius is measured in Fermi.

($1\text{fm}=10^{-15}$ m).

(b) IF m is the average mass of a nucleon and R is the nuclear radius, then mass of nucleus = mA, where A is the mass number of the element.

17. Plot of the potential energy of a pair of nucleons as a function of their separation is given in the figure.



Conclusions-

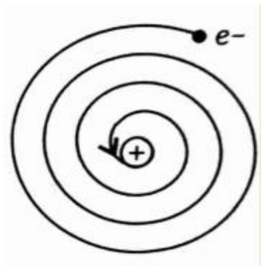
1- The nuclear force is much stronger than the coulomb force acting between charges or the gravitational forces between masses.

2- The nuclear force between two nucleons falls rapidly to zero as their distance is more than few Fermi.

3- For a separation greater than r_0 the force is attractive and for separation less than r_0, the force is strongly repulsive.

Section -D

18. (a) Limitation of Rutherford's model –



1- Rutherford's atomic model is inconsistent with classical physics. According to electromagnetic theory, an electron

2- beam is a charged particle moving in the circular orbit around the nucleus and is accelerated, so it should emit radiation continuously and thereby loose energy. Due to this, radius of the electron would decrease continuously and also the atom should then produce continuous spectrum, and ultimately electron will fall into the nucleus and tom will collapse in 10^{-8} s. But the atom is fairly stable and it emits line line spectrum .

3- Rutherford's model is not able to explain the spectrum of even most simplest H-spectrum.

Bohr's postulates to resolve observed features of atomic spectrum:

1- Quantum condition : Of all the possible circular orbits allowed by the classical theory, the electrons are permitted to circulate only in those orbits in which the angular momentum of an electron is an integral multiple of $h/2\pi$

h being Plank's constant. Therefore for nay permitted orbit

Where ($L = nh/2\pi$) n is called the principal quantum number and this equation is called

Volume of the nucleus, $V = \frac{4}{3}\pi R^3$

$$\therefore \quad V = \frac{4}{3}\pi\left(R_0 A^{1/3}\right)^3 \quad \Rightarrow \quad V = \frac{4}{3}\pi R_0^3 A$$

Density of nucleus, $\rho = \frac{mA}{V}$

$$\Rightarrow \quad \rho = \frac{mA}{\frac{4}{3}\pi R_0^3 A} \quad \Rightarrow \quad \rho = \frac{3m}{4\pi R_0^3}$$

This shows that the nuclear density is independent of A.

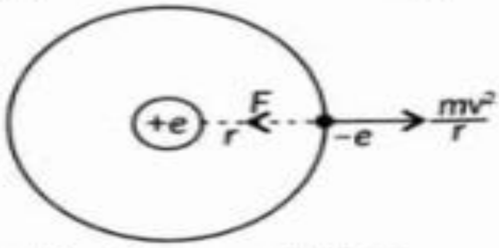
Bohr’s quantization condition.

2- Stationary orbit- While resolving in the permissible orbit an electron does not radiate energy. These non-radiation orbits are called stationary orbits.
3- Frequency condition- An atom can emit or absorb radiation in the form of discrete energy photons only when an electron jumps from a higher to a lower orbit or from a lower to a higher orbit respectiverly.

Where $h\upsilon = E_f - Ei$ υ is frequency of radiation emitted E_i and E_f are the energies associated with stationary orbits of principal quantum number n_i and n_f respectively (where $n_i > n_f$)

(b) Radius of n^{th} orbit of hydrogen atom : In H-atom, an electron having charge $-e$ revolves around the nucleus of charge $+e$ in a circular orbit of radius r, such that necessary centripetal force is provided by the electrostatic force of attraction between the electron and nucleus.

i.e., $$\frac{mv^2}{r} = \frac{1}{4\pi\varepsilon_0}\frac{e.e}{r^2} \text{ or } mv^2 = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r} \quad ...(i)$$



From Bohr's quantization condition

$$mvr = \frac{nh}{2\pi} \text{ or } v = \frac{nh}{2\pi mr} \quad ...(ii)$$

Using equation (ii) in (i), we get

$$m\cdot\left(\frac{nh}{2\pi mr}\right)^2 = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r} \text{ or } \frac{m\cdot n^2h^2}{4\pi^2m^2r^2} = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r}$$

$$\text{or} \quad r = \frac{n^2h^2\varepsilon_0}{\pi me^2} \quad ...(iii)$$

where $n = 1, 2, 3, ...$ is principal quantum number. Equation (iii), gives the radius of n^{th} orbit of H-atom. So the radii of the orbits increase proportionally with n^2 i.e., $[r \propto n^2]$. Radius of first orbit of H-atom is called Bohr radius a_0 and is given by

$$a_0 = \frac{h^2\varepsilon_0}{\pi me^2} \text{ for } n=1 \text{ or } a_0 = 0.529 \text{ Å}$$

So, radius of n^{th} orbit of H-atom then becomes

$$r = n^2 \times 0.529 \text{ Å}$$

PREVIOUS YEAR QUESTIONS

SEMICONDUCTOR AND DEVICES (MULTIPLE CHOICE QUESTIONS)

1. To make a p-type semiconductor, an intrinsic semiconductor is doped with
   (a) gallium or indium (b) arsenic or phosphorus
   (c) aluminum or boron (d) Both (a) and (c)Ans. (b)

2.In the depletion region of unbiased p-n junction,
(a) it is vacant of charge carriers
(b) has only electrons(c) has only holes
(d) p-n junction has a weak electric field.Ans. (a)

3. The impurity atom with which pure Si should be doped to make a p-type semiconductor is
a. Phosphorus b. Boron
c. Antimony d. arsenic
Ans. (b

4.The unidirectional flow of current through p-n junction makes it ideal to be used as
a. an oscillator b. a modulator
c. a rectifier d. a resistor
Ans. ©

5.The forbidden gap for germanium is
(a) 0.12 eV (b)0.72 eV (c)7.2 eV (d)None of theseAns. (b)

6.When a forward bias is applied to a p-n junction, it
(a) raises the potential barrier. (b)reduces the majority carrier current to zero.
(b) lowers the potential barrier (d)None of the above.Ans. (b)

Two statements are given – One labeled Assertion (A) and other labeled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below:

(a) Both A and R are true and R is the correct explanation of A
(b) Both A and R are true but R is not the correct explanation of A.
© A is true but R is false.
(d) A is false but R is true

7. **Assertion** (A): The electrons in the conduction band have higher energy than thosein the valance band of a semi-conductor.
Reason (R): The conduction band lies above the energy gap and valance band liesbelow the energy gap.
Ans. (a)

8. **Assertion** (A): The energy gap between the valance band and conduction band isgreater in silicon than a germanium.

Reason (R): Thermal energy produces fewer minority carriers in silicon than ingermanium.
Ans. (a)

(2 MARKS QUESTIONS)

1. A semiconductor has equal electron and hole concentrations of 2×10^8 /m^3 . Ondoping with a certain impurity, the hole concentration increases to 4×10^{10}/m^3.
(i) What type of semiconductor is obtained from doping?

(ii) Calculate the new electron concentration of the semiconductor.

(iii) How does the energy gap vary with doping?

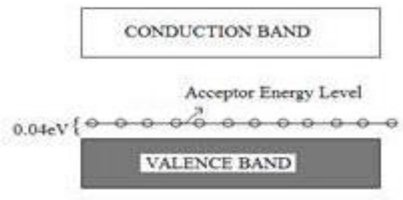
Ans. (i) as on doping the hole concentration has increased, the doped semiconductoris a p-type semiconductor.

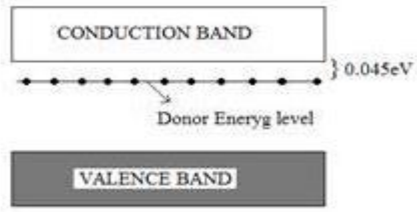
(ii) As $n_i = 2 \times 10^8$ /m^3 and $n_h = 4 \times 10^{10}$/m^3 . From the relation $n_e . n_h = n_i^2$,we get, $n_e = n_i^2 / n_h = (2 \times 10^8)^2 / 4 \times 10^{10} = 10^6$/m^3.

(iii) The energy gap decreases with doping.

2. For a extrinsic semiconductor, indicate on the energy band diagram the donor andacceptor levels?

Ans. N-type Extrinsic Semiconductor P-type Extrinsic Semiconductor



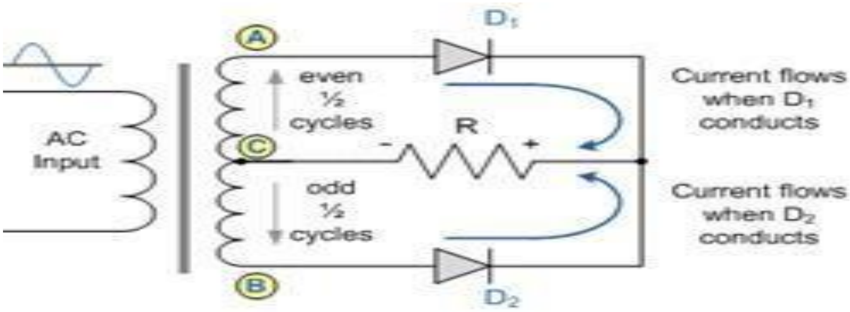


3. What do you mean by depletion region and potential barrier in junction diode?**Ans.** A layer around the junction between p and n-sections of a junction diode where mobile charge carriers electrons and holes are less in number is called depletion region. The potential difference created across the junction due to the diffusion of charge carriers across the junction is called potential barrier.

(3 MARKS QUESTIONS)

1. With the help of a labeled circuit diagram, explain full wave rectification usingjunction diode. Draw input and output wave forms?

Ans. Full wave rectifier consists of two diodes and a transformer with central tap. For any half cycle of a.c. input only one diode is forward biased where as the other one isreverse biased.



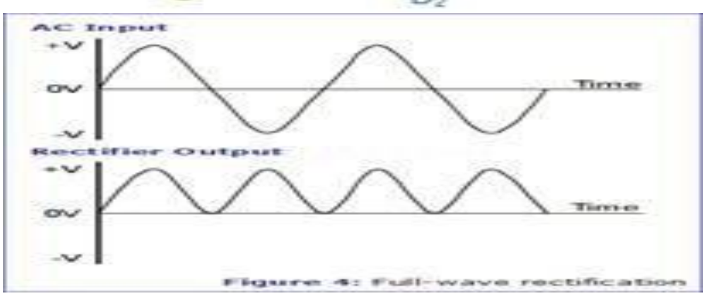
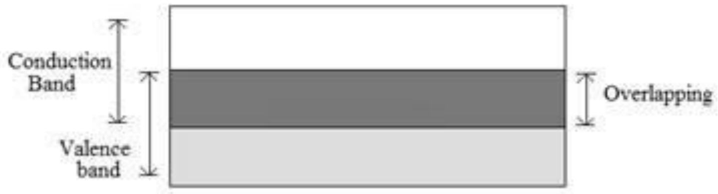


Figure 4: Full-wave rectification

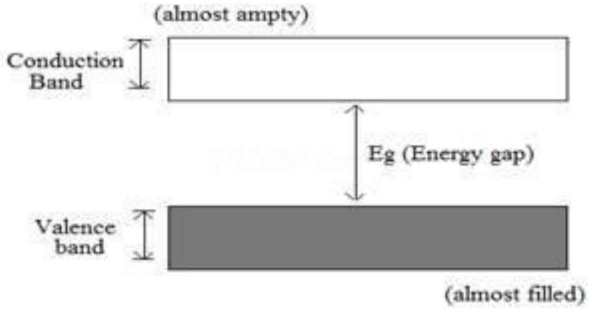
Suppose for positive half of a.c. input diode D1 is forward biased and D2 is reverse biased, then the current will flow across D1 where as for negative half of a.c. input diode D2 is forward biased and the current flows across D2. Thus for both the halvesoutput is obtained and current flows in the same direction across load resistance
R2 and thus a.c. is converted into d.c.

2. Distinguish between conductors, insulators and semiconductors on the basis ofenergy band diagrams?

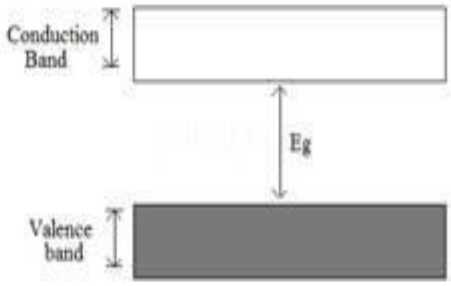
Ans.Conductor – Conduction band in a conductor is either partially filled or conduction and valence band overlaps each other. There is no energy gap in aconductor.



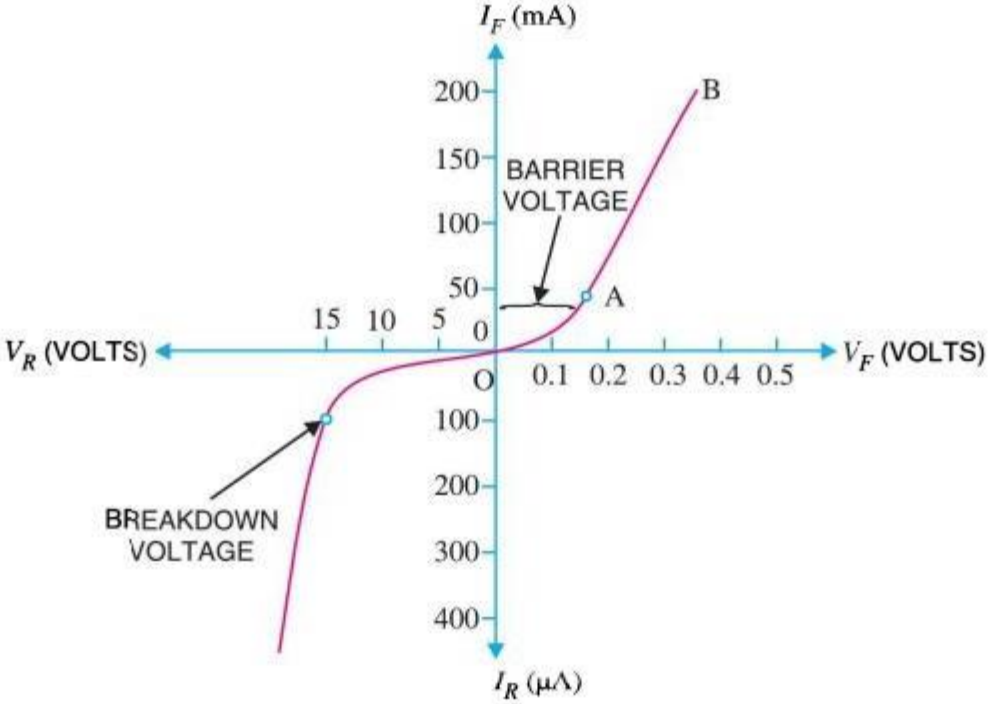
Insulators – conduction band and valence band of all insulator are widely separated byand energy gap of the order 6 to 9 eV Also conduction band of an insulator is almost empty.



Semiconductor – In semiconductors the energy gap is very small i.e. about 1ev only.



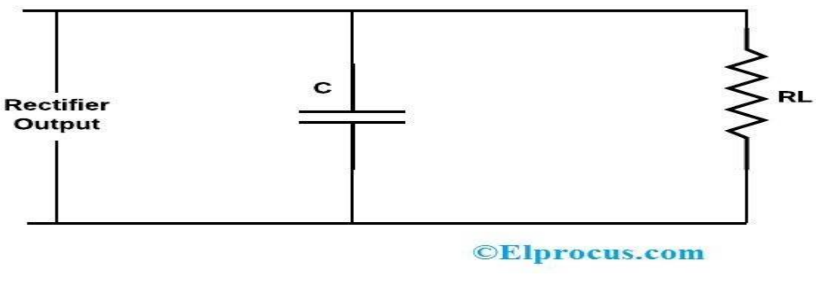
3. Draw V-I characteristics of a p-n junction diode. Answer the following questions,giving reasons:
(i) Why is the current under reverse bias almost independent of the applied potentialup to a critical voltage.
(ii) Why does the reverse current show a sudden increase at the critical voltageAns.

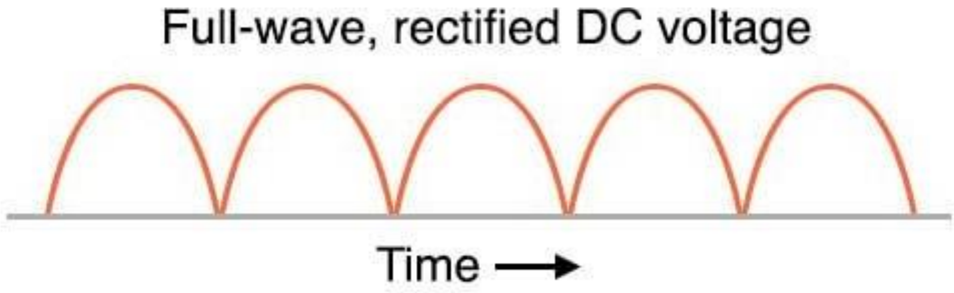


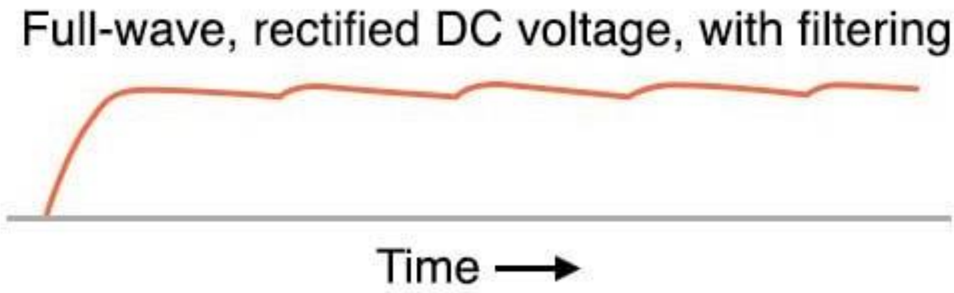
(i) In the reverse biasing, the current of order of μA is due to movement/drifting of minority charge carriers from one region to another through the junction. A small applied voltage is sufficient to sweep the minority charge carriers through the junction.So, reverse current is almost independent of critical voltage.
(ii) At critical voltage (or breakdown Reverse bias voltage), a large number of covalent bonds break, resulting in the increase of a large number of charge carriers.Hence, current increases at critical voltage.

(5 MARKS QUESTIONS)

1. What is a filter? With the help of a circuit diagram describe the role of capacitor infiltering. Draw input and output waveforms too.
Ans. In the output obtained from a full wave rectifier, the output is unidirectional butdoes not have a steady value.
To get steady output we use a filter circuit which filters the a.c. ripple and give a pure d.c. voltage. A capacitor-based filter circuit has been shown in figure.







The presence of an AC component is indicated by the ripple in the signal.To attain pure dc output, this ac component must be entirely removed.

Therefore, a circuit is required to convert the rectified output into a pure dc signal.

A filter circuit is one that lets the dc component go to the load while removing the ac component from the rectified output. The simplest sort of filter used in rectifiers is thecapacitor filter.

A capacitor permits ac and blocks dc.

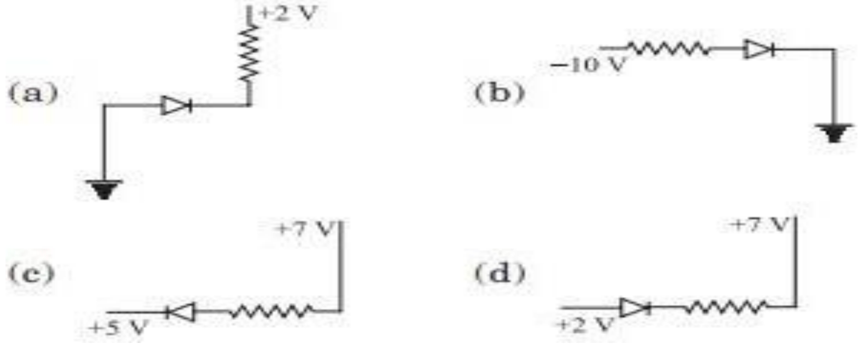
Capacitor filter: The AC component of the rectified signal is filtered away, leavingonly the DC component, using a capacitor in parallel with the load. A smoother DC output is produced as a result of the capacitor charging during the peak of the AC voltage and discharging during the off period.

(CASE BASED QUESTIONS)

1. When the diode is forward biased, it is found that beyond forward voltage V = V_k,called knee voltage, the conductivity is very high. At this value of battery biasing forthe p-n junction, the potential barrier is overcome, and the current increases rapidly with an increase in forwarding voltage. When the diode is reverse biased, the reverse

bias voltage produces a very small current of about a few microamperes which almostremains constant with bias. This small current is a reverse saturation current.

(i) In which of the following figures, the p-n diode is forward biased



(ii) What role do semiconductors play in simple circuits?
(a) They store energy.
(b) They produce light.
(c) They convert mechanical energy into electrical energy.
(b) They play a role in rectification and voltage regulation.
(iii) The potential barrier height is reduced and the width of the depletion layerdecreases in-
Reverse bias (b) Forward bias (c) forward or reverse (d) none of theseOR
In forward bias diode current is-
(a) More of drift current than diffusion current. (b) Predominately drift current
(c) Predominately diffusion current (d) Diffusion and drift both are equal

(iv) In case of p-type semiconductors-
(a) $n_h < n_e$ (b) $n_h = n_e$ (c) $n_h > n_e$ (d) $n_h = n_e = 0$
OR

Ans. (i) c (ii) d (iii) b OR c (iv) c

2. **SEMICONDUCTOR** : A pure semiconductor germanium or silicon, free of everyimpurity is called intrinsic semiconductor. At room temperature, a pure semiconductor has very small number of current carriers (electrons and holes) .Henceits conductivity is low. When the impurity atoms of valance five or three are doped ina pure semiconductor, we get respectively n- type or p- type extrinsic semiconductor.In case of doped semiconductor ne nh=ni2. Where ne and nh are the number density of electron and hole charge carriers in a pure semiconductor. The conductivity of extrinsic semiconductor is much higher than that of intrinsic semiconductor. Answer the following questions.

Q (1). Which of the following statements is not true?
(a) The resistance of intrinsic semiconductor decreases with increase of temperature
(b) Doping pures Si with trivalent impurities gives p- type semiconductors.
© The majority charges in n- type semiconductors are holes.(d). A p-n junction can act as semiconductor diode.
Q (2). The impurity atoms with which pure Si should be doped to make a p- typesemiconductor is
(a) Phosphorus (b) Boron © Arsenic (d) AntimonyQ (3). Holes are majority charge carriers in
(a) Intrinsic semiconductors. (b) Ionic Solids
(b) p- type semiconductors (d) MetalsQ (4). At absolute zero, Si acts as
(a) Non- metal (b) Metal © Insulator (d) None of these
OR
A piece of copper and another of germanium are cooled from room temperature to 80 K. The resistance of :
a. Each of them increases
b. Each of them decreases
c. Copper increases and germanium decreases
d. Copper decreases and germanium increases

Answers 1. (c) The majority Charge carriers in n-type semiconduch as holes2.(b) Boron

3. (c) p-type semiconductors
(c) Insulators or (d) Copper decreases and germanium increases

3. **Rectifiers** : A semiconductor device is used as a rectifier that allows the voltage toflow in positive direction and very small value in the reverse direction. Now a days, there is a problem of supply of less voltage that damages the household appliances.

Q (1). In the depletion region of a diode
(a) There are no mobile charges
(b) Equal number of holes and electrons exist, making the region neutral.
(c) Recombination of holes and electrons has taken place.
(d) Immobile charge ions exist.

Q(2).When a p-n junction diode is reverse biased then
(a) No Current flows
(b) The depletion reason is increased
(c) The depletion reason is reduced
(d) Height of potential barrier is reducedQ(3). Diode is used as
(a) Oscillator (b) Amplifier © Rectifier (d) ModulatorQ(4).Which one statement is incorrect?
(a) Diode is used as rectifier
(b) Diode is used as half wave rectifier
(c) Diode is used as Amplifier
(d) Diode is used as full wave rectifier

OR

In a full wave rectifier, input AC has a frequency ‘ν’. The output frequency of currentis
(a) ν /2 (b) ν (c) 2 ν (d) None of theseAnswers:

Ans-C