# LIST OF MEMBERS WHO PREPARED QUESTION BANK FOR PHYSICS FOR CLASS XII

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# CONTENTS

# UNIT I

# ELECTROSTATICS

***Weightage – 8 Marks***

## TOPICS TO BE COVERED

Electric charges, Conversation of charges, Coulomb's Law; Force between two points charges, forces between multiple charges, Superposition Principle.

Continuous charge distribution.

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

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

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

Conductors and Insulators, free charges and bound charges inside a conductor, Dielectric and electric polarization, Capacitors and Capacitance, combination of capacitances in series and parallel.

Capacitance of a parallel plate capacitor with or without dielectirc medium between the plates energy stored in a capacitor, Van de Graff Generator.

## KEY POINTS

| *Physical Quantity* | *Formulae Used* | *SI Unit* |
|---|---|---|
| Quantization of charge | $q = \pm ne$ | C |
| Coulomb's force | $F = \frac{Kq_1q_2}{r^2}$ | N |
| In vector from | $F_{12} = \frac{Kq_1q_2}{r^2_{21}}\hat{r}_{21} = \frac{Kq_1q_2}{r^3_{21}}\vec{r}_{21}$ | |
| Dielectric constant (or relative permitivity) | $K_D = \epsilon_r = \frac{F_0}{F_m} = \frac{\epsilon_m}{\epsilon_0} = \frac{C_m}{C_0} = \frac{\phi_0}{\phi_m} = \frac{E_0}{E_m}$ | $\epsilon_r$ |

Hence $F_0 \geq F_m$ as free space has minimum permittivity

| | | |
|---|---|---|
| Linear charge density | $\lambda=\frac{q}{L}$ | $Cm^{-1}$ |
| Surface charge density | $\sigma=\frac{q}{A}$ | $Cm^{-2}$ |
| Electric field due to a point charge | $\vec{E}=\underset{q_0\to 0}{Lt}\frac{F}{q_0}(\text{theoretical})$<br>$\left(\text{In numerical, we use } E=\frac{Kq_1}{r^2}\right)$ | |
| The components of electric field, | $E_x=\frac{1}{4\pi\in_0}\frac{qx}{r^3}, E_y=\frac{1}{4\pi\in_0}\frac{qy}{r^3},$ | $NC^{-1}$ |
| Torque on a dipole in a uniform electric field | $E_z=\frac{1}{4\pi\in_0}\frac{q_z}{r^3}$ | Nm |
| Electric dipole moment | $\vec{\tau}=\vec{p}\times\vec{E}(\text{or } \tau=pE\sin\theta)$ | Cm |
| Potential energy of a dipole in a unifor electric field | $\vec{P} = q\cdot(\overrightarrow{2a})$ or $\lvert\vec{p}\rvert = q(2a)$ | J |
| | $U=-\vec{p}\cdot\vec{E}l(\text{or } U=-pE\cos\theta)$ | |
| Electric field on axial line of an electric dipole | $E_{axial}=\frac{1}{4\pi E_0}\frac{2pr}{(r^2-a^2)^2}$<br>$\text{When } 2a<<r, E_{axial}=\frac{1}{4\pi E_0}\frac{2p}{r^3}$ | $NC^{-1}$ |
| Electric field on equatorial line of an electric dipole | $E_{equatorial}=\frac{1}{4\pi\in_0}\frac{q\times 2a}{(r^2+a^2)^{\frac{3}{2}}}$<br>$\text{When } 2a<<r, E_{equatorial}=\frac{1}{4\pi E_0}\frac{p}{r^3}$ | |
| Electric field as a gradient of potential | $E=\frac{dV}{dr}$ | |
| Electrical potential differences between points A & B | $V_B-V_A=\frac{W_{AB}}{q_0}$ | Volts (or $JC^{-1}$) |
| Electric potential at a point | $V_A=\frac{1}{4\pi E_0}\frac{q}{r_A}=\frac{W}{q}$ | |
| Electric potential due to a system of charges | $V=\frac{1}{4\pi E_0}\sum_{i=1}^{n}\frac{q_i}{r_i}$ | |
| Electric potential at any point due to an electric dipole | $V=\frac{1}{4\pi E_0}\frac{P\cos\theta}{r^2-a^2\cos^2\theta}$<br>$\text{When}, \theta=0^\circ \text{ or } \theta=77, V=\frac{\pm 1}{4\pi E_0}\frac{p}{r^2-a^2}$<br>$\text{If } r>>a, V=\frac{1}{4\pi E_0}\frac{p}{r^2}$<br>$\text{When}, \theta=90^\circ, V_{equi}=0$ | |

| | | |
|---|---|---|
| Total electric flux through a closed surface S | $\phi = \oint \vec{E}.d\vec{S} = \oint E_n dS$ <br> $= E \times$ Effective Area $= \dfrac{q}{E_0}$ | $Nm^2\ C^{-1}$ |
| Electric field due to line charge | $E = \dfrac{1}{2\pi \in_0} \dfrac{\lambda}{r}$ | $NC^{-1}$(or V/m) |
| Electric field due to an infinite plane sheet of charge | $E = \dfrac{\sigma}{2 \in_0}$ | |
| Electric field due to two infinitely charged plane parallel sheets | $E = \dfrac{\sigma}{\in_0}$ | |
| Electric field due to a uniformly charged spherical shell | $E = \dfrac{\sigma}{\in_0} \dfrac{R^2}{r^2}$ <br> $\text{When}\ r = R,\ \in_0 = \dfrac{\sigma}{\in_0}$ <br> $\text{When}\ r < R,\ E \times 4\pi r^2 = 0$ | |
| Electrical capacitance | $C = \dfrac{q}{V}$ | F(SI Unit) $\mu$F (Practical Unit) |
| Capacitance of an isolated sphere | $C = 4\pi \in_0 r$ | |
| Capacitance of a parallel plate | $C = \dfrac{A \in_0}{d}$ | |
| Capacitors in series | $\dfrac{1}{C} = \dfrac{1}{C_1} + \dfrac{1}{C_2} + \dfrac{1}{C_3}$ | |
| Capacitors in parallel | $C = C_1 + C_2 + C_3$ | |
| Capacitance of a parallel plate capacitor with dielectric slab between plates | $C = \dfrac{\in_0 A}{d - t\left(1 - \dfrac{1}{K_D}\right)}$ | |
| Capacitance of a parallel plate capacitor with conducting slab between plates | $C = \dfrac{C_0}{\left(1 - \dfrac{t}{d}\right)}$ | |
| Energy stored in a charged capacitor | $U = \dfrac{q^2}{2C} = \dfrac{1}{2}CV^2 = \dfrac{1}{2}qV$ | J |
| Resultant electric field in a polarised dielectric slab | $\vec{E} = \vec{E_0} - \vec{E_p}$, where <br> $\vec{E_0}$ = Applied electric field and <br> $\vec{E_p}$ = Electric field due to polarization | $Cm^{-1}$ |
| Polarization density | $P = n\alpha\ E = \chi E$ | $Vm^{-1}$ or $Nc^{-1}$ |
| Dielectric constant (in terms of electric susceptibility or atomic polarisability) | $K_D = 1 + \chi$ | |

| | | |
|---|---|---|
| Potential difference between inner and outer shell in van de Graaff generator | $V_{r_0} - V_R = \frac{q}{4\pi E_o}\left(\frac{1}{r_o} - \frac{1}{R}\right)$ | Volts (or $JC^{-1}$) |

# QUESTIONS

## VERY SHORT ANSWER QUESTIONS (I Mark)

1. Draw schematically an equipotential surface of a uniform electrostatic field along X axis.
2. Sketch field lines due to (i) two equal positive charges near each other (ii) a dipole.
3. Name the physical quantity whose SI unit is volt/meter. Is it a scalar or a vector quantity?
4. Two point charges repel each other with a force F when placed in water of dielectric constant 81. What will the force between them when placed the same distance apart in air? **Ans. :** (81F)
5. Electric dipole moment of $CuSO_4$ molecule is $3.2 \times 10^{-32}$ Cm. Find the separation between copper and sulphate ions. **Ans. :** ($10^{-3}$m)
6. Net capacitance of three identical capacitors connected in parallel is 12 microfarad. What will be the net capacitance when two of them are connected in (i) parallel (ii) series?

   **Ans. :** Cp = 8μf Cs = 2μf
7. A charge q is placed at the centre of an imaginary spherical surface. What will be the electric flux due to this charge through any half of the sphere. **Ans :** $q/2\epsilon_0$
8. Draw the electric field vs distance (from the centre) graph for (i) a long charged rod raving linear charge density $\lambda < 0$ (ii) spherical shell of radius R and charge $Q > 0$.
9. Diagrammatically represent the position of a dipole in (i) stable (ii) unstable equilibrium when placed in a uniform electric field.
10. A charge Q is distributed over a metal sphere of radius R. What is the electric field and electric potential at the centre? **Ans. :** E = 0, V = kQ/R
11. If a body contains $n_1$ electrons and $n_2$ protons then what is the total charge on the body? **Ans. :** $(n_2 \sim n_2)e$
12. What is the total positive or negative charge present in 1 molecule of water. **Ans. :** 10e.
13. How does the energy of dipole change when it in rotated from unstable equilibrium to stable equilibrium in a uniform electric field. **Ans. :** decreases
14. Write the ratio of electric field intensity due to a dipole at apoint on the equatorial line to the field at a point at a point on the axial line, when the points are at the same distance from the centre of dipole.
15. Draw equipotential surface for a $\partial_3$ dipole.
16. An uncharged conductor A placed on an insulating stand is brought near a charged insulated conductor B. What happens to the charge and potential of B?

   **Ans :** charge same, p.d. decrease

17. A point charge Q is placed at point O shown in Fig. Is the potential difference $V_A - V_B$ positive, negative or zero, if Q is (i) positive (ii) negative charge.

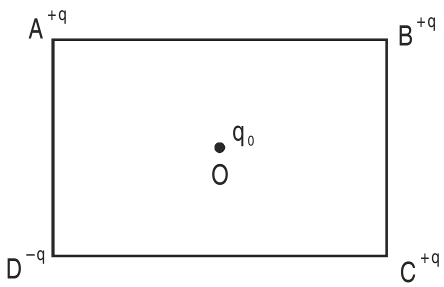
**Ans :** When Q is + ive. $V_A – V_B > 0$
When Q is – ive, $V_A – A_B < 0$


18. An electron and proton are released from rest in a uniform electrostatic field. Which of them will have larger acceleration? **Ans :** $a_e > a_p$

19. In an uniform electric field of strength E, a charged particle Q moves point A to point B in the direction of the field and back from B to A. Calculate the ratio of the work done by the electric field in taking the charge particle from A to B and from B to A. **Ans :** 1 : 1

20. If a dipole of charge 2μC is placed inside a sphere of radius 2m, what is the net flux linked with the sphere. **Ans :** Zero

21. Four charges + q, –q, +q, –q are placed as shown in the figure. What is the work done in bringing a test charge from ∞ to point 0.




**Ans :** Zero

23. If the metallic conductor shown in the figure is continuously charged from which of the points A,B,C or D does the charge leak first. Justify. **Ans :** 'A'

24. What is dielectric strength? Write the value of dielectric strength of air. **Ans :** $3x10^6$ $Vm^{-1}$

25. Two charge –q and +q are located at points A (0, 0, –a) and B(0, 0, +a). How much work is done in moving a test charge from point (b, 0, 0) to Q (–b, 0, 0)? **Ans :** Zero

26. If an electron is accelerated by a Potential difference of 1 Volt, Calculate the gain in energy in Joul and electron volt.

27. Draw schematically the equipotential surface corresponding to a field that uniformly increases in magnitude but remains in a constant (say z) direction.

28. What is the work done in rotating a dipole from its unstable equilibrium to stable equilibrium? Does the energy of the dipole increase or decrease?

## SHORT ANSWER QUESTIONS (2 Marks)

1. An oil drop of mass m carrying charge –Q is to be held stationary in the gravitational field of the earth. What is the magnitude and direction of the electrostatic field required for this purpose?

**Ans :** E = m8/Q, doninward.

2. Find the number of field lines originating from a point charge of q = 8.854 μC.

**Ans :** d = 10 $NC^{-1}$ $m^2$

3. If q is the positive charge on each molecule of water, what is the total positive charge in (360g) a Mug of water.

$$\textbf{Ans : } q\left(\frac{360}{18}\times 6.02\times 10^{23}\right)C$$

4. Derive an expression for the work done in rotating an electric dipole from its equilibrium position to an angle θ with the uniform electrostatic field.

5. Show that there is always a loss of energy when two capacitors charged to different potentials share charge (connected with each other).

6. A thin long conductor has linear charge density of 20 μC/m. Calculate the electric field intensity at a point 5 cm from it. Draw a graph to show variation of electric field intensity with distance from the conductor. **Ans. :** 72 x $10^5$ N/C

7. What is the ratio of electric field intensity at a point on the equatorial line to the field at a point on axial line when the points are at the same distance from the centre of the dipole?

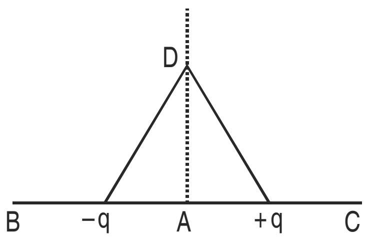
**Ans :** 1:2

8. Show that the electric field intensity at a point can be given as negative of potential gradient.

9. A charged metallic sphere A having charge $q_A$ is brought in contact with an uncharged metallic sphere of same radius and then separated by a distance d. What is the electrostatic force between them. **Ans :** $\frac{kq^2_A}{4d^2}$

10. An electron and a proton fall through a distance in an uniform electric field E. Compare the time of fall.

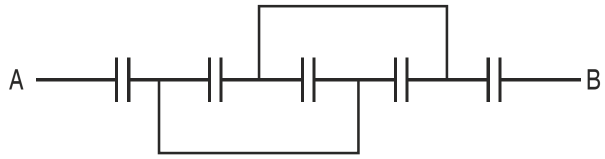
11. Two point charges –q and +q are placed 2l metre apart, as shown in fig. Give the direction of electric field at points A,B,C and D.



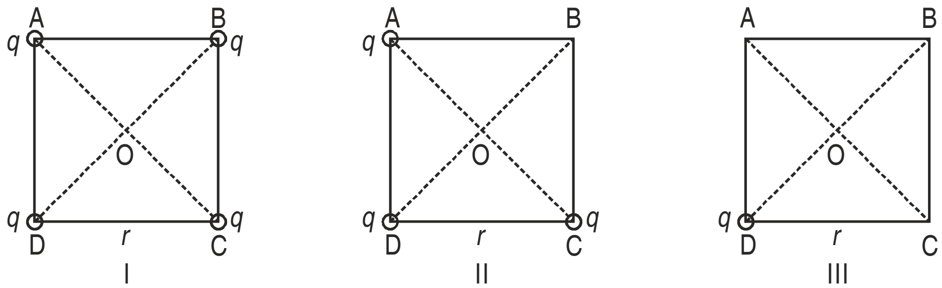

12. The electric potential V at any point in space is given V = $20x^3$ volt, where x is in meter. Calculate the electric intensity at point P (1, 0, 2). **Ans :** $60NC^{-1}$

13. Justify why two equipotential surfaces cannot intersect.

14. Find equivalent capacitance between A and B in the combination given below : each capacitor is of 2 μF. **Ans. :** 6/7 μF




15. What is the electric field at O in Figures (i), (ii) and (iii). ABCD is a square of side *r*.




**Ans : (i) Zero, (ii)** $\frac{2q}{4\pi \epsilon_0}\frac{1}{r^2}$ **(iii)** $\frac{2q}{4\pi \epsilon_0}$

16. What should be the charge on a sphere of radius 4 cm, so that when it is brought in contact with another sphere of radius 2cm carrying charge of 10 μC, there is no transfer of charge from one sphere to other? **Ans :** Va = Vb, Q = 20μC

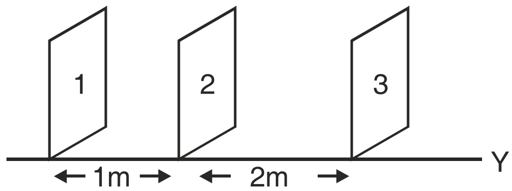
17. For an isolated parallel plate capacitor of capacitance C and potential difference V, what will happen to (i) charge on the plates (ii) potential difference across the plates (iii) field between the plates (iv) energy stored in the capacitor, when the distance between the plates is increased?
**Ans :** (i) No change (ii) increases (iii) No change (iv) increases.

18. Does the maximum charge given to a metallic sphere of radius R depend on whether it is hollow or solid? Give reason for your answer. **Ans :** No charge resides on the surface of conductor.

19. Two charges $Q_1$ and $Q_2$ are separated by distance r. Under what conditions will the electric field be zero on the line joining them (i) between the charges (ii) outside the charge?
**Ans :** (i) Charge are alike (ii) Unlike charges of unequal magnitude.

20. Obtain an expression for the field due to electric dipole at any point on the equatorial line.

21. The electric field component in the figure are $\vec{E}_x = 2\times\hat{i}, \vec{E}_y = E_z = 0,$. Calculate the flux through, (1,2,3) the square surfaces of side 5m.




22. Calculate the work required to separate two charges 4μc and –2μc placed at (–3cm, 0, 0) and (+3cm, 0, 0) infinitely away from each other.

23. What is electric field between the plates with the separation of 2cm and (i) with air (ii) dielectric medium of dielectric constant K. Electric potential of each plate is marked in Fig.

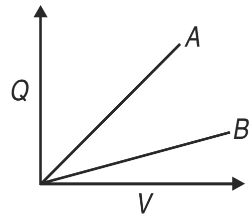
____________150 V

(i) ____________–50 V **Ans.** : $E_0 = 10^4 NC^{-1}$, $E = \frac{10^4}{k} NC^{-1}$

24. A storage capacitor on a RAM (Random Access Memory) chip has a capacity of 55pF. If the capacitor is charged to 5.3V, how may excess electrons are on its negative plate?

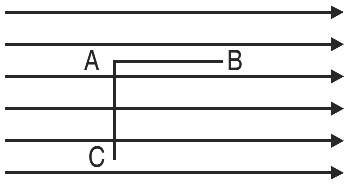
**Ans. :** $1.8 \times 10^9$

25. The figure shows the Q (charge) versus V (potential) graph for a combination of two capacitors. Identify the graph representing the parallel combination.




**Ans :** A represents parallel combination

26. Calculate the work done in taking a charge of 1 μC in a uniform electric field of 10 N/C from B to C given AB = 5 cm along the field and AC = 10 cm perpendicular to electric field.




**Ans :** $W_{AB} = W_{BC} = 50 \times 10^{-8}$ J, $W_{AC} = 0J$

27. Can two equi potential surfaces intersect each other? Give reasons. Two charges –q and +q are located at points A (0, 0, –a) and B (0, 0, +a) respectively. How much work is done in moving a test charge from point P(7, 0, 0) to Q(–3, 0, 0)? (zero)

28. The potential of a pt A to –500V and that of another point B is +500V. What is the work done by external agent to take 2 units of negative charge from B to A.

29. How does the Potential energy of (i) mutual interaction (ii) net electrostatic P.E. of two charges change when they are placed in an external electric field.

30. With the help of an example, show the bigness of 1 Farad.

31. What is meant by dielectric polarisation? Why does the electric field inside a dielectric decrease when it in placed in an external field?

## SHORT ANSWER QUESTIONS (3 Marks)

1. Define electrostatic potential and its unit. Obtain expression for electrostatic potential at a point P in the field due to a point charge.

2. Calculate the electrostatic potential energy for a system of three point charges placed at the corners of an equilateral triangle of side ‘a’.

3. What is polarization of charge? With the help of a diagram show why the electric field between the plates of capacitor reduces on introducing a dielectric slab. Define dielectric constant on the basis of these fields.

4. Using Gauss’s theorem in electrostatics, deduce an expression for electric field intensity due to a charged spherical shell at a point (i) inside (ii) on its surface (iii) outside it. Graphically show the variation of electric field intensity with distance from the centre of shell.

5. Three capacitors are connected first in series and then in parallel. Find the equivalent capacitance for each type of combination.

6. A charge Q is distributed over two concentric hollow sphere of radii r and R (R>r), such that their surface density of charges are equal. Find Potential at the common centre.

7. Derive an expression for the energy density of a parallel plate capacitor.

8. You are given an air filled parallel plate capacitor. Two slabs of dielectric constants $K_1$ and $K_2$ having been filled in between the two plates of the capacitor as shown in Fig. What will be the capacitance of the capacitor of initial area was A distance between plates d?

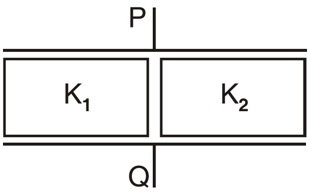



**Fig. 1**

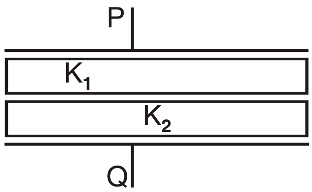
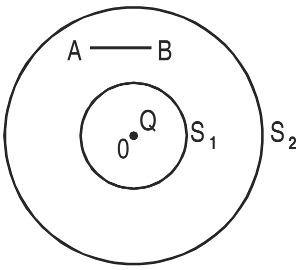



**Fig. 2**

$$C_1 = (K_1 + K_2)C_0$$

$$C_2 = \frac{K_1 K_2 C_0}{(K_1 + K_2)}$$

9. In the figure shown, calculate the total flux of the electrostatic field through the sphere $S_1$ and $S_2$. The wire AB shown has a liner charge density $\lambda$ given $\lambda = kx$ where x is the distance measured along the wire, from end A.




**Ans.** Total charge on wire AB = Q = $\int_o^l \lambda dx = \int_o^l k x dn = \frac{1}{2}Kl^2$

By Gauss’s the orem.

Total flux through $S_1 = \frac{Q}{\epsilon_0}$

Total flun through $S_2 = \frac{Q+\frac{1}{2}kl^2}{\epsilon_0}$

10. Explain why charge given to a hollow conductor is transferred immediately to outer surface of the conductor. (*See* Page 83. NCERT Vol I)

11. Derive an expression for total work done in rotating an electric dipole through an angle $\theta$ in an uniform electric field. Hence calculate the potential energy of the dipole.

12. Define electric flux. Write its SI unit. An electric flux of $\theta$ units passes normally through a spherical Gaussian surface of radius r, due to point charge placed at the centre.

    (1) What is the charge enclosed by Gaussian surface?

    (2) If radius of Gaussian surface is doubled, how much flux will pass through it?

13. A conducting slab of thickness 't' is introduced between the plates of a parallel plate capacitor, separated by a distance d ($t<d$). Derive an expression for the capacitance of the capacitor. What will be its capacitance when $t = d$?

14. If a dielectric slab is introduced between the plates of a parallel plate capacitor after the battery is disconnected, then how do the following quantities change.

    (i) Charge

    (ii) Potential

    (iii) Capacitance

    (iv) Energy.

15. What is an equipotential surface? Write three properties Sketch equipotential surfaces of

    (i) Isolated point charge

    (ii) Uniform electric field

    (iii) Dipole

## LONG ANSWER QUESTIONS (5 MARKS)

1. State the principle of Van de Graaff generator. Explain its working with the help of a neat labeled diagram.

2. Derive an expression for the strength of electric field intensity at a point on the axis of a uniformly charged circular coil of radius R carrying charge Q.

3. Derive an expression for potential at any point distant *r* from the centre O of dipole making an angle $\theta$ with the dipole.

4. Suppose that three points are set at equal distance r = 90 cm from the centre of a dipole, point A and B are on either side of the dipole on the axis (A closer to +ve charge and B closer to B) point C which is on the perpendicular bisector through the line joining the charges. What would be the electric potential due to the dipole of dipole t $3.6 \times 10^{-19}$ Cm at points A, B and C?

5. Derive an expression for capacitance of parallel plate capacitor with dielectric slab of thickness t(t<d) between the plates separated by distance d. How would the following (i) energy (ii) charge, (iii) potential be affected if dielectric slab is introduced with battery disconnected, (b) dielectric slab is introduced after the battery is connected.

6. Derive an expression for torque experienced by dipole placed in uniform electric field. Hence define electric dipole moment.

7. State Gauss's theorem. Derive an expression for the electric field due to a charged plane sheet. Find the potential difference between the plates of a parallel plate capacitor having surface density of charge $5 \times 10^{-8}$ $Cm^{-2}$ with the separation between plates being 4 mm.

8. Derive an expression for capacitance of parallel plate capacitor with dielectric slab of thickness t (t<d) between the plates separated by distance d.
   If the dielectric slab is introduced with the battery connected, then how do the following quantities change (i) charge (ii) potential (iii) capacitance (iv) energy

9. Using Gauss's theorem obtain an expression for electric field intensity due to a plane sheet of charge. Hence obtain expression for electric field intensity in a parallel plate capacitor.

10. Write five to six important results regarding eloectro statics of conductors. (See Page 68, NCERT Vol I).

## NUMERICALS

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

2. Two point charges 4e and e each, at a separation r in air, exert force of magnitude F. They are immersed in a medium of dielectric constant 16. What should be the separation between the charges so that the force between them remains unchanged. (1/4 the original separation)

3. Two capacitors of capacitance 10 μF and 20 μF are connected in series with a 6V battery. If E is the energy stored in 20 μF capacitor what will be the total energy supplied by the battery in terms of E. (6E)

4. Two point charges 6 μC and 2 μC are separated by 3 cm in free space. Calculate the work done in separating them to infinity. (3.6 joule)

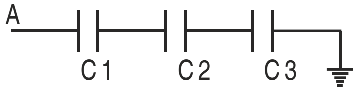
5. ABC is an equilateral triangle of side 10 cm. D is the mid point of BC, charge 100 μC, – 100 μC and 75 μC are placed at B, C and D respectively. What is the force experienced by a 1 μC positive charge placed at A? ($90\sqrt{2} \times 10^3$ N)

6. A point charge of 2 μC is kept fixed at the origin. Another point charge of 4 μC is brought from a far point to a distance of 50 cm from origin. Calculate the electrostatic potential energy of the two charge system. Another charge of 11 μC is brought to a point 100 cm from each of the two charges. What is the work done? ($3.2 \times 10^{-3}$J)

7. A 5 MeV $\alpha$ particle is projected towards a stationary nucleus of atomic number 40. Calculate distance of closest approach. ($1.1 \times 10^{-4}$ m)

8. To what potential must a insulated sphere of radius 10 cm be charged so that the surface density of charge is equal to 1 μC/m$^2$. ($1.13 \times 10^4$V)

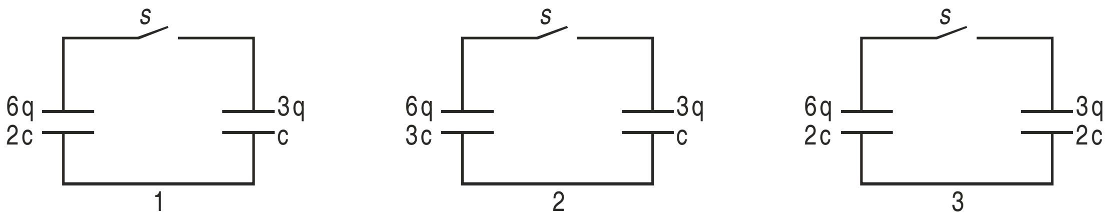
9. In the following fig. calculate the potential difference across capacitor $C_2$. Given potential at A is 90 V. $C_1$ = 20 μF, $C_2$ = 30 μF, and $C_3$ = 15 μF. (20V)




10. A point charge develops an electric field of 40 N/C and a potential difference of 10 J/C at a point. Calculate the magnitude of the charge and the distance from the point charge.

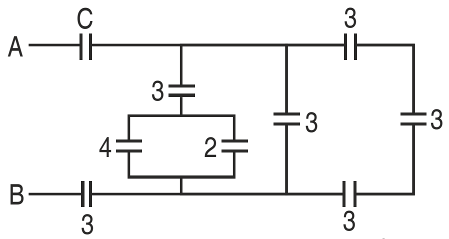
($2.9 \times 10^{-10}$ C, 25 cm)

11. Figure shows three circuits, each consisting of a switch and two capacitors initially charged as indicated. After the switch has been closed, in which circuit (if any) will the charges on the left hand capacitor (i) increase (ii) decrease (iii) remain same?




(1 remains unchanged, 2 increases, 3 decreases).

12. For what value of C does the equivalent capacitance between A and B is 1μF in the given circuit.



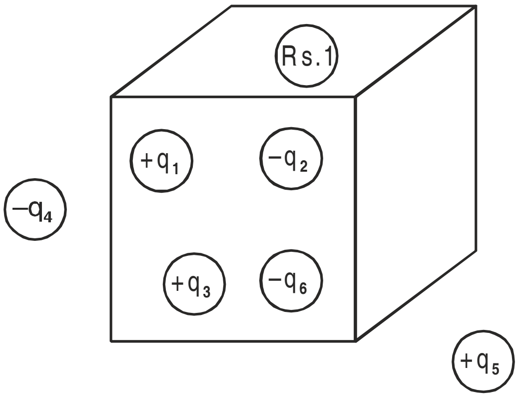

All capacitance given in micro farad

**Ans. :** 2 μF

## HOTS

### VERY SHORT ANSWER QUESTIONS (I MARK)

1. Figure shows five charged lumps of plastic and an electrically neutral coin. The cross-section of a Gaussian surface S is indicated. What is the net electric flux through the surface?




2. Without referring to the formula $C = \in_0 A/d$. Explain why the capacitance of a parallel plate capacitor reduce on increasing the separation between the plates?

3. Draw field lines to show the position of null point for two charges $+Q_1$ and $-Q_2$ when magnitude of $Q_1 > Q_2$ and mark the position of null point.

## SHORT ANSWER QUESTIONS (2 Marks)

4. In charging a capacitor of capacitance C by a source of emf V, energy supplied by the sources QV and the energy stored in the capacitor is ½QV. Justify the difference.

5. An electric dipole of dipole moment p, is held perpendicular to an electric field; (i) $p = E_0\ \mathbf{i}$ (ii) $E = E_0 \times \mathbf{i}$. If the dipole is released does it have (a) only rotational motion (b) only translatory motion (c) both translatory and rotatory motion?

6. The net charge of a system is zero. Will the electric field intensity due to this system also be zero.

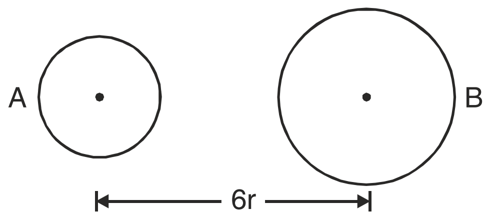
7. A point charge Q is kept at the intersection of (i) face diagonals (ii) diagonals of a cube of side a. What is the electric flux linked with the cube in (i) and (ii)?

8. There are two large parallel metallic plates S1 and S2 carrying surface charge densities $\sigma_1$ and $\sigma_2$ respectively ($\sigma_1 > \sigma_2$) placed at a distance d apart in vacuum. Find the work done by the electric field in moving a point charge q a distance a (a < d) from S1 and S2 along a line making an angle $\pi/4$ with the normal to the plates.

## SHORT ANSWER QUESTIONS (3 Marks)

9. If a charge Q is given to the parallel plates of a capacitor and E is the electric field between the plates of the capacitor the force on each plate is 1/2QE and if charge Q is placed between the plates experiences a force equal to QE. Give reasons to explain the above.

10. Two metal spheres A and B of radius r and 2r whose centres are separated by a distance of 6r are given charge Q, are at potential V1 and V2. Find the ratio of V1/V2. These spheres are connected to each other with the help of a connecting wire keeping the separation unchanged, what is the amount of charge that will flow through the wire?



## NUMERICALS

11. A pendulum bob of mass 80 mg and carrying charge of $3 \times 10^{-8}$ C is placed in an horizontal electric field. It comes to equilibrium position at an angle of 370 with the vertical. Calculate the intensity of electric field. (g = 10m/s$^2$) $(2 \times 10^4$ N/C)

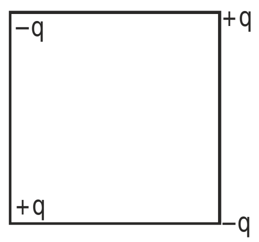
12. Eight charged water droplets each of radius 1 mm and charge $10 \times 10^{-10}$C coalesce to form a single drop. Calculate the potential of the bigger drop. (3600 V)

13. What potential difference must be applied to produce an electric field that can accelerate an electron to 1/10 of velocity of light. $(2.6 \times 10^3$ V)

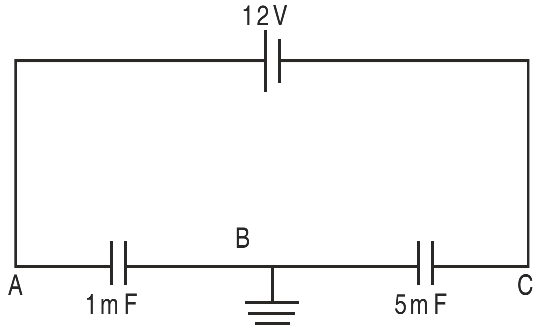
14. A 10 μF capacitor can withstand a maximum voltage of 100 V across it, whereas another 20 μF capacitor can withstand a maximum voltage of only 25 V. What is the maximum voltage that can be put across their series combination? (75V)

15. Three concentric spherical metallic shells A < B < C of radii a, b, c (a < b < c) have surface densities σ, –σ and σ respectively. Find the potential of three shells A, B and (ii). If shells A and C are at the same potential obtain relation between a, b, c.

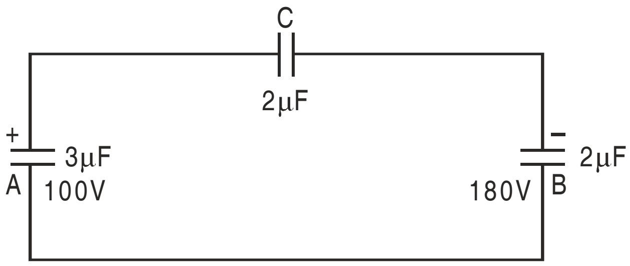
16. Four point charges are placed at the corners of the square of edge a as shown in the figure. Find the work done in disassembling the system of charges. $\left[\frac{kq^2}{a}\left(\sqrt{2}-4\right)\right]$ J



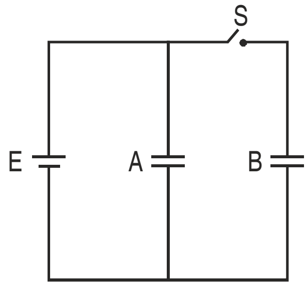

17. Find the potential at A and C in the following circuit :




18. Two capacitors A and B with capacitances 3 μF and 2 μF are charged 100 V and 180 V respectively. The capacitors are connected as shown in the diagram with the uncharged capacitor C. Calculate the (i) final charge on the three capacitors (ii) amount of electrostatic energy stored in the system before and after the completion of the circuit.




19. Two identical parallel plate capacitors connected to a battery with the switch S closed. The switch is now opened and the free space between the plates of the capacitors is filled with dielectric of dielectric constant 3. Find the ratio of the total electrostatic energy stored in both capacitors before and after the introduction of dielectric.

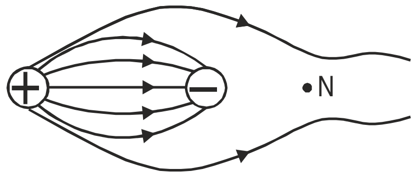



# ANSWERS OF HOTS

## 1 MARK QUESTIONS

1. $(q_1 + q_3 + q_2 - q_6)/\in_0$

3.




## 2 MARKS QUESTIONS

4. In the capacitor the voltage increases from O to V, hence energy stored will correspond to average which will be ½ QV. While the source is at constant emf V. So energy supplied will be QV. The difference between the two goes as heat and em radiations.

7. Construct a closed system such that charge is enclosed within it. For the charge on one face, we need to have two cubes place such that charge is on the common face. According to Gauss's theorem total flux through the gaussian surface (both cubes) is equal to $\frac{q}{\varepsilon_0}$. Therefore the flux through one cube will be equal to $\frac{q}{2\varepsilon_0}$.

8. Work done = fd cos θ = qEd cos θ = $\dfrac{q(\sigma_1 - \sigma_2)}{\varepsilon_0}\dfrac{a}{\sqrt{2}}$

## 3 MARKS QUESTIONS

9. If E′ be the electric field due to each plate (of large dimensions) then net electric field between them

$$E = E' + E' \Rightarrow E' = E/2$$

Force on change Q at some point between the plates F = QE

Force on one plate of the capacitor due to another plate F′ = QE′ = Q E/2

10.
$$V_1 = \frac{kq}{r} + \frac{kq}{6r} = \frac{7kq}{6r}$$

$$V_2 = \frac{kq}{2r} + \frac{kq}{6r} = \frac{3kq + kq}{6r} = \frac{4kq}{6r}$$

$$\frac{V_1}{V_2} = \frac{7}{4}$$

$$V_{common} = \frac{2q}{4\pi\varepsilon_0(r + 2r)} = \frac{2q}{12\pi\varepsilon_0 r} = V'$$

Charge transferred equal to

$$q' = C_1V_1 - C_1V' = \frac{r}{k}.\frac{kq}{r} - \frac{r}{k}.\frac{k_2q}{3r}$$

$$= q - \frac{2q}{3} = \frac{q}{3}.$$

# NUMERICALS

15.
$$V_A = k\left[\frac{q_1}{a} + \frac{q_2}{b} + \frac{q_3}{c}\right]$$

$$= k\,4\pi a\sigma - k\,4\pi b\sigma + k\,4\pi c\sigma$$

$$= 4\pi a\sigma\,(a - b + c)$$

$$= \frac{\sigma}{\varepsilon_0}(a - b + c)$$

$$V_B = k\left[\frac{q_1}{b} + \frac{q_2}{b} + \frac{q_3}{c}\right] = k\left[\frac{4\pi a^2\sigma}{b} - 4\pi kb\sigma + 4\pi kc\sigma\right]$$

$$= \frac{\sigma}{\varepsilon_0}\left(\frac{a^2}{b} - b^2 + c^2\right)$$

$$V_C = \frac{\sigma}{\varepsilon_0 c}\left(a^2 - b^2 + c^2\right)$$

When $V_A = V_C$

$$\frac{\sigma}{\varepsilon_0}(a - b + c) = \frac{\sigma}{\varepsilon_0 C}\left(a^2 - b^2 + c^2\right)$$

$$ac - bc + c^2 = a^2 - b^2 + c^2$$

$$c\,(a - b) = (a - b)\,(a + b)$$

$$c = a + b.$$

17. $Q = CV$

Total charge $Q$ = Total capacitance in series × voltage

$$= \left(\frac{5}{6} \times 10^{-3}\right) \times 12 = 10 \times 10^{-3}\text{coulomb}$$

$$V_{AB} = \frac{Q}{c_1} = \frac{10 \times 10^{-3}}{1 \times 10^{-3}} = 10V$$

$$V_{BC} = \frac{Q}{c_2} = \frac{10 \times 10^{-3}}{5 \times 10^{-3}} = 2V.$$

When B is earthed $V_B = 0$, $V_A = 10$V and $V_C = -2$V.

19. Before dielectric is introduced.

$$E_A = \frac{1}{2}CV^2; \qquad E_B = \frac{1}{2}CV^2$$

$$E = E_A + E_B = CV^2$$

After disconnecting the battery and then introducing dielectric

$$E'_A = \frac{1}{2}(3C)\,V^2$$

$$E'_B = \frac{Q^2}{2C} = \frac{(CV)^2}{2 \times 3C} = \frac{1}{3}\left(\frac{1}{2}CV^2\right), \quad E' = E'_A + E'_B$$

$$\frac{E'}{E} = \frac{5}{3}.$$

# UNIT II

# CURRENT ELECTRICITY

***Weightage : 07 Marks***

## TOPICS TO BE COVERED

Electric current; flow of electric charges in a metllic conductor, drift velocity, mobility and their relation with electric current. Ohm's law electrical resistance, V-I characteristics (linear and non-linear)

Electrical energy and power, Electrical resistivity and connectivity, carbon resistors, colour code for carbon resistors; Series and parallel combinations of resistors; temperature dependence of resistance.

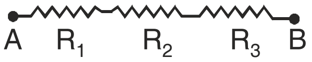
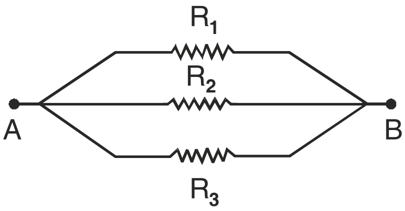
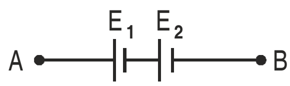
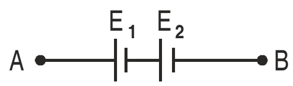
Internal resistance of a cell, potential difference and emf of a cell. Combination of cells in series and in parallel.

Kirchhoff's laws and simple applications, wheatstone bridge, metre bridge.

Potentiometer-principle and its applications to measure potential difference and for comparing emf of two cells, measurement of internal resistance of a cell.

## CURRENT ELECTRICITY IMPORTANT FORMULA

| | | | |
|---|---|---|---|
| 1. | Drift Velocity | $\vec{V}_d = -\frac{e\vec{E}}{m}\tau$ | $\vec{E}$ – electric fuld<br>$\tau$ = Relaxation time |
| 2. | Relation b/w current and Drift Velocity | $I = enAV_d$ | e = charge on electrons<br>m = mass of electron<br>n = number density of electrons |
| 3. | Ohm's Law | V = RI | A = cross Section Area |
| 4. | Resistance | $R = \frac{\rho l}{A}$ | V = potential difference across conductor |

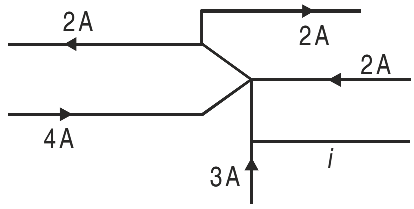
| | | | |
|---|---|---|---|
| 5. | Specific Resistance or Resistivity | $\rho = \frac{RA}{\rho} = \frac{m}{ne^2\tau}$ | l = length of conductor |
| 6. | Current density | $j = I/A = neV_d$ | |
| 7. | Electrical Conductivity | $\sigma = 1/\rho$ | |
| 8. | Resistances in | | |
| | Series | $R_{eq} = R_1 + R_2 + R_3$ |   |
| | Parallel | $\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}$ |   |
| 9. | Temperature Dependance of Resistance | $R_t = R_o(1 + \alpha t)$ | |
| 10. | Internal Resistance of a cell | $r = \left(\frac{E}{V} - 1\right)R$ | |
| 11. | Power | $P = VI = I^2R = \frac{V^2}{R}$ | |
| 12. | Cells in Series | $Eeq = E_1 + E_1$ |   |
| | Equivalent emf | $Eeq = E_1 - E_1$ | $E_1 > E_2$   |
| | Equivalent Internal Resistance | $req = r_1 + r_2$ | E1 & E2 are emf of two cells $r_1$ and $r_2$ are their internal resistances respectively |
| | Equivalent Current | $I = \frac{nE}{R + nr}$ | n = no. of cells in series. |
| 13. | Cells in parallel | Equivalent e.m.f $E_{eq} = \frac{E_1 r_2 + E_2 r_1}{r_1 + r_2}$ | |
| | | Equivalent resistance $r_{eq} = \frac{r_1 r_2}{r_1 + r_2}$ | |

| | | | |
|---|---|---|---|
| | Equivalent Current | $I=\frac{mE}{mR+r}$ | m = number of cells in parallel |
| 14. | Kirchoff's Laws | $\Sigma i$ = o (at a junction)<br>$\Sigma iR = \Sigma E$ (in a closed loop) | i = Current<br>R = Resistance<br>E = e.m.f. |
| 15. | Wheatstone Bridge | $\frac{P}{Q}=\frac{R}{S}$ | P,Q,R and S are resistances in Ohm in four arms of Wheatstone Bridge. |
| 16. | Slide wire Bridge or metre Bridge | $S=\left(\frac{100-l}{l}\right)R$ | |
| 17. | Potentiometer | | |
| | Comparison of Emf | $\frac{E_1}{E_2}=\frac{l_1}{l_2}$ | $l_1$ and $l_2$ are balancing lengths on polentiometer wire for cells $E_1$ and $E_2$ |
| | Internal Resistance | $r=\left(\frac{l_1-l_2}{l_2}\right)R$<br>$=\left(\frac{E}{V}-1\right)R$ | $l_1$ and $l_2$ are balancing lengths on polentiometer wire in open circuit and closed circuit. |

## QUESTIONS

### VERY SHORT ANSWER QUESTIONS (I Mark)

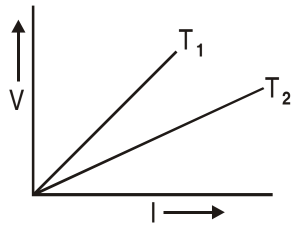
1. How does the relaxation time of electron in the conductor change when temperature of the conductor decreases.
2. Sketch a graph showing variation of resistivity with temperature of (i) Copper (ii) Carbon.
3. The emf of the driver cell (Auxillary battery) in the potentiometer experiment should be greater than emf of the cell to be determined. Why?
4. You are required to select a carbon resistor of resistance 47kΩ ± 10% from a large collection. What should be the sequence of color bands used to code it?
5. The fig. here shows a part of a circuit. What are the magnitude and direction of the current *i* in the lower right-hand wire? (8 Amp)



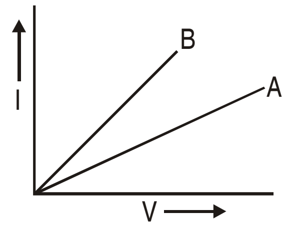

6. Two wire one of copper and other of manganin have same resistance and equal length. Which wire is thicker?

7. You are given three constantan wires P, Q and R of length and area of cross-section (*L, A*), $\left(2L, \frac{A}{2}\right), \left(\frac{L}{2}, 2A\right)$ respectively. Which has highest resistance?

8. V – I graph for a metallic wire at two different temperatures $T_1$ and $T_2$ is as shown in the figure. Which of the two temperatures is higher and why?




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

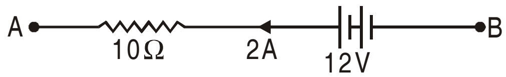



10. Why is the potentiometer preferred to a voltmeter for measuring emf of a cell?

11. How can a given 4 wires potentiometer be made more sensitive?

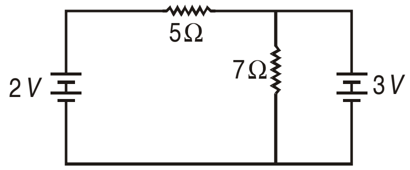
12. Why is copper not used for making potentiometer wires?

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

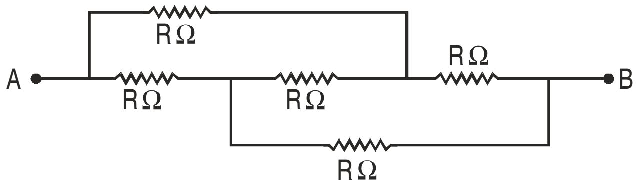



14. A copper wire of resistance R is uniformally stretched till its length is increased to n times its original length. What will be its new resistance?

15. Two resistances 5Ω and 7Ω are joined as shown to two batteries of emf 2V and 3V. If the 3V battery is short circuited. What will be the current through 5Ω?




16. Calculate the equivalent resistance between points A and B in the figure given below.




17. What is the largest voltage that can be safely put across a resistor marked 196Ω, 1W?

18. When does the terminal voltage of a cell become (i) greater than its emf (ii) less than its emf?

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

20. Two electric lamps A and B marked 220V, 100W and 220V, 60W respectively. Which of the two lamps has higher resistance?

21. Constantan is used for making the standard resistance. Why?

22. A 16Ω thick wire is stretched so that its length becomes two times. Assuming there is no change in density on stretching. Calculate the resistance of new wire.

23. State the Condition under which the terminal potential difference across a battery and its emf are equal.

24. State the Condition for max current to be drawn from the Cell.

25. Name the physical quantity measured by potential gradient.

## SHORT ANSWER QUESTIONS (2 Marks)

1. Define mobility of electron in a conductor. How does electron mobility change when (i) temperature of conductor is decreased (ii) Applied potential difference is doubled at constant temperature?

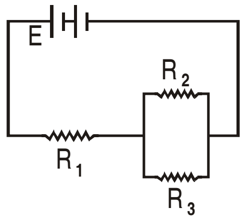
2. On what factor does potential gradient of a potentiometer wire depend?

3. What are superconductors? Give one of their applications.

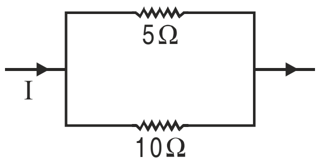
4. Two manganin wires whose lengths are in the ratio 1 : 2 and whose resistances are in the ratio 1 : 2 are connected in series with a battery. What will be the ratio of drift velocities of free electrons in the two wires?

5. The current through a wire depends on time as $i = i_0 + at$ where $i_0$ = 4A and $a$ = 2As$^{-1}$. Find the charge crossing a section of wire in 10 seconds.

6. Three identical resistors $R_1$, $R_2$ and $R_3$ are connected to a battery as shown in the figure. What will be the ratio of voltages across $R_1$ and $R_2$. Support your answer with calculations. (2:1)




7. In the arrangement of resistors shown, what fraction of current I will pass through 5Ω resistor? $\left(\frac{2I}{3}\right)$

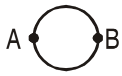



8. A 100W and a 200 W domestic bulbs joined in series are connected to the mains. Which bulb will glow more brightly? Justify. (100W)

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

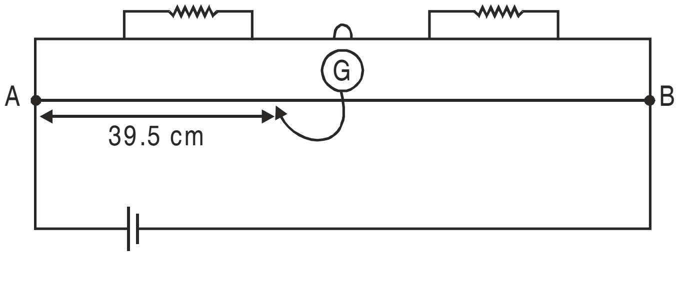
10. A battery has an emf of 12V and an internal resistance of 2Ω. Calculate the potential difference between the terminal of cell if (a) current is drawn from the battery (b) battery is charged by an external source.

11. A uniform wire of resistance R ohm is bent into a circular loop as shown in the figure. Compute effective resistance between diametrically opposite points A and B. [**Ans.** R/4]




12. In a potentiometer arrangement, a cell of emf 1.25V gives a balance point at 35 cm length of the wire. If the cell is replaced by another cell, then the balance point shifts to 63 cm. What is the emf of the second cell? [**Ans.** 2.25V]

13. In a meter bridge, the balance point is found to be 39.5 cm from end A. The known resistance Y is 12.5Ω. Determine unknown resistance X. [**Ans.** 8.16Ω]



14. A meterbridge is in balance condition. Now if galvanometer and cell are interchanged, the galvanometer shows no deflection. Give reason.

[**Ans.** Galvanometer will show no deflection. Proportionality of the arms are retained as the galvanometer and cell are interchanged.]

15. If the emf of the driving cell be decreased. What will be effect on the position of zero deflection in a potentiometer.

16. Why should the area of cross section of the meter bridge wire be uniform? Explain.

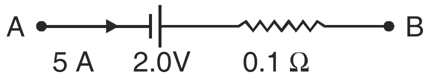
17. Given any two limitations of Qhm's law.

18. Which one of the two, an ammeter or a milliammeter has a higher resistance and why?

19. Name two factors on which the resistivity of a given material depends? A carbon resistor has a value of 62kΩ with a tolerance of 5%. Give the colour code for the resistor.

20. If the electron drift speed is so small ($\sim 10^{-3}$ m/s) and the electron's charge is very small, how can we still obtain a large amount of current in a conductor

21. A battery of emf 2.0 volts and internal Resistance 0.1Ω is being charged with a current of 5.0A. What is the potential difference between the terminals of the battery?




22. Why should the jockey be not rubbed against potentiometer wire?

23. What is meant by the sensitivity of a potentiometer of any given length?

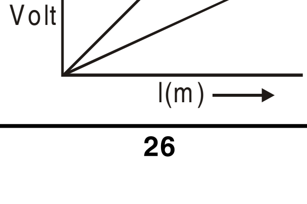
## SHORT ANSWER QUESTIONS (3 Marks)

1. Define specific resistance. Write its SI unit. Derive an expression for resistivity of a wire in terms of its material's parameters, number density of free electrons and relaxation time.

2. A potential difference V is applied across a conductor of length L and diameter D. How are the electric field E and the resistance R of the conductor affected when (i) V is halved (ii) L is halved (iii) D is doubled. Justify your answer.

*3. Define drift velocity. A conductor of length L is connected to a dc source of emf E. If the length of conductor is tripled by stretching it, keeping E constant, explain how do the following factors would vary in the conductor? (i) Drift speed of electrons (ii) Resistance and (iii) Resistivity.

4. Define potential gradient. How can potential gradient of a potentiometer be determined experimentally. In the graph shown here, a plot of potential drop versus length of the potentiometer is made for two potentiometers. Which is more sensitive –A or B?

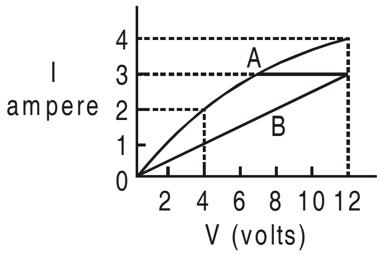


*5. Define conductivity of a substance. Give its SI units. How does it vary with temperature for (i) Copper (ii) Silicon?

*6. State the principle of potentiometer. Draw a circuit diagram used to compare the emf of two primary cells. Write the formula used.

7. The graph shows how the current I varies with applied potential difference V across a 12 V filament lamp (A) and across one metre long nichrome wire (B). Using the graph, find the ratio of the values of the resistance of filament lamp to the nichrome wire

   (i) when potential difference across them is 12 V.




   (ii) when potential difference across them is 4V. Give reason for the change in ratio of resistances in (i) and (ii).

8. Electron drift speed is estimated to be only a few mm/s for currents in the range of few amperes? How then is current established almost the instant a circuit is closed.

9. Give three points of difference between e.m.f and terminal potential difference of a cell.

10. Define the terms resistivity and conductivity and state their S.I. units. Draw a graph showing the variation of resistivity with temperature for a typical semiconductor.

11. The current flowing through a conductor is 2mA at 50V and 3mA at 60V. Is it an ohmic or non-ohmic conductor? Give reason.

12. Nichrome and copper wires of same length and area of cross section are connected in series, current is passed through them why does the nichrome wire get heated first?

13. Under what conditions is the heat produced in an electric circuit:

   (i) directly proportional

   (ii) inversely proportional to the resistance of the circuit

## LONG ANSWER QUESTIONS (5 Marks)

1. State Kirchhoff's rules for electrical networks. Use them to explain the principle of Wheatstone bridge for determining an unknown resistance. How is it realized in actual practice in the laboratory? State the formula used.

2. Define emf and terminal potential difference of a cell. When is the terminal charging potential difference greater than emf? Explain how emf and terminal potential difference can be compared using a potentiometer and hence determine internal resistance of the cell.

3. For three cells of emf $E_1$, $E_2$ and $E_3$ with internal resistances $r_1$, $r_2$, $r_3$ respectively connected in parallel, obtain an expression for net internal resistance and effective current. What would be the maximum current possible if the emf of each cell is E and internal resistance is *r* each?

4. Derive an expression for drift velocity of the electron in conductor. Hence deduce ohm's law.

5. State the principle of potentiometer. How can it be used to :

   (i) Compare e.m.f of two cells

   (ii) Measure internal resistance of a cell?

6. Explain how does the conductivity of a :

   (i) Metallic conductor

   (ii) Semi conductor and

   (iii) Insulator varies with the rise of temperature.

7. Derive expression for equivalent e.m.f and equivalent resistance of a :

   (a) Series combination

   (b) Parallel combination

   of three cells with e.m.f $E_1$, $E_2$, $E_3$ & internal resistances $r_1$, $r_2$, $r_3$ respectively.

8. Deduce the condition for balance in a Wheatstone bridge. Using the principle of Wheatstone bridge, describe the method to determine the specific resistance of a wire in the laboratory. Draw the circuit diagram and write the formula used. Write any two important precautions you would observe while performing the experiment.

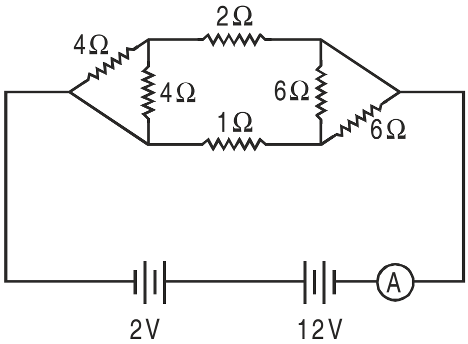
## NUMERICALS

1. The charge passing through a conductor is a function of time and is given as $q = 2t^2 - 4t + 3$ milli coulomb. Calculate (i) Current through the conductor (ii) Potential difference across it at $t = 4$ second. Given resistance of conductor is 4 ohm. [**Ans. :** I = 12A, V = 48 V]

2. The resistance of a platinum wire at a point 0°C is 5.00 ohm and its resistance at steam point is 5.40Ω. When the wire is immersed in a hot oil bath, the resistance becomes 5.80Ω. Calculate the temperature of the oil bath and temperature coefficient of resistance of platinum. [**Ans. :** a = 0.004°C; T = 200°C]

3. Three identical cells, each of emf 2V and internal resistance 0.2 ohm, are connected in series to an external resistor of 7.4 ohm. Calculate the current in the circuit and the terminal potential difference across an equivalent cell. [**Ans. :** I = 0.75; V = 5.55 V]

4. Calculate the equivalent resistance and current shown by the ammeter in the circuit diagram given. [**Ans. :** R = 2Ω; I = 5A]




5. A storage battery of emf 12V and internal resistance of 1.5Ω is being charged by a 12V dc supply. How much resistance is to be put in series for charging the battery safely, by maintaining a constant charging current of 6A. [**Ans. :** R = 16.5Ω]

6. Three cell are connected in parallel, with their like poles connected together, with wires of negligible resistance. If the emf of the cell are 2V, 1V and 4 V and if their internal resistance are 4Ω, 3Ω and 2 ohm respectively, find the current through each cell.

$$\left[\textbf{Ans. :}\ I_1 = \frac{-2}{13}A,\ I_2 = \frac{-7}{13}A,\ I_3 = \frac{9}{13}A\right]$$

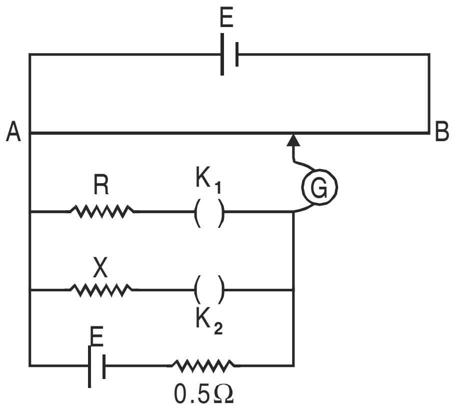
7. A 16 ohm resistance wire is bent to form a square. A source of emf 9 volt is connected across one of its sides. Calculate the potential difference across any one of its diagonals. [**Ans. :** 1V]

8. A length of uniform 'heating wire' made of nichrome has a resistance 72Ω. At what rate is the energy dissipated if a potential difference of 120V is applied across (a) full length of wire (b) half the length of wire (wire is cut into two). Why is it is not advisable to use the half length of wire?

   [**Ans. :** (a) 200W (b) 400W. 400W >> 200W but since current becomes large so it is not advisable to use half the length]

9. With a certain unknown resistance X in the left gap and a resistance of 8Ω in the right gap, null point is obtained on the metre bridge wire. On putting another 8Ω in parallel with 8Ω resistance in the right gap, the null point is found to shift by 15cm. Find the value of X from these observations. [**Ans. :** 8/3Ω]

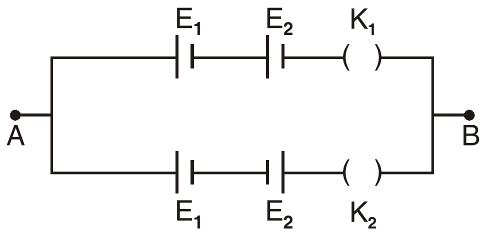
10. Figure show a potentiometer circuit for comparison of two resistances. The balance point with a standard resistance R = 10W is found to be 160 cm. While that with the unknown resistance X is 134.4 cm. Determine the value of X. [**Ans. :** 2Ω]



11. Two cells of E.M.F. $E_1$ and $E_2$ ($E_1 > E_2$) are connected as shown in figure. Potentiometer is connected between points A and B. Calculate the ratio of $E_1$ and $E_2$ when

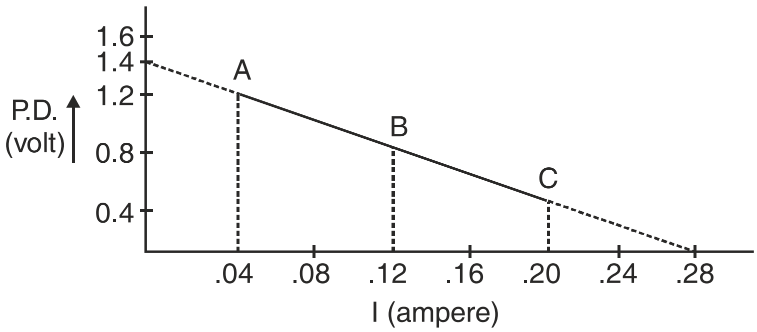
(a) $K_1$ is closed and $K_2$ is open

(b) $K_1$ is open and $K_2$ is closed **[Ans. :** 2:1]




12. Potential difference across terminals of a cell are measured (in volt) against different current (in ampere) flowing through the cell. A graph was drawn which was a straight line ABC. Using the data given in the graph, determine (i) the emf. (ii) The internal resistance of the cell.

[**Ans. :** $r$ = 5Ω emf = 1.4V]

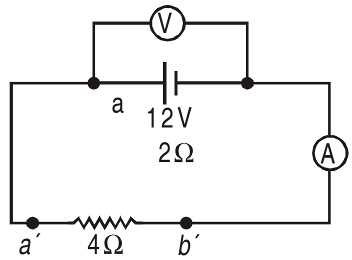



13. Four cells each of internal resistance 0.8Ω and emf 1.4V, *d* are connected (i) in series (ii) in parallel. The terminals of the battery are joined to the lamp of resistance 10Ω. Find the current through the lamp and each cell in both the cases.

[**Ans. :** Is = 0.424A, Ip = 0.137A current through each cell is 0.03A]

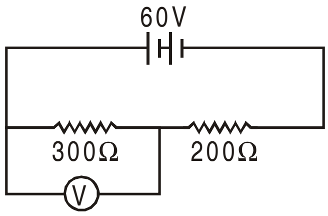
14. In the figure an ammeter A and a resistor of resistance $R$ = 4Ω have been connected to the terminals of the source to form a complete circuit. The emf of the source is 12V having an internal resistance of 2Ω. Calculate voltmeter and ammeter reading.

[**Ans. :** Voltmeter reading : 8V, Ammeter reading = 2A]

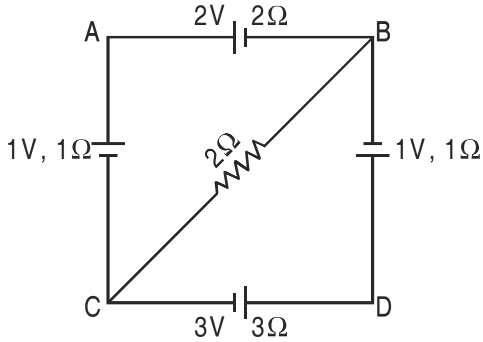



15. In the circuit shown, the reading of voltmeter is 20V. Calculate resistance of voltmeter. What will be the reading of voltmeter if this is put across 200Ω resistance?

$\left[\textbf{Ans. :}\ R_V = 150\Omega; \quad V = \frac{40}{3} V\right]$

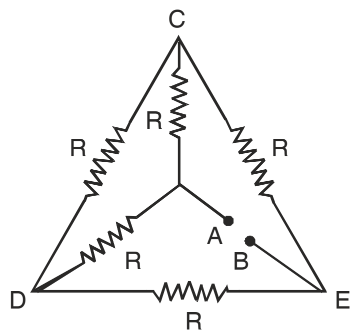



16. For the circuit given below, find the potential difference b/w points B and D. [**Ans. :** 1.46 Volts]

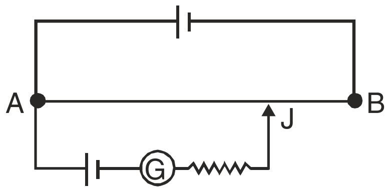



17. (i) Calculate Equivalent Resistance of the given electrical network b/w points A and B.

    (ii) Also calculate the current thru CD & ACB if a 10V d.c source is connected b/w point A and B and the value of R = 2Ω




18. A potentiometer wire AB of length 1m is connected to a driver cell of emf 3V as shown in figure. When a cell of emf 1.5V is used in the secondary circuit, the balance point is found to be 60 cm. On replacing this cell by a cell of unknown emf, the balance point shifts to 80cm :



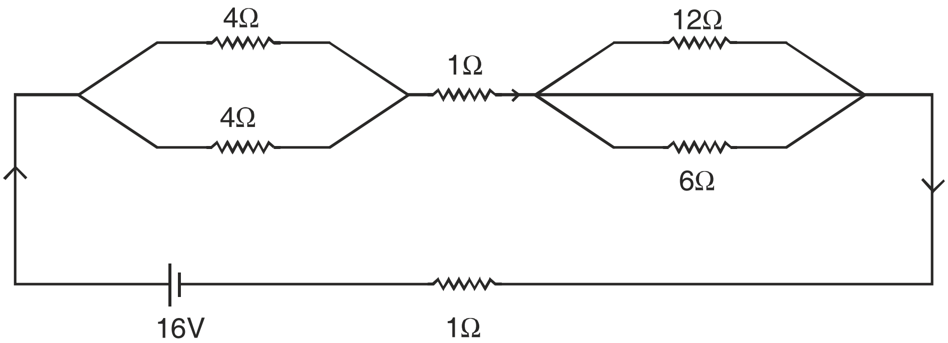

    (i) Calculate unknown emf of the Cell.

    (ii) Explain with reason, whether the circuit works if the driver cell is replaced with a cell of emf IV.

(iii) Does the high resistance R, used in the secondary circuit affect the balance point? Justify your answer.

19. A battery of emf 10V and internal resistance 3Ω is connected to a resistor. If the current in the circuit is 0.5A, what is the resistance of the resistor? What is the terminal voltage of the battery when the circuit is closed?

20. A network of resistances is connected to a 16V battery with internal resistance of 1Ω as shown



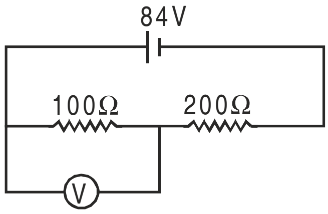

(i) Compute the Equivalent Resistance of the network.

(ii) Obtain the current in each resistor.

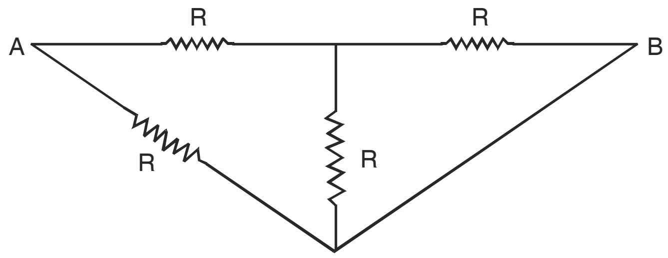
(iii) Obtain the voltage drop $V_{AB}$, $V_{BC}$ & $V_{CD}$.

21. The number density of conduction electrons in a Copper Conductor estimated to be 8.5 x $10^{28}$ $m^{-3}$. How long does an electron take to drift from one end of a wire 3.0m long to its other end? The area of cross section of the wire is 2.0 x $10^{-6}$ $m^2$ and it is carrying a current of 3.0 A.

22. A Voltmeter of resistance 400Ω is used to measure the potential difference across the 100Ω resistor in the circuit shown in figure. What will be the reading of voltmeter.




23. The Equivalent Resistance between points A and B of the adjoing circuit.



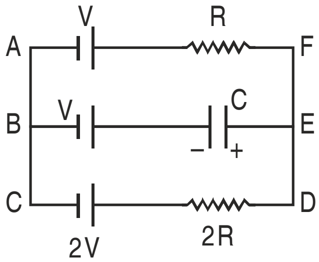
# HOTS

## SHORT ANSWER QUESTIONS (2 Marks)

1. Five identical cells, each of emf. E and internal resistance *r,* are connected in series to form (a) an open (b) closed circuit. If an ideal voltmeter is connected across three cells, what will be its reading? [**Ans. :** (a) 3E; (b) zero]

2. An electron in a hydrogen atom is considered to be revolving around a proton with a velocity $\frac{e^2}{n}$ in a circular orbit of radius $\frac{n^2}{me^2}$. If I is the equivalent current, express it in terms of m, e, n $\left(n = \frac{h}{2\pi}\right)$. $\left(\frac{me^5}{2\pi n^3}\right)$

3. In the given circuit, with steady current, calculate the potential drop across the capacitor in terms of V.




4. A cell of e.m.f. 'E' and internal resistance 'r' is connected across a variable resistor 'R'. Plot a graph showing the variation of terminal potential 'V' with resistance 'R'. Predict from the graph the condition under which 'V' becomes equal to 'E'.

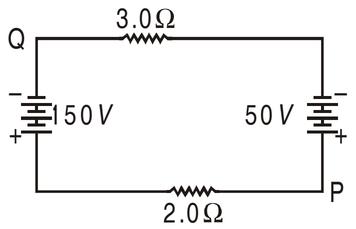
# NUMERICALS

1. A copper wire of length 3m and radius *r* is nickel plated till its radius becomes 2*r*. What would be the effective resistance of the wire, if specific resistance of copper and nickel are $\rho_c$ and $\rho_n$ respectively.

[**Hint. :** $P_c = P_e \frac{l}{\pi r^2}$; $R_n = \ln \frac{l}{\pi (2r)^2 - \pi r^2}$

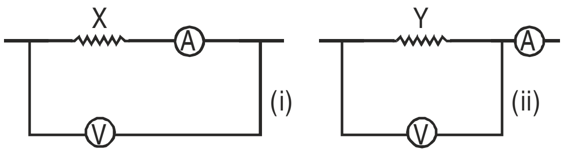
$R = \frac{R_C R_n}{R_C + R_n}$. $\left[\textbf{Ans. :} R = \frac{3\rho_n \rho_c}{\pi r^2 (3\rho_c + \rho_n)}\right]$

2. In the figure, if the potential at point P is 100V, what is the potential at point Q?




[**Ans.** : – 10V]

3. Given two resistors X and Y whose resistances are to be determined using an ammeter of resistance 0.5Ω and a voltmeter of resistance 20 kΩ. It is known that X is in the range of a few ohms, while Y is in the range of several thousand ohm. In each case, which of the two connection shown should be chosen for resistance measurement?



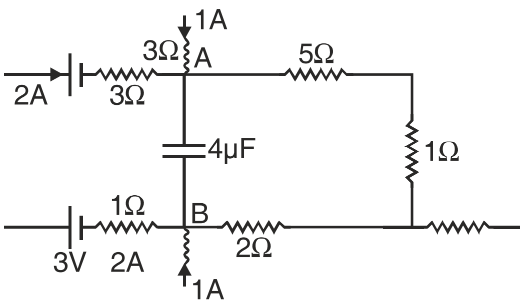

[**Ans.** : Small resistance : X will be preferred; large resistance : Y will be preferred]

4. When resistance of 2Ω is connected across the terminals of a battery, the current is 0.5A. When the resistance across the terminal is 5Ω, the current is 0.25A. (i) Determine the emf of the battery (ii) What will be current drawn from the cell when it is short circuited.

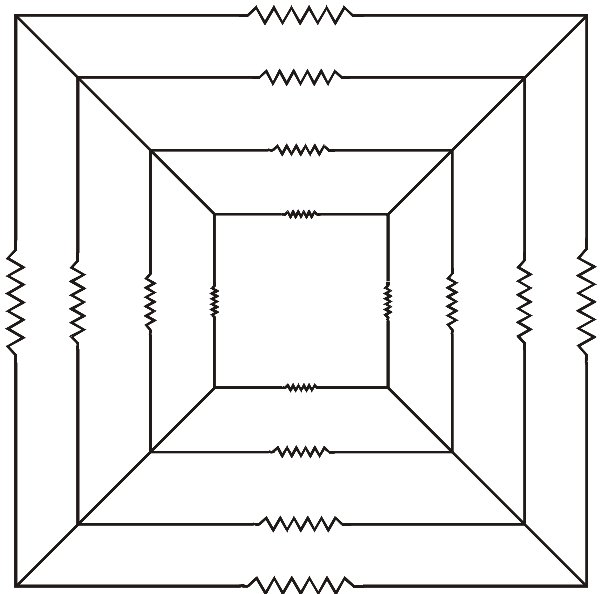
[**Ans.** : $E$ = 1.5V, I = 1.5A]

5. A part of a circuit in steady state, along with the currents flowing in the branches and the resistances, is shown in the figure. Calculate energy stored in the capacitor of 4μF capacitance.

[**Ans.** : $V_{AB}$ = 20V, U = 8 × $10^{-4}$ J]




*6. Sixteen resistors each of resistance 16Ω are connected in circuit as shown. Calculate the net resistance between A and B. [**Ans.** : 3Ω]



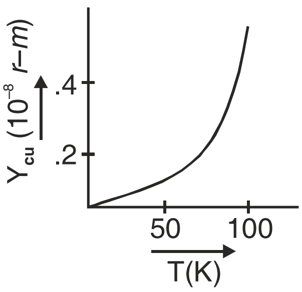

7. A voltmeter with resistance 500Ω is used to measure the emf of a cell of internal resistance 4Ω. What will be the percentage error in the reading of the voltmeter. [**Ans.:** 0.8%]

## ANSWERS

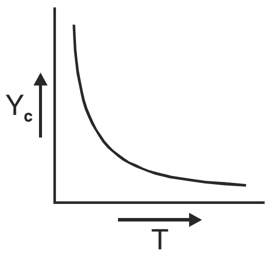
### I MARK QUESTIONS

1. Relaxation time increases.

2. 




For Copper




For Carbon

3. If emf of driver cell is less, then null point will not be obtained on the potentiometer wire.

4. Yellow, Violet, Orange, Silver.

5. 8 ampere.

6. $$R = \rho_c \frac{l_c}{a_c} = \rho_m \frac{l_m}{a_m}$$

$$\frac{\rho_c}{\rho_m} = \frac{a_c}{a_m} < 1$$

$\therefore$ managing in thicker.

7. $$R_p = \rho \frac{L}{A}, \; R_Q = \rho \frac{2L.2}{A} = \frac{4\rho L}{A}, \; R_R = \frac{\rho L}{4A}$$

Q has the highest resistance.

8. Slope of $T_1$ is large so $T_1$ represents higher temperature as resistance increase with temperature for a conductor; $R = \frac{V}{I}$ = slope.

9. The resistance for parallel combination is lesser than for series combination for a given set of resistors. Hence B will represent parallel combination since I/V for it is more *i.e.,* Resistance $= \frac{V}{I}$ is less.

10. Emf measured by potentiometer is more accurate because the cell is in open circuit, giving no current.

11. By connecting a resistance in series with the potentiometer wire in the primary circuit, the potential drop across the wire is reduced.

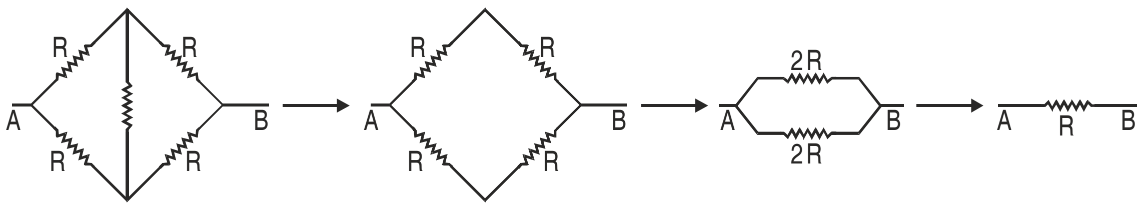
12. Copper has high temperature coefficient of resistance and hence not preferred.

13. $V_A - V_B = -8$ volt.

14. $R' = n^2$ R

15. $I = \frac{2}{5} A$

16.




$\therefore$ Req = R.

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

$V^2 = PR = 1 \times 196 = 196$

V = 14 volt.

18. (i) When the cell is being charged terminal potential difference becomes greater than emf; $V = E + Ir$.

(ii) When the cell is discharged terminal potential is lesser than emf; $V = E - Ir$.

19. Dry cells used in series will have high resistance (≈ 10Ω) and hence provide low current, while a car battery has low internal resistance (0.1Ω) and hence gives high current for the same emf, that is needed to start the car.

20. 220V, 60W lamp has higher resistance as $R = \frac{V^2}{P}$ and hence current reduces.

21. High resistivity and low temperature coefficient of resistance

22. $R = \rho\frac{\ell}{A} = \rho\frac{\ell^2}{Al} = \frac{\rho\ell^2}{V}$ ρ and V are constant

$\therefore$ R $\alpha l^2$ $\therefore$ $\frac{R_1}{R_2} = \left(\frac{\ell_1}{\ell_2}\right)^2$;

$$\frac{16}{R_2} = \left(\frac{\ell_1}{2\ell_2}\right)^2 \quad \therefore R_2 = 64\Omega$$

23. When battery is in open circuit *i.e.,* when no current is being drawn from the cell.

24. $I = \frac{E}{R+r}$ External resistance R should be zero, *i.e.,* for maximum current the terminals of a cell must be short circuited.

## 2 MARKS QUESTIONS

2. $I = \frac{\text{Charge circulating}}{\text{Time for one revolution}} = \frac{e}{3\pi r/v}$ v → speed

$$= \frac{e}{2\pi}\frac{e^2/\hbar}{\hbar/me^2} \qquad \hbar = \frac{h}{2\pi}$$

$$= \frac{m\,e^5}{2\pi\,\hbar^3}$$

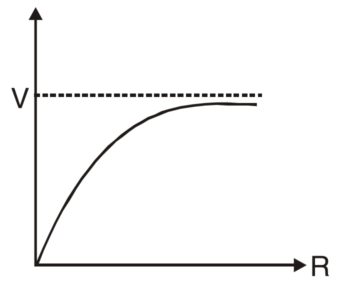
3. In steady state the branch containing C can be omitted hence the current

$$I = \frac{2V - V}{R + 2R} = \frac{V}{3R}$$

For loop EBCDE

$$-V_C - V + 2V - I(2R) = 0$$

$$\Rightarrow \qquad V_C = \frac{V}{3}$$




4. $V = IR = \dfrac{ER}{R + r} = \dfrac{E}{\dfrac{r}{R} + 1}$

When R approaches infinity V becomes equal to E (or for R $\to$ 00)

5. If e.m.f decreases $\Rightarrow \dfrac{V}{\ell}$ decreases $\therefore$ position of zero deflection increases.

6. Otherwise resistance per unit length of Bridge wire be different over different length of meter Bridge.

7. N.C.E.R.T page 101

8. Milliammeter. To produce large deflection due to small current we need a large number of turns we need a large number of turns in armature coil $\therefore$ Resistance increases.

9. Temperature, Material
Blue, Red, Orange Gold

10. The electron number density is of the order of $10^{29}$ $m^{-3}$. $\therefore$ the net current can be very high even if the drift spread is low.

11. V = E + ir

= 2 + 0.1 5

= 2.5 V

12. Affects the uniformity of the cross-section area of wire and hence changes the potential drop across wire.

13. A potentiometer is said to be sensitive if :

(i) It can measure very small potential differences.

(ii) For a small change in potential diff. being measured it shows large change in balancing length.

## 3 MARKS ANSWERS

11. $R_1 = \frac{V_1}{I_1} = \frac{50}{2 x 10^{-3}} = 25,000\Omega$

$R_2 = \frac{V_2}{I_2} = \frac{60}{3 x 10^{-3}} = 20,000\Omega$

As Resistance changes with I, therefore conductor is non ohmic.

12. Rate of Production of heat, P = $I^2R$, for given I, P x R, $\therefore \rho_{nichrome} > \rho_{cu}$

$\therefore$ $R_{Nichrome} > R_{cu}$ of same length and area of cross section.

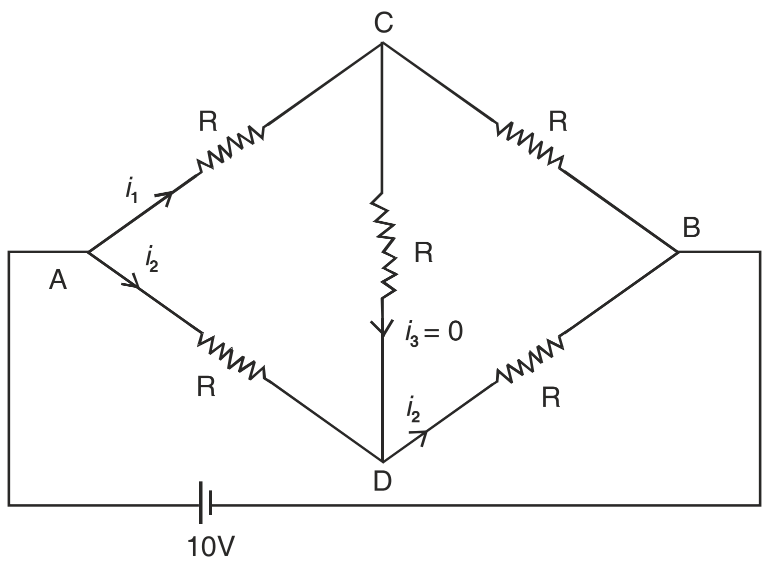
13. (i) If I in circuit is constant because H = $I^2$ Rt

(ii) If V in circuit is Constant because $H = \frac{V^2}{R} t$

17. $R_{AB}$ = 2Ω

$I_{CD}$ = 0

$I_{ACB} = \frac{V}{2R} = \frac{10}{2 \times 2} = 2.5A$




18. (i) $\frac{E_2}{E_1} = \frac{l_2}{l_1} \Rightarrow E_2 \frac{l_2}{l_1} E_1 = \frac{80}{60} \times 1.5 = 2.0V$

(ii) The Circuit will not work if emf of driven Cell is IV, \ total Vottage across AB is IV, which cannot balance the voltage 1.5V.

(iii) No, since at balance point no current flows through galvanometer G, *i.e.,* cell remains in open circuit.

19. E = I (R + r)
10 = 0.5 (R + 3)
R = 17Ω
V = E − Ir = 10 − 0.5 × 3 = 8.5V

20. Req = 7W

$I_{4\Omega}$ = 1A, $I_{1\Omega}$ = 2A, $I_{12\Omega} = \frac{2}{3}A$, $I_{6\Omega} = \frac{4}{3}A$, $V_{AB}$ = 4V, $V_{BC}$ = 2V, $V_{CD}$ = 8V

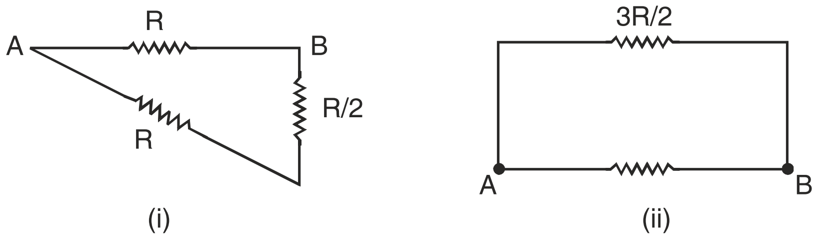
21. $I = enAV_d = enA\frac{\ell}{t}$

$t = \frac{enA\ell}{I} = 2.7 \times 10^4 s$

22. $I = \frac{84}{\left(\frac{100 \times 400}{100 + 400} + 200\right)} = \frac{84}{280} = 0.3A$

P.d across Voltmeter & 100Ω Combination

$= 0.3 \times \frac{100 \times 400}{100 + 400} = 24V$.




**Ans. :** (i) $R_{AB} = \frac{3}{5}R$ (ii) $R_{AB} = 3/5\,R$

## UNIT III

# MAGNETIC EFFECTS OF CURRENT AND MAGNETISM

***Weightage 8 Marks***

## TOPICS TO BE COVERED

Concept of magnetic field and Oersted's experiment Biot-savart law and its application to current carrying circular loop.

Ampere's law and its applications to infinitely long straight wire, straight and toroidal solenoids.

Force on a moving charge in uniform magnetic and electric fields.

**Cyclotron**

Force on a current carrying conductor in a uniform magnetic field, force between two parallel current carrying conductors, definition of ampere. Torque experienced by a current loop in a uniform magnetic field.

Moving coil Galvanometer – its current sensitivity.

Moving Coil Galvanometer – Conversion to ammeter and voltmeter, Current loop as a magnetic dipole and it's magnetic dipole moment, Magnetic dipole moment of a revolving electron, Magnetic field intensity due to a magnetic dipole (bar magnet) along it's axis and perpendicular to it's axis.

Torque on a magentic dipole (bar magnet) in a uniform magnetic field; bar magnet as an equivalent solenoid, Magnetic field lines Earth's Magnetic field and magnetic elements. Para-, dia- and ferro-magnetic substances with examples.

Electromagnets and factors affecting their strengths, Permanent magnets.

## KEY POINTS

| ***Physical Quantity*** | ***Formulae*** | ***SI Unit*** |
|---|---|---|
| Biot-Savart's Law | $d\vec{B} = \frac{\mu_0}{4\pi} \frac{I d\vec{l} \times \vec{r}}{r^3}$ | Tesla (T); |
| | $\lvert d\vec{B} \rvert = \frac{\mu_0}{4\pi} \frac{I dl \sin\theta}{r^2}$ | $10^4$ Gauss = 1T |

| | | |
|---|---|---|
| Magnetic field due to a straight current carrying conductor | $B=\frac{\mu_0 I}{2\pi R}$ | T |
| Magnetic field at the centre of a circular loop For *n* loops, | $B=\frac{\mu_0 I}{2a}$<br>$B=\frac{\mu_0 nI}{2a}$ | T |
| Magnetic Field at a Point on the Axis of a current carrying loop | $B=\frac{\mu_0 I}{4\pi}\frac{2\pi a^2}{(a^2+x^2)^{\frac{3}{2}}}$ | T |
| | When, x = 0, $B=\frac{\mu_0 I}{2a}$ | |
| | For a << x, $B = \frac{\mu_0 Ia^2}{2x^3}$ | |
| | For *n* loops, $B=\frac{\mu_0 nIa}{2x^3}$ | |
| Ampere's Circuital Law | $\oint \vec{B}.d\vec{l}=\mu_0 I$ | T – m |
| Magnetic field due to a long straight solenoid | $B=\mu_0 nI$ | T |
| | At the end of solenoid,<br>$B=\frac{1}{2}\mu_0 nI$<br>If solenoid is filled with material having magnetic permeability $\mu r$<br>$B = \mu_0\mu_r nI$ | |
| Magnetic field due to a toroidal solenoid | $B = \mu_0 n I$ | T |
| Motion of a charged partical inside electric field | $y=\frac{qE}{2m}\left(\frac{x}{v_x}\right)^2$ | m |
| Magnetic force on a moving charge | $\vec{F}=q(\vec{v}\times\vec{B})$ | N |
| | Or $F = B qv \sin\theta$ | |
| Lorentz Force (Electric and magnetic) | $\vec{F}=q\vec{E}+q(\vec{v}\times\vec{B})$ | N |

**The Cyclotron**

| | | |
|---|---|---|
| Radius of circular path | $r=\frac{mv}{qB}$ | |
| The period of circular motion | $T=\frac{2\pi m}{Bq}$ | |
| The cyclotron frequency | $\nu=\frac{1}{T}=\frac{Bq}{2\pi m}$ | |
| Maximum energy of the positive ions | $\frac{1}{2}mv^2{}_{max}=\frac{B^2q^2r^2}{2m}=qV$ | |
| The radius corresponding to maximum velocity | $r=\frac{1}{B}\left(\frac{2mV}{q}\right)^{\frac{1}{2}}$ | |
| The maximum velocity | $v_{max}=\frac{Bqr}{m}$ | |
| The radius of helical path when $\vec{V}$ and $\vec{B}$ are inclined to each other by an angle $\theta$ | $r=\frac{mv\sin\theta}{qB}$ | |
| Force on a current carrying conduct placed in a magnetic field | $I\,\vec{l}\times\vec{B}$ | N |
| Force per unit length between tow parallel current carrying conductors | $f=\frac{\mu_0}{4\pi}\frac{2I_1I_2}{r}$ | $Nm^{-1}$ |
| Magnetic dipole moment | $\vec{M}=I\vec{A}$ | $Am^2$ or $JT^{-1}$ |

Torque on a rectangular current carrying loop ABCD

$\tau$ = BIA cos $\theta$

$\theta \rightarrow$ angle between loop and magnetic field

$\vec{\tau}=\vec{M}\times\vec{B} \Rightarrow \tau = MB\sin\alpha$

If coil has $n$ turns, $\tau = n$ B I A sin $\alpha$

$\tau = n$ BIA sin $\alpha$;

$\tau = n$ BIA sin $\alpha$

$\alpha \rightarrow$ angle between notmal drawn on the plane of loop and magnetic field

| | | |
|---|---|---|
| Period of oscillation of bar magnet if external magnetic field | $T = 2\pi\sqrt{\frac{I}{MB}}$ | s |
| The potential energy associated with magnetic field | $U = \vec{M} \cdot \vec{B}$ | J |
| Current through a galvanometer $\phi \rightarrow$ angle by which the coil rotates | $I = \frac{k}{nBA}\phi = G\phi;$ $G \rightarrow$ galvanometer constant | A |
| Sensitivity of a galvanometer or | | |
| Current sensitivity | $\frac{\phi}{I} = \frac{nBA}{k} = \frac{1}{G}$ | rad $A^{-1}$ |
| Voltage sensitivity | $\frac{\theta}{V}, \frac{nBA}{KR} = \frac{1}{GR}$.......... | rad $V^{-11}$ |
| The current loop as a magnetic dipole | $B = \frac{\mu_0}{4\pi}\frac{2M}{x^3}$ | T |
| Gyromagnetic ratio | $\frac{\mu_e}{l} = \frac{e}{2m_e} = 8.8 \times 10^{10}\frac{C}{kg}$ | C $Kg^{-1}$ |
| Bohr magneton | $(\mu_e)_{min} = \frac{e}{4\pi\, m_e}h = 9.27 \times 10^{-24}$ | $Am^2$ |
| Magnetic dipole moment | $\vec{M} = m \times (2\vec{l})$ | $JT^{-1}$ or $Am^2$ |
| Magnetic field on axial line of a bar magnet | $B_{axial} = \frac{\mu_0}{4\pi}\left[\frac{2Mr}{(r^2 - l^2)^2}\right]$ | T |
| | When, $l << r$, $B_{axial} = \frac{\mu_0}{4\pi}\frac{2M}{r^3}$ | |
| Magnetic field on equatorial line of a bar magnet | $B_{eq} = \frac{\mu_0}{4\pi}\left[\frac{M}{(r^2 + l^2)^{\frac{3}{2}}}\right]$ | T |
| | When, $l << r$, $B_{eq} = \frac{\mu_0}{4\pi}\frac{M}{r^3}$ | |
| Gauss' Law in magnetism | $\oint_S \vec{B}.d\vec{S} = 0$ | $Tm^2$ or weber |

| | | |
|---|---|---|
| Magnetic inclination (or Dip) | $\tan\delta = \frac{B_V}{B_H}$, | $\delta \to$ angle of dip |
| Magnetic intensity (or Magnetic field strength) | $H = \frac{B_0}{\mu_0} = nI$<br>*n* is the no. of terms/length | $Am^{-1}$ |
| Intensity of magnetization | $I_m = \frac{M}{V}$ | $Am^{-1}$ |
| Magnetic flux | $\phi = \vec{B}.\Delta\vec{S}$ | Weber ($Tm^2$) |
| Magnetic induction (or Magnetic flux density or Magnetic field) | $B = B_0 + \mu_0 I_m$<br>$= \mu_0 (H + I_m)$ | T |
| Magnetic susceptibility | $\chi_m = \frac{I_m}{H}$ | — |
| Magnetic permeability | $\mu = \frac{B}{H}$ | $TmA^{-1}$<br>(or $NA^{-2}$) |
| Relative permeability ($\mu$) | $\frac{\mu}{\mu_0} = \mu_r = (1 + \chi_m)$ | — |
| Curie's Law | $\chi_m = \frac{C\mu_0}{T}$ | — |

# QUESTIONS

## VERY SHORT ANSWERS QUESTIONS (I Mark)

1. Must every magnetic field configuration have a north pole and a south pole? What about the field due to a toroid?
2. How are the figure of merit and current sensitivity of galvanometer related with each other?
3. Show graphically the variation of magnetic field due to a straight conductor of uniform cross-section of radius 'a' and carrying steady currently as a function of distance *r* (*a* > *r*) from the axis of the conductor.
4. The force per unit length between two parallel long current carrying conductor is F. If the current in each conductor is tripled, what would be the value of the force per unit length between them?
5. How does the angle of dip vary from equator to poles?
6. What is the effect on the current measuring range of a galvanometer when it is shunted?
7. An electric current flows in a horizontal wire from East to West. What will be the direction of magnetic field due to current at a point (i) North of wire; (ii) above the wire.

8. Suggest a method to shield a certain region of space from magnetic fields.

*9. Why the core of moving coil galvanometer is made of soft iron?

10. Where on the earth's surface, is the vertical component of earth's magnetic field zero?

11. If the current is increased by 1% in a moving coil galvanometer. What will be percentage increase in deflection?

12. Write S.I. unit of (i) Pole strength and (ii) Magnetic dipole moment.

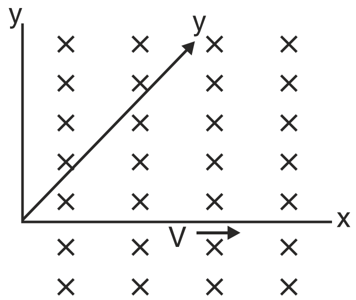
13. If the magnetic field is parallel to the positive y-axis and the charged particle is moving along the positive x-axis, which way would the Lorentz force be for (a) an electron (negative charge), (b) a proton (positive charge)

**Sol :** When velocity $(\vec{v})$ of positively charged particle is along x-axis and the magnetic field $(\vec{B})$ is along y-axis, so $\vec{v} \times \vec{B}$ is along the z-axis (Fleming's left hand rule).

Therefore,

(a) for electron Lorentz force will be along –z axis;

(b) for a positive charge (proton) the force is along +z axis.




14. If a toroid uses Bismuth as its core, will the field in the core be lesser or greater than when it is empty?

**Ans :** Bismuth is diamagnetic, hence, the overall magnetic field will be slightly less.

15. An electron beam projected along + x-axis, experiences a force due to a magnetic field along the + y-axis. What is the direction of the magnetic field?

**Ans :** +Z axis.

16. What is the principle of a moving coil galvanometer?

**Ans :** When a current carrying coil is placed in uniform magnetic field, it experiences a torque.

17. What is the direction of magnetic dipole moment?

**Ans :** S to N

18. What is the angle of dip at a place where vertical and horizontal component of earth's field are equal?

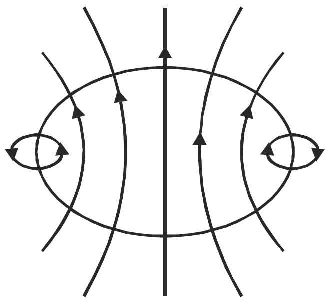
**Ans :** 45°

19. Is any work done on a moving charge by a magnetic field?

**Ans :** No, as magnetic field is in perpeudicular direction.

20. Sketch the magnetic field lines for a current carrying circular loop.

**Ans :**

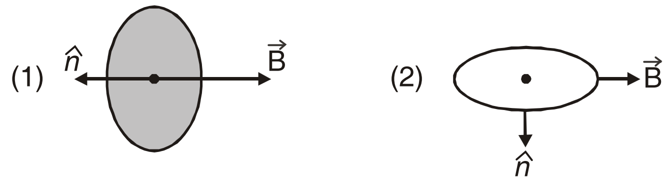


## SHORT ANSWERS QUESTIONS (2 MARKS)

1. Write the four measures that can be taken to increase the sensitivity of a galvanometer.

2. A galvanometer of resistance 120Ω gives full scale deflection for a current of 5mA. How can it be converted into an ammeter of range 0 to 5A? Also determine the net resistance of the ammeter.

3. A current loop is placed in a uniform magnetic field in the following orientations (1) and (2). Calculate the magnetic moment in each case.




4. A current of 10A flows through a semicircular wire of radius 2cm as shown in figure (a). What is direction and magnitude of the magnetic field at the centre of semicircle? Would your answer change if the wire were bent as shown in figure (b)?

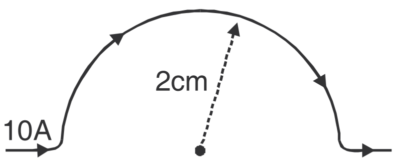


Fig. (a)

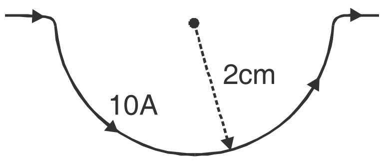


Fig. (b)

5. A proton and an alpha particle of the same enter, in turn, a region of uniform magnetic field acting perpendicular to their direction of motion. Deduce the ratio of the radii of the circular paths described by the proton and alpha particle.

6. Which one of the two an ammeter or milliammeter, has a higher resistance and why?

7. Mention two properties of soft iron due to which it is preferred for making electromagnet.

8. A magnetic dipole of magnetic moment M is kept in a magnetic field B. What is the minimum and maximum potential energy? Also give the most stable position and most unstable position of magnetic dipole.

9. What will be (i) Pole strength (ii) Magnetic moment of each of new piece of bar magnet if the magnet is cut into two equal pieces :

   (a) normal to its length?

   (b) along its length?

10. A steady current I flows along an infinitely long straight wire with circular cross-section of radius R. What will be the magnetic field outside and inside the wire at a point *r* distance far from the axis of wire?

11. A circular coil of *n* turns and radius R carries a current I. It is unwound and rewound to make another square coil of side 'a' keeping number of turns and current same. Calculate the ratio of magnetic moment of the new coil and the original coil.

12. A coil of N turns and radius R carries a current I. It is unwound and rewound to make another coil of radius R/2, current remaining the same. Calculate the ratio of the magnetic moment of the new coil and original coil.

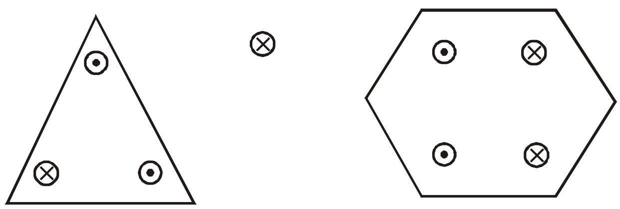
13. At a place horizontal component of the earths magnetic field is B and angle of dip at the place is 60°. What is the value of horizontal component of the earths magnetic field.

    (i) at Equator; (ii) at a place where dip angle is 30°

14. A galvanometer coil has a resistance G. 1% of the total current goes through the coil and rest through the shunt. What is the resistance of the shunt?

15. Prove that the magnetic moment of a hydrogen atom in its ground state is $eh/4\pi m$. Symbols have their usual meaning.

16. Each of eight conductors in figure carries 2A of current into or out of page. Two path are indicated for the line integral $\oint \vec{B} \cdot d\vec{l}$. What is the value of the integral for the path (a) and (b).



(a) (b)

17. What is the radius of the path of an electron (mass $9 \times 10^{-31}$ kg and charge $1.6 \times 10^{-19}$ C) moving at a speed of $3 \times 10^{7}$ m/s in a magnetic field of $6 \times 10^{-4}$ T perpendicular to it? What is its frequency? Calculate its energy in keV. (1 eV = $1.6 \times 10^{-19}$ J).

    **Sol :** Radius, r = mv/ (qB)

    $= 9.1 \times 10^{-31}\text{kg} \times 3 \times 10^{7}\ \text{ms}^{-1} / (1.6 \times 10^{-19}\ \text{C} \times 10^{-4}\ \text{T}) = 26$ cm

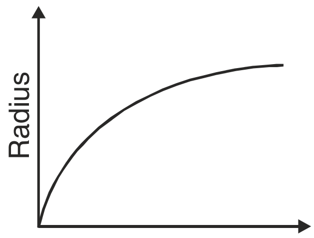
$\nu = v/(2\pi r) = 2 \times 10^8\ s^{-1} = 2 \times 10^8$ Hz = 200 MHz.

$E = (½)mv^2 = (½)\ 9 \times 10^{-31}$ kg $\times\ 9 \times 10^{14}\ m^2/s^2$

$= 40.5 \times 10^{-17}$ J $= 4 \times 10^{-16}$ J = 2.5 keV.

18. A particle of mass m and charge q moves at right angles to a uniform magnetic field. Plot a graph showing the variation of the radius of the circular path described by it with the increase in its kinetic energy, where, other factors remain constant.

**Ans :** $r \alpha \sqrt{K.E}$




19. Magnetic field arises due to charges in motion. Can a system have magnetic moments even though its net charges is zero? Justify.

**Ans :** Yes; for example the atoms of a paramapnetic substance possess a net magnetic moment though its net charge is zero.

20. Define the term magnetic dipole moment of a current loop. Write the expression for the magnetic moment when an electron resolves at a speed '*v*', around an orbit of radius '*r*' in hydrogen atom.

**Ans :** The product of the current in the loop to the area of the loop is the magnetic dipole moment of a current loop.
The magnetic moment of electron

$$\mu = -\frac{e}{2}(\vec{r} \times \vec{v}) = -\frac{e}{2m_e}(\vec{r} \times \vec{p}) = -\frac{e}{2m_e}\vec{\ell}$$

## SHORT ANSWERS QUESTIONS (3 MARKS)

1. Derive the expression for force between two infinitely long parallel straight wires carrying current in the same direction. Hence define 'ampere' on the basis of above derivation.

2. Define (i) Hysteresis (ii) Retentivity (iii) Coercivity

3. Distinguish between diamagnetic, paramagnetic and ferromagnetic substances in terms of susceptibility and relative permeability.

*4. Name all the three elements of earth magnetic field and define them with the help of relevant diagram.

5. Describe the path of a charged particle moving in a uniform magnetic field with initial velocity

   (i) parallel to (or along) the field.

(ii) perpendicular to the field.

(iii) at an arbitrary angle $\theta(0° < \theta < 90°)$.

6. Obtain an expression for the magnetic moment of an electron moving with a speed 'v' in a circular orbit of radius 'r'. How does this magnetic moment change when :

   (i) the frequency of revolution is doubled?

   (ii) the orbital radius is halved?

7. State Ampere, circuital law. Use this law to obtain an expression for the magnetic field due to a toroid.

*8. Obtain an expression for magnetic field due to a long solenoid at a point inside the solenoid and on the axis of solenoid.

9. Derive an expression for the torque on a magnetic dipole placed in a magnetic field and hence define magnetic moment.

10. Derive an expression for magnetic field intensity due to a bar magnet (magnetic dipole) at any point (i) Along its axis (ii) Perpendicular to the axis.

*11. Derive an expression for the torque acting on a loop of N turns of area A of each turn carrying current I, when held in a uniform magnetic field B.

*12. How can a moving coil galvanometer be converted into a voltmeter of a given range. Write the necessary mathematical steps to obtain the value of resistance required for this purpose.

13. A long wire is first bent into a circular coil of one turn and then into a circular coil of smaller radius having n turns. If the same current passes in both the cases, find the ratio of the magnetic fields produced at the centres in the two cases.

    **Ans :** When there is only one turn, the magnetic field at the centre, $B = \mu oI/2a$
    $2\pi a^1 xn = 2\pi a \Rightarrow a^1 = a/n$
    The magnetic field at its centre, $B1 = \mu onI/(2\ a/n) = n^2B$
    The ratio is, $B^1/B = n^2$

## LONG ANSWER QUESTIONS (5 Marks)

1. How will a diamagnetic, paramagnetic and a ferromagnetic material behave when kept in a non-uniform external magnetic field? Give two examples of each of these materials. Name two main characteristics of a ferromagnetic material which help us to decide suitability for making (i) Permanent magnet (ii) Electromagnet.

2. State Biot-Savart law. Use it to obtain the magnetic field at an axial point, distance d from the centre of a circular coil of radius 'a' and carrying current I. Also compare the magnitudes of the magnetic field of this coil at its centre and at an axial point for which the value of d is $\sqrt{3}a$.

3. Write an expression for the force experienced by a charged particle moving in a uniform magnetic field B. With the help of diagram, explain the principle and working of a cyclotron. Show that cyclotron frequency does not depend on the speed of the particle.

*4. Write the principle, working of moving coil galvanometer with the help of neat labelled diagram. What is the importance of radial field and phosphor bronze used in the construction of moving coil galvanometer?

## NUMERICALS

1. An electron travels on a circular path of radius 10m in a magnetic field of $2 \times 10^{-3}$ T. Calculate the speed of electron. What is the potential difference through which it must be accelerated to acquire this speed? [**Ans. :** Speed = $3.56 \times 10^9$ m/s; V = $3.56 \times 10^7$ volts]

2. A ship is to reach a place 15° south of west. In what direction should it be steered if declination at the place is 18° west? [**Ans. :** 87° west of North]

3. Calculate the magnetic field due to a circular coil of 500 turns and of mean diameter 0.1m, carrying a current of 14A (i) at a point on the axis distance 0.12m from the centre of the coil (ii) at the centre of the coil. [**Ans. :** (i) $5.0 \times 10^{-3}$ Tesla; (ii) $8.8 \times 10^{-2}$ tesla]

4. An electron of kinetic energy 10 keV moves perpendicular to the direction of a uniform magnetic field of 0.8 milli testa. Calculate the time period of rotation of the electron in the magnetic field. [**Ans. :** $4.467 \times 10^{-8}$ s.]

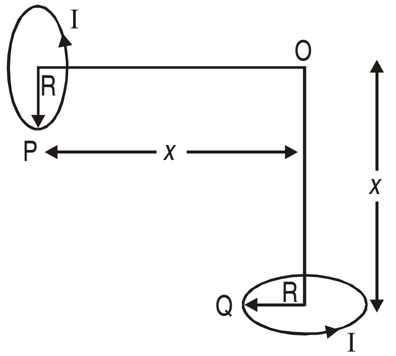
5. If the current sensitivity of a moving coil galvanometer is increased by 20% and its resistance also increased by 50% then how will the voltage sensitivity of the galvanometer be affected? [**Ans. :** 25% decrease]

6. A uniform wire is bent into one turn circular loop and same wire is again bent in two turn circular loop. For the same current passed in both the cases compare the magnetic field induction at their centres. [**Ans. :** Increased 4 times]

7. A horizontal electrical power line carries a current of 90A from east to west direction. What is the magnitude and direction of magnetic field produced by the power line at a point 1.5m below it? [**Ans. :** $1.2 \times 10^{-5}$ T south ward]

*8. A galvanometer with a coil of resistance 90Ω shows full scale deflection for a potential difference 225 mV. What should be the value of resistance to convert the galvanometer into a voltmeter of range 0V to 5V. How should it be connected? [**Ans. :** 1910Ω in series]

9. Two identical circular loops P and Q carrying equal currents are placed such that their geometrical axis are perpendicular to each other as shown in figure. And the direction of current appear's anticlockwise as seen from point O which is equidistant from loop P and Q. Find the magnitude and direction of the net magnetic field produced at the point O.




$$\left[\textbf{Ans. :}\ \frac{\mu_0 I R^2 \sqrt{2}}{2\left(R^2 + x^2\right)^{3/2}}\right]$$

10. A cyclotron's oscillator frequency is 10 MHz. What should be the operating magnetic field for accelerating protons, if the radius of its dees is 60cm? What is the kinetic energy of the proton beam produced by the accelerator? Given $e = 1.6 \times 10^{-19}$ C, m = $1.67 \times 10^{-27}$ kg. Express your answer in units of MeV 1MeV = $1.6 \times 10^{-13}$ J. [**Ans. :** B = 0.656T, Emax = 7.421 MeV]

11. The coil of a galvanometer is $0.02 \times 0.08$ $m^2$. It consists of 200 turns of fine wire and is in a magnetic field of 0.2 tesla. The restoring forque constant of the suspension fibre is $10^{-6}$ Nm per degree. Assuming the magnetic field to be radial.

    (i) what is the maximum current that can be measured by the galvanometer, if the scale can accommodate 30° deflection?

    (ii) what is the smallest, current that can be detected if the minimum observable deflection is 0.1°? [**Ans. :** (i) $4.69 \times 10^{-4}$ A; (ii) $1.56 \times 10^{-6}$ A]

12. A voltmeter reads 8V at full scale deflection and is graded according to its resistance per volt at full scale deflection as 5000 $\Omega V^{-1}$. How will you convert it into a voltmeter that reads 20V at full scale deflection? Will it still be graded as 5000 $\Omega V^{-1}$? Will you prefer this voltmeter to one that is graded as 2000 $\Omega V^{-1}$? [**Ans. :** $7.5 \times 10^4$ $\Omega$]

13. A short bar magnet placed with its axis at 30° with an external field 1000G experiences a torque of 0.02 Nm. (i) What is the magnetic moment of the magnet. (ii) What is the work done in turning it from its most stable equilibrium to most unstable equilibrium position?
[**Ans. :** (i) 0.4 $Am^2$; (ii) 0.08 J]

14. What is the magnitude of the equatorial and axial fields due to a bar magnet of length 4cm at a distance of 40 cm from its mid point? The magnetic moment of the bar magnet is 0.5 $Am^2$.
[**Ans. :** $B_E = 7.8125 \times 10^{-7}$ T; $B_A = 15.625 \times 10^{-7}$ T]

15. What is the magnitude of magnetic force per unit length on a wire carrying a current of 8A and making an angle of 30° with the direction of a uniform magnetic field of 0.15T?

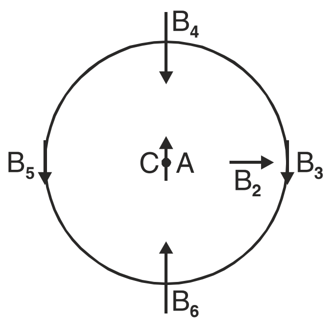
16. Two moving coil galvanometers, $M_1$ and $M_2$ have the following specifications.

    R1 = 10Ω, $N_1$ = 30, $A_1 = 3.6 \times 10^{-3} m^2$, $B_1$ = 0.25T

    R2 = 14Ω, $N_2$ = 42, $A_2 = 1.8 \times 10^{-3} m^2$, $B_2$ = 0.50T

    Given that the spring constants are the same for the two galvano meters, determine the ratio of (a) current sensitivity (b) voltage sensitivity of $M_1$ & $M_2$.

17. In the given diagram, a small magnetised needle is placed at a point O. The arrow shows the direction of its magnetic moment. The other arrows shown different positions and orientations of the magnetic moment of another identical magnetic needs B



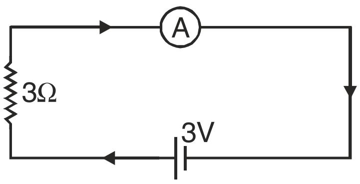
(a) In which configuration is the systems not in equilibrium?

(b) In which configuration is the system.

(i) stable and (ii) unstable equilibrium?

(c) Which configuration corresponds to the lowest potential energy among all the configurations shown?

18. In the circuit, the current is to be measured. What is the value of the current if the ammeter shown :

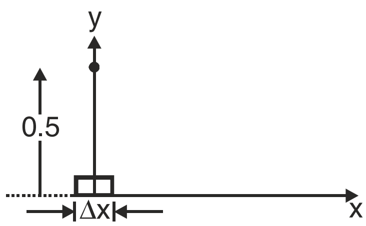



(a) is a galvanometer with a resistance RG = 60Ω,

(b) is a galvanometer described in (i) but converted to an ammeter by a shunt resistance $r_s$ = 0.02Ω

(c) is an ideal ammeter with zero resistance?

19. An element $\Delta l = \Delta x \cdot \hat{i}$ is placed at the origin and carries a large current I = 10A. What is the magnetic field on the y-axis at a distance of 0.5m. Δx = 1 cm.




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

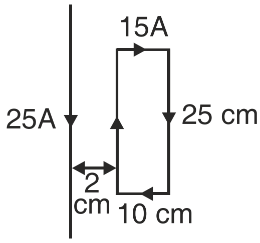
21. A rectangular loop of sides 25 cm and 10 cm carrying current of 15A is placed with its longer side parallel to a long straight conductor 2.0 cm apart carrying a current of 25A. What is the new force on the loop? **Ans :** 7.82 x $10^{-4}$ N towards the conductor

**Hint :**

$$F_1 = \frac{\mu_0}{4\pi}\frac{2I_1I_2}{r_1}\times \ell = \frac{10^{-7}\times 2\times 25\times 15\times 0.25}{0.02} = 9.38\times 10^{-4}\text{ N attractive}$$

$$F_2 = \frac{\mu_0}{4\pi}\frac{2I_1I_2}{r_2}\times \ell = \frac{10^{-7}\times 2\times 25\times 15\times 0.25}{0.12} = 1.56\times 10^{-4}\text{ Nrepalsive}$$

Net F = $F_1 - F_2$ = 7.82 x $10^{-4}$ N




22. In a chamber of a uniform magnetic field 6.5G is maintained. An electron is shot into the field with a speed of 4.8 x $10^6$ $ms^{-1}$ normal to the field. Explain why the path of electron is a circle.

(a) Determine the radius of the circular orbit (e = 1.6 x $10^{-19}$ C, $m_e$ = 9.1 x $10^{-31}$ kg)

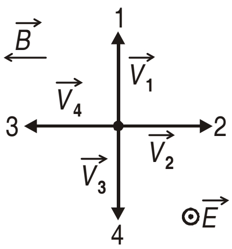
(b) Obtain the frequency of resolution of the electron in its circular orbit.

**Hint :** (a) $r=\frac{m_e v}{eB}=\frac{9.1\times10^{-31}\times4.8\times10^6}{1.6\times10^{-19}\times6.5\times10^{-4}}=4.2\,\text{cm}$

(b) frequenc $v=\frac{1}{T}=\frac{eB}{2\pi m_e}\frac{1.6\times10^{-19}\times6.510^{-4}}{2\times3.14\times9.1\times10^{-31}}=1.8\ MH_2$

## SHORT ANSWER QUESTIONS (2 Marks)

1. The figure shows four directions of motion of a positively charged particle moving through a uniform electric field $\vec{E}$ (directed out of the page and represented with an encircled dot) and a uniform magnetic field $\vec{B}$. (a) Rank, directions 1, 2 and 3 according to the magnitude of the net force on the particle, maximum first. (b) Of all four directions, which might result in a net force of zero?




$|\vec{V_1}| = |\vec{V_2}| = |\vec{V_3}| = |\vec{V_4}|$

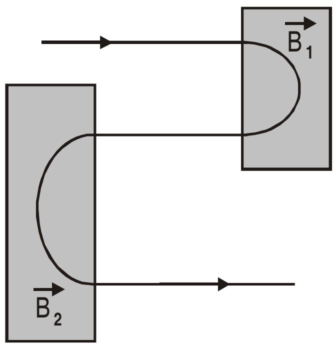
## NUMERICALS

2. The true value of dip at a place is 30°. The vertical plane carrying the needle is turned through 45° from the magnetic meridian. Calculate the apparent value of dip. [**Ans. :** δ′ = 39°14′]

3. Figure shows the path of an electron that passes through two regions containing uniform magnetic fields of magnitude $B_1$ and $B_2$. Its path in each region is a half circle. (a) Which field is stronger?

(b) What are the directions of two fields? (c) Is the time spend by the electron in the $\vec{B_1}$, region greater than, less than, or the same as the time spent in $\vec{B_2}$ region?

[**Ans. :** (a) $B_1 > B_2$; (b) $B_1$ inward; $B_2$ outward. (c) Time spent in $B_1$ < Time spent in $B_2$]




# ANSWERS / HINTS

## I MARK QUESTIONS

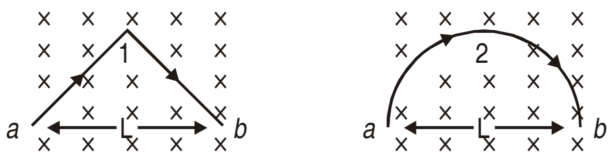
1. No, pole exists only when the source has some net magnetic moment. In toroid, there is no pole.

# HOTS

## VERY SHORT ANSWER QUESTIONS (I Mark)

1. The figure shows two wires 1 and 2 both carrying the same current I from point a to point b through the same uniform magnetic field B. Determine the force acting on each wire.

**Ans. :** Same for both




2. Reciprocal.
3. Fig. NCERT.
4. Nine Times.
5. 0° to 90°
6. Increased.
7. (i) Going into the plane of the paper; (ii) Emerging out of the plane of the paper.
8. By putting in a ferromagnetic case

10. At equator.

11. 1%.

12. (i) Am; (ii) $Am^2$.

## 2 MARKS QUESTIONS

2. $S = \frac{I_g}{(I - I_g)} G = \frac{5 \times 10^{-3}}{5 - 5 \times 10^{-3}} \times 120 = 0.12\Omega.$

3. (i) – mB (ii) zero

4. (i) $B = \frac{10^{-7} \times \pi \times 10}{2 \times 10^{-2}} = 5\pi \times 10^{-5} T \text{ (outwards)}.$

   (ii) $B = 5p \times 10^{-5}$ T (inwards).

5. $r_p = \frac{m\nu}{qB}$ and $r_\alpha = \frac{4m\nu}{(2q)B} = 2r_\alpha \quad \Rightarrow \quad \frac{r_p}{r_a} = \frac{1}{2}.$

6. $R_{mA} > R_A$.

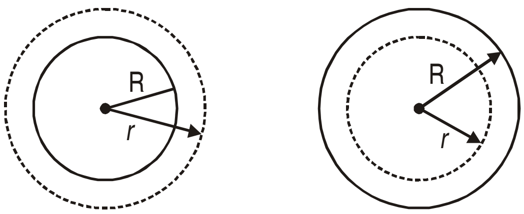
7. Low Retentivity and high permeability.

8. Minimum potential = – $MB$ when $\theta = 0$ (most stable position)

   Maximum potential = $MB$ when $\theta = 180°$ (most unstable position).

9. (a) Pole strength same; magnetic moment half.

   (b) pole strength half; magnetic moment half.




10. $$B(2\pi r) = \mu_0 \left[ \frac{I}{\pi R^2} (\pi r^2) \right]$$

$$B = \left( \frac{\mu_0 I}{2\pi R^2} \right) r \qquad (R \geq r)$$

$$\oint \vec{B} . d\vec{l} = \mu_0 I$$

$$\therefore \qquad B = \frac{\mu_0 I}{2\pi r} \qquad (r \geq R).$$

11. $$M_1 = MI\pi R^2; \; M_2 = MIa^2$$

$$2\pi rN = 4aN \Rightarrow a = \frac{\pi R}{2}$$

$$\frac{M_2}{M_1} = \pi/4$$

12. $$\frac{m_{new}}{m_{original}} = \frac{2I \times \pi\left(\frac{r}{2}\right)^2}{I \times \pi R^2} = \frac{1}{2}.$$

13. 0° and 90°.

14. Low resistance $R_1$ for current and high resistance $R_2$ for voltage.

15. Force experienced by current carrying conductor in magnetic field., $F = I\vec{L} \times \vec{B} = ILB\sin\theta$

Hence, force permit length, $f = \frac{F}{L} IB\sin 30°$

= 8 x 0.15 x ½ = 0.6 $Nm^{-1}$

16. (a) $\oint \vec{B}.\vec{dl} = \mu_0 I = 2\mu_0$ Tm

(b) zero

17. (a) Current sensitivity, $\frac{\phi}{I} = \frac{NBA}{K}$

Ratio of current Sensitivity = $\left(\frac{N_1 B_1 A_1}{K}\right) \Big/ \left(\frac{N_2 B_2 A_2}{K}\right)$

$$= \frac{30 \times 0.25 \times 3.6 \times 10^{-3}}{42 \times 0.50 \times 1.8 \times 10^{-3}} = 5/7$$

(b) Voltage sensitivity, $\frac{\phi}{V} = \frac{NBA}{kR}$

Ratio of voltage sensitivity $= \left(\frac{N_1 B_1 A_1}{kR_1}\right) \Big/ \left(\frac{N_2 B_2 A_2}{kR_2}\right)$

$$= \frac{30 \times 0.25 \times 3.6 \times 10^{-3} \times 14}{42 \times 0.50 \times 1.8 \times 10^{-3} \times 10} = 1$$

18. (a) For equilibrium, the dipole moment should be parallel or auto parallel to B. Hence, $AB_1$ and $AB_2$ are not in equilibrium.

(b) (i) for stable equilibrium, the dipole moments should be parallel, examples : $AB_5$ and $AB_6$
(ii) for unstable equilibrium, the dipole moment should be anti parallel examples : $AB_3$ and $AB_4$

(c) Potential energy is minimum when angle between M and B is 0°, *i.e,* U = –MB Example : $AB_6$

19. (a) Total resistance, $R_G + 3 = 63\Omega$.

Hence, $I = \frac{3V}{63\Omega} = 0.048A$

(b) Resistance of the galvanometer as ammeter is

$$\frac{R_G r_S}{R_G r_S} = \frac{60\Omega \times 0.02\Omega}{(60+0.02)} = 0.02\Omega.$$

Total resistance R = 0.02Ω + 3Ω = 3.02Ω

Hence, $I = \frac{3}{302} = 0.99A$

(c) For the ideal ammeter, resistance is zero, the current, I = 3/3 = 1.00A.

20. From Biot-Sayart's Law, $|\vec{d\beta}| = Id\ell \sin\theta / r^2$

dl = Δx = 1 cm = $10^{-2}$m, I = 10A, r = y = 0.5m

$\mu o/4\pi = 10^{-7}$ Tm/A, θ = 90° so sinθ = 1

$$|d\vec{B}| = \frac{10^{-7} \times 10 \times 10^{-2}}{25 \times 10^{-2}} = 4 \times 10^{-8}\,T\,along + z\,axis$$

21. Force experienced by wire $F_m = BIl$ (due to map field)
The force due to gravity, Fg = mg

mg = BI$l$ ⇒ B = mg/I$l$ $= \frac{0.2 \times 9.8}{2 \times 1.5} = 0.657T$ [Earth's magigield ≃ 4 x $10^{-5}$ T is negligible]

## I MARK QUESTIONS

1. ILB same for both.

## UNIT IV

# ELECTROMAGNETIC INDUCTION AND ALTERNATING CURRENTS

***Weightage Marks : 8***

## TOPICS TO BE COVERED

Electromagnetic induction; Faraday's laws induced emf and current; Lenz's law, Eddy currents self and mutual inductance.

Need for displacement current Altrenating currents, peak and rms value of altering current/voltage

Reactance and Impedance. Lc oscillations (qualitative treatment only).

LCR series circuit; Resaonance; Power in AC circuits, wattless current.

AC generator and transformer.

## KEY POINTS

| *Physical Quantity* | *Formulae* | *SI Unit* |
|---|---|---|
| **Self-inductance** of a long solenoid | $L = \mu_0 n^2 l A$ | Henry (H) |
| **Mutual inductance** of two long solenoids (Theorem of reciprocity) | $M_{12} = M_{21} = M = \mu_0 n_1 n_2 A l$ | |
| Factors affecting mutual inductance | $K = \sqrt{\frac{M}{L_1 L_2}}$ | |
| **Magnetic Flux** | $\phi = \vec{B}.\vec{A} = BA\cos\theta$ | $Tm^2$ or Weber |
| Due to self induction | $\phi = LI$ | |
| Due to mutual indication | $\phi_{21} = \mu_0 n_1 n_2 A l I_1 = MI_1$ | |
| | $\phi_{12} = \mu_0 n_1 n_2 A l I_1 = MI_2$ | |

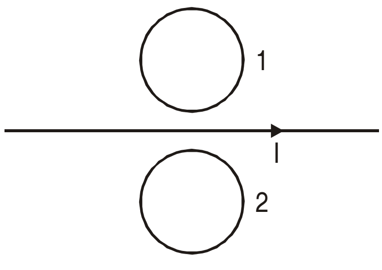
| | | |
|---|---|---|
| Induced EMF | $e = -N\frac{d\phi}{dt} = Blv = -L\frac{dI}{dt}$ | Volt |
| Power produced due to induced EMF | $P = \frac{B^2 l^2 v^2}{R}$ | Watt |
| Alternative current | $I = I_0 \sin \omega t$ | |
| | Or $I = I_0 \cos \omega t$ | A |
| Alternating EMF | $E = E_0 \sin \omega t$ | |
| | Or $E = E_0 \cos \omega t$ | v |
| **Root Mean Square (RMS) or Virtual Value of AC** | | |
| Current | $I_v = \frac{I_0}{\sqrt{2}} = 0.707 I_0$ | A |
| EMF | $E_v = \frac{E_0}{\sqrt{2}} = 0.707 E_0$ | V |
| **AC through an inductor** | | |
| Current | $I = \frac{E_0}{\omega L}\sin\left(\omega t - \frac{\pi}{2}\right)$ | A |
| Inductive Reactance | $X_L = \omega L$ | Ω |
| **AC through a capacitor** | | |
| Current | $I = \omega C E_0 \sin\left(\omega t + \frac{\pi}{2}\right)$ | A |
| | $= I_0 \cos \omega t$ | |
| Capacitive reactance | $X_C = \frac{1}{\omega C}$ | Ω |
| **LCR series circuit** | | |
| Current | $I = \frac{E}{\sqrt{\left\{R^2 + (X_L - X_C)^2\right\}}}$ | A |
| Impedance | $Z = \sqrt{\left\{R^2 + (X_L - X_C)^2\right\}}$ | Ω |
| **Resonance condition** | $X_L = X_C \Leftrightarrow \omega L = \frac{1}{\omega C}$ | |
| | $\omega_0 = \frac{1}{\sqrt{LC}} \Leftrightarrow v_0 = \frac{1}{2\pi}\frac{1}{\sqrt{LC}}$ | |
| **Quality factor** | $Q = \frac{\omega}{2\Delta\omega} = \frac{\omega_0 L}{R} = \frac{1}{\omega_0 RC}$ | |

| | | |
|---|---|---|
| **Total Bandwidth** | $2\Delta\omega = \frac{R}{L} = \frac{1}{RC}$ | rad $s^{-1}$ |
| **Power factor** | $\cos\phi = \frac{R}{Z}$ | |
| **Average power** | $P_{av} = E_v I_v \cos\theta = I_v^2 Z \cos$ | Watt |
| **Wattless current** | $I_v \sin\phi$ | |
| **The energy of the oscillator** | | |
| Total energy stored in an inductor | $U = \frac{1}{2} L I^2{}_0$ | |
| Total energy stored in the capacitor | $U = \frac{1}{2}\frac{q_0^2}{C}$ | |
| For LC oscillator | $U = \frac{1}{2} L I^2 + \frac{1}{2}\frac{q^2}{C}$ | |
| LC oscillator loop (Kirchhoff's Law) | $\frac{q}{C} - L\frac{dI}{dt} = 0$ | |
| **Transformer** | | |
| Transformation ratio | $\frac{N_s}{N_p} = K$ | |
| EMF ratio vs current ratio | $\frac{E_s}{E_p} = \frac{I_p}{I_s} = \frac{N_s}{N_p}$ | |
| Efficiency of the transformer | $\eta = \frac{I_s E_s}{I_p E_p}$ | |

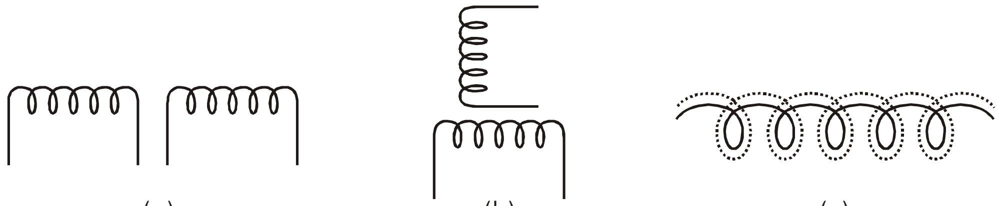
## QUESTIONS

### VERY SHORT ANSWER QUESTIONS (I Mark)

1. Why core of a transformer is laminated?
2. What is the direction of induced currents in metal rings 1 and 2 seen from the top when current I in the wire is increasing steadily?



3. In which of the following cases will the mutual inductance be (i) minimum (ii) maximum?



(a) (b) (c)

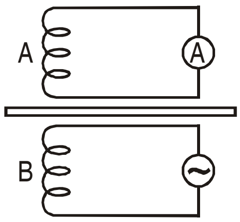
4. In a series *L–C–R* circuit, voltages across inductor, capacitor, and resistor are $V_L$, $V_C$ and $V_R$ respectively. What is the phase difference between (i) $V_L$ and $V_R$ (ii) $V_L$ and $V_C$?

5. Why can't transformer be used to step up or step down dc voltage?

6. In an a.c. circuit, instantaneous voltage and current are $V = 200 \sin 300\, t$ volt and $i = 8 \cos 300t$ ampere respectively. What is the average power dissipated in the circuit?

7. Sketch a graph that shows change in reactance with frequency of a series LCR circuit.

8. A coil A is connected to an A.C. ammeter and another coil B to A source of alternating e.m.f. What will be the reading in ammeter if a copper plate is introduced between the coils as shown.

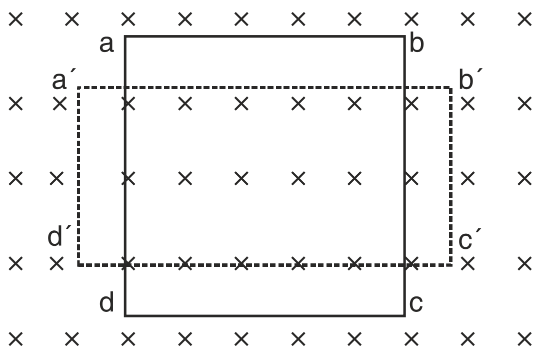



9. In a circuit instantaneously voltage and current are $V = 150 \sin 314$ volt and $i = 12 \cos 314\, t$ ampere respectively. Is the nature of circuit is capacitive or inductive?

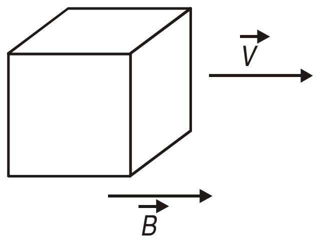
10. In a series L-C-R circuit $V_L = V_C \neq V_R$. What is the value of power factor?

11. In an inductor L, current passed $I_0$ and energy stored in it is U. If the current is now reduced to $I_0/2$, what will be the new energy stored in the inductor?

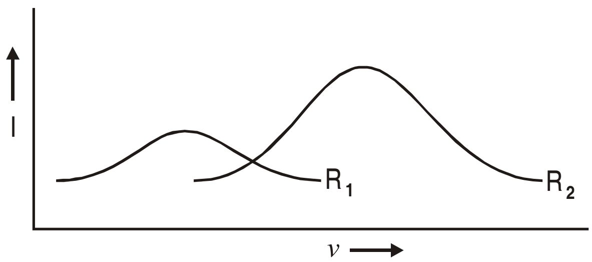
12. A rectangle loop *a b c d* of a conducting wire has been changed into a square loop *a′ b′ c′ d′* as shown in figure. What is the direction of induced current in the loop?



13. Twelve wires of equal lengths are connected in the form of a skeleton of a cube, which is moving with a velocity $\vec{V}$ in the direction of magnetic field $\vec{B}$. Find the *emf* in each arm of the cube.



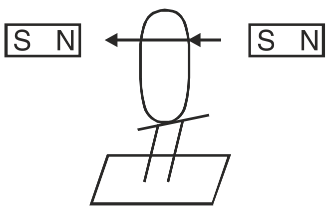

14. Current versus frequency ($I$ – ν) graphs for two different series L–C–R circuits have been shown in adjoining diagram. $R_1$ and $R_2$ are resistances of the two circuits. Which one is greater–$R_1$ or $R_2$?




15. Why do we prefer carbon brushes than copper in an a.c. generator?

*16. What are the values of capacitive and inductive reactance in a dc circuit?

17. Give the direction of the induced current in a coil mounted on an insulating stand when a bar magnet is quickly moved along the axis of the coil from one side to the other as shown in figure.

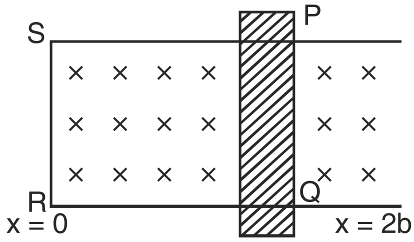



**Ans :** If observer is situated at the side from which bar magnet enters the loop. The direction of current is clockwise when magnet moves towards the loop and direction of current is anticlockwise when magnet moves away from the loop.

18. In figure, the arm PQ is moved from x = o to x = 2b with constant speed V. Consider the magnet field as shown in figure. Write

   (i) direction of induced current in rod

   (ii) polarity induced across rod.

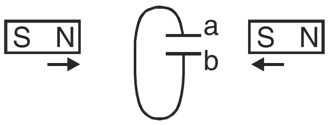



19. A wire moves with some speed perpendicular to a magnetic field. Why is emf induced across the rod?

    **Ans :** Lorentz force acting on the free charge carrier of conducting wire hence polarity developed across it.

20. Predict the polarity of the capacitor in the situation described in the figure below.

    **Ans :** Plate a will be positive with respect to 'b'.



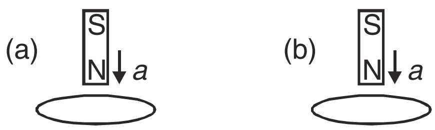

21. A circular coil rotates about its vertical diameter in a uniform horizontal magnetic field. What is the average emf induced in the coil? **Ans :** Zero

22. Define RMS Value of Current.

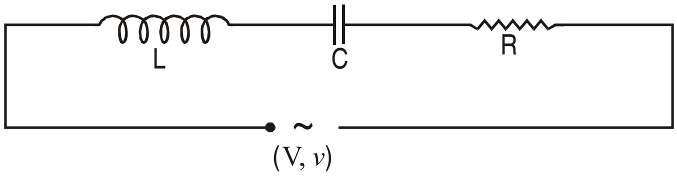
## SHORT ANSWER QUESTIONS (2 Marks)

1. An ac source of rms voltage V is put across a series combination of an inductor L, capacitor C and a resistor R. If $V_L$, $V_C$ and $V_R$ are the rms voltage across *L, C* and *R* respectively then why is $V \neq V_L + V_C + V_R$? Write correct relation among $V_L$, $V_C$ and $V_R$.

2. A bar magnet is falling with some acceleration 'a' along the vertical axis of a coil as shown in fig. What will be the acceleration of the magnet (whether $a > g$ or $a < g$ or $a = g$) if (*a*) coil ends are not connected to each other? (b) coil ends are connected to each other?

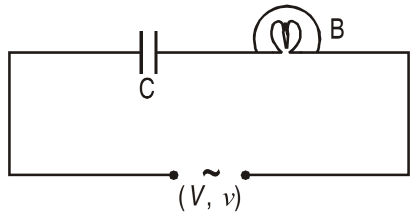



3. The series L–C–R circuit shown in fig. is in resonance state. What is the voltage across the inductor?

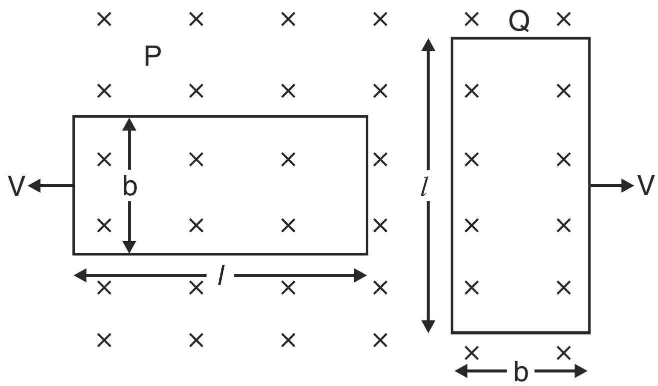


4. The divisions marked on the scale of an a.c. ammeter are not equally spaced. Why?

5. Circuit shown here uses an airfield parallel plate capacitor. A mica sheet is now introduced between the plates of capacitor. Explain with reason the effect on brightness of the bulb B.




6. In the figure shown, coils P and Q are identical and moving apart with same velocity V. Induced currents in the coils are $I_1$ and $I_2$. Find $I_1/I_2$.




7. A 1.5 μF capacitor is charged to 57V. The charging battery is then disconnected, and a 12 mH coil is connected in series with the capacitor so that LC Oscillations occur. What is the maximum current in the coil? Assume that the circuit has no resistance.

8. The self inductance of the motor of an electric fan is 10H. What should be the capacitance of the capacitor to which it should be connected in order to impart maximum power at 50Hz?

9. How does an inductor behave in a DC circuit after the current reaches to steady state? Justify.

10. How does an inductor behave in a AC circuit at very high frequency? Justify.

11. An electric bulb is commected in series with an inductor and an AC source. When switch is closed and after sometime an iron rod is inserted into the interior of inductor. How will the brightness of bulb be affected? Justify your answer.

    **Ans :** Decreases, due to increase in inductive reactance.

12. Show that in the free oscillation of an LC circuit, the sum of energies stored in the capacitor and the inductor is constant with time.

    **Ans :** Hint : $U=\frac{1}{2}LI^2+\frac{1}{2}\frac{q^2}{c}$

13. Show that the potential difference across the LC combination is zero at the resonating frequency in series LCR circuit

**Ans :** Hint P.d. across L is = $IX_L$

P.D. across C is – $IX_C$

$\Rightarrow \qquad V = IX_L - IX_C$

at resonance $X_L = X_C$

$\Rightarrow \qquad V = O.$

14. How does an capacitor behave in a DC circuit after the steady state? Explain your answer.

**Ans :** Capacitor acts as an open key.

15. For circuits used for transmitting electric power, a low power factor implies large power loss in transmission. Explain.

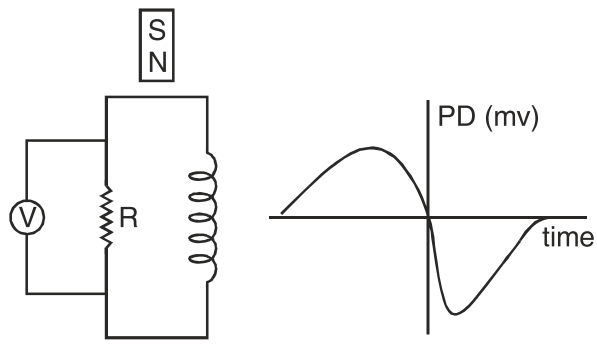
$\therefore \qquad P = VI \cos \theta$

Or $\qquad I = \dfrac{P}{V \cos \phi}$

if Cos $\theta$ is Low I will be high $\Rightarrow$ Large power loss.

16. An applied Voltage signal consists of a superposition of DC Voltage and an AC Voltage of high frequency. The circuit consists of an inductor and a capacitor in series. Show that the DC signal will appear across C where as AC signal will appear across L.

17. A bar magnet M is dropped so that is falls vertically through the coil C. The graph obtained for voltage produced across the coil Vs time is shown in figure.




(i) Explain the shape of the graph

(ii) Why is the negative peak longer than the positive peak?

18. What is the Significance of Q-factor in a series LCR resonant circuit?

19. How does mutual inductance of a pair of coils kept coaxially at a distance in air change when

    (i) the distance between the coils is increased?

    (ii) an iron rod is kept between them?

## SHORT ANSWER QUESTIONS (3 Marks)

1. Obtain an expression for the self inductance of a straight solenoid of length l and radius $r$ ($l >> r$).

2. Distinguish between : (i) resistance and reactance (ii) reactance and impedance.

3. In a series L–C–R circuit $X_L$, $X_C$ and R are the inductive reactance, capacitive reactance and resistance respectively at a certain frequency f. If the frequency of a.c. is doubled, what will be the values of reactances and resistance of the circuit?

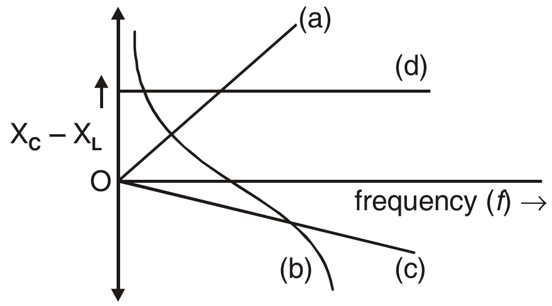
4. What are eddy currents? Write their any four applications.

5. In a series L–R circuit, $X_L$ = R and power factor of the circuit is $P_1$. When capacitor with capacitance C such that $X_L = X_C$ is put in series, the power factor becomes $P_2$. Find $P_1/P_2$.

*6. Instantaneous value of a.c. through an inductor $L$ is $e = e_0 \cos \omega t$. Obtain an expression for instantaneous current through the inductor. Also draw the phasor diagram.

7. In an inductor of inductance L, current passing is $I_0$. Derive an expression for energy stored in it. In what forms is this energy stored?

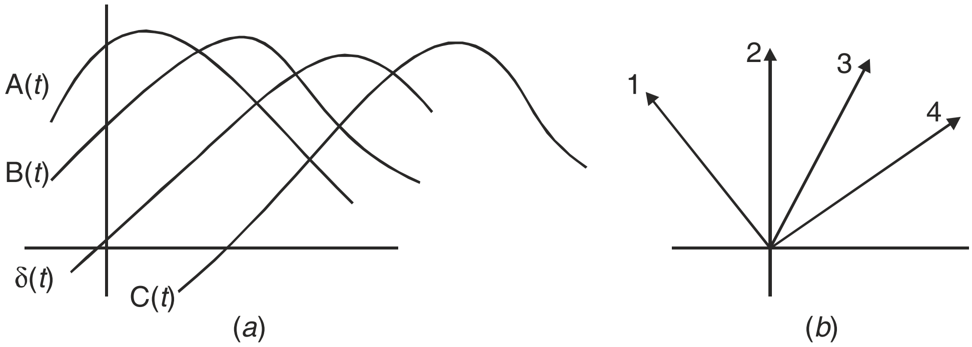
8. Which of the following curves may represent the reactance of a series LC combination.




[**Ans. :** (b)]

9. A sunusoidal e.m.f. device operates at amplitude $E_0$ and frequency $\nu$ across a purely (1) resistive (2) capacitive (3) inductive circuit. If the frequency of driving source is increased. How would (a) amplitude $E_0$ and (b) amplitude $I_0$ increase, decrease or remain same in each case?

10. The figure shows, in (a) a sine curved $\delta(t) = \sin \omega t$ and three other sinusoidal curves A($t$), B($t$) and C($t$) each of the form $\sin(\omega t - \phi)$. (a) Rank the three curves according to the value of $\phi$, most positive first and most negative last (b) Which curve corresponds to which phase as in (b) of the figure? (c) which curve leads the others? [**Ans. :** (a) C, B, A; (b) 1, A; 2, B; (c) A]




11. In an LC circuit, resistance of the circuit is negligible. If time period of oscillation is T them
(i) at what time is the energy stored completely electrical
(ii) at what time is the energy stored completely magnetic
(iii) at what time is the total energy shared equally between the inductor and capacitor.

**Ans :** (i) t = 0, T/2, 3T/2,...........

(ii) t = T/4, 3T/4, 5T/4.............

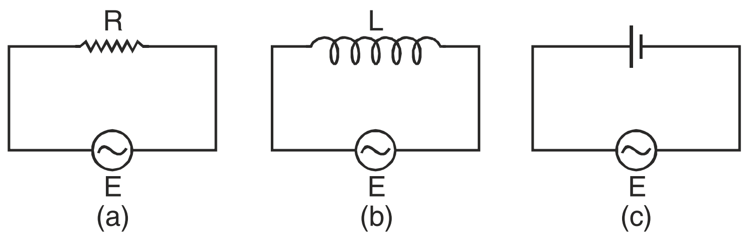
(iii) $t = \frac{T}{8}, \frac{3T}{8}, \frac{5T}{8}$,..........

12. An alternating voltage of frequency f is applied across a series 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 (i) f > fr (ii) f < fr ? Explain your answer in each case.

**Ans :** (i) Current will Lag because.
$V_L > V_C$ Hence $V_L - V_C > O$

(i) Current will lead, because.
$V_L < V_C$ Hence $v_L - V_C < O$

13. Figure (a), (b), (c) Show three alternating circuits withe equal currents. If frequency of alternating emf be increased, what will be the effect on current in the three cases? Explain.




**Ans :** (i) No effect, R is not affected by frequency.

(ii) Current will decrease as $X_L$ increase.

(iii) Current will increase as $X_C$ decrease.

## LONG ANSWER QUESTIONS (5 Marks)

1. Draw a labelled diagram to explain the principle and working of an a.c. generator. Deduce the expression for emf generated. Why cannot the current produced by an a.c. generator be measured with a moving coil ammeter?

2. Explain, with the help of a neat and labelled diagram, the principle, construction and working of a transformer.

3. An L–C circuit contains inductor of inductance L and capacitor of capacitance C with an initial charge $q_0$. The resistance of the circuit is negligible. Let the instant the circuit is closed be $t = 0$.

   (i) What is the total energy stored initially?

   (ii) What is the maximum current through inductor?

   (iii) What is frequency at which charge on the capacitor will oscillate?

   (iv) If a resistor is inserted in the circuit, how much energy is eventually dissipated as heat?

4. An a.c. $i = i_0 \sin \omega t$ is passed through a series combination of an inductor (L), a capacitor (C) and a resistor (R). Use the phasor diagram to obtain expressions for the (a) impedance of the circuit and phase angle between voltage across the combination and current passed in it. Hence show that the current

   (i) leads the voltage when $\omega < \frac{1}{\sqrt{LC}}$

   (ii) is in phase with voltage when $\omega = \frac{1}{\sqrt{LC}}$.

5. Write two differences in each of resistance, reactance and impedance for an ac circuit. Derive an expression for power dissipated in series LCR circuit.

## NUMERICALS

1. In a series C–R circuit, applied voltage is $V = 110 \sin 314t$ volt. What is the (i) The peak voltage (ii) Average voltage over half cycle?

2. Magnetic flux linked with each turn of a 25 turns coil is 6 milliweber. The flux is reduced to 1 mWb in 5 s. Find induced emf in the coil.

3. The current through an inductive circuit of inductance 4mH is $i = 12 \cos 300t$ ampere. Calculate :

   (i) Reactance of the circuit.

   (ii) Peak voltage across the inductor.

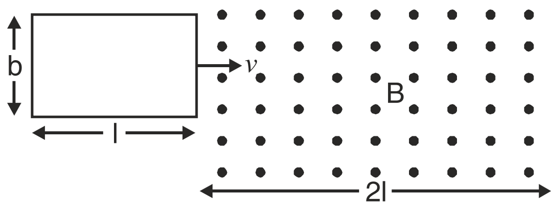
4. A power transmission line feeds input power at 2400 V to a step down ideal transformer having 4000 turns in its primary. What should be number of turns in its secondary to get power output at 240V?

5. The magnetic flux linked with a closed circuit of resistance 8Ω varies with time according to the expression $\phi = (5t^2 - 4t + 2)$ where $\phi$ is in milliweber and $t$ in second. Calculate the value of induce current at $t$ = 15 s.

6. A capacitor, a resistor and $\frac{4}{\pi^2}$ henry inductor are connected in series to an a.c. source of 50 Hz. Calculate capacitance of capacitor if the current is in phase with voltage.

7. A series C–R circuit consists of a capacitance 16 mF and resistance 8Ω. If the input a.c. voltage is (200 V, 50 Hz), calculate (i) voltage across capacitor and resistor. (ii) Phase by which voltage lags/leads current.

8. A rectangular conducting loop of length l and breadth $b$ enters a uniform magnetic field B as shown below.




The loop is moving at constant speed $v$ and at $t$ = 0 it just enters the field B. Sketch the following graphs for the time interval $t$ = 0 to $t = \frac{3l}{v}$.

(i) Magnetic flux – time

(ii) Induced emf – time

(iii) Power – time

Resistance of the loop is R.

9. A charged 8mF capacitor having charge 5mC is connected to a 5mH inductor. What is :

(i) the frequency of current oscillations?

(ii) the frequency of electrical energy oscillations in the capacitor?

(iii) the maximum current in the inductor?

(iv) the magnetic energy in the inductor at the instant when charge on capacitor is 4mC?

10. A 31.4Ω resistor and 0.1H inductor are connected in series to a 200V, 50Hz ac source. Calculate

(i) the current in the circuit

(ii) the voltage (rms) across the inductor and the resistor.

(iii) Is the algebraic sum of voltages across inductor and resistor more than the source voltage? If yes, resolve the paradox.

11. A square loop of side 12 cm with its sides parallel to X and Y-axis is moved with a velocity of 8 cm/s in positive x-direction. Magnetic field exists in z-directions.

    (i) Determine the direction and magnitude of induced current if field changes with $10^{-3}$ Tesla/cm along negative x-direction.

    (ii) Determine the direction and magnitude of induced current if field changes with $10^{-3}$ Tesla/s.

**Ans :** (i) Rate of change of flux = induced emf = $(0.12)^2 \times 10^{-3} \times 8$

$= 11.52 \times 10^{-5}$ Wb/s.

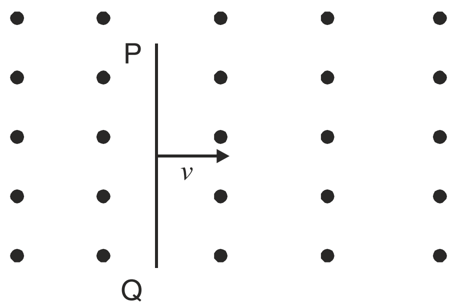
(ii) Rate of change of flux = induced emf = $(0.12)^2 \times 10^{-3}$

$= 1.44 \times 10^{-5}$ Wb/s

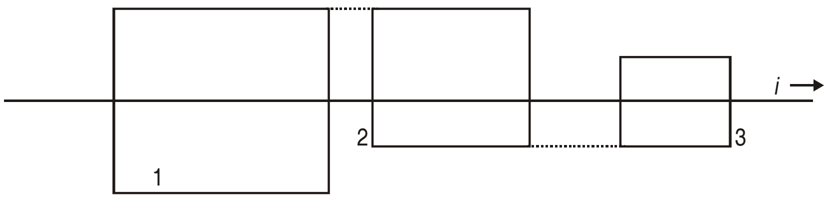
## HOTS

### VERY SHORT ANSWER QUESTIONS (I Mark)

1. A conducting rod PQ is in motion at speed $v$ in uniform magnetic field as shown in Fig. What are the polarities at P and Q?



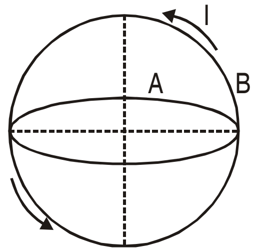

2. A long straight wire with current $i$ passes (without touching) three square wire loops with edge lengths 2L, 1.5L land L. The loops are widely spaced (so as to not affect one another). Loops 1 and 3 are symmetric about the long wire. Rank the loops according to the size of the current induced in them if current $i$ is (a) constant and (b) increasing greatest first.




3. In an L–C circuit, current is oscillating with frequency $4 \times 10^6$ Hz. What is the frequency with which magnetic energy is oscillating?

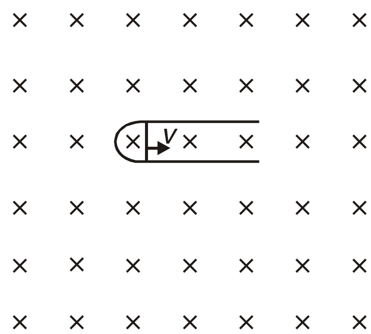
### SHORT ANSWER QUESTIONS (2 Marks)

1. Two circular conductors are perpendicular to each other as shown in figure. If the current is changed in conductor B, will a current be induced in the conductor A,




## NUMERICALS

1. Figure shows a wire of length *l* which can slide on a U-shaped rail of negligible resistance. The resistance of the wire is R. The wire is pulled to the right with a constant speed *v*. Draw an equivalent circuit diagram representing the induced emf by a battery. Find the current in the wire using this diagram.

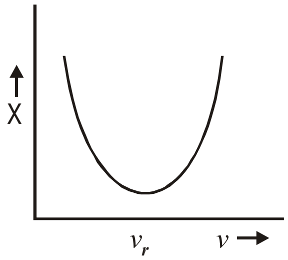



## ANSWERS

### I MARK QUESTIONS

1. To reduce loss due to eddy currents
2. Ring 1 clockwise, Ring 1, anticlockwise.
3. (i) b; (ii) c.
4. (i) $\pi/2$; (ii) $\pi$.
5. In steady current no induction phenomenon will take place.
7. P(–) Q(+).
6. Capacitor circuit, $P_{av} = 0$.
7. Reactance = $X_L - X_C$

$\nu_r \rightarrow$ resonant frequency




8. Reading of ammeter will be zero.

9. As current leads voltage by $\pi/2$ : purely capacitive circuit.

10. Resonance : $\cos\phi = 1$.

11. Energy $U_L \propto I^2 \Rightarrow U' = \frac{U}{4}$.

12. Clockwise.

13. emf in each branch will be zero.

14. $R_1 > R_2$ as current is smaller at larger resistance.

15. Corrosion free and also with small expansion on heating maintains proper contact.

16. Capacitive reactance – infinity

    Inductive reactance – zero.

## 2 MARKS QUESTIONS

2. (i) $a = g$ because the induced emf set up in the coil does not produce any current and hence no opposition to the falling bar magnet.

   (ii) $a < g$ because of the opposite effect caused by induced current.

3. Current at resonance $I = \frac{V}{R}$.

   $\therefore$ Voltage across inductor $V_L = I.X_L = I.\omega L = \frac{V}{R}(2\pi\nu)L$.

4. A.C. ammeter works on the principle of heating effect $H \propto I^2$.

5. Brightness of bulb depends on current. $P \propto I^2$ and

$$I = \frac{V}{Z} \quad \text{where} \quad Z = \sqrt{X_c^2 + R^2} \qquad \text{and} \qquad X_C = \frac{1}{\omega C} = \frac{1}{2\pi\nu C}$$

$X_C \propto \frac{1}{C}$, when mica sheet is introduced capacitance C increases $\left(C = \frac{K \epsilon_0 A}{d}\right)$,

$X_C$ decreases, current increases and therefore brightness increases.

6. Current $I = \varepsilon/R =$

   In coil $P$, $I_1 = E_1/R = \dfrac{Bvb}{R}$

   In coil Q, $I_2 = E_2/R = \dfrac{Bvl}{R}$ $\qquad I_1/I_2 = b/l$.

7. em energy is conserved

$$\mu_E(\text{max}) = \mu_B(\text{max})$$

$$1/2\,\frac{Q^2}{C} = \frac{1}{2}LI^2$$

$$I = 637 \text{ mA}$$

8. $10^{-6}$ F.

## NUMERICALS

1. (i) $V_0 = 110$ volt

   (ii) $V_{av\,1/2} = \dfrac{2V_0}{\pi} = \dfrac{2 \times 110 \times 7}{22} = 70$ volt.

2. Induced emf $\quad \varepsilon = -N\dfrac{d\phi}{dt} = -25\dfrac{(1-6)\times 10^{-3}}{.5} = 0.25$ volt.

3. (i) Reactance $X_L = \omega_L = 300 \times 4 \times 10^{-3} = 1.2\ \Omega$.

   (ii) Peak Voltage $V_0 = i_0.X_L = 12 \times 1.2 = 14.4$ volt.

4. In ideal transformer $\quad P_{in} = P_0$

$$V_P I_P = V_s I_s$$

$$\frac{V_S}{V_P} = \frac{I_P}{I_S} = \frac{N_S}{N_P} \qquad N_S = \left(\frac{V_S}{V_P}\right)N_P = \frac{240}{2400} \times 4000 = 400$$

5. Induced current $I = \varepsilon/R$

   where $\quad \varepsilon = \dfrac{-d\phi}{dt} = -10t + 4$

$\varepsilon = -10(15) + 4 = -146$ mV

where $\phi = 5t^2 - 4t + 2 = 18.3$ mA $\therefore$ $I = -\frac{.146}{8}$

6. When $V$ and $I$ in phase

$$X_L = X_C, \quad v = \frac{1}{2\pi}\frac{1}{\sqrt{LC}}$$

$$C = \frac{1}{4\pi^2 v^2 L} = \frac{1}{4\pi^2 \times 50 \times 50 \times \frac{4}{\pi^2}}$$

$$= 2.5 \times 10^{-5} = 25\ \mu F.$$

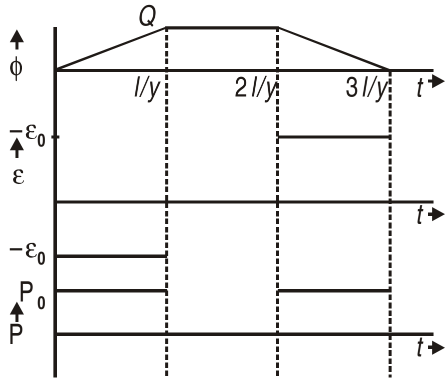
7. Current in the circuit $I = \frac{V}{Z}$

When $Z = \sqrt{X_c^2 + R^2}, \quad X_C = \frac{1}{\omega C} = \frac{1}{2\pi v C}$

Then total voltage across capacitor and resistor

$V_C = i X_C, \qquad V_R = IR.$

8.




$\phi = Blb$

$\varepsilon_0 = Bvb$

$P_0 = \frac{\varepsilon_0^2}{R}$

$= \frac{B^2 v^2 b^2}{R}$

9. (i) Frequency of current oscillations

$$\nu = \frac{1}{2\pi\sqrt{LC}}$$

(ii) Frequency of electrical energy oscillation $\nu_c = 2\nu$

(iii) Maximum current in the circuit $I_0 = \frac{q_0}{\sqrt{LC}}$

(iv) Magnetic energy in the inductor when charge on capacitor is 4mC.

$$U_L = U - U_C = \frac{1}{2}\frac{q_0^2}{C} - \frac{1}{2}\frac{q^2}{C} = \frac{q_0^2 - q^2}{2C}$$

Here $q_0$ = 5mC; $q$ = 4mC

10. Current in the circuit :

(i) $I = \frac{V}{Z}$, where $Z = \sqrt{X_L^2 + R^2}$

(ii) RMS voltage across $L$ and $R$

$V_L = I \,.\, X_L$; $V_R = IR$

(iii) $(V_L + V_R) > V$ because $V_L$ and $V_R$ are not in same phase.

## ANSWERS OF HOTS

### 1 MARK QUESTIONS

1. P (–) Q (+)
2. (a) No induced current

   (b) Current will be induced only in loop 2.
3. Frequency of magnetic energy oscillation is equal to $v_m = 2v = 8 \times 10^6$ Hz

### 2 MARKS QUESTIONS

1. No current is induced in coil A since θ is 90°.

## NUMERICAL

1. $i = \frac{e}{R}$

UNIT V

# ELECTROMAGNETIC WAVES

***Weightage Marks : 03***

## TOPICS TO BE COVERED

Displacement current, electromagnetic waves and their characteristics (qualitative ideas only).

Transverse nature of electromagnetic waves. Electromagnetic spectrum (radio-waves, micro-waves, infrared, visible, ultraviolet, X-rays, gamma rays) including elementary facts about their uses.

## KEY POINTS

- EM waves are produced by accelerated (only by the change in speed) charged particles.
- $\vec{E}$ and $\vec{B}$ vectors oscillate with the frequency of oscillating charged particles.
- Properties of em waves :
  - (i) Transverse nature
  - (ii) Can travel though vacuum.
  - (iii) $E_0/B_0 = E/B = v$ $v \to$ Speed of EM waves.
  - (iv) Speed = $3 \times 10^8$ m/s in vacuum.
  - (v) In some medium $v = \frac{1}{\sqrt{\mu \in}}$

    Where $\mu = \mu_r \mu_0, \varepsilon = \varepsilon_r \varepsilon_0$

    $\sqrt{\in_r} = n$ refractive index of medium

    Also $V = c/n$
  - (vi) Wave intensity equals average of Poynting vector $I = |\vec{S}|_{av} = \frac{B_0 E_0}{2\mu_0}$
  - (vii) Average electric and average magnetic energy densities are equal.
- In an em spectrum, different waves have different frequency and wavelengths.

- Penetration power of em waves depends on frequency. Higher, the frequency larger the penetration power.
- Wavelength $\lambda$ and frequency $\nu$ are related with each other $v = \lambda\nu$. Here $\nu$ is the wave velocity.
- A wave travelling along +x axis is represented by

$$E_y = E_{oy} \cos(wt - kx)$$

$$B_z = B_{oz} \cos(wt - kx)$$

$$\omega = \frac{2\pi}{T} = 2\pi\nu \qquad \frac{\omega}{k} = \lambda\nu = v \text{ wave speed}$$

$$k = \frac{2\pi}{T} = 2\pi\bar{\nu}$$

$v \rightarrow$ frequency

$\bar{\nu} = \dfrac{1}{\lambda}$ wave number.

## QUESTIONS

### VERY SHORT ANSWER QUESTIONS (I Mark)

1. Every *EM* wave has certain frequency. Name two parameters of an em wave that oscillate with this frequency.
2. What is the phase difference between electric and magnetic field vectors in an em wave?
3. Name em radiations used for detecting fake currency notes.
4. Give any two uses of microwaves.
5. Name the phenomenon which justifies the transverse nature of em waves.
6. Arrange the following em waves in descending order of wavelengths : $\gamma$ ray, microwaves UV radiations.
7. Which component $\vec{E}$ or $\vec{B}$ of an em wave is responsible for visible effect?
8. Write expression for speed of em waves in a medium of electrical permittivity $\in$ and magnetic permeability $\mu$.
9. Which of the following has longest penetration power?

   UV radiation, X-ray, Microwaves.
10. Which of the following has least frequency?

    IR radiations, visible radiation, radio waves.

11. Which physical quantity is the same for microwaves of wavelength 1 mm and UV radiations of 1600 A° in vacuum?

12. Name two physical quantities which are imparted by an em wave to a surface on which it falls.

13. Name the physical quantity with unit same as that of $\left[\epsilon_0 \cdot \frac{d\,\phi_e}{dt}\right]$ where $\phi_e \rightarrow$ electric flux.

14. What is the source of energy associated with propagating em waves?

15. What is the wavelength range of em waves that were produced and observed by J.C. Bose?

16. Name the device used for producing microwaves.

17. Name the em radiations which are detected using Gieger tube.

18. Relative electric permittivity of a medium is 8 and relative permeability is close to unity. What is the speed of em waves in the medium.

19. Identify the part of the electromagnetic spectrum to which the following wavelengths belong :

    (i) $10^{-1}$ m (ii) $10^{-12}$ m

20. Name the part of the electromagnetic spectrum of wavelength $10^{-2}$ m and mention its one application.

21. Which of the following, if any, can act as a source of electromagnetic waves?

    (i) A charge moving with a constant velocity.

    (ii) A charge moving in a circular obit.

    (iii) A charge at rest.

22. Mention the pair of space and time varying E and B fields which would generate a plane em wave trevelling in Z-direction.

23. The charging current for a capacitor is 0.2A. What is the displacement Current?

24. Give the ratio of Velocities of light waves of wavelengths 4000Aº and 8000Aº in Vaccum.

25. Which physical quantity, If any has the same value for waves belonging to the different parts of the electromagnetic spectrum?

## SHORT ANSWER QUESTIONS (2 Marks)

1. Give one use of each of the following (i) UV ray (ii) $\gamma$-ray

2. Represent *EM* waves propagating along the *x*-axis. In which electric and magnetic fields are along *y*-axis and *z*-axis respectively.

3. State the principles of production of *EM* waves. An *EM* wave of wavelength $\lambda$ goes from vacuum to a medium of refractive index n. What will be the frequency of wave in the medium?

4. An *EM* wave has amplitude of electric field $E_0$ and amplitude of magnetic field is $B_0$ the electric field at some instant become $\frac{3}{4}E_0$. What will be magnetic field at this instant? (Wave is travelling in vacuum).

5. State two applications of Infrared radiations.

6. State two applications of ultraviolet radiations.

7. State two applications of x-rays.

8. Write Maxwell's Equations for electromagnetic waves.

9. Show that the average energy density of the electric field $\vec{E}$ equals the average energy density of the magnetics fields $\vec{B}$?

### SHORT ANSWER QUESTIONS (3 Marks)

1. Name *EM* radiations used (i) in the treatment of cancer.

   (ii) For detaching flaw in pipes carrying oil.

   (iii) In sterilizing surgical instruments.

2. How would you experimentally show that *EM* waves are transverse in nature?

3. List any three properties of *EM* waves.

4. Find the wavelength of electromagnetic waves of frequency $5 \times 10^{19}$ Hz in free space. Give its two applications

## NUMERICALS

1. The refractive index of medium is 1.5. A beam of light of wavelength 6000 A° enters in the medium from air. Find wavelength and frequency of light in the medium.

2. An *EM* wave is travelling in vaccum. Amplitude of the electric field vector is $5 \times 10^4$ V/m. Calculate amplitude of magnetic field vector.

3. Suppose the electric field amplitude of an em wave is $E_0 = 120\ NC^{-1}$ and that its frequency is $\nu = 50.0$ MHz.

   (a) Determine $B_0$, $\omega$, $\kappa$ and $\lambda$

   (b) Find expressions for E and B.

4. A radio can tune into any station of frequency band 7.5 MHz to 10 MHz. Find the corresponding wave length range.

5. The amplitude of the magnetic field vector of an electromagnetic wave travelling in vacuum is 2.4mT. Frequency of the wave is 16 MHz. Find :

(i) Amplitude of electric field vector and

(ii) Wavelength of the wave.

6. An *EM* wave travelling through a medium has electric field vector.

$E_y = 4 \times 10^5 \cos (3.14 \times 10^8\ t - 1.57\ x)$ N/C. Here $x$ is in $m$ and $t$ in $s$.

Then find :

(i) Wavelength

(ii) Frequency

(iii) Direction of propagation

(iv) Speed of wave

(v) Refractive index of medium

(vi) Amplitude of magnetic field vector.

# UNIT VI

# OPTICS

***Weightage Marks : 14***

## TOPICS TO BE COVERED

Reflection of light, spherical mirrors, mirror formula.

Refraction of light, total internal reflection and its applications, optical fibres, refraction through spherical surfaces, lenses thin lens formula

Lens makers formula.

Magnification, power of a lens, Combination of thin lenses in contact, Refraction and dispersion of light through a prism, scattering of light – blue colour of the sky and reddish appearance of the sun at sunrise and sunset.

Optical Instruments; Human eye, image formation and accommodation, correction of eye defects (myopia, hyper-metropia, presbyopia and astigmatism) using lenses.

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

Wave optics: Wave front and huygen's principle, reflection and refraction of plane wave at a plane surface using wave fronts, Proof of laws of reflection and refraction using huygen's Principle. Interference, Young's double slit experiment and expression for fringe width coherent sources and sustained interference of light; Diffraction due to a single slit, width of central maximum.

Resolving power of microscopes and astronomical telescopes, Plane polarized light, Brewster's law, uses of plane polarized light and polaroids.

## KEY POINTS

| ***Physical Quantity*** | ***Formulae*** | ***SI Unit*** |
|---|---|---|
| | **Ray Optics** | |
| Refractive index of medium '*b*' w.r.t. '*a*' | ${}^{a}\mu_{b} = \dfrac{\sin i}{\sin r}$ | |
| Refractive index of medium w.r.t. vacuum (or air) | $\mu = \dfrac{\text{Velocity of Light in Vacuum }(c)}{\text{Velocity of Light in Medium }(v)}$ | – |
| Real and Apparent Depth (Normal Shift) | ${}^{a}\mu_{w} = \dfrac{AO}{AI} = \dfrac{\text{Real Depth}}{\text{Apparent Depth}}$ | |

| | | |
|---|---|---|
| Relation *b/w* refractive index of medium and critical angle | ${}^a\mu_b = \frac{1}{\sin i_C}$ | |
| Lateral shift | $d = \frac{t \sin(i - r)}{\cos r}$ | m |
| Spherical refracting surface | $\frac{\mu_2 - \mu_1}{R} = \frac{\mu_2}{\nu} - \frac{\mu_1}{u}$ | |
| | or $\frac{\mu - 1}{R} = \frac{\mu}{\nu} - \frac{1}{u}$ | $m^{-1}$ |
| Lens Maker's formula | $\frac{1}{f} = \frac{1}{\nu} - \frac{1}{u} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$ | |
| Magnification | $m = \frac{h_i}{h_o} = +\frac{\nu}{u} = \frac{f}{f + u} = \frac{f - \nu}{f}$ | – |
| Combination of thin lenses | $\therefore \frac{1}{f} = \frac{1}{f_1} = \frac{f}{f_2}$ | |
| | $\Rightarrow P = P_1 + P_2$ and $m = m_1 \times m_2$ | |
| Refraction in a prism | $\delta + A = i + e$ | |
| | $\mu = \frac{\sin i}{\sin r} = \frac{\sin \frac{(A + \delta_m)}{2}}{\sin \frac{A}{2}}$ | – |
| Cauchy's formula (Relation *b/w* refractive index and $\lambda$) | $\mu = a + \frac{b}{\lambda^2} + \frac{c}{\lambda^4}$ | |
| Rayleigh's criteria of scattering | Amount of scattering $\propto \frac{1}{l^4}$ | |
| **Compound Microscope** | | |
| Magnification | $m = \frac{\beta}{\alpha} = m_e m_o = \frac{\nu_o}{\mu_o}\left(1 + \frac{D}{f_e}\right)$ | |
| When image is formed at D | $m = \frac{L}{f_0}\left(1 + \frac{D}{f_e}\right) = \frac{L}{f_0}\frac{D}{f_e}$ | |
| When image is formed at infinity | $m = \frac{\nu_0}{\mu_0} \times \frac{D}{f_e}$ | |
| The limit of resolution | $d = \frac{1.22\lambda}{2\mu \sin\theta}$ | |
| Numerical aperture | $\mu \sin\theta$ | |
| The resolving power | $\frac{1}{d} = \frac{2\mu \sin\theta}{1.22\lambda}$ | |

**Astronomical Telescope**

Magnification

(a) When image is formed at infinity $m = \frac{\beta}{\alpha} = \frac{f_0}{f_e}$

(b) When image is formed at D $m = \frac{f_0}{f_e}\left(1 + \frac{f_0}{D}\right)$

Length of tube $L = f_o + f_e$

Angular limit of resolution $\alpha = \frac{1.22\lambda}{D}$

The resolving power $\frac{1}{\alpha} = \frac{D}{1.22\lambda}$

**Reflection Telescope**

Magnifying power $m = \frac{f_0}{f_e}$

Brightness $B = \frac{D^2}{d^2}$

**Wave Optics**

**Young's Double Slit Experiment**

Intensity of light $I = a_1^2 + a_2^2 + 2a_1a_2 \cos\phi$

**Constructive Interference**

Phase difference $\phi = 2n\pi$

Path difference $x = n\lambda$

**Destructive Interference**

Phase difference $\phi = (2n + 1)\pi$

Path difference $x = (2n + 1)\ \lambda/2$

Ratio of light intensity at maxima and minima $\frac{I_{max}}{I_{min}} = \frac{(a_1 + a_2)^2}{(a_1 - a_2)^2}$

Path difference $x = \frac{yd}{D}$

Fringe width (For Dark and Bright Fringes) $\beta = y_n - y_{n-1} = \lambda D/d$

The angular width of each fringe $\Delta\theta = \frac{\beta}{D} = \frac{\lambda}{d}$

**Single Slit Diffraction**

Central maximum $\sin\theta_1 = \frac{\lambda}{a}$; $\theta_1 \rightarrow \angle$ up to which central maximum extends on both sides from centre.

Angular width = $2\theta_1$

For $n^{th}$ secondary minima $\sin\theta_n = n\lambda/a$

For $n^{th}$ secondary maxima — $\sin \theta'_n = \frac{(2n = 1)\lambda}{2a}$

Fringe width (For Dark and Bright Fringes) — $\beta = y_n - y_{n-1} = y'_n - y'_{n-1} = \frac{\lambda D}{a}$

Fresnel distance — $Z_F = \frac{a^2}{\lambda}$

Brewster's Law — $r + p = 90°$

Law of Malus — $I = I_0 \cos^2 \theta$

If two coherent beams have different intensities I and $I_2$, the resulting minima and maxima will be

$$I_{max} = I_1 + I_2 + 2\sqrt{I_1 + I_2} \cos 0^0$$

$$= \left(\sqrt{I_1} + \sqrt{I_2}\right)^2$$

$$I_{min} = I_1 + I_2 + 2\sqrt{I_1 I_2} \cos 180°$$

If two plane mirror are kept at an angle θ w.r.t. each other and an object is kept between them, then the number of images formed. — $n = \frac{360°}{\theta} - 1$

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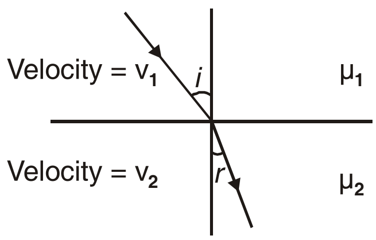
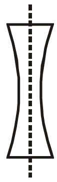
# QUESTIONS

## VERY SHORT ANSWER QUESTIONS (I Mark)

1. Write the value of angle of reflection for a ray of light falling normally on a mirror.
2. How does the dispersive power of glass prism change when it is dipped in water?
3. Light falls from glass to air. Find the angle of incidence for which the angle of deviation is 90°.
4. Name the phenomenon due to which one cannot see through fog.
5. What is the ratio of sin*i* and sin*r* in terms of velocities in the given figure.




6. What is the shape of fringes in young's double slit experiment?
7. A equiconcave lens of focal length 15 cm is cut into two equal halves along dotted line as shown in figure. What will be new focal length of each half.



8. For the same angle of the incidence the angle of refraction in three media A, B and C are 15°, 25° and 35° respectively. In which medium would the velocity of light be minimum?

9. What is the phase difference between two points on a cylindrical wave front?

10. What is the 'power' of plane glass plate.

11. Show with the help of diagram, why a beam of white light passing through a hollow prism does not give spectrum.

12. How does focal length of lens change when red light incident on it is replaced by violet light?

13. A myopic person prefers to remove his spectacles while reading a book. Why?

14. Lower half of the concave mirror is painted black. What effect will this have on the image of an object placed in front of the mirror?

**Ans. :** The intensity of the image will be reduced (in this case half) but no change in size of the image.

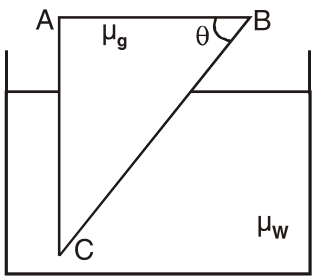
## SHORT ANSWER QUESTIONS (2 Marks)

1. A near sighted person can clearly see objects up to a distance of 1.5m. Calculate power of the lens necessary for the remedy of this defect. (P = – 0.67D)

2. A person can adjust the power of his eye lens between 50D and 60D. His far point is infinity. Find the distance between retina and eye lens.

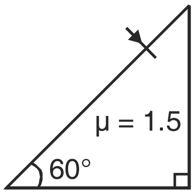
3. Calculate the value of θ, for which light incident normally on face AB grazes along the face BC.

$\mu_{glass} = 3/2$ $\mu_{water} = 4/3$




4. Name any two characteristics of light which do not change on polarisation.

5. Complete the path of light with correct value of angle of emergence.



6. Define diffraction. What should be the order of the size of the aperture to observe diffraction.

7. Show that maximum intensity in interference pattern is four times the intensity due to each slit if amplitude of light emerging from slits is same.

8. Two poles-one 4m high and the other is 4.5 m high are situated at distance 40m and 50m respectively from an eye. Which pole will appear taller?

9. $S_1$ and $S_2$ are two sources of light separated by a distance d. A detector can move along $S_2P$ perpendicular to $S_1S_2$. What should be the minimum and maximum path difference at the detector?


10. If a jogger runs with constant speed towards a vehicle, how fast does the image of the jogger appear to move in the rear view mirror when

   (i) the vehicle is stationery

   (ii) the vehicle is moving with constant speed.

   **Ans :** The speed of the image of the jogger appears to increase substantially, though jogger is moving with constant speed.

   Similar phenomenon is observed when vehicle is in motion.

11. A person looking at a mesh of crossed wire is able to see the vertical wire more distinctly than the horizontal wire. Which defect he is suffering from? How can this defect be corrected?

12. Is optical density same as mass density? Give an example.

   **Ans :** Optical density is the ratio of the speed of light in two media whereas mass density is mass per unit volume of a substance.

   Eg Mass density of turpention in less than that of water but its optical density is higher.

13. When does (i) a plane mirror and (ii) a convex mirror produce real image of objects.

   **Ans :** Plane and convex mirror produce real image when the object is virtual that is rays converging to a point behind the mirror are reflected to a point on a screen.

14. A virtual image cannot be caught on a screen. Then how do we see it?

   **Ans :** The image is virtual when reflected or refracted rays divergent, these are converged on to the retina by convex lens of eye, as the virtual image serves as the object.

15. Draw a diagram to show the advance sunrise and delayed sunset due to atmospheric refraction.
NCERT Pg 318

16. Define critical angle for total internal reflection. Obtain an expression for refractive index of the medium in terms of critical angle.

17. The image of a small bulb fixed on the wall of a room is to be obtained on the opposite wall 's' m away by means of a large convex lens. What is the maximum possible local length of the lens required.

    **Ans :** For fixed distance 's' between object and screen, for the lens equation to give real solution for u and v, 'f' should not be greater than s/4.

    $\therefore$ f = s/4

18. The angle subtended at the eye by an object is equal to the angle subtended at the eye by the virtual image produced by a magnifying glass. In what sense then does magnifying glass produce angular magnification?

    **Ans :** The absolute image size is bigger than object size, the magnifier helps in bringing the object closer to the eye and hence it has larger angular size than the same object at 25 cm, thus angular magnification is achieved.

19. Obtain relation between focal length and radius of curvature of (i) concave mirror (ii) convex mirror using proper ray diagram.

20. Two independent light sources cannot act as coherent sources. Why?

21. How is a wave front different from a ray? Draw the geometrical shape of the wavefronts when.

    (i) light diverges from a point source,

    (ii) light emerges out of convex lens when a point source is placed at its focus.

22. What two main changes in diffraction pattern of single slit will you observe when the monochromatic source of light is replaced by a source of white light.

23. You are provided with four convex lenses of focal length 1cm, 3cm, 10cm and 100 cm. Which two would you prefer for a microscope and which two for a telescope.

24. Give reasons for the following

    (i) Sun looks reddish at sunset

    (ii) clouds are generally white

25. Using Huygens Principle draw ray diagram for the following

    (i) Refraction of a plane wave front incident on a rarer medium

    (ii) Refraction of a plane wave front incident on a denser medium.

## SHORT ANSWER QUESTIONS (3 Marks)

1. Using mirror formula show that virtual image produced by a convex mirror is always smaller in size and is located between the focus and the pole.

2. Obtain the formula for combined focal length of two thin lenses in contact, taking one divergent and the other convergent.

3. Derive snell's law on the basis of Huygen's wave theory.

4. A microscope is focussed on a dot at the bottom of the beaker. Some oil is poured into the beaker to a height of '*b*' cm and it is found that microscope has to raise through vertical distance of 'a' cm to bring the dot again into focus. Express refractive index of oil is terms of a and b.

5. Define total internal reflection. State its two conditions. With a ray diagram show how does optical fibres transmit light.

6. A plane wave front is incident on (i) a prism (ii) A convex lens (iii) a concave mirror. Draw the emergent wavefront in each case.

7. Explain with reason, how the resolving power of a compound microscope will change when (i) frequency of the incident light on the objective lens is increased. (ii) focal length of the objective lens is increased. (iii) asperture of objective lens is increased.

8. Derive Mirror formula for a concave mirror forming real Image.

9. Two narrow slits are illuminated by a single monochromatic sources.

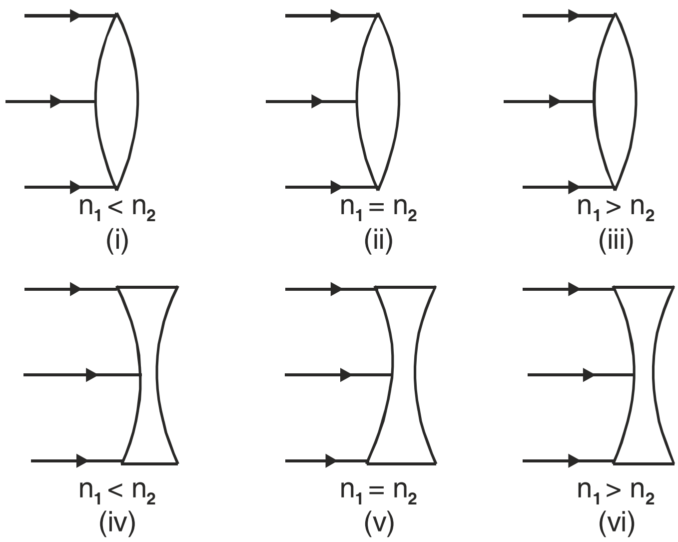
   (a) Draw the intensity pattern and name the phenomenon

   (b) One of the slits is now completely covered. Draw the intensity pattern now obtained and name the phenomenon.

10. Explain briefly (i) sparkling of diamond (ii) use of optical fibre in communication.

11. Using appropriate ray diagram obtain relation for refractive index of water in terms of real and apparent depth.

12. Complete the ray diagram in the following figure where, $n_1$, is refractive index of medium and $n_2$ is refractive index of material of lens.



## LONG ANSWER QUESTIONS (5 MARKS)

1. With the help of ray diagram explain the phenomenon of total internal reflection. Obtain the relation between critical angle and refractive indices of two media. Draw ray diagram to show how right angled isosceles prism can be used to :

    (i) Deviate the ray through 180°.

    (ii) Deviate the ray through 90°.

    (iii) Invert the ray.

2. Draw a labelled ray diagram of a compound microscope and explain its working. Derive an expression for its magnifying power.

3. Diagrammatically show the phenomenon of refraction through a prism. Define angle of deviation in this case. Hence for a small angle of incidence derive the relation $\delta = (\mu - 1) A$.

4. Name any three optical defects of eye. Show by ray diagram :

    (i) Myopic eye and corrected myopic eye.

    (ii) Hypermetropic eye and corrected hypermetropic eye.

5. Define diffraction. Deduce an expression for fringe width of the central maxima of the diffraction pattern, produced by single slit illuminated with monochromatic light source.

6. What is polarisation? How can we detect polarised light? State Brewster's Law and deduce the expression for polarising angle.

7. Derive lens maker formula for a thin converging lens.

8. Derive lens formula $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$ for

    (a) a convex lens,

    (b) a concave lens.

9. Describe an astronomical telescope and derive an expression for its magnifying power using a labelled ray diagram.

10. Draw a graph to show the angle of deviation with the angle of incidence i for a monochromatic ray of light passing through a prisin of refracting angle A. Deduce the relation

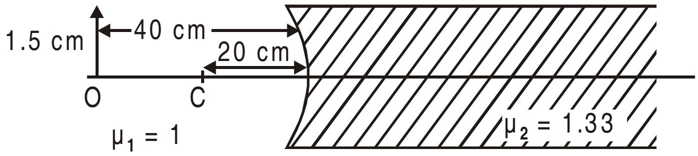
$$\mu = \frac{\sin(A + \delta m)/2}{\sin A/2}$$

11. State the condition under which the phenomenon of diffraction of light takes place. Derive an expression for the width of the central maximum due to diffraction of light at a single slit. Also draw the intensity pattern with angular position.

## NUMERICALS

1. An object of length 2.5cm is placed at a distance of 1.5f from a concave mirror where f is the focal length of the mirror. The length of object is perpendicular to principal axis. Find the size of image. Is the image erect or inverted?

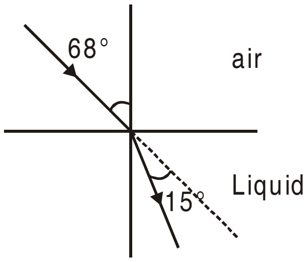
2. Find the size of image formed in the situation shown in figure. (0.6 cm) [–32 cm approx.]



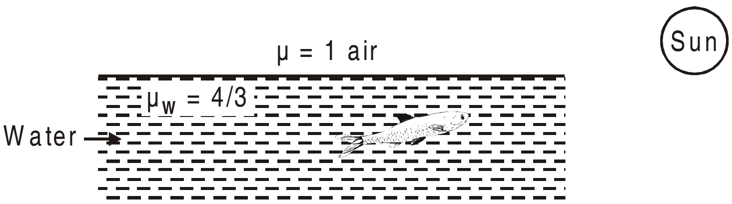

3. A ray of light passes through an equilateral prism in such a manner that the angle of incidence is equal to angle of emergence and each of these angles is equal to 3/4 of angle of prism. Find angle of deviation. [**Ans. :** 30°]

4. Critical angle for a certain wavelength of light in glass is 30°. Calculate the polarising angle and the angle of refraction in glass corresponding to this. [$i_p = \tan^{-1} 2$

5. A light ray passes from air into a liquid as shown in figure. Find refractive index of liquid.
$\left[ {}^{air}\mu_{Liquid} = \sqrt{3/2} \right]$

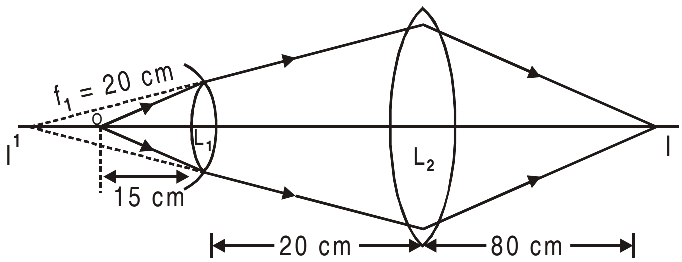



6. At what angle with the water surface does fish in figure see the setting sun?




[At critical angle, fish will see the sun.]

7. In the following diagram, find the focal length of lens $L_2$. [40 cm]



8. A hypermetropic person whose near point is at 100 cm wants to read a book. Find the nature and power of the lens needed.

**Ans.** $\nu = -100$ cm

$u = -25$ cm

$$\frac{1}{f} = \frac{1}{\nu} - \frac{1}{u} = \frac{-1}{100} + \frac{1}{25} = \frac{3}{100}$$

$$f = \frac{100}{3} = \pm 33.3cm$$ so a converging lens

$$\rho = \frac{100}{f} = 3 \textit{ dioptre}$$

9. For a man shortest distance of distinct vision is 20 cm. What will be the type and power of lens which would enable him to read a book at a distance of 60 cm?

**Ans.** $v = -20$ cm

$u = -60$ cm

$$\frac{1}{f} = \frac{-1}{20} + \frac{1}{60} = \frac{-2}{60} = \frac{-1}{30}$$

$f = -30$ cm. So a diverging lens

$$\rho = \frac{100}{-30} = -3.3 \textit{ dioptre}$$

10. Using the data given below, state which two of the given lenses will be preferred to construct a (i) telescope (ii) Microscope. Also indicate which is to be used as objective and as eyepiece in each case.

| *Lenses* | *Power (p)* | *Apetune (A)* |
|---|---|---|
| $L_1$ | 6 D | 1 cm |
| $L_2$ | 3 D | 8 cm |
| $L_3$ | 10 D | 1 cm |

**Ans. :** For telescope, less $L_2$ is chosen as objective as it aperture is largest, $L_3$ is chosen as eyepiece as its focal length is smaller.

For microscope lens $L_3$ is chosen as objective because of its small focal length and lens $L_1$, serve as eye piece because its focal length is not larges.

11. Two thin converging lens of focal lengths 15 cm and 30 cm respectively are held in contact with each other. Calcualte power and focal length of the combination.

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} = \frac{1}{15} + \frac{1}{30} = \frac{1}{10}$$

F = 10 cm

P = 10 D

## HOTS

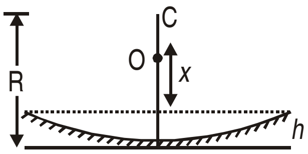
### VERY SHORT ANSWER QUESTIONS (I Mark)

1. An air bubble is formed inside water. Does it act as converging lens or a diverging lens? [Diverging lens]

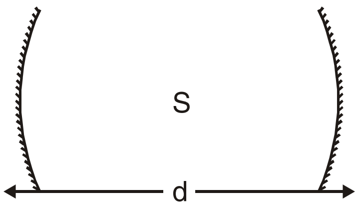
2. A water tank is 4 meter deep. A candle flame is kept 6 meter above the level. $\mu$ for water is 4/3. Where will the image of the candle be formed? [6m below the water level]

### SHORT ANSWER QUESTIONS (2 Marks)

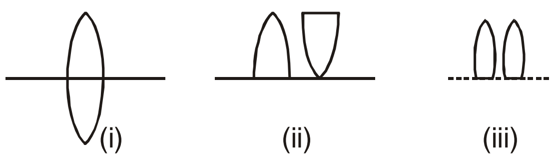
1. Water is poured into a concave mirror of radius of curvature 'R' up to a height h as shown in figure. What should be the value of $x$ so that the image of object 'O' is formed on itself?




2. A point source S is placed midway between two concave mirrors having equal focal length $f$ as shown in Figure. Find the value of $d$ for which only one image is formed.

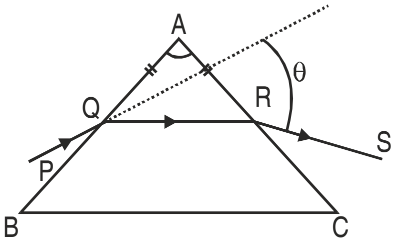



3. A thin double convex lens of focal length $f$ is broken into two equal halves at the axis. The two halves are combined as shown in figure. What is the focal length of combination in (ii) and (iii).



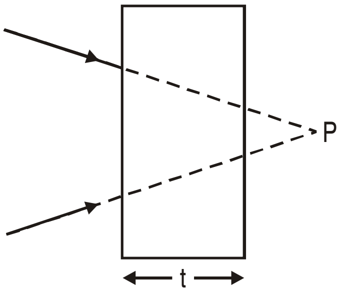
4. How much water should be filled in a container 21 cm in height, so that it appears half filled when viewed from the top of the container. ($^a\mu_\omega$ = 4/3)?

5. A ray PQ incident on the refracting face BA is refracted in the prism BAC as shown in figure and emerges from the other refracting face AC as RS such that AQ = AR. If the angle, of prism A = 60° and μ of material of prism is $\sqrt{3}$ then find angle θ.



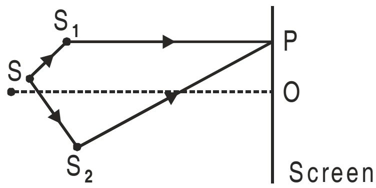

## SHORT ANSWER QUESTIONS (3 Marks)

1. A converging beam of light is intercepted by a slab of thickness *t* and refractive index μ. By what distance will the convergence point be shifted? Illustrate the answer.




$$x = \left(1 - \frac{1}{\mu}\right) t$$

2. In double slit experiment $SS_2$ is greater than $SS_1$ by 0.25λ. Calculate the path difference between two interfering beam from $S_1$ and $S_2$ for minima and maxima on the point P as shown in Figure.




# ANSWERS

## I MARK QUESTIONS

1. Zero

2. Decreases.

3. Angle of incidence is 45°.

4. Scattering.

6. Hyperbolic

7. 30 cm

8. 15°

9. Zero.

10. Zero

12. Decreases

13. A myopic person is short sighted.

## 2 MARKS QUESTIONS

2. For point is infinity so in this case focal length is maximum. Hence power is minimum.

3. $\theta = \sin^{-1}(8/9)$

4. Speed and frequency

5. $\sin^{-1}(3/4)$

8. 4 m pole

9. Minimum path difference is zero (when p is at infinity)

   Maximum path difference = *d.*

11. Astigmatism – Cylindrical lens

21. A wavefront is a surface obtained by joining all points vibrating in the same phase.

    A ray is a line drawn perpendicular to the wavefront in the direction of propagation of light.

    (i) Spherical

    (ii) Plane

22. (i) In each diffraction order, the diffracted image of the slit gets dispersed into component colours of white light. As fringe width $\alpha$ $\lambda$, $\therefore$ red fringe with higher wavelength is wider than violet fringe with smaller wavelength.

    (ii) In higher order spectra, the dispersion is more and it causes overlapping of different colours.

23. $f_0$ = 1 cm and $f_e$ = 3 cm for Microscope and

    $f_0$ = 100 cm and $f_e$ = 1 cm for a Telescope

25. N.C.E.R.T. Fig. 10.5; Fig. 10.4.

## 3 MARKS QUESTIONS

7. R.P. of a compound Microscope

$$= \frac{2\mu \sin\theta}{\lambda} = 2\mu \sin\theta \frac{\nu}{c}$$

(i) When frequency $\nu$ increases, R.P. increases

(ii) R.P. does not change with change in focal length of objective lens.

(iii) When aperture increases, $\theta$ increases $\therefore$ R.P. increases.

# ANSWERS OF HOTS

## 2 MARKS QUESTIONS

1. Distance of object from $p$ should be equal to radius of curvature.

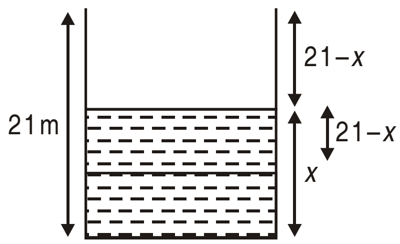
$$R = \mu x + h \quad \Rightarrow \quad x = \frac{R - h}{\mu}.$$

2. Distance between mirror will be $2f$ or $4f$.

3. (i) Focal length of combination is infinite.

(ii) f/2

4.




$$\frac{\text{Real depth}}{\text{Apparent depth}} = \mu$$

$$\frac{x}{21 - x} = \frac{4}{3} \quad \Rightarrow \quad x = 12 \text{ cm.}$$

5. This is a case of min. deviation $\theta = 60°$.

## 3 MARKS QUESTIONS

1. $x = \left(1 - \frac{1}{\mu}\right) t$

2. Path diff. : $(SS_2 + S_2P) - (SS_1 + S_1P) = (SS_2 - SS_1) + (S_2P - S_1P) = (0.25\lambda + S_2P - S_1P)$

   For maxima, path diff. = $n\lambda$

   So $S_2P - S_1P = n\lambda - 0.25\lambda = (n - 0.25)\lambda$

   For minima, path diff. $= (2n + 1)\frac{\lambda}{2}$

   So $S_2P - S_1P = (2n + 0.5)\ \lambda/2$

## UNIT VII

# DUAL NATURE OF MATTER AND RADIATION

***Weightage Marks : 14***

## TOPICS TO BE COVERED

Dual nature of radiation, Photoelectric effect Hertz and Lenard's observations; Einstein's photoelectrical equation, Particle nature of light.

Mattre waves-wave nature of particles, de-broglie relation Davisson Germer experiment.

## KEY POINTS

- Light consists of individual photons whose energies are proportional to their frequencies.
- A photon is a quantum of electromagnetic energy :

  Energy of photon

$$E = h\nu = \frac{hc}{\lambda}$$

  Momentum of a photon

$$= \frac{h\nu}{c} = \frac{h}{\lambda}$$

  Dynamic mass of photon

$$= \frac{h\nu}{c^2} = \frac{h}{c\lambda}$$

  Rest mass of a photon is zero.

- *Photoelectric effect :* Photon of incident light energy interacts with a single electron and if energy of photon is equal to or greater than work function, the electron is emitted.
- Max. Kinetic energy of emitted electron = $h(v - v_0)$ Here $v_0$ is the frequency below which no photoelectron is emitted and is called threshold frequency.
- A moving body behaves in a certain way as though it has a wave nature having wavelength,

$$\lambda = \frac{h}{mv}.$$

# QUESTIONS

## VERY SHORT ANSWER QUESTIONS (I Mark)

1. What is the rest mass of photon?
2. A good mirror reflects 80% of light incident on it. Which of the following is correct.
   (a) Energy of each reflected photon decreases by 20%.
   (b) Total no. of reflected photons decreases by 20%. Justify your answer.
3. Why in a photocell the cathode is coated with alkali metals.?
4. Name the phenomenon which shows quantum nature of electromagnetic radiation.
5. Write Einstein's photoelectric equations and specify each term.
6. Which of the following radiations is more effective for electron emission from the surface of sodium?
   (i) Microwave
   (ii) Infrared
   (iii) Ultraviolet.
7. A metal emits photoelectrons when red light falls on it. Will this metal emit photoelectrons when blue light falls on it?
8. Name any two phenomena which show the particle nature of radiation.
9. The photoelectric cut off voltage in a certain photoelectric experiment is 1.5V. What is the max kinetic energy of photoelectrons emitted?
10. What is the de-Broglie wavelength of a 3 kg object moving with a speed of 2m/s?
11. What factors determine the maximum velocity of the photoelectrons from a surface?
12. What is the stopping potential applied to a photocell, in which electrons with a maximum kinetic energy of 5.6 eV are emitted. **Ans. :** 5.6 V
13. Work functions of caesium and lead are 2.14 eV and 4.25 eV respectively. Which of the two has a higher threshold wavelength?

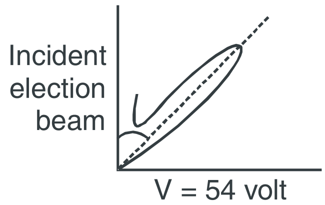
    **Ans. :** Work function, $\phi_0 = h\nu_0 = h\frac{c}{\lambda_0}$ *or* $\lambda_0 \propto \frac{1}{\phi_0}$

    Hence caesium has a higher threshold wavelength for photoelectric emission.
14. What is the de-Broglie wavelength of a neutron at absolute temperature TK?

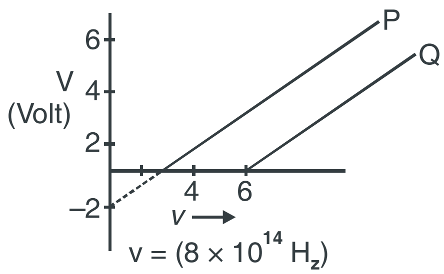
    **Ans. :** $\lambda = \frac{h}{\sqrt{2m_n Ek}} = \frac{h}{\sqrt{2m_n\left(\frac{3}{2}K - k_B\right)}} = \frac{h}{\sqrt{3m_n K - k_B}}$

## SHORT ANSWER QUESTIONS (2 Mark)

1. Write one similarity and one difference between matter wave and an electromagnetic wave.
2. Does a photon have a de Broglie wavelength? Explain.
3. A photon and an electron have energy 200 eV each. Which one of these has greater de-Broglie wavelength?
4. The work function of the following metal is given Na = 2.75 eV, K = 2.3 eV, Mo = 4.14 eV, Ni = 5.15 eV which of these metal will not give a photoelectric emission for radiation of wave length 3300 A° from a laser source placed at 1m away from the metal. What happens if the laser is brought nearer and placed 50 cm away.
5. Name the experiment for which the followings graph, showing the variation of intensity of scattered electron with the angle of scattering, was obtained. Also name the important hypothesis that was confirmed by this experiment.




6. In a photoelectric effect experiment, the graph between the stopping potential V and frequency of the incident radiation on two different metals P and Q are shown in Fig. :




   (i) Which of the two metals has greater value of work function?

   (ii) Find maximum K.E. of electron emitted by light of frequency $\nu = 8 \times 10^{14}$ Hz for metal *P*.

7. Do all the photons have same dynamic mass? If not, why?
8. Why photoelectrons ejected from a metal surface have different kinetic energies although the frequency of incident photons are same?
9. Find the ratio of de-Broglie wavelengths associated with two electrons 'A' and 'B' which are accelerated through 8V and 64 volts respectively.

10. The photoelectric current at distances $r_1$ and $r_2$ of light source from photoelectric cell are $I_1$ and $I_2$ respectively. Find the value of $\frac{I_2}{I_1}$. **Ans. :** $I \propto \frac{I}{r^2} \Rightarrow \frac{I_2}{I_1} = \left(\frac{r_1}{r_2}\right)^2$

11. How does the maximum kinetic energy of emitted electrons vary with the increase in work function of metals? **Ans. :** $KE_{max} = h\nu - W_0 \Rightarrow KE_{max}$ decreases with increase in $W_0$.

## SHORT ANSWER QUESTIONS (3 Marks)

1. Explain the working of a photocell? Give its two uses.
2. Find the de Broglie wavelength associated with an electron accelerated through a potential difference V.
3. What is Einstein's explanation of photo electric effect? Explain the laws of photo electric emission on the basis of quantum nature of light.
4. If kinetic energy of thermal neutron is $\frac{3}{2}kT$ then show that de-Broglie wavelength of waves associated with a thermal neutron of mass m at temperature T kelvin is $\frac{h}{\sqrt{3mkT}}$ where k is boltz mann constant.
5. Explain Division and Germer experiment to verify the wave nature of electrons.
6. Explain the effect of increase of (i) frequency (ii) intensity of the incident radiation on photo electrons emitted by a metal.
7. X-rays of wave length $\lambda$ fall on a photo sensitive surface emitting electrons. Assuming that the work function of the surface can be neglected, prove that the de-Broglie wavelength of electrons emitted will be $\sqrt{\frac{h\lambda}{2mc}}$.
8. A particle of mass M at rest decays into two particles of masses $m_1$ and $m_2$ having velocities $V_1$ and $V_2$ respectively. Find the ratio of de-broglie Wavelengths of the two particles.

**Ans. :** 1 : 1

## NUMERICALS

1. Ultraviolet light of wavelength 350 nm and intensity 1W/m$^2$ is directed at a potassium surface having work function 2.2eV.

   (i) Find the maximum kinetic energy of the photoelectron.

   (ii) If 0.5 percent of the incident photons produce photoelectric effect, how many photoelectrons per second are emitted from the potassium surface that has an area 1cm$^2$.

$$K\max = 1.3\ eV;\ n = 8.8 \times 10^{11} \frac{\text{photo electron}}{\text{second}}$$

2. A metal surface illuminated by $8.5 \times 10^{14}$ Hz light emits electrons whose maximum energy is 0.52 eV the same surface is illuminated by $12.0 \times 10^{14}$ Hz light emits elections whose maximum energy is 1.97eV. From these data find work function of the surface and value of Planck's constant. [Work Function = 3ev]

3. An electron and photon each have a wavelength of 0.2 nm. Calculate their momentum and energy.

   (i) $3.3 \times 10^{-24}$ kgm/s

   (ii) 6.2 keV for photon

   (iii) 38eV for electron

4. What is the (i) Speed (ii) Momentum (ii) de-Broglie wavelength of an electron having kinetic energy of 120eV? [**Ans. :** (a) $6.5 \times 10^6$ m/s; (b) $5.92 \times 10^{-24}$ kg m/s; (c) 0.112 nm.]

5. If the frequency of incident light in photoelectric experiment is doubled then does the stopping potential become double or more than double, justify? (More than double)

6. A proton is accelerated through a potential difference V. Find the percentage increase or decrease in its deBroglie wavelength if potential difference is increased by 21%. (9.1%)

7. For what Kinetic energy of a neutron will the associated de Broglie wavelength be $5.6 \times 10^{-10}$m?

**Ans. :** $\sqrt{2m_n \times K.E.} = \frac{h}{\lambda} \Rightarrow K.E. = \left(\frac{h}{\lambda}\right)^2 \frac{1}{2m_n}$

$$= \left(\frac{6.625 \times 10^{-34}}{5.6 \times 10^{-10}}\right)^2 \frac{1}{2 \times 1.67 \times 10^{-27}} = 3.35 \times 10^{-21} J$$

8. A nucleus of mass M initially at rest splits into two fragments of masses $\frac{M}{3}$ and $\frac{2M}{3}$. Find the ratio of de Broglie wavelength of the fragments.

**Ans. :** Following the law of conservation of momentum,

$$\frac{M}{3}\nu_1 + \frac{2M}{3}\nu_2 = 0 \quad \text{or} \quad \left|\frac{M}{3}\nu_1\right| = \left|\frac{2M}{3}\nu_2\right|$$

$$\lambda = \frac{h}{m\nu} \Rightarrow \left|\frac{\lambda_1}{\lambda_2}\right| = \left|\frac{2\frac{M}{3}\nu_2}{\frac{M}{3}\nu_1}\right| = 1$$

9. An electron and a proton are possessing same amount of K.E., which of the two have greater de-Broglie, wavelength? Justify your answer.

**Ans. :** $E_e = \frac{1}{2}m_e\nu_e^2$ and $E_p = \frac{1}{2}m_p\nu_p^2 \Rightarrow m_e\nu_e = \sqrt{2E_e m_e}$ and $m_p\nu_p = \sqrt{2E_p m_p}$

But. $E_e = E_p \Rightarrow \frac{\lambda_e}{\lambda_p} = \sqrt{\frac{m_p}{m_e}} > 1$

$\therefore \lambda_e > \lambda_p$.

# ANSWERS

## 1 MARK QUESTIONS

1. Zero
2. (b) Total no. of reflected photons decreases by 20%.
3. Lower work function sensitive to visible light.
4. Photoelectric effect.
6. Ultraviolet (maximum frequency).
7. Yes, it will emit photoelectrons.
8. Photoelectric effect, Compton effect.
9. $2.3 \times 10^{-19}$ eV
10. $1.1 \times 10^{-34}$ m
11. (a) frequency of incident radiation.

    (b) Work function of surface.

## 2 MARKS QUESTIONS

7. No.

$$m = \frac{E}{c^2} = \frac{h\nu}{c^2}$$

$\Rightarrow$ $m$ depends on frequency of photon.

8. Because electrons lose their energy in collision. And energy is different for different electrons.
9. $2\sqrt{2}$

# UNIT VIII

# ATOMS AND NUCLEI

***Weightage Marks : 06***

## TOPICS TO BE COVERED

Alpha-particles scattering experiment, Rutherford's model of atom, Bohr Model, energy levels, Hydrogen spectrum. Composition and size of Nucleus, atomic masses, isotopes, isobars; isotones, Radioactivity-alpha, beta and gamma particles/rays and their properties; radioactive decay law.

## KEY POINTS

- Gieger-Marsden $\alpha$-scattering experiment established the existence of nucleus in an atom.

  Bohr's atomic model

  (i) Electrons revolve round the nucleus in certain fixed orbits called stationary orbits.

  (ii) In stationary orbits, the angular momentum of electron is integral multiple of $h/2\pi$.

  (iii) While revolving in stationary orbits, electrons do not radiate energy. The energy is emitted (or absorbed) when electrons jump from higher to lower energy orbits. (or lower to higher energy orbits). The frequency of the emitted radiation is given by $h\nu = E_f - E_i$. An atom can absorb radiations of only those frequencies that it is capable of emitting.

- As a result of the quantisation condition of angular momentum, the electron orbits the nucleus in circular paths of specific radii. For a hydrogen atom it is given by.

$$r_n = \left(\frac{n^2}{m}\right)\left(\frac{h}{2\pi}\right)^2 \frac{4\pi\varepsilon_0}{e^2} \quad \Rightarrow \quad r_n \propto n^2$$

  The total energy is also quantised : $E_n = \dfrac{-me^4}{8n2\varepsilon_0^2 h^2} = -13.6\ \text{eV}/\text{n}^2$

  The $n$ = 1 state is called the ground state.

  In hydrogen atom, the ground state energy is – 13.6 eV.

- de Broglie's hypothesis that electron have a wavelength $\lambda = h/mv$ gave an explanation for the Bohr's quantised orbits.

- Neutrons and protons are bound in nucleus by short range strong nuclear force. Nuclear force does not distinguish between nucleons.

- The nuclear mass 'M' is always less than the total mass of its constituents. The difference in mass of a nucleus and its constituents is called the **mass defect.**

$$\Delta M = [Zm_p + (A - Z)m_n] - \text{M} \text{ and } \Delta E_b = (\Delta M)c^2$$

  The energy $\Delta E_b$ represents the binding energy of the nucleus.

  For the mass number ranging from A = 30 to 170 the binding energy per nucleon is nearly constant at about 8MeV per nucleon.

- *Radioactive Decay Law :* The number of atoms of a radioactive sample disintegrating per second at any time is directly proportional to the number of atoms present at that time. Mathematically :

$$\frac{dN}{dt} = -\lambda N \text{ or } N_{(t)} = N_0 e^{-\lambda t}$$

  where $\lambda$ is called decay constant. It is defined as the reciprocal of the time during which the number of atoms of a radioactive substance decreases to 1with of their original number.

- Number of radioactive atoms N in a sample at any time *t* can be calculated using the formula.

$$N = N_0 \left(\frac{1}{2}\right)^{t/T}$$

  Here No = no. of atoms at time $t = 0$ and T is the half-life of the substance.

  **Half life :** The half life of a radio active substances is defined as the time during which the number of atoms disintegrate to one half of its initial value.

$$T_{1/2} = \frac{\ln 2}{\lambda} = \ln 2 \times \text{mean life}$$

$$\text{or} \quad 0.693/\lambda = \frac{0.693}{\lambda}$$

  Here $\quad \lambda = \text{decay constant} = \dfrac{1}{\text{mean life}}.$

- Radius *r* of the nucleus of an atom is proportional to the cube root of its mars number thereby implying that the nuclear density is the same. (Almost) for all substances/nuclei.

- $\alpha$-decay : ${}_Z X^A \rightarrow {}_{Z-2}Y^{A-4} + {}_2He^4 + Q$

  $\beta$-decay : ${}_Z X^A \rightarrow {}_{Z-1}Y^A + {}_{-1}e^0 + \bar{\nu} + Q$

  $\gamma$-decay : When $\alpha$ or $\beta$-decay leave, the nucleus in excited state; the nucleus goes to lower energy state or ground state by the emission of $\gamma$-ray(s).

## VERY SHORT ANSWER QUESTIONS (I Mark)

1. Define atomic mass unit. Write its energy equivalent in MeV.
2. What was the drawback of Rutherford model of atom?
3. What are the number of electrons and neutrons in singly ionised $^{236}_{92}U$ atom?
4. Name the series of hydrogen spectrum which has least wavelength.

*5. Any two protons repel each other, then how is this possible for them to remain together in a nucleus.

6. Define radioactive decay constant.
7. You are given reaction : $_1H^2 + {}_1H^2 \rightarrow {}_2He^4 + 24$ MeV. What type of nuclear reaction is this?
8. After losing two electrons, to which particle does a helium atom get transformed into?
9. Write two important inferences drawn from Gieger-Marsden's $\alpha$-particle scattering experiment.
10. What will be the ratio of the radii of the nuclei of mass number $A_1$ and $A_2$?
11. In nuclear reaction $^1_1H \rightarrow {}^1_0n + {}^P_Qx$ find P, Q and hence identify X.
12. Binding energies of neutron $\left({}^2_1H\right)$ and $\alpha$-particle ($_2He^4$) are 1.25 MeV/nucleon and 7.2 MeV/nucleon respectively. Which nucleus is more stable?
13. $\alpha$-particles are incident on a thin gold foil. For what angle of deviation will the number of deflected $\alpha$-particles be minimum?
14. A and B are two isotopes having mass numbers 14 and 16 respectively. If the number of electrons in A is 7, then give the number of neutrons in B.
15. If the amount of a radioactive substance is increased four times then how many times will the number of atoms disintegrating per unit time be increased?
16. An electron jumps from fourth to first orbit in an atom. How many maximum number of spectral lines can be emitted by the atom?
17. Under what conditions of electronic transition will the emitted light be monochromatic?
18. Why does only a slow neutron (.03eV energy) cause the fission in the uranium nucleus and not the fast one?
19. Write the relation for distance of closest approach.
20. In Bohr's atomic model, the potential energy is negative and has a magnitude greater than the kinetic energy, what does this imply? **Ans. :** The electron revolving is bound to the nucleus.
21. Name the physical quantity whose dlimensions are same as Planck's constant.

    **Ans. :** Angular momentum

22. Define ionisation potential.

23. The ionisation potential of helium atom is 24.6 V. How much energy will be required to ionise it?
**Ans. :** 24.6 eV

24. What is the energy possessed by an electron whose principal quantum number is infinite?

25. Write the value of Rydberg constant? **Ans. :** $1.097 \times 10^7\ m^{-1}$

26. Name the spectral series of hydrogen atom which lie in *uv* region. **Ans. :** Lyman Series

27. Name the series of hydrogen spectrum lying in the infra red region.

28. What is the order of velocity of electron in a hydrogen atom in ground state. **Ans. :** $10^6$ ms$^{-1}$

29. Write a relation for Paschen sone's lines of hydrogen spectrum.

**Ans. :** $\bar{\nu} = R\left(\frac{1}{3^2} - \frac{1}{n^2}\right) n = 4, 5........$

30. Arrange radioactive radiation in the increasing order of penetrating power.

31. Write a relation between average life and decary constant.

32. Write two units for activity of radioactive element and relate them with number of disintegration per second.

33. The half life of a radioactive element A is same as the mean life time of another radioactive element B. Initially, both have same number of atoms. B decay faster than A. Why?
**Ans. :** $T_A = \tau_B = 1.44\ T_B \therefore T_A > T_B \therefore \lambda_A < \lambda_B$. Therefore B decay faster than A.

34. Draw the graph showing the distribution of Kinetic energy of electrons emitted during $\beta$ decay.

35. Compare radii of two nuclei of mass numbers 1 and 27 respectively (**Ans. :** 1 : 3).

36. Define atomic mass unit.

37. Write the energy equivalent of MeV.

38. Which element has highest value of Binding Energy per nucleon.

39. Mention the range of mass number for which the Binding energy curve is almost horizontal.

40. What is the ratio of nuclear densities of the two nuclei having mass numbers in the ratio 1 : 4?

41. Write two important inferences drawn from Rutherford $\alpha$ particle scattering experiment.

42. Draw a graph of number of undecayed nuclei to the time, for a radioactive nuclei.

NCERT pg. 447

43. Write an equation to represent $\alpha$ decay.

## SHORT ANSWER QUESTIONS (2 Marks)

1. Define distance of the closest approach. An $\alpha$-particle of kinetic energy 'K' is bombarded on a thin gold foil. The distance of the closet approach is 'r'. What will be the distance of closest approach for an $\alpha$-particle of double the kinetic energy?

2. Show that nuclear density is independent of the mass number.

3. Which of the following radiations $\alpha$, $\beta$ and $\gamma$ are :

   (i) similar to x-rays?

   (ii) easily absorbed by matter

   (iii) travel with greatest speed?

   (iv) similar to the nature of cathode rays?

4. Some scientist have predicted that a global nuclear war on earth would be followed by 'Nuclear winter'. What could cause nuclear winter?

5. If the total number of neutrons and protons in a nuclear reaction is conserved how then is the energy absorbed or evolved in the reaction?

6. In the ground state of hydrogen atom orbital radius is $5.3 \times 10^{-11}$ m. The atom is excited such that atomic radius becomes $21.2 \times 10^{-11}$ m. What is the principal quantum number of the excited state of atom?

7. Calculate the percentage of any radioactive substance left undecayed after half of half life.

8. Why is the density of the nucleus more than that of atom?

9. The atom $_8O^{16}$ has 8 protons, 8 neutrons and 8 electrons while atom $_4Be^8$ has 4 proton, 4 neutrons and 4 electrons, yet the ratio of their atomic masses is not exactly 2. Why?

*10. What is the effect on neutron to proton ratio in a nucleus when $\beta^-$ particle is emitted? Explain your answer with the help of a suitable nuclear reaction.

11. Why must heavy stable nucleus contain more neutrons than protons?

12. Show that the decay rate R of a sample of radio nuclide at some instant is related to the number of radio active nuclei N at the same instant by the expression $R = -N\lambda$.

13. What is a nuclear fusion reaction? Why is nuclear fusion difficult to carry out for peaceful purpose?

14. Write two characteristic features of nuclear forces which distinguish them from coulomb force.

15. Half life of certain radioactive nuclei is 3 days and its activity is 8 times the 'safe limit'. After how much time will the activity of the radioactive sample reach the 'safe limit'?

16. Derive $mvr = \frac{nh}{2\pi}$ using de Broglie equation.

17. Draw graph of number of scattered particles to scattering angle in Ratherford's experiment.

18. Show that nuclear density is same for all the nuclei.

19. What is the shortest wavelength present in the (i) Paschen series (ii) Balmer series of spectral lines? **Ans. :** 820nm, (ii) 365 nm

20. The radius of the inner most electron orbit of a hydrogen atom 0.53 Å. What are the radii of the $n = 2$ and $n = 3$ orbits.

21. The ground state energy of hydrogen atom is –13.6 eV. What are the Kinetic and potential energies of the electron in this state?

22. Write formula of frequency to represent (i) Lyman series (ii) Balmer series.

23. From the relation $R = R_0 A^{1/3}$ where $R_0$ is a constant and A is the mass number of a nucleus, show that nuclear matter density is nearly constant.

**Ans. :** Nuclear matter density $= \dfrac{\text{Mass of nucleus}}{\text{Volume of nucleus}}$

$$= \frac{\text{mA}}{\frac{4}{3}\pi \text{R}^3} = \frac{mA}{\frac{4}{3}\pi R_0^3 A}$$

$$= \frac{m}{\frac{4}{3}\pi R_0^3} \approx 2.3 \times 10^{17} kg / m^3$$

= Constant

24. Find the energy equivalent of one atomic mass unit in joules and then in MeV.

**Ans. :** $E = \Delta mc^2$ $\Delta m = 1.6605 \times 10^{-27}$ kg

$= 1.6605 \times 10^{-27} \times (3 \times 10^8)^2$

$= 1.4924 \times 10^{-4}\ J$

$$= \frac{1.4924 \times 10^{-10}}{1.6 \times 10^{-19}} eV$$

$= 0.9315 \times 10^9$ eV

= 931.5 MeV

25. Write four properties of nuclear force.

## SHORT ANSWER QUESTIONS (3 Marks)

*1. Give one example of a nuclear reaction. Also define the Q-value of the reaction. What does Q > 0 signify?

2. Explain how radio-active nucleus can-emit β-particles even though nuclei do not contain these particles. Hence explain why the mass number of radioactive nuclide does not change during β-decay.

3. Define the term half life period and decay constant. Derive the relation between these terms.

4. State the law of radioactive decay. Deduce the relation $N = N_0e^{-\lambda t}$, where symbols have their usual meaning.

5. Give the properties of $\alpha$-particles, $\beta$-particles and $\gamma$-rays.

6. With the help of one example, explain how the neutron to proton ratio changes during alpha decay of a nucleus.

7. Distinguish between nuclear fusion and fission. Give an example of each.

8. A radioactive isotope decays in the following sequence $A \xrightarrow{{}_0n^1} A_1 \xrightarrow{\alpha} A_2$. If the mass and atomic numbers of $A_2$ are 171 and 76 respectively, find mass and atomic number of A and $A_1$. Which of the three elements are isobars?

9. Obtain a relation for total energy of the electron in terms of orbital radius. Show that total energy is negative of K.E. and half of potential energy.

$$E = -\frac{e^2}{8\pi E_0 r}.$$

10. Draw energy level diagram for hydrogen atom and show the various line spectra originating due to transition between energy levels.

11. The total energy of an electron in the first excited state of the hydrogen atom is about –3.4 eV. What is

    (a) the kinetic energy,

    (b) the potential energy of the electron?

    (c) Which of the answers above would change if the choice of the zero of potential energy in changed to (i) + 0.5 eV (ii) –0.5 eV.

    **Ans.**

    (a) When P.E. is chosen to be zero at infinity E = – 3.4 eV, using E = – K.E., the K.E. = + 3.4 eV.

    (b) Since P.E. = – 2E, PE = – 6.8 eV.

    (c) If the zero of P.E. is chosen differently, K.E. does not change. The P.E. and T.E. of the state, however would alter if a different zero of the P.E. is chosen.

    (i) When P.E. at ∞ is + 0.5 eV, P.E. of first excited state will be –3.4 – 0,5 = – 3.9 eV.

    (iii) When P.E. at ∞ is + 0.5 eV, P.E. of first excited state will be –3.4 – (–0.5) = –2.9 eV.

12. What is beta decay? Write an equation to represent $\beta^-$ and $\beta^+$ decay. Explain the energy distribution curve is $\beta$ decay.

13. Using energy level diagram show emission of $\gamma$ rays by $^{60}_{27}Co$ nucleus and subsequent $\beta$ decay to obtain $^{60}_{28}Ni$. NCERT pg. 457

## LONG ANSWER QUESTIONS (5 Marks)

1. State Bohr's postulates. Using these postulates, drive an expression for total energy of an electron in the $n^{th}$ orbit of an atom. What does negative of this energy signify?
2. Define binding energy of a nucleus. Draw a curve between mass number and average binding energy per nucleon. On the basis of this curve, explain fusion and fission reactions.
3. State the law of radioactive disintegration. Hence define disintegration constant and half life period. Establish relation between them.
4. Explain the process of release of energy in a nuclear reactor. Draw a labelled diagram of a nuclear reactor and write the functions of each part.
5. What is meant by nuclear fission and nuclear chain reaction? Outline the conditions necessary for nuclear chain reaction.
6. Briefly explain Rutherford's experiment for scattering of $\alpha$ particle with the help of a diagram. Write the conclusion made and draw the model suggested.
7. State law of radioactive decay obtain relation

   (i) $N = N_0 e^{-\lambda t}$

   (ii) $R = R_0 e^{-\lambda t}$

   where $N$ is number of radioactive nuclei at time $t$ and

   $N_0$ is number of radioactive nuclei at time $t_0$ $\lambda$ is decay constant

   $R$ is rate of decay at any instant $t$

   $R_0$ is rate of decay at any time $t_0$ (initial time).

# NUMERICALS

1. The radius of innermost orbit of Hydrogen atom is $5.3 \times 10^{-1}$ m. What are the radii of $n = 2$ and $n = 3$ orbits. **Ans. :** $r_2 = 2.12 \times 10^{-10}$ m, and $r_3 = 4.77 \times 10^{-10}$ m
2. Calculate the radius of the third Bohr orbit of hydrogen atom and energy of electron in that orbit. **Ans. :** $r_3 = 4775$ A° and $E_3 = -2.43 \times 10^{-19}$ J
3. Calculate the longest and shortest wavelength in the Balmer series of Hydrogen atom. Rydberg constant = $1.0987 \times 10^7$ m$^{-1}$. **Ans. :** $\lambda_l = 6563$ A°, $\lambda_s = 3646$ A°
4. What will be the distance of closest approach of a 5 MeV proton as it approaches a gold nucleus? **Ans. :** $4.55 \times 10^{-14}$ m

5. A 12.5 MeV alpha – particle approaching a gold nucleus is deflected by 180°. What is the closest distance to which it approaches the nucleus? **Ans. :** $1.82 \times 10^{-14}$ m

6. Determine the speed of the electron in $n = 3$ orbit of hydrogen atom. **Ans. :** $7.29 \times 10^5$ ms$^{-1}$

7. There are $4\sqrt{2} \times 10^6$ radioactive nuclei in a given radio active element. If half life is 20 seconds, how many nuclei will remain after 10 seconds? **Ans. :** $4 \times 10^6$

8. The half life of a radioactive substance is 5 hours. In how much time will 15/16 of the material decay? **Ans. :** 20 hours

9. At a given instant, there are 25% undecayed radioactive nuclei in a sample. After 10 seconds, the number of undecayed nuclei reduces to 12.5%. Calculate the mean life of nuclei. **Ans. :** 14.43

10. Binding energy of $_2He^4$ and $_3Li^7$ nuclei are 27.37 MeV and 39.4 MeV respectively. Which of the two nuclei is more stable? Why? **Ans. :** $_2He^4$ because its BE/nucleon is greater

11. Find the binding energy and binding energy per nucleon of nucleus $_{83}B^{209}$. Given : mass of proton = 1.0078254 u. mass of neutron = 1.008665 u. Mass of $_{83}Bi^{209}$ = 208.980388u.
**Ans. :** 1639.38 MeV and 7.84 MeV/Nucleon

12. Is the fission of iron ($_{26}Fe^{56}$) into ($_{13}Al^{28}$) as given below possible?

$$_{26}Fe^{56} \longrightarrow {}_{13}Al^{28} + {}_{13}Al^{28} + Q$$

Given mass of $_{26}Fe^{56}$ = 55.934940 and $_{13}Al^{28}$ = 27.98191 U
**Ans. :** Since Q value comes out negative, so this fission is not possible

13. Find the maximum energy that β-particle may have in the following decay :

$$_8O^{19} \rightarrow {}_9F^{19} + {}_{-1}e^0 + \bar{\nu}$$

Given

m ($_8O^{19}$) = 19.003576 a.m.u.

m ($_9F^{19}$) = 18.998403 a.m.u.

m ($_{-}e^0$) = 0.000549 a.m.u. **Ans. :** 4.3049 MeV

14. The value of wavelength in the lyman series is given as

$$\lambda = \frac{93.4 n_i^2}{n_i^2 - 1} A^o$$

Calculate the wavelength corresponding to transition from energy level 2, 3 and 4. Does wavelength decreases or increase.

**Ans. :** $$\lambda_{21} = \frac{913.4 \times 2^2}{2^2 - 1} = 1218\ A^o$$

$$\lambda_{31} = \frac{913.4 \times 3^2}{3^2 - 1} = 1028\ A^o$$

$$\lambda_{41} = \frac{913.4 \times 4^2}{4^2 - 1} = 974.3\ A^o$$

$\lambda_{41} < \lambda_{31} < \lambda_{21}$

15. The half life of $^{238}_{92}u$ undergoing $\alpha$ decay is $4.5 \times 10^9$ years what is the activity of 1g. sample of $^{238}_{92}u$.

**Ans. :** $T_{1/2} = 4.5 \times 10^9\ y$

$= 4.5 \times 10^9 \times 3.16 \times 10^7$ s

$= 1.42 \times 10^{17}$ s

1g of $^{238}_{92}u$ contains $= \frac{1}{238 \times 10^{-3}} \times 6.025 \times 10^{26}$ atom

$= 25.3 \times 10^{20}$ atoms

$\therefore$ decay rate $= R = \lambda N = \frac{0.693}{T} \times \lambda$

$$= \frac{0.693 \times 25.3 \times 10^{20}}{1.42 \times 10^{17}}\ s^{-1}$$

$= 1.23 \times 10^4\ B_q$.

## ANSWERS

### I MARK QUESTIONS

1. An a.m.u. is 1/12 of the mass of a carbon isotope $^{12}C_6$, 1u = 931 MeV.
2. Rutherford's model of atom failed to explain the existence of sharp lines in hydrogen spectrum.
3. No. of electrons = 91, No. of neutrons = 236 – 92 = 144
4. Lyman Series
5. Nuclear force between two protons is 100 times stronger than the electrostatic force.
6. The decay constant of radioactive substance is defined as the reciprocal of that time in which the number of atoms of substance becomes $\frac{1}{e}$th times the atoms present initially.

7. Fusion reaction.

8. $\alpha$-particle.

9. (i) Positive charge is concentrated in the nucleus.

   (ii) size of nucleus is very small in comparison to size of atom.

10. $R_1/R_2 = (A_1/A_2)^{1/3}$

11. $P = 0$, $Q = 1$, X is a positron $({}_{+1}e^0)$.

12. Binding energy of ${}_2{}^4He$ is more than neutron $({}_1H^2)$, So, ${}_2He^4$ is more stable.

13. 180°.

14. 9.

15. Four times $\because$ R = $-\lambda N$.

16. 6

17. Only fixed two orbits are involved and therefore single energy value.

18. Slow neutron stays in the nucleus for required optimum time and disturbs the configuration of nucleus.

## ANSWERS 2 MARKS QUESTIONS

1. It will be halved.

2. Using the relation $R = R_0A^{1/3}$.

$$\frac{R_1}{R_2} = \left(\frac{A_1}{A_2}\right)^{1/3} \quad \Rightarrow \quad \frac{\frac{4\pi}{3}R_1^3}{\frac{4}{3}\pi R_2^3} = \frac{A_1}{A_2} \text{ or } \frac{\frac{4}{3}\pi R_1^3}{A_1} = \frac{\frac{4}{3}\pi R_2^3}{A_2}$$

   Hence nuclear density of 1st element = Nuclear density of 2nd element.

3. (i) Similar to x-rays — $\gamma$-rays.

   (ii) $\alpha$-particle.

   (iii) $\gamma$-rays.

   (iv) $\beta$-particle.

4. Nuclear radioactive waste will hang like a cloud in the earth atmosphere and will absorb sun radiations.

5. The total binding energy of nuclei on two sides need not be equal. The difference in energy appears as the energy released or absorbed.

6. $n = 2$ as $r_n \alpha n^2$

7. From relation $\dfrac{N}{N_0} = \left(\dfrac{1}{2}\right)^{t/T}$ when $t = T/2$

$$\frac{N}{N_0} = \left(\frac{1}{2}\right)^{1/2} \quad \text{or} \quad \frac{N}{N_0} = \frac{1}{\sqrt{2}} = \frac{100}{\sqrt{2}} = 70.9\%.$$

8. Because radius of atom is very large than radius of nucleus.

9. Due to mass defect or different binding energies.

10. Decreases as number of neutrons decreases and number of protons increases.

11. To counter repulsive coulomb forces, strong nuclear force required between neutron–neutron, neutron–proton and proton–proton.

12. $N = N_0 e^{-\lambda t}$ differentiating both sides we get $\dfrac{dN}{dt} = -\lambda N_0 e^{-\lambda t} = -\lambda N$ *i.e.,* decay rate

$$R = \frac{dN}{dt} = -\lambda N.$$

13. For fusion, temperature required is from $10^6$ to $10^7$ K. So, to carry out fusion for peaceful purposes we need some system which can create and bear such a high temperature.

14. Nuclear forces are short range forces (within the nucleus) and do not obey inverse equare law while coulomb forces are long range (infinite) and obey inverse square law.

15. $$\left(\frac{A}{8A}\right) = \left(\frac{1}{2}\right)^{t/T_{1/2}}$$

or $$\left(\frac{1}{2}\right)^3 = \left(\frac{1}{2}\right)^{t/3}$$

or $$3 = \frac{t}{3}$$

⇒ $$t = 9 \text{ days.}$$

# UNIT IX

# ELECTRONIC DEVICES

**Weightage Marks : 07**

## TOPICS TO BE COVERED

**Semiconductors**

Semiconductors diode-I-V characteristics in forward and reverse bias, diode as rectifier.

I-V characteristics of LED, Photodiodes, solarcell and Zener diode as a voltage regulator, Junction transistor, transistor action, characteristics of a transistor.

Transistor as an amplifier (common emitter configuration)

Oscillator

Logic gates (OR, AND, NOT, NAND and NOR)

**Transistor as a switch**

## KEY POINTS

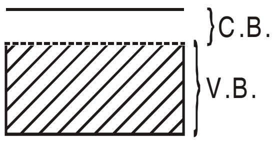
1. Solids are classified on the basic of

(i) **Electrical conductivity**

| **Electrical conductivity** | **Resistivity** | **conductivity** |
|---|---|---|
| Metals | $\rho(\Omega m)$ | $\sigma(Sm^{-1})$ |
| | $10^{-2} - 10^{-8}$ | $10^{2} - 10^{8}$ |
| Semiconductors | $10^{-5} - 10^{6}$ | $10^{-6} - 10^{5}$ |
| Insulators | $10^{11} - 10^{19}$ | $10^{-19} - 10^{-11}$ |

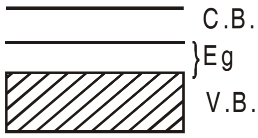
(ii) **Energy Bands**

Metal




Band Gap energy

Eg W 0

| | | |
|---|---|---|
| Semiconductor |  | Eg < 3eV |
| Intrinsic | $n_e = n_n = n_i$ | $n_e$ = free electron density in conduction band.<br>$n_n$ = the hole density in valence band.<br>$n_i$ = the instinsic cassier concentration |
| Extrinsic | | |
| *n*-type | $n_e \simeq N_D >> n_n$ | |
| *p*-type | $n_h \infty N_A > n_e$ | |
| | $n_e n_n = n_i^2$ | |
| Mobility | $\mu = v/E$ | $\mu$ = drift velocity acquired by a charge carrier.<br>$E$ = Electric field. |
| *p-n* junction diode | | |
| Transistors | | |
| *n–p–n* | | |
| *p–n–p* | | |
| Common Emitter Transistor | | |
| Input Resistance | $r_i = \left[\frac{\Delta V_{BE}}{\Delta I_B}\right]_{V_{CE=\text{constant}}}$ | |
| Output resistance $r_0$ | $r_0 = \left[\frac{\Delta V_{CE}}{\Delta I_C}\right]_{I_{B=\text{constant}}}$ | |
| Three states of a transistor | Cut off state active state Saturation state | |
| Oscullator | $f = \frac{1}{2\pi\sqrt{LC}}$ | $f$ = frequency of<br>osculations in the tank CKL. |

Gates

Not

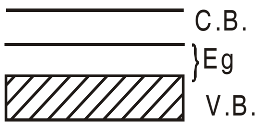
| Input | Output |
|---|---|
| A | Y |
| 0 | 1 |
| 1 | 0 |

OR

| Input | | Output |
|---|---|---|
| A | B | Y |
| 0 | 1 | 1 |
| 1 | 0 | 1 |
| 1 | 1 | 1 |

And

| Input | | Output |
|---|---|---|
| A | B | Y |
| 0 | 0 | 0 |
| 0 | 1 | 0 |
| 1 | 0 | 0 |
| 1 | 1 | 1 |

Insulator 


Eg > 3eV

2. Types of Semiconductors

2 Types of semiconductors
- Elemental
- Compound
  - Inorganic CdS, GaAS, CdSe, InP etc.
  - Organic, Anthracene Doped Pthalocyamines etc.

3. In intrinsic semiconductors (Pure Si, Ge) carrier (electrons and holes) are generated by breaking of bonds within the semiconductor itself. In extrinsic semiconductors carriers (e and h) are increased in numbers by 'doping'.

4. An intrinsic semiconductor at 0 K temperature behaves as an insulator.

5. Pentavalent (donor) atom (As, Sb, P etc.) when doped to Si or Ge give *n*-type and trivalent (acceptor) atom (In, Ga, Al etc.) doped with Si or Ge give *p*-type semiconductor.

6. Net charge in *p*-type or *n*-type semiconductor remains zero.

7. Diffusion and drift are the two process that occur during formation of *p-n* junction.

8. Diffusion current is due to concentration gradient and direction is from p to n side drift current is due to electric field and its direction is from *n* to *p*-side.

9. In depletion region movement of electrons and holes depleted it of its free charges.

10. Because of its different behaviours in forward biasing (as conductor for $V > V_b$) and reverse biasing (as insulator for $V < V_B$) a *p–n* junction can be used as Rectifier, LED, photodiode, solar cell etc.

11. In half wave rectifier frequency output pulse is same as that of input and in full wave rectifier frequency of output is double of input.

12. When a zener diode is reverse biased, voltage across it remains steady for a range of currents above zener breakdown. Because of this property, the diode is used as a voltage regulator.

13. In a transistor current goes from low resistances (forward biasing) to high resistance (reverse biasing).

14. Current relationship in a transistor

$$I_e = I_b + I_c \text{ (} I_b \text{ is only 2\% to 8\% of } I_e\text{)}$$

15. In common emitter transistor characteristic we study

$I_b$ versus $V_{BE}$ at constant $V_{CE}$ (Input characteristic)

$I_c$ versus $V_{CE}$ at constant $I_B$ (output characteristic)

Input resistance $r_i = \left(\frac{\delta V_{BE}}{\delta I_B}\right) V_{CE}$

Output resistance $r_0 = \left(\frac{\delta V_{CE}}{\delta I_C}\right) I_B$

16. Current amplifications factors

$$\beta_{ac} = \left(\frac{\delta I_c}{\delta I_b}\right) V_{CE}$$

$$\beta_{dc} = I_c/I_b.$$

$$\beta_{ac} \approx \beta_{dc}.$$

Both $\beta_{ac}$ and $\beta_{dc}$ vary with $V_{CE}$ and $I_B$ Slightly.

17. Transistor is used (i) as a switch in cut off and saturation state. (ii) as amplifier in active region.

18. In CE configuration, transistor as amplifier output differ in phase them input by $\pi$.

19. Transistor as an amplifier with positive feedback works as an oscillator.

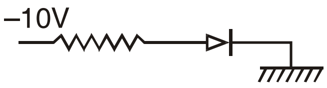
20. Gates used for performing binary operations in digital electronics mainly consist of diodes and transistors.

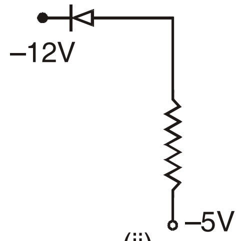
21. NAND gates alone can be used to obtain OR gate and similarly a NOR gates alone cant be used to obtain AND gate, OR gate.

# QUESTIONS

## VERY SHORT ANSWER QUESTIONS (I Mark)

1. Write the relation between number density of holes and number density of free electrons in an intrinsic semiconductor.
2. Write the value of resistance offered by an ideal diode when (i) forward based (ii) reverse biased.
3. Write any one use of (i) photodiode (ii) LED.
4. Write the truth table for a two input AND gate.
5. At what temperature does a semiconductor behave as an insulator?
6. Write two uses of logic gates in daily life.
7. If L and C are the inductance and capacitance of the tank circuit of an oscillator, what will be the frequency of oscillation?
8. Semiconductors do not support strong current *i.e.,* a semiconductor is damaged when strong current passes through it. Why?
9. Draw I–V characteristic of a solar cell.
10. What is the phase difference between input and output waveform in the common emitter transistor amplifier?
11. What type of feedback is required in an oscillator? Why?
12. What is the direction of diffusion current in a junction diode?
13. Draw a circuit diagram showing the biasing of a photodiode.
14. Name the semiconductor device that can be used to regulate an unregulated dc power supply.
15. Name the p.n. junction diode which emits spontaneous radiation when forward biased.
16. Name any one semiconductor used to make LED.
17. What is meant by 'regulation' as applied to a power supply?
18. A semiconductor device is connected in a series circuit with a battery and a resistance. A current is found to pass through the circuit. When polarity of the battery is reversed, the current drops to almost zero. Name the semiconductor device.
19. In the following diagram write which of the diode is forward biased and which is reverse biased?




20. How does the energy gap in a semiconductor vary, when doped, with a pentavalent impurity?

21. Name the types in which the electronic circuits have been classified.

22. Name the electrical circuits used to get smooth D.C. output from a rectifier circuit.

23. What is the order of energy gap in a conductor, semiconductor and insulator.

24. The ratio of the number of free electrons to holes $n_e/n_h$ for two different materials *A* and *B* are 1 and < 1 respectively. Name the type of semiconductor to which *A* and *B* belong.

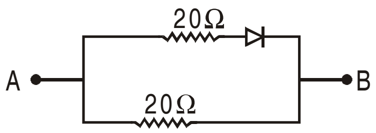
## SHORT ANSWER QUESTIONS (2 Marks)

1. If the frequency of the input signal is f. What will be the frequency of the pulsating output signal in case of:

   (i) half wave rectifier? (ii) full wave rectifier?

2. Find the equivalent resistance of the network shown in figure between point A and B when the p-n junction diode is ideal and :

   (i) A is at higher potential (ii) B is at higher potential

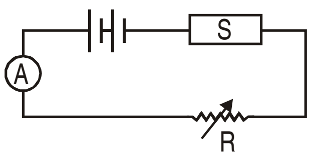



3. Potential barrier of p.n. junction cannot be measured by connecting a sensitive voltmeter across its terminals. Why?

4. Diode is a non linear device. Explain it with the help of a graph.

5. A *n*-type semiconductor has a large number of free electrons but still it is electrically neutral. Explain.

6. The diagram shows a piece of pure semiconductor S in series with a variable resistor R and a source of constant voltage V. Would you increase or decrease the value of R to keep the reading of ammeter A constant, when semiconductor S is heated? Give reason.



7, What is the field ionisation in zener diode? Write its order of magnitude.

8. Power gain of a transistor is high. Does it mean the power is generated by the transistor itself? Explain.

9. What is the role of feedback in an oscillator circuit?

10. Why is a photo diode used in reverse bias?

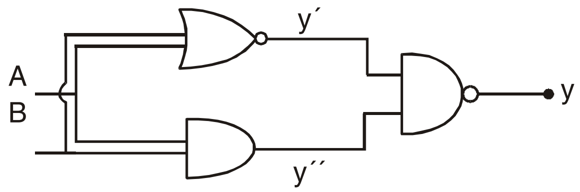
11. Give four advantages of LED over incandescent lamp.

12. Explain the amplifying action of a transistor.

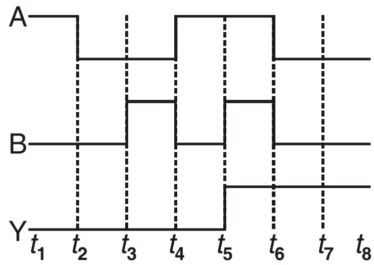
13. Draw a labelled circuit diagram of *n-p-n* transistor amplifier in CE–configuration.

14. The output of a 2 input AND gate is fed as input to a NOT gate. Write the truth table for the final output of the combination. Name this new logic gate formed.

15. Write the truth table for the combination of gates shown.



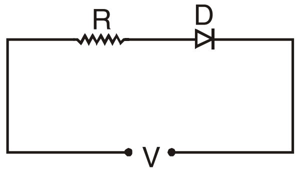

16. The following figure shows the input waveform 'A' and 'B' and output wave form Y of a gate. Write its truth table and identify the gate.




17. In the given circuit, D is an ideal diode. What is the voltage across R. When the applied voltage V makes the diode.

(a) Forward bias?

(b) Reverse bias?

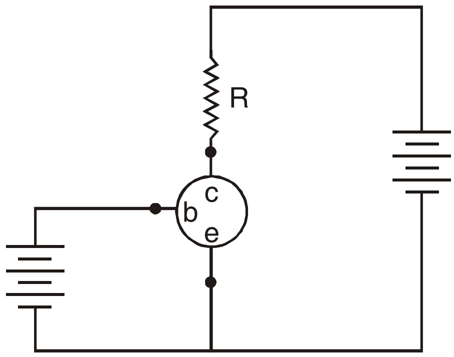



18. A transistor is a current operated device. Explain.

19. Given here is a circuit diagram of a transistor as a NOT gate. Here the transistor has been represented by a circle with the emitter (e), base (b) and collector (c) terminals marked clearly. Carefully look at the polarity of the voltages applied and answer the following question.

    (a) What is the type of transistor *pnp* or *npn*?

    (b) Is the transistor in saturation or cutoff?




20. Why is photodiode used in reverse bias? Give one use of a photodiode.

21. Which special type of diode can act as a voltage regulator? Give the symbol of this diode and draw the general shape of its V-I characteristics.

22. In the working of a transistor, emither base junction is forward biased, while the collector base junction is neverse based, why?

23. In a transistor, base is leghtly doped and is a thin layer, why?

24. Show the donor energy level in energy band diagram of *n*-type semiconductor.

25. Show the acceptor energy level in energy band diagram of *p*-type semiconductor.

26. What is the value of knee voltage in

    (a) Ge junction diode.

    (b) Si junction diode.

27. Which of the input and output circuits of a transistor has a higher resistance and why?

28. Draw the transfer characteristic for a transistor, indicating cut off region, active region and saturation region.

## SHORT ANSWER QUESTIONS (3 Marks)

1. What is depletion region in *p-n* junction diode. Explain its formation with the help of a suitable diagram.

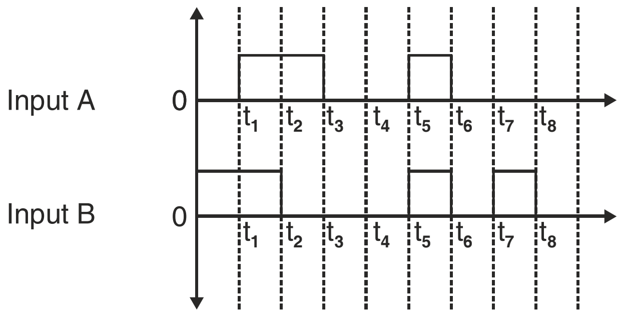
2. Explain the working of *npn* transistor as an amplifier and find an expression for its voltage gain.

3. What is rectification? With the help of a labelled circuit diagram explain half wave rectification using a junction diode.

4. Explain the working of a transistor as a switch with the help of a suitable circuit diagram.
5. Using block diagram show the feedback in an oscillator.
6. With the help of a circuit diagram explain the V–I graph of a *p-n* junction in forward and reverse biasing.
7. With the help of a circuit diagram, explain the input and output characteristic of a transistor in common emitter configuration.
8. What is *p-n* junction? How is *p-n* junction made? How is potential barrier developed in a *p-n* junction?
9. What is a transistor? Draw symbols of *npn* and *pnp* transistor. Explain action of transistor.
10. Give three differences between forward bias and reverse bias.
11. What is integrated circuit? Give two advantages of integrated circuit over conventional electronic circuit.
12. Write three differences between *n*-type semiconductor and *p*-type semiconductor.
13. Construct AND gate using NAND gate and give its truth table.
14. Construct NOT gate using NAND gate and give its truth table.

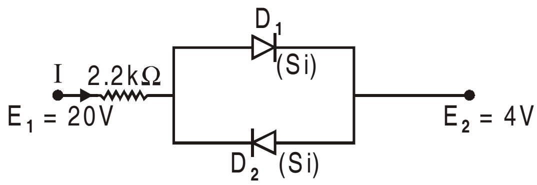
## LONG ANSWER QUESTIONS (5 Marks)

1. How does a transistor work as an oscillator? Explain its working with suitable circuit diagram. Write the expression for frequency of output.
2. What is the function of base region of a transistor? Why is this region made thin and lightly doped? Draw a circuit diagram to study the input and output characteristics of *npn* transistor in a common emitter configuration. Show these characteristics graphically.
3. What is *p-n* junction diode? Define the term dynamic resistance for the junction. With the help of labelled diagram, explain the working of *p-n* junction as a full wave rectifier.
4. What are logic gates? Why are they so called? Draw the logic symbol and write truth table for AND, OR and NOT gate.
5. Describe (i) NAND gate (ii) NOR gate and (iii) XOR gate.
6. Two signals *A*, *B* as given below are applied as input to (i) AND (ii) NOR and (iii) NAND gates. Draw the output waveform in each case.

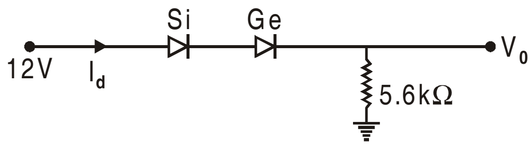


## NUMERICALS

1. In a *p-n* junction, width of depletion region is 300 nm and electric field of $7 \times 10^5$ V/m exists in it.
   (i) Find the height of potential barrier.
   (ii) What should be the minimum kinetic energy of a conduction electron which can diffuse from the *n*-side to the *p*-side?
2. In an *npn* transistor circuit, the collector current is 10mA. If 90% of the electrons emitted reach the collector, find the base current and emitter current.
3. An LED is constructed from a *p-n* junction of a certain semiconducting material whose energy gap is 1.9eV. What is the wavelength of light emitted by this LED?
4. Determine the current I for the network. (Barrier voltage for Si diode is 0.7 volt).

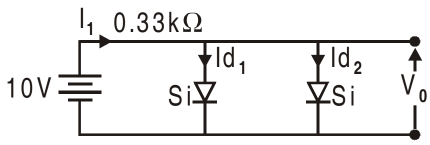



5. Determine $V_0$ and $I_d$ for the network.




6. A *p-n* junction is fabricated from a semiconductor with a band gap of 2.8 eV. Can it detect a wavelength of 600 nm? Justify your answer.
7. Determine $V_0$, $I_{dl}$ and $I_{d2}$ for the given network. Where $D_1$ and $D_2$ are made of silicon.

$$\left(I_{d1} = I_{d2} = \frac{I_1}{2} = 14.09\ mA\right)$$




8. Two amplifiers with voltage gain 10 and 20 are connected in series. Calculate the output voltage for an input signal of 0.01 volt. [**Ans. :** 2 volt]
9. A transistor has a current gain of 30. If the collector resistance is 6kW and input resistance 1kΩ. Calculate the voltage gain. [**Ans. :** 180]
10. If the current gain of a CE – Amplifier is 98 and collector current $I_c$ = 4mA, determine the base current. [**Ans. :** $I_b$ = 0.040mA]

11. Pure Si at 300 K has equal electron ($n_e$) and hole ($n_h$) concentration of $1.5 \times 10^{16}/m^3$. Doping by indium increases $n_h$ to $4.5 \times 10^{22}/m^3$. Calculate $n_e$ in the doped silicon. [**Ans. :** $5\times 10^9\ m^{-3}$]

12. The solar radiation spectrum shows that maximum solar intensity is near to energy $h\nu$ = 1.5 eV. Answer the following :

    (i) Why are *Si* and *GaAs* are preferred materials for solar cells.

    (ii) Why *Cd S* or *CdSe* (*Eg* ~ 2.4 *eV*) are not preferred.

    (iii) Why we do not use materials like *PbS* (*Eg* ~ 0.4 *eV*).

    **Ans.**

    (i) For photo-excitation, $h\nu > Eg$. *Si* has *Eg*. ~ 1.1 *eV* and for *GaAs*, *Eg*. ~ 1.53 *eV*.

    GaAs is better than *Si* because of its relatively higher absorption coefficient.

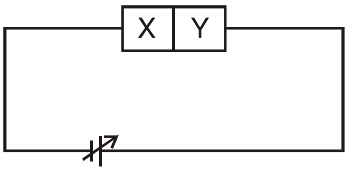
    (ii) If we choose *CdS* or *CdSe*, we can use only the high energy component of the solar energy for photo-conversion and a significant part of energy will be of no use.

    (iii) The condition $h\nu > Eg$. is satisfied, but if we use *Pbs*, most of solar radiation will be absorbed on the top-layer of solar cell and will not reach in or near depletion region.

## HOTS

### SHORT ANSWER QUESTIONS (2 Marks)

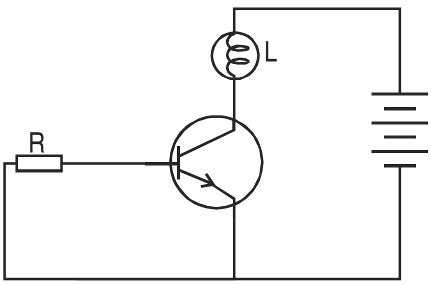
1. Two semiconductor materials X and Y shown in the given figure, are made by doping germanium crystal with indium and arsenic respectively. The two are joined end to end and connected to a battery as shown.



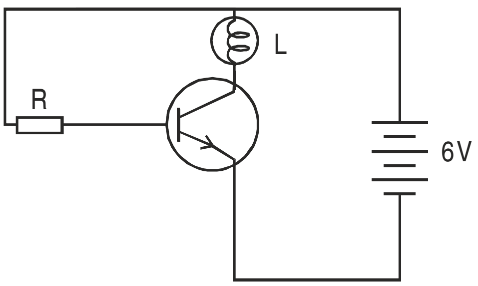

    (i) Will the junction be forward biased or reversed biased?

    (ii) Sketch a V–I graph for this arrangement.

2. In only one of the circuits given below the lamp L lights. Which circuits is it? Give reason for your answer.

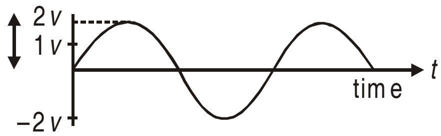



(a)




(b)

3. Following voltage waveform is fed into half wave rectifier that uses a silicon diode with a threshold voltage of 0.7V. Draw the output voltage. waveform.

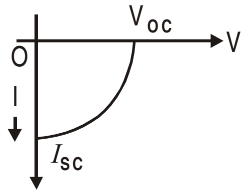



4. Why are Si and GaAs are preferred materials for solar cell.

## ANSWERS

### VERY SHORT ANSWER QUESTIONS (I Mark)

1. $n_e = n_h$.
2. At 0 K semiconductors behave as an insulator.
7. Frequency of A.C. $f = \frac{1}{2\pi\sqrt{LC}}$.
8. Because bonds break up, crystal breakdown takes place and crystal becomes useless.
9. I – V characteristic of solar cell :




10. Phase difference between input and output waveform is π or 108°.
11. Positive feedback.
12. Direction of diffusion current is from P to N in a semiconductor junction diode.
15. Light emitting diode.
16. GaAs, GaP.
17. *p-n* junction diode.
20. The energy gap decreases.
22. Filters
23. Conductor – no energy gap

    Semi conductor – < 3 *eV*

    Insulator – > 3 *eV*.

24. $n_e/n_h = 1 \Rightarrow n_e = n_n$ ∴ intrinsic semiconductor.

$n_e/n_n < 1 \Rightarrow n_e = n_n$ ∴ *p*-type extrinsic semiconductor.

## SHORT ANSWER QUESTIONS (2 Marks)

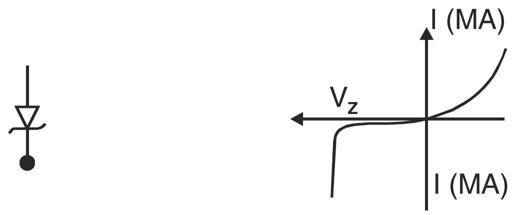
1. Frequency of output in half wave Rectifier is *f* and in full have rectifier is 2*f*.
2. Equivalent resistance is

   (i) 10Ω (ii) 20Ω

3. Because there is no free charge carrier in depletion region.
6. On heating S, resistance of semiconductors S is decreased so to compensate the value of resistance in the circuit R is increased.
10. In this case diode is sensitive and it gives very large amount of current in this situation.
15.

| A | B | Y |
|---|---|---|
| 0 | 0 | 1 |
| 0 | 1 | 1 |
| 1 | 0 | 1 |
| 1 | 1 | 1 |

17. (a) V. (b) Zero
18. Change in $I_c$ is related to $I_b$ and not to the base voltage change ($\delta V_{be}$).
19. (a) *npn* (ii) saturation
21. Zever diode




(i) Reverse Bias (ii) Iosmard Bias

22. To make transistor to act as an amplifier.
24. N.C.E.R.T. pg. 477
25. N.C.E.R.T. pg. 477
26. Ge ~ 0.2V

Si ~ 0.7 V.

27. Output circuit is reverse biased, which has large resistance.

## NUMERICALS

1. (i) $V = Ed = 7 \times 10^5 \times 300 \times 10^{-9} = 0.21V$

   (ii) Kinetic energy = eV = 0.21 eV

2. Emitter current $I_e = \dfrac{10}{90} \times 100 = 11.11$ mA

   Base current $I_b = I_e - I_c = 11.11$ mA

4. $$I = \frac{E_1 - E_2 - V_d}{R} = \frac{20 - 4 - 0.7}{2.2 \times 10^3} = 6.95 \text{ mA}$$

5. $$V_0 = E - V_{si} - V_{Ge} = 12 - 0.7 - 1.1 = 12 - 1.8 = 10.2 \text{ V}$$

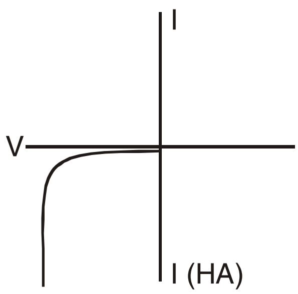
$$I_d = \frac{V_0}{R} = \frac{10.2}{5.6 \times 10^3} = 1.82 \text{ mA.}$$

## ANSWERS OF HOTS

### 2 MARK QUESTIONS

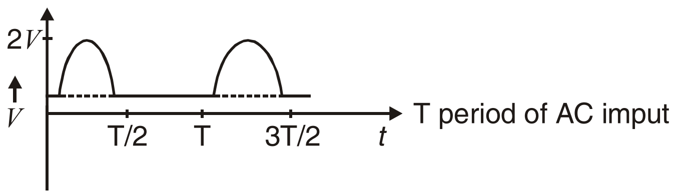
1. (i) Reverse bias

   (ii)




2. (b)

3. Output waveform is :



## UNIT X

# COMMUNICATION SYSTEMS

***Weightage Marks : 05***

## TOPICS TO BE COVERED

Elements of communication system (block diagram) only, Band width signals (speech, TV and digital data) band width of transmission medium.

Propagation of electromagnetic waves in the atmosphere, sky and space wave propogation, Need for modulation, production and detection of na amplitude modulated wave.

## KEY POINTS

- Communication is the faithful transfer of message from one place to another.
- A communication system consists of three basic elements.


- **Transmitter :** An equipment which converts the information data into electrical signal.
- A transmitter consists of

  (i) Transducer or Converter (ii) Modulator

  (iii) Carrier Oscillator (iv) Transmitting Antenna
- **Channel :** It is the medium through which the electrical signals from the transmitter pass to reach the receiver.
- **Receiver :** An equipment which receives and retrieves information from the electrical signals.
- A Receiver section consists of

  (i) Receiver Antenna (ii) Transducer/Converter (iii) Demodulator
- Two important forms of communication system are **Analog** and **Digital**. In Analog communication, the information is in analog form.
- In Digital communication, the information has only discrete or quantised values.

- Modulation is a process by which any electrical signal (called input, baseband or modulating signal) of low frequency is mounted on to another signal (carrier) of high frequency.
- Need of Modulation :
  - (i) To avoid interference between different base band signals.
  - (ii) To have a practical size of antenna.
  - (iii) To increase power radiated by antenna.
- **Demodulation :** It is a process by which a base band signal is recovered from a modulated wave.
- **Amplitude Modulation :** In this type of modulation, the amplitude of carrier wave is varied in accordance with the information signal, keeping the frequency and phase of carrier wave constant.
- **Bandwidth :** Bandwidth is the range of frequencies over which an equipment operates.
- Space communication uses free space between transmitter and receiver for transfer of data/ information.
- **Ground Wave :** These are the waves radiated by antenna that travel at zero or lower angle with respect to earth surface. They are heavily absorbed by earth surface and not suitable for long range communication.
- **Space Wave :** These are the waves that travel directly through space between transmitting and receiving antennas. The space waves are within the troposphere region of atmosphere and have two **Modes of Transmission :**
  - (i) Line of sight communication
  - (ii) Satellite communication

| *Physical Quantity* | *Formulae* | *SI Unit* |
|---|---|---|
| Power radiated by an antena | $\alpha \frac{1}{\lambda^2}$ | W |
| Sinusoidal carrier wave | $E = E_C \cos(\omega_c t + \phi)$ | V |
| The range of tower | $d = \sqrt{2Rh}$<br>$R \rightarrow$ radius of earth<br>$h \rightarrow$ Height of antena | m |
| The number of channels | $\frac{\text{Bandwidth}}{\text{Bandwidth per channel}}$ | |
| The maximum rang of broadcast between transmitting and receiving tower | $d_{max} = \sqrt{2Rh_t} + \sqrt{2Rh_r}$<br>where $R \rightarrow$ Radius of earth<br>$h_t$ and $h_r \rightarrow$ height of transmitting and receiving towers | |

# QUESTIONS

## VERY SHORT ANSWER QUESTIONS (I Mark)

1. What are ground waves?
2. What are the two basic modes of communication?
3. On what factors does the maximum coverage range of ground wave communication depend?
4. What is a base band signal?
5. What is the least size of an antenna required to radiate a signal of wavelength $\lambda$?
6. Why do we use high frequencies for transmission?
7. Why is ionisation low near the earth and high far away from the earth?
8. Define is modulation index.
9. What should be the length of dipole antenna for a carrier wave of frequency $2 \times 10^6$ Hz?
10. Why is the transmission of signals using ground wave communication restricted to a frequency of 1500 kHz?
11. What is meant by tranducer? Give one example of a transducer.
12. A T.V. transmitting antenna is 81m tall. How much service area can it cover if the receiving antenna is at ground level?
13. What is attenuation?
14. Why are repeaters used in communication?
15. What is the significane of modulation index? What is its range?

    **Ans :** Modulation index determines the stenght and quality of the transmitted signal. High modulation index ensures better quality and better strength. Its range is 0 to 1.

## SHORT ANSWER QUESTIONS (2 Marks)

1. Write two differences between point to point communication and broadcast mode of communication. Give one example of each.
2. An audio signal of amplitude one fourth of the carrier wave, is used in amplitude modulation. What is the modulation index?
3. What are the essential components of a communication system? Explain with the help of a Block diagram.
4. Explain by a diagram, how space waves are used for Television broadcast.
5. Long distance radio broadcasts use short wave bands. Why?

**Ans :** The short waves are the waves of wavelength less than 200*m* or frerquency greater than 1.5 MHz. Theya are absorbed by the earth due to their high frequency. These waves are reflected from ionosphere. These waves after reflection from ionosphere reach the surface of earth only at a large distance from the place of transmission. It means attenuation is less for short waves. It is due to this reason; the short waves are used in long distance broadscasts.

6. What is modulation? Why do we need modulation? Give two reasons.
7. Give two reasons for using satellite for long distance T.V. transmission.
8. Explain the propagation of sky wave in ionospheric layers with the help of a neat, labelled diagram.
9. Derive an expression for maximum range of an antenna of height '*h*' for LOS communication.
10. Plot amplitude v/s frequency for an amplitude modulated signal.
11. Draw block diagram of simple modulator to obtain amplitude modulated signal.
12. It is necessary to use satellites for long distance TV transmission. Why?

    **Ans :** Yes, TV signals being of high frequency are not reflected by the ionosphere. Therefore, to reflect these signals, satellites are needed. That is why; satellities are used for long distance TV transmission.

13. What is the basic difference between an analog communication system and a digital communication system?

    **Ans :** An analog communication system makes use of analog signals, which vary continuously with time. A digital communication system makes use of a digital signal, which has only two valuse of votage either high or low.

14. What is ground wave? Why short wave communication over long distance is not posible via ground waves?

    **Ans :** The amplitude modulated radiowaves having frequency 1500 kHz upto 40 MHz (or wavelength between 7.5 m to 200 m) which are travelling directly following the surface of earth and known as ground waves. The short wave communication over long distance is not possible via sky waves. It is not bossible via ground, waves because the ground waves can bend round the corners of the objects on earth and hence, their intensity falls with distance. Moreover the ground wave transmission becomes weaker as frequency increases.

## SHORT ANSWER QUESTIONS (3 MARKS)

1. With the help of Block Diagram show how an amplitude modulated wave can be demodulated.
2. How an amplitude modulated wave can be produced? Give the equation of amplitude modulated wave.
3. What is amplitude modulation? Derive the equation of an amplitude modulated wave.
4. What are the different ways of propagation of radiowaves? Explain briefly.

5. Draw block diagram for a :

   (a) Transmitter

   (b) Receiver

6. Write the band width of the following :

   (1) Telephonic communication

   (2) Video signal

   (3) TV signal

7. Explain the following terms :

   (1) Ground waves

   (2) Space waves

   (3) Sky waves

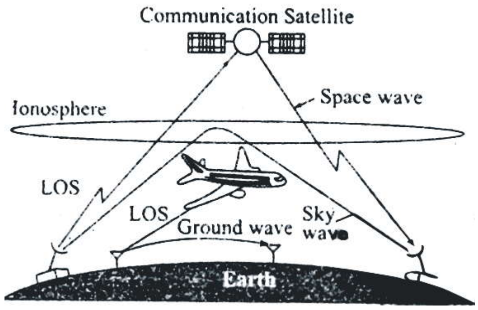
**Sol :** (i) At low frequencies ($v < 2$MHz), radio-waves radiated by antenna travel directly following the surface of earth and are known as ground waves. [*($v < 2$MHz) (About this frequency, it weakens rapidly)]

(ii) Frequencies ranging from 100-200 MHz penetrate ionosphere and hence can only be transmitted by using line-of-sight antenna or satellites, are known as space wave propagation.

(iii) Frequencies between 2-20 MHz are reflected by the ionosphere and known as sky waves (or ionospheric propagation)

8. What does 'LOS communciation[1] mean? Name the types of waves that are used for this communication. Give typical examples, with the help of suitable figure, of communication systems that use space mode propagation.

**Sol :** Mode of radiowave propagation by space waves, in which the wave travells in a straight line from transmitting antenna to the receiving antenna, is called *line-of-sight* (LOS) communication. Two types of waves that are used for LOS communication are : Space wave and Ground wave. At frequencies above 40 MHz, LOS communication is essentially limited to line-of-sight paths.




*Various propagation modes for EMW*

## NUMERICALS

1. A sinusoidal carrier wave of frequency 1.5 MHz and amplitude 50 volt is amplitude modulated by sinusoidal wave of frequency 10 kHz producing 50% modulation. Calculate the frequency

(*i*) amplitude; (ii) frequencies of lower and upper side bands.

$$\boxed{\begin{aligned}\text{Lower side band} &= 1490\ \text{kHz}\\ \text{Upper side band} &= 1510\ \text{kHz}\\ \text{Amplitude} &= 125\ \text{volt}\end{aligned}}$$

2. An amplitude modulator consist of L–C circuit having a coil of inductance 8mH and capacitance of 5pF. If an audio signal of frequency 10kHz is modulated by the carrier wave generated by the L–C circuit, find the frequency of upper and lower side bands.
[**Ans.** $f_c = 7.96 \times 10^5$ Hz; Lower side band = 786 kHz; Upper side band = 806 kHz]

3. A T.V. Tower has height of 70m.
   (i) How much population is covered by the T.V. broadcast if the average population density around the tower is 1000km$^{-2}$? Radius of earth is $6.4 \times 10^6$ m.
   (ii) By How much should the height of the tower be increased to double the coverage area?
   [**Ans. :** Population covered = 28.16 lacs; Change in height = 70m]

4. A communication system is operating at wavelength $\lambda$ = 750 nm. If only 1% of the frequency is used as channel bandwidth for optical communication then find the number of channels that can be accommodated for transmission of
   (i) an Audio signal requiring a bandwidth of 8 kHz.
   (ii) an Video T.V. signal requiring a bandwidth of 4.5 KHz.

5. Calculate the percentage increase in the range of signal reception, if the height of TV tower is increased by 44%. [**Ans. :** 20% increase]

6. A transmitting antenna at the top of a tower has a height 32m and the hight of the receiving antenna is 50m. What is the maximum distance between them for satisfactory communication in LOS mode? Given radius of earth 6.4 X 10$^6$m.

**Sol :**
$$d_m = \sqrt{2+64\times10^5\times32}+\sqrt{2\times64\times10^5\,50}\,\text{m}$$
$$=64\times10^2\times\sqrt{10}+8\times10^3\times\sqrt{10}\,\text{m}$$
$$=144\times10^2\times\sqrt{10}\,\text{m}=45.5\text{km}$$

**7.** A message singnal of frequency 10 kHz and peak voltage of 10 volts is used to modulate a carrier of frequency 1 MHz and peak voltage of 20 volts. Determine (a) modululation index, (b) the side bands produced.

**Sol :** (a) Modulation index = 10/20 = 0.5 = $\dfrac{A_m}{A_c}$

(b) The side bands are at (1000 + 10) kHz = 1010 kHz and (1000 – 10) kHz = 990 kHz.

8. A carrier wave of peak voltage 12*v* is used to transmit a message signal. What should be the peak voltage of the modulating signal in order to have a modulation index of 75%?

**Sol :** $\mu = 0.75 = \frac{A_m}{A_c}$

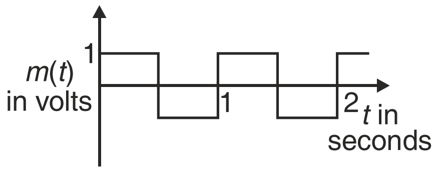
Hence, $A_m$ = 0.75 Ac = 0.75 x 12 V = 9 V

9. A modulating signal is a square wave, as shown in figure.

The carrier wave is given by c(t) = 2 sin (8 $\pi$t) volts.

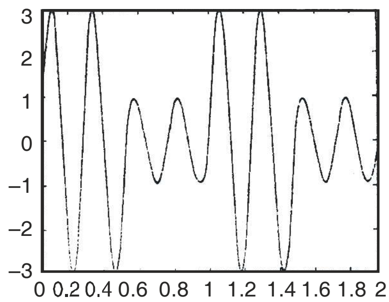
(i) Sketch the amplitude modulated waveform

(ii) What is the modulation index?




**Sol :** (i)

(ii) $\mu$ = 0.5




10. For an amplitude modulated wave, the maximum amplitude is found to be 10 V while the minimum amplitude is found to be 2 V. Determine the modulation index, $\mu$.

What would be the value of $\mu$ if the minimum amplitude is zero volt?

**Sol :** The AM wave is given by ($A_c$ + $A_m$ + Sin $\omega_m$t) cos $\omega_c$t,

The maximum amplitude is $M_1 = A_c + A_m$ while the minimum amplitude is $M_2 = A_c - A_m$

Hence the modulation index is

$$\mu = \frac{A_m}{A_c} = \frac{M_1 - M_2}{M_1 - M_2} = \frac{8}{12} = \frac{2}{3}$$

# SAMPLE PAPER – I

**Time Allowed : 3 hours** **Maximum Marks : 70**

*Note : Attempt All questions. Marks allotted to each question are indicated against it.*

1. The magnetic field lines form closed curves. Why? 1

2. Light is incident at 60° on glass slab. If reflected and refracted rays are perpendicular to each other then what is the refractive index of glass. 1

3. What is band pass filter. 1

4. How does magnifying power of a microscope change on decreasing the aperture of its objective? 1

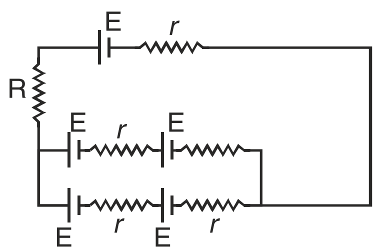
5. Name the part of Electimagnetic spectrum which is suitable for (i) Physical therapy (ii) TV communication. 1

6. Why is energy distribution of $\beta$ ray continuous? 1

7. A point source of light is at the focus of a convex lens. What is the type of refracted wavefront? 1

8. Drawn a graph showing variation of de Broglie wavelength of an electron with the variation of its momentum 1

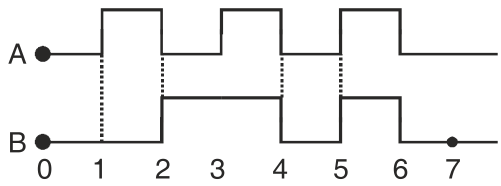
9. All the cells are identical each of emf E and internal resistance 'r'. What is the current passing through R. 2




10. What is a repeater? Explain with the help of a diagram. How does it increase the communication range. 2

11. In a wire connected across a source, drift speed and electric field are *v* and *E* respectively. The wire is stretched uniformly of double the length, what will be new (i) drift speed (ii) electric field. 2

12. Sketch the output wave form from an OR gate. The input A and B are shown in the figure. If the output of above OR gate is fed to a Not gate, name the gate so formed. 2

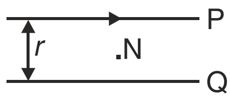



13. A charged particle of charge q and mass m is accelerated through potential different V befor entering a magnetic field B, perpendicular to the direction of motion. What will be the radius of circular path 2

**OR**

A circular coil of radius r is carrying current I. at what distance from the centre of loop on the axis magnetic field is one eight the magnetic field at the centre.

14. P and Q are long straight conductors r distance apart. N is a point in the plane of wires $\frac{r}{4}$ distance away from P carrying current I. What is the magnitude and direction of current in the wire Q, so that net magnetic field at N is zero.




15. In an electiomagnetic wave propagating along + x-axis electric field vector is Ey = 4 x $10^3$ Cos (3 x $10^8$ t – 1.5 x) V/m. What is (i) the frequency of emwave (ii) amplitude of magnetic field.

16. A and B are two concentric metallic spherical shell of radii a and b having charge q and Q respectively. How much work will be done in moving a test charge $q_0$ from A to B (a < b). 2

17. What is the SI unit of radioactivity. Express curie in SI unit. The mean life of radio active substance is 2400 yrs. What is its half life 2

18. What is meant by term modulation? Draw a block diagram of a simple modulator for obtaining an AM signal 2

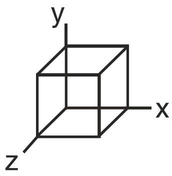
19. In interference pattern obtained in young's double slit experiment, explain how will the angular width of fringe be affected if

    (i) Slits seperation is increased

    (ii) Screen is moved away

    (iii) Experiment is performed in a denser medium 1+½+½+1

20. State Gauss's law in electrostatics. Find (i) net electric flux and (ii) charge enclosed by the cube of side 'a'. Given $E = E_0 x \vec{i}$




21. In an atom energy of electron in $n^{th}$ orbit is $E_n = \frac{-13.6Z^2}{n^2} ev$, where Z is atomic number.

    What is the shortest and longest wave length of emitted radiation in singly ionized $He^+$. 3

22. With the helps of a schematic diagram explain the principle and working of a cyclotron. 3
    A bar magnet of magnetic moment Mv held in magnetic field of strength B. What is

    (i) maximum torque on the magnet

    (ii) work done in turning it from stable equilibrium to unstable equilibrium.

23. A parallel plate capacitor of capacitance 4.8 μF has been charged by a battery of 6 V. After disconnecting the battery dielectric medium of dielectric contant 5 in introduced between its plates

    (i) Find new capacitance.

    (ii) What is the ratio of electrostatic energy stored before and after.

    (iii) calculate new potential difference across the plates. 3

24. Define mutual inductance. Write its SI Unit. Derive an expression for mutual inductance of a system of two concentric and coplaner circular loop P and Q of radii a and b and number of turn $N_1$ or $N_2$ respectively (a << b).

25. State the principle of a potentiometer. In the following figure find the length PJ where J si null deflection position. Given PQ = 400cm, Resistance of PQ is 20Ω, Driver cell emf E = 4V and $E^1$ = 40 mV.

26. What is photo electric efect. Two monochromatic radiations, blue and violet, of the same intensity, are incident on a photo sensitive surface and cause photo electric emission. Would (i) the number of electrons emitted per second and (ii) the maximum kinetic energy of the electrons, be equal in the two cases? Justify your answer. 3

27. When white light is passed through prism it gets dispersed. Give reason for dispersion.

    The following table given the value of the angle of deviation for different values of the angle of incidence, for a triangular prism :

    Angle of incidence 33°, 38°, 42°, 52°, 60°, 71°

    Angle of deviation 60°, 50°, 46°, 40°, 43°, 50°

    (a) For what value of the angle of incidence, is the angle of emergence likely to be equal to the angle of incidence itself

    (b) Draw ray diagram, showing the path of a ray of light throuph this prism when the angle of incidence has the above value. 3

28. Derive lens makers formula for a double convex lens of radii $R_1$ and $R_2$ and refraction index $n_2$ of the material of lens kept in a medium of refractive index $n_1$. How will this lens behave if $n_1 > n_2$, trace the required ray diagram.

**OR**

Draw a labelled diagram of compound microscope for the formation of image.
Derive an expression for the magnifying power of a compound microscope.

29. Derive an expression for impedence of a series LCR circuit connected to an ac source. When does its value become minimum.

Sketch graph (i) $X_L$ Vs $v$ (ii) $X_C$ Vs $v$ (iii) Z Vs $v$.

**OR**

Derive the relationship between the peak and rms value of current in an ac circuit. For circuits used for transmission of electric power a low power factor implies large power loss in the transmission explain. 5

30. With the help of circuit diagram of an npn transister in common emitter mode, explain its use as an amplifier.

Drawn the output versus input voltage curve and mark region in which the transister is used a (i) switch, and (ii) amplifier.

**OR**

Draw forward and reverse characterestic curves of a pn junction diode. Explain briefly with the help of a circuit diagram, how a pn junction diode works as a full wave rectifier. If frequency of input ac signal is 'f' what is the frequency of output.

## MARKING SCHEME

# SAMPLE PAPER – I

1. Because magnetic monopole does not exist.
2. Angle of polarization = 60°, $\mu$ = tan ip $\Rightarrow \mu = \sqrt{3}$
3. A device that allows the passage of a number of frequencies ($W_c \pm W_m$) along with carrier frequency $W_c$
4. Magnifying power is independent of aperture.
5. (i) IR radiation (ii) Radiowaves
6. Because $\beta$ emission is followed by antiparticles $\alpha$ and $\overline{\alpha}$.
7. Plane Wavefront.
8. 
9. 
10. A device consisting of a transmitter and a receiver. This is used to increase communication Range as

    1,2,3 and 4 etc are the repeaters arranged between source of information and the use of information.

11. Drift speed $V_d = a\tau = \frac{eV}{m\rho}\tau$

    $\tau \rightarrow$ Relaxation time

    $V \rightarrow$ potential diff. across the conductor

    $V_d \times \frac{1}{\rho}$

    (i) Drift speed is halved.

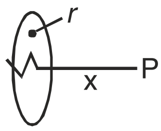
    (ii) $E' = \frac{V'}{l'} = \frac{V}{2\rho} = \frac{E}{2}$ $\therefore$ Electric field is halved.

12.

| B | B | Y |
|---|---|---|
| 0 | 0 | 0 |
| 1 | 0 | 1 |
| 0 | 1 | 1 |
| 1 | 1 | 1 |

OR + NOT $\rightarrow$ NOR

13. $$\text{Baxial} = \frac{B_{\text{centre}}}{8}$$




$$\frac{\mu_0 . I r^2}{2\left(r^2 + x^2\right)^{3/2}} = \frac{r_0 I}{8(2r)}$$

$\Rightarrow$ $x = \sqrt{3}r.$

14. $B_N = B_P - B_Q$

$\Rightarrow$ $B_P = B_Q$

$$\frac{\mu_o I_p}{2\pi(r/4)} = \frac{\mu_o I_Q}{2\pi(3r/4)}$$

$\Rightarrow$ $I_Q = 3I_P.$

15. $E_y = E_{oy} \cos (wt - kx)$

$$\omega = 2\pi\gamma \Rightarrow \gamma = \frac{\omega}{2\pi}$$

$$\gamma = \frac{3 \times 10^8}{2\pi} Hz$$

(i) Speed of *em* waves $V = \frac{3 \times 10^8}{1.5} = 2 \times 10^8 m/s$

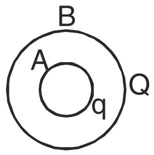
(ii) $B_o = \frac{E_o}{V} = \frac{4 \times 10^3}{2 \times 10^8} = 2 \times 10^{-2} T.$

16. $W_{AB} = q_o \, \Delta V = q_o \, (V_B - V_A)$

$$V_A = \frac{kq}{a} + \frac{kQ}{b}$$

$$V_B = \frac{kq}{b} + \frac{kQ}{b}$$

$\therefore \quad W_{AB} = q_o kq\left(\frac{1}{b} - \frac{1}{a}\right).$




17. In S.I. system the unit of radioactivity is becquerel.

1 becquerel = 1 disintegration/second.

1 curie = $3.7 \times 10^{10}$ bq.

$T_{½}$ = mean life × *ln* 2

$$= \frac{\text{mean life}}{1.44}$$

$$= \frac{2400}{1.44}$$

= 1667 years

18. Definition of modulation N.C.E.R.T. Pg. 517 Vol-II.

19. Linear fringe width $\beta = \frac{\lambda D}{d}$

Angular fringe width, $\theta = \frac{\beta}{D} = \frac{\lambda}{d}$

$$\theta = \frac{\lambda}{\mu d} (\text{in some medium})$$

(i) $\theta = \alpha \frac{1}{d} \Rightarrow \theta$ decreases

(ii) $\theta$ is undependent of D, $\Rightarrow$ no effect.

(iii) $\theta \alpha \lambda \Rightarrow$ angular width increases

(iv) $\theta \alpha$ 1/M $\Rightarrow$ angular width decreases.

20. Statement of Gauss's law

$$\phi_E = \phi \vec{E} \cdot d\vec{A}$$

$$= \phi_1 + \phi_2 + \phi_3 + \phi_4 + \phi_5 + \phi_6$$

$$= \int \vec{E} \cdot d\vec{A}_1 + 0 + 0 + 0 + 0 + 0$$

$$= E_0 a\hat{i}\ a^2 \hat{i}$$

$$= E_0 a^3$$

(ii) $\phi_E = q/E0 \Rightarrow q = \phi_E E_0 = E_0 a^3\ E_0$

21. $\lambda = \dfrac{hc}{E_2 - E_1}$

$$= \frac{hc}{13.6 z^2 \left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)}$$

For $\lambda_{\text{shortest}}$ $n_1 = 1,\ n_2 = \infty$

$$\lambda_{\text{shortest}} = \frac{6.624 \times 10^{-34} \times 3 \times 10^8}{13.6 \times 4 \left(\frac{1}{1} - \frac{1}{\infty}\right)} = 2.25 \times 10^{-8} m$$

For $\lambda_{\text{longest}}$ $n1 = 1, n_2 = 2$

For $\lambda_{\text{longest}}$ $\frac{4}{3}\lambda_{shortest}$

$\frac{4}{3} \times 2.25 \times 10^{-8} m$

$3 \times 10^{-8}$m

t ® Re

22. Principle, working 1, 2

**OR**

(i) $\tau$ = MB Sin$\theta$

$\tau_{max}$ = MB sun 90° = MB

(ii) W = $U_2 - U_1$ U = MB Cosθ

= MB – (–MB) U = – MB (stable equilib)

= 2 MB U = + MB (Unstable equilib)

23. (i) C = k $C_o$ = 5 x 4.8 = 24.0 μf

(ii) $\frac{q^2/2C_o}{q^2/2C} = \frac{C}{C_o} = 5$

(iii) $V = \frac{V_0}{k_1} = \frac{6}{5} = 1.2\,volt.$

24. NCERT (Part I) Solved Example

25. Principle of potentiometer when a steady current is passed through a potentiometer wire AB of length L, and V is the potential difference across wire AB, then

Potential gradient $k\frac{V}{L}$

$I = \frac{E}{R + R_{PQ}} = \frac{4}{480 + 20} = 8 \times 10^{-3} A$

$V_{PQ} = I\,R_{PQ} = 8 \times 10^{-3} \times 20 = 0.16$ Volt.

Potential gradient $k = \frac{V_{PQ}}{L_{PQ}} \frac{0.16}{400} = V/cm$

$AJ = \frac{40 \times 10^{-3}}{0.16} \times 400 \quad = 100\,cm.$

26. Define photoelectric effect

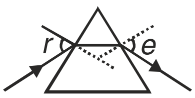
(i) Since Intensity is same, ∴ number of electrons emitted per second remain same

(ii) K. Emax a ha

$\alpha_{violet} > \alpha_{blue}$

∴ $(E.E_{max})_{violet} > (K.\ E_{max})_{blue}$

27. (a) angle of incidence is equal to the angle of emergence, for minimum deviation position

(b) 

$i = e$ for $\delta = \delta m$

28. Refer NCERT

**OR**

29. Refer NCERT

$P = V_{rms}\ I_{rms}\ \text{Cos}\theta$

$$\text{Cos}\,\theta = \frac{P}{I_{rms} V_{rms}}$$

$P_{loss} = I^2_{rms}$ R. R Þ resistance of transmission line.

$P_{loss}$ a $I^2_{rms}$

Low power factor (cosθ) ⇒ high

⇒ high power loss.

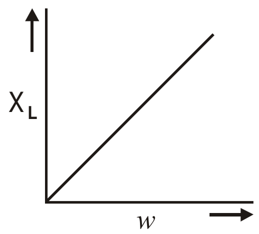
30. Refer NCERT

# SAMPLE PAPER – II

***Time Allowed : 3 hours*** ***Maximum Marks : 70***

*Note : Attempt All questions. Marks allotted to each question are indicated against it.*

1. Name the physical quantity given by the slope of the graph shown below. What is its S.I. Unit?



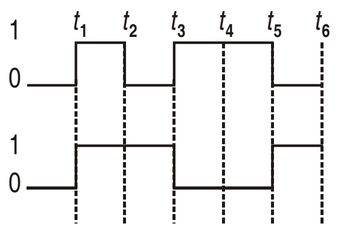

2. Define the term 'dielectric constant' of a medium in terms of capacitance of a capacitor. 1

3. A proton and a deutron having equal momenta enter a uniform magnetic field B perpendicular to its direction. Compare radii of their trajectories. 1

4. Name the device used for producing microwaves. 1

5. A double concave lens of refractive index $\mu_1$ has been immersed in a liquid of refractive index $\mu_2$ ($\mu_2 > \mu_1$). What change, if any, would occur in its nature? 1

6. Kinetic energies of an $\alpha$-particle and of a proton are equal. Which of them has higher value of de-Broglie wavelength? 1

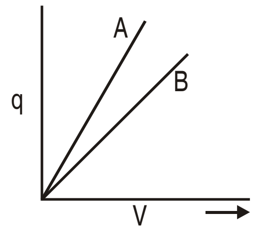



7. Input waveforms in an OR gate is as shown in Fig. above. What is the output waveform? 1

8. What is the direction of (i) diffusion current (ii) drift current in a *p-n* junction? 1

9. Charge versus potential difference graphs for two capacitors A and B are as shown : 1

(i) Which of the them has larger capacitance and




(ii) for a given P.D. which of them would store larger amount of electrostatic potential energy? 1,1

10. Calculate temperature at which resistance of a conductor becomes 10% more of its resistance at 27°C. The value of temperature coefficient of resistance of the conductor is $2 \times 10^{-3}$ $K^{-1}$. 2

11. Which one of the two, an ammeter or a milliammeter has a higher resistance and why? 2

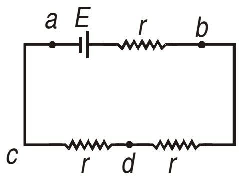
12. A rectangular conducting loop of N turns, each of area. A and total resistance R is rotated in uniform magnetic field about an axis passing through centre and parallel to longer side. If the number of rotations made per seconds is *n*, find maximum value of (i) induced emf. and (ii) induced current in the loop. 1, 1

13. Define EMF of a cell. When is the terminal voltage across a source (i) greater than EMF (ii) zero. 1, 1

**OR**

What will be reading in an ideal voltmeter across :

(i) ab (ii) cd




14. Name the radiations used :

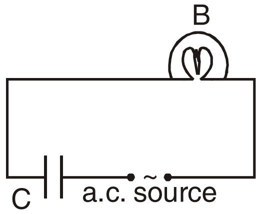
(i) to kill germs in impure water (ii) in the study of crystal structure

(iii) in T.V. communication ½ × 2

Which of these radiations has highest frequency?

15. What is an ideal diode? Frequency of a.c. input for rectification is 48 Hz. What is the frequency of output if rectifier is (i) Half wave (ii) Full wave? 2

16. A bulb B, a capacitance C and a.c. source of rms voltage V have been connected in series. How will brightness of bulb be affected if (i) frequency of a.c. is increased (ii) dielectric slab is introduced between plates of capacitor? 2




17. A message signal of frequency 10 kHz and peak voltage 10 volt is used to modulate a carrier of frequency 1 MHz and peak voltage of 20 volt. Determine (i) the modulation index (ii) the side band produced. 2

18. A parallel beam of light of wavelength 560 nm is incident on a slit of width 1mm. Find (i) angular width and (ii) linear width of principal maxima in the resulting diffraction pattern on screen kept 1.4 m away. 2

19. Define resolving power of an optical device. How will the R.P. of a telescope be changed if (i) diameter of objective is increased (ii) yellow light is replaced by green light? 3

20. Photons of certain frequency and intensity are incident on a surface of work function $W_0$. Kinetic energy of emitted electrons and photoelectric current are $E_k$ and I respectively. For photons of 50% higher frequency, find (i) kinetic energy of emitted electrons (ii) photoelectric current. 3

21. State Huygen's Postulates. Draw diagrams to show the refracted wavefront from a convex lens if point source is (i) at 2F (ii) at F. 3

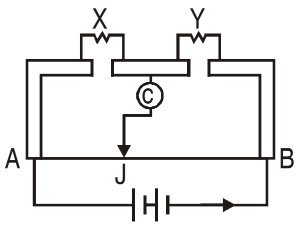
22. When a circuit element X is connected across a.c. source, current of 2A flows in phase with the a.c. voltage. For another element Y same current of 2A lags in phase by $\pi/2$ with the voltage.

    (i) Name the element X and Y.

    (ii) What is the current in the circuit if X and Y are in series across the same a.c. source?

    (iii) What is the phase by which voltage V differs current I? 3

23. In the given figure balancing length AJ is 55 cm. When a resistance of 20Ω is connected in parallel to Y, balancing length shifts by 5cm towards B. If 20Ω resistance is connected in series with Y what will be the balancing length? AB = 100 cm.




**OR**

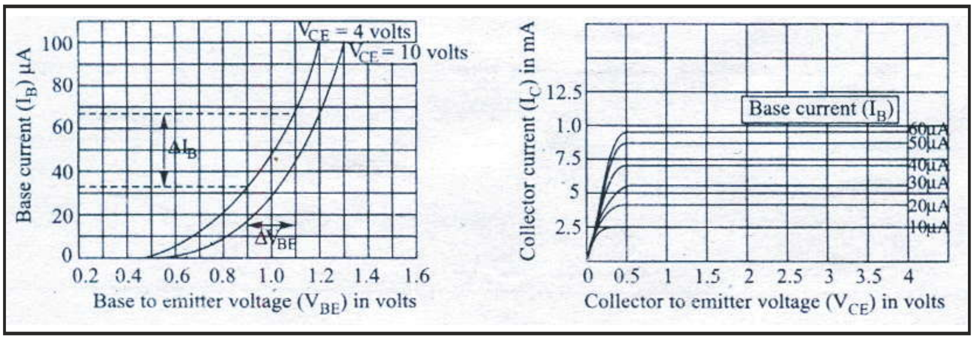
State the principle of potentiometer. Two cells of EMF $E_1$ and $E_2$ are connected in the manner (a) and (b). Balancing points for (a) and (b) on potentiometer wire are at 356 cm, and 71.2 cm respectively. Calculate the ratio of EMF of two cells.

24. Define the decay constant of a radioactive substance. Half life of radioactive substance is T, initial concentration $N_0$ and at instants $t_1$ and $t_2$ concentrations are $N_1$ and $N_2$ respectively. Find concentration at time $(t_1 + t_2)$ 3

25. What is meant by 'detection'? Draw the block diagram of a detector for AM signal. 3

26. State Bohr's postulates for the permitted state of electron in hydrogen atom. Energy of an electron in a hydrogen like atom is $-\frac{54.4}{n^2}$ eV. Calculate kinetic and potential energies of electron in first excited state of the atom. 3

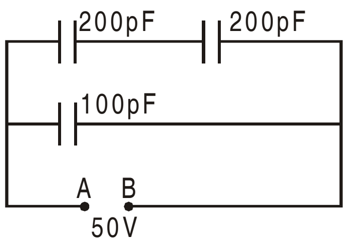
27. (a) From the output characteristics shown, calculate the values of current amplification factor of the transistor when $V_{CE}$ is 2V.




(b) Calculate the input resistance of the transistor operating at $V_{CE}$ = 4 V in CE configuration having its input characteristic as shown. 3

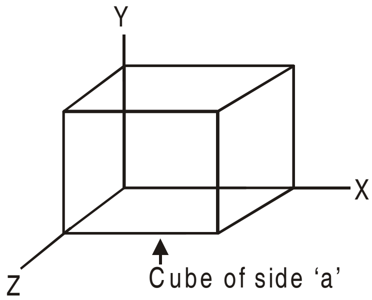
28. Obtain an expression for electrostatic energy stored in a capacitor of capacitance C charged to a potential difference *V*.

Calculate charge and energy in equivalent capacitor across AB. 5




**OR**

State Gauss' Law in electrostatics. Obtain an expression for electric field intensity E due to this charged sheet of large dimensions at a point near it. Given electric field in the region $\overline{E} = 2x\,\hat{i}$. Find (i) net electric flux through the cube (ii) charge enclosed by it. Side of the cube is 'a'.




29. Draw a diagram to depict the behaviour of magnetic field lines near a bar of (i) Aluminium (ii) Niobium lead at 90K.

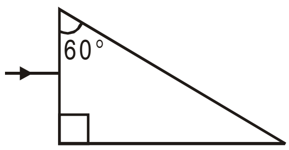
At a place, horizontal component of earth's magnetic field is $\frac{1}{\sqrt{3}}$ times the vertical component and total intensity of earth's field is 4G. Find (iii) angle of dip (iv) vertical component of earth's magnetic field. 5

**OR**

Draw a labelled diagram of moving coil galvanometer. What is the significance of radial magnetic field used in it?

A galvanometer can be converted into an ammeter to measure upto a current I by connecting resistance $S_1$ in parallel and upto 2I by connecting resistance $S_2$ in parallel of the galvanometer. Find resistance S in terms of $S_1$ and $S_2$ that should be connected in parallel of galvanometer to convert it into ammeter to read current upto I/2.

30. Complete the path of light in the adjoining figure. Give the required mathematical explanation. Given refracting index of material of prism is $\sqrt{2}$. In an equiangular prism, angle of incidence equals angle of emergence and are 45° each. Find (i) angle of deviation (ii) refractive index of material of prism. 5




**OR**

With the help of a labelled diagram show image formed by a compound microscope. Derive expression for its magnifying power when final images is at near point. How is magnifying power changed on increasing (i) diameter of objective lens (ii) the focal length of the objective lens?

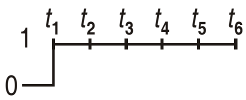
MARKING SCHEME

# SAMPLE PAPER – I

1. Physical quantity is 'Self Inductance'. S.I. unit Henery.
2. Dielectric constant of a medium is defined as the ratio of capacitance of the capacitor when filled with the medium to that when it is filled with air. Mathematically, $K = \frac{C_m}{C_0}$
3. Radius of circulator trajectory in a magnetic field $r = \frac{m\nu}{Bq}$ $r \times \frac{1}{q}$

   $\therefore$ $\boxed{\frac{r_{proton}}{r_{deubon}} = \frac{q_d}{q_p} = \frac{e}{c} = 1}$ Given $b_{proton} = b_{deuton}$.
4. Klystron valve or magnetron valve.
5. Nature of lens in the medium will change from concave to convex. ($\mu_2 > \mu_1$).
6. de-Broglie wavelength $\lambda = \frac{h}{m\nu} = \frac{h}{\sqrt{2mE_x}}$

   Given $E_{k_\alpha} = E_{k_{proton}}$

   $\therefore$ $\frac{\lambda_\alpha}{\lambda} = \sqrt{\frac{m_{proton}}{m_\alpha}} = \sqrt{\frac{m}{4m}} = \frac{1}{2}$.
7. 

8. Diffusion current due to concentration gradient is *p* to *n* and driff current due to electric field from *n* to *p* side across the junction.
9. (i) Capacitance C = *q/V* = slope of *q* · *v* graph which is greater for B

   $\therefore$ $C_B > C_A$

   (ii) Electrostatic potential energy

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

$U_E \propto C$ for given P.D.

$\because \quad C_B > C_A \qquad \therefore \quad U_B > U_A$.

10. Resistance of a conductor as a function of temperature $R_2 = R_1 (1 + \alpha \, \Delta t)$ (1)

where $\Delta t = t_2 - t_1$ tem. difference.

Given $R_2 = R_1 + 10\% \; R_1 = 1.1 \; R_1$

$\therefore$ From (1) $\qquad 1.1 \; R_1 = R_1 (1 + \alpha \Delta t)$

$$\Delta t = .\frac{1}{\alpha} = \frac{.1}{2 \times 10^{-3}} = 50$$

$$t_2 - 27 = 50$$

$$t_2 = 77°C.$$

11. Milliammeter.

In order to produce large deflection due to small current, we need large number of turns in the armature coil; hence the resistance across the milliameter will be higher.

12. Maximum induced emf in the loop

$$e_{max} = NBA\omega \qquad \text{(loop is parallel to B momentarily)}$$

Maximum current $I_{max} = \frac{\varepsilon_{max}}{R} = \frac{NBA\omega}{R}$.

13. Correct definition of emf.

Terminal voltge (i) $V > \varepsilon$ during charging

(ii) Zero during short circuiting.

**OR**

Current in the circuit

$$I = \frac{\varepsilon}{r + r + r} = \frac{\varepsilon}{3r}$$

$\therefore$ (i) $\qquad V_{ab} = \varepsilon - Ir = \varepsilon - \frac{\varepsilon}{3r} . r = 2/3 \, \varepsilon$

(ii) $\qquad V_{cd} = Ir = \frac{\varepsilon}{3r} . r = \varepsilon/3$.

14. (i) UV radiations

(ii) X-rays.

(iii) Microwaves.

Highest frequency of X-rays.

15. Diode that has zero resistance in forward biasing and infinite resistance in reverse biasing.

(i) Frequency of output in half wave rectifier = $\nu$ = 48 Hz

(ii) In full wave rectifier frequency of output = $2\nu$ = 96 Hz.

16. Brightness of bulb depends on current (I) in it ($P \alpha I^2$)

where $I = \frac{V}{Z}$

Z $\rightarrow$ impedance of circuit

$Z = \sqrt{X_C^2 + R_b^2}$ $R_b$ $\rightarrow$ resistence of bulb.

$$X_C = \frac{1}{\omega C} = \frac{1}{2\pi\nu C}$$

17. (i) At higher frequency $X_C$ is small $\therefore$ Z is also small and current is large.

$\therefore$ brightness of bulb is more.

(ii) Also $X_C \alpha \frac{1}{C}$ $C = \frac{K\varepsilon_0 A}{d}$.

When dielectric is introduced $X_C$ decreases, Z decreases current I increases $\therefore$ brightness in the bulb also increases.

18. (i) Modulation inxed $\mu = \frac{A_m}{A_c} = \frac{10}{20} = .5$

$A_m$ $\rightarrow$ amplitude of modulating wave

$A_c$ $\rightarrow$ amplitude of carrier wave.

(ii) Side band produced $= V_c \pm V_m$.

= 1 MHz ± 10 kHz

= 1 MHz ± 0.1 MHz

= 1.01MHz and 0.99 MHz.

19. (i) Angular width of principle maxima in single slit diffraction pattern

$$B_0 = \frac{2\lambda}{a} = \frac{2 \times 560 \times 10^{-9}}{1 \times 10^{-3}}$$

$= 1.12 \times 10^{-3}$ radian.

(ii) Linear width $= y_1 + y_1 = 1$

$= 2y_1 = \frac{2\lambda D}{a}$

$= .12 \times 10^{-3} \times 1.4$

$= 1.568 \times 10^{-3}$m

$= 1.568$ mm.

20. Resolving power of a device is the ability of the device to resolve two nearby objects.

R.P. of a telescope $= \frac{1}{\theta}$. where $\theta \rightarrow$ angular limit of resolution.

$$\theta = \frac{1.22\lambda}{a}$$

$a \rightarrow$ diameter of objective lens

l $\rightarrow$ wavelength object used.

(i) $\Rightarrow$ R.P. $\alpha$ $a$

$\therefore$ R.P. increases

(ii) Also $R.P.\ \alpha \frac{1}{\lambda}$ $\lambda_{green} < \lambda_{yellow}$

$\therefore$ In green light R.P. is more than that in yellow light.

21. (i) Kinetic energy of photoelectrons

$E_K = E - W_0 = h\nu - W_0$ (1)

$E_K + W_0 = h\nu$ (2) $\nu \rightarrow$ frequency of incident photon.

$E_K' = h\nu' - W_0$ (3) where $\nu' = \nu + 50\%$ of $\nu$

$= 1.5\ \nu$

$\therefore$ $E_K = \text{h}\ (1.5\ \text{n}) - \text{W}_0$

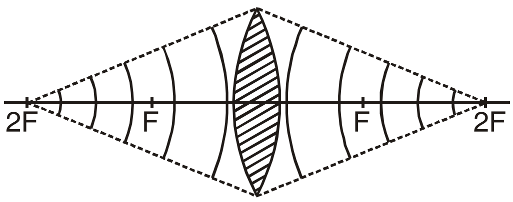
$= 1.5\ (E_K + W_0) - W_0 = 1.5\ E_K + 0.5\ \text{W}_0$

(ii) As Photoelectric current is independent of frequency

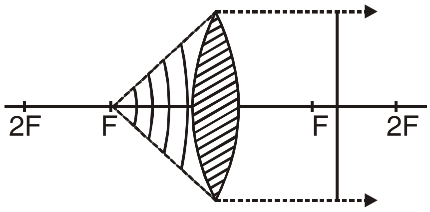
$\therefore$ $\text{I}' = \text{I}$

22. Huygens Postulates – Two statements.

Refracted wave front when point source is (i) at 2F. (ii) at F.,



Refrated wavefront : Converging at 2F



Refracted wavefront is a plane wavefront.

(i) $V$ and $I$ is phase in resistive circuit $\therefore$ × is resistor, and $I$ lags by $\pi/2$ is inductive circuit.

$\therefore$ y is inductor

(ii) $R = \frac{V}{I} = \frac{V}{2}$; Inductive reactance of $y$;

$$X_L = \frac{V}{I} = \frac{V}{2}.$$

Impedance of circuit $Z = \sqrt{R^2 + X_L^2} = \frac{V}{2}\sqrt{2}$

$\therefore$ Current $I = \frac{V}{Z} = \frac{V}{\frac{V}{2}\sqrt{2}} = \sqrt{2}\ A$

(iii) Phase by which $V$ differ current $I$

$$\tan\phi = \frac{X_L}{R} = 1$$

$$\phi = \pi/4.$$

23. $\frac{X}{Y} = \frac{l}{100 - l} = \frac{55}{100 - 55} = \frac{11}{9}$

when 20Ω resistor is connected is parallel of y.

$$\frac{X(20 + 4)}{20y} = \frac{60}{100 - 60} = 3/2 \quad (2)$$

and when 20Ω is in series with y.

$$\frac{X}{Y + 20} = \frac{l}{100 - l} \quad (3)$$

Solving (3) using (1) and (2) balancing length l = 18.5 cm.

**OR**

On a uniform unit voltage drop is proportional to length of the wave.

In (a) $(E_1 + E_2) \propto l_1 \Rightarrow \varepsilon_1 + \varepsilon_2 = kl_1$

In (b) $(\varepsilon_1 - \varepsilon_2) \propto l_2 \Rightarrow (\varepsilon_1 - \varepsilon_2) = kl_1$

$$\Rightarrow \quad \frac{\varepsilon_1 + \varepsilon_2}{\varepsilon_1 - \varepsilon_2} = \frac{l_1}{l_2} \quad \Rightarrow \quad \frac{\varepsilon_1}{\varepsilon_2} = \frac{l_1 + l_2}{l_1 - l_2} = 1.54$$

where $l_1$ = 356 cm, $l_2$ = 71.2 cm.

24. Decay constant $\lambda$ is the reciprocal of time in which concentration of a radioactive substance decreases to $1/e$ times the initial concentration.

Amount of radioactive substance left undecayed at time $t$ is $N = N_0\, e^{-\lambda t}$ (1)

$\therefore$ At instants $t_1$ and $t_2$ amounts are

$$N_1 = N_0 \quad e^{\lambda t_1} \qquad (2)$$

$$N_2 = N_0 \quad e^{-\lambda t_2} \qquad (3)$$

Amount of the substances at time $(t_1 + t_2)$

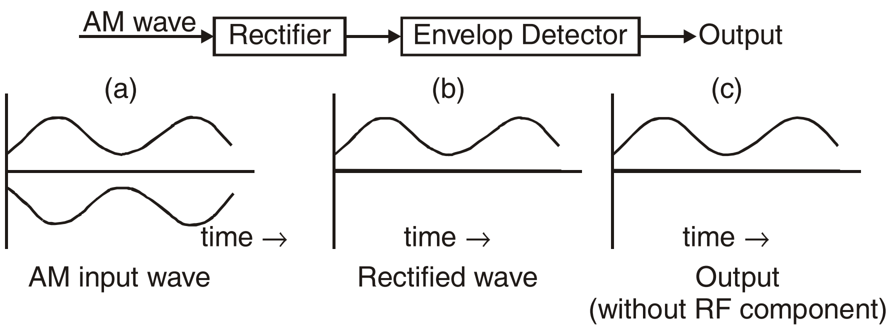
$$N = N_0 \quad e^{\lambda(t_1+t_2)} \qquad (4)$$

(2) × (3) gives $N_1 N_2 = N_0^2 \; e^{-\lambda(t_1+t_2)}$

$= N_0\, N$

$$\Rightarrow \quad \boxed{N = \frac{N_1 N_2}{N_0}}$$

25. 'Detection' is the process of recovering the modulating signal from the modulated carrier wave.




Quantity on y-axis is voltage or current.

26. Bohr's Postulates – 1, 2 and 3.

Energy of electron is H–like atom $E_4 = -\dfrac{54.4}{n^2}\, eV$

In first excited state $n = 2.$

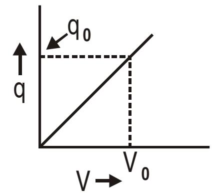
Kinetic energy $E_K = -E = -\left(\frac{-54.4}{2^2}\right)$

$= 13.6 \text{ eV}.$

Potential Energy $E_p = 2E = -2E_K = -27.2 \text{ eV}.$

27. For Solution Refer NCERT Q.NO. 28 UNIT – IX
28. Derive expression for electrostatic potential energy in capacitor as follows

$q \propto V \quad \text{or} \quad q = CV$ (1)




Area under $qV$ graph gives

Work done in charging the capacitor = change in electrostatic potential energy.

$\therefore \quad U_f - U_i = \frac{1}{2} \text{ base} \times \text{height}$

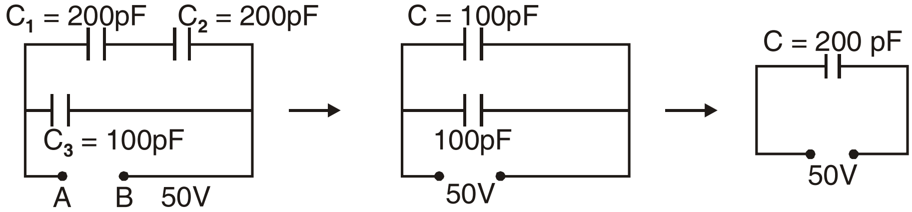
$= \frac{1}{2} V_0 \cdot q_0 = \frac{1}{2} q_0 V_0$ (2)

From (1) in (2) $U_f - U_i = \frac{1}{2} CV \cdot V$

$U_i = 0 \qquad U - 0 = \frac{1}{2} CV^2$

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

Equivalent capacitance across AB.




$C_1$ and $C_2$ in series which equals $C'$.

$C'$ is in parallel of $C_3$.

Charge on equivalent capacitors

$$q = C^1 V = 200 \times 50 = 10^{-8} \text{ coulomb}$$

Energy $\quad U = \frac{1}{2}CV^2 = \frac{1}{2} \times 200 \times 10^{-12} \times 50 \times 50$

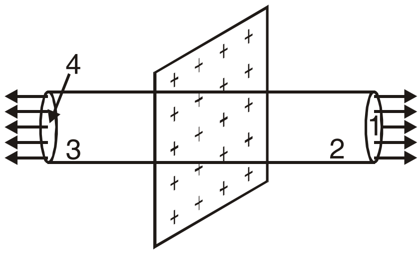
$$= 2.5 \times 10^{-7} \text{ J.}$$

**OR**

Statement of Gauss Law.

Field intensity due to chain charged sheet of large dimensions

$\sigma \to$ Surface Charge Density




Charge enclosed by Gaussian surface

$$q = \sigma A. \qquad (1)$$

Electric flux linked with the surface

$$\phi_E = \phi_1 + \phi_2 + \phi_3 + \phi_4 = \int \vec{E}\, d\vec{A}_1 + \int \vec{E}\, d\vec{A}_2 + \int \vec{E}\, d\vec{A}_3 + \int \vec{E}\, d\vec{A}_4$$

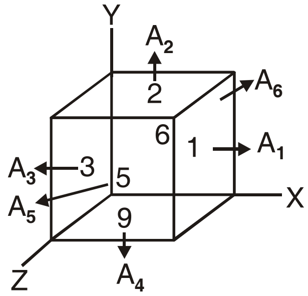
$$= \int E dA_1 + 0 + 0 + \int E dA_4 = EA + EA = 2EA \qquad (2)$$

According to Gauss Law

$$\phi_e = \oint \vec{E} \cdot d\vec{A} = q/\varepsilon_0$$

$$2EA = \frac{\sigma A}{\varepsilon_0}$$

$$\Rightarrow \quad \boxed{E = \frac{\sigma}{2\varepsilon_0}} \qquad \vec{E} = \frac{\sigma}{2\varepsilon_0}\hat{n}$$




Electric flux linked with the cube

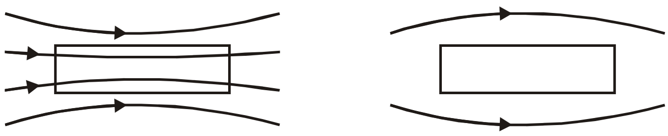
$$\phi_e = \phi_1 + \phi_2 + \phi_3 + \phi_4 + \phi_5 + \phi_6 = \int \vec{E}_1 d\vec{A}_1 + \int \vec{E}_2 d\vec{A}_2 + \int \vec{E}_3 d\vec{A}_3 + \int \vec{E}_4 d\vec{A}_4 + \int \vec{E}_5 d\vec{A}_5 + \int \vec{E}_6 d\vec{A}_6$$

$$= 2a\hat{i} \,.\, a^2\hat{i} + 0 + 0 + 0 + 0 + 0 = 2a^3$$

Charge enclosed by the cube

$$q = \varepsilon_0 \phi_e = \varepsilon_0 2a^3.$$

29.



Aliminiumics paramaphetic
μs > 1

(i)

Niobium lead is super conductor at 90K. Super conductors exhibit dismagnetism

(ii)

Given horizontal component $B_H = \frac{1}{\sqrt{3}} B_V$

$B_V \rightarrow$ vertical component

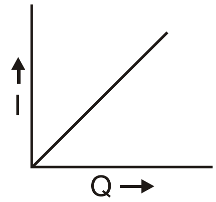
Angle of dip $\theta = \tan^{-1}\left(\frac{B_V}{B_H}\right) = \tan^{-1}\left(\sqrt{3}\right) = 60°$

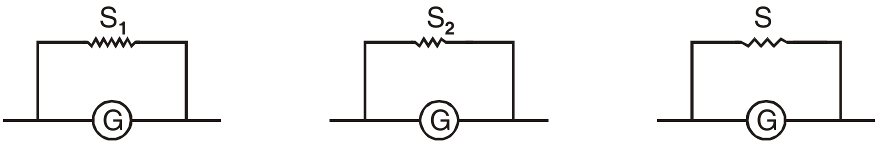
$$= .2 \times \sqrt{3} = .35\ G$$

**OR**

Labelled diagram of moving coil galvanometer. Then

In radial magnetic field torque on the loop remain maximum and hence the relation between current in the loop and deflection in it remains linear $\boxed{I \propto \theta}$.




(i) Ammeter of range $0 \to I$ (ii) Range $0 \to 2I$; (iii) Range $0 \to I/2$

If $I_g$ be the current in (G) for full scale deflection then

$$S_1 = \left(\frac{I_g}{I - I_g}\right) G. \qquad (1)$$

$$S_2 = \left(\frac{I_g}{2I - I_g}\right) G. \qquad (2)$$

$$S = \frac{I_g}{\left(\frac{I}{2} - I_g\right)} . G \qquad (3)$$

G $\to$ resistances of (G)

from (1) $I_g\ G = S_1\ (I - I_g)$ (4)

Also solving (1) and (2) for $I_g$

$$I_g = \left(\frac{2S_2 - S_1}{S_2 - S_1}\right) I \qquad (5)$$

Using (4) and (3)

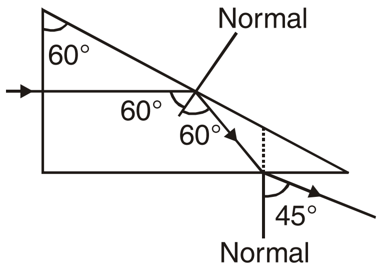
$$S = \frac{S_1 (I - I_g)}{I/2 - I_g}$$

Solving $$= \frac{2S_1 (I - I_g)}{(I - 2I_g)}$$

$$= \frac{2S_1\left[l - \frac{2S_2 - S_1}{(S_2 - S_1)}\right]}{l - 2l\frac{(2S_2 - S_1)}{(S_2 - S_1)}}$$

$$\boxed{S = \left(\frac{2S_2^2}{3S_2 - S_1}\right)}.$$

30.




Given refractive index of material of prism $\mu = \sqrt{2}$

$\therefore$ Critical angle $i_c = \delta n^{-1}\left(\frac{1}{\mu}\right) = \delta n^{-1}\left(\frac{1}{\sqrt{2}}\right) = 45°$

On the face AB angle of incidence is greater than $i_c$. $\therefore$ total internal reflects will occur on AB. Where as on the face *OB* angle of incidence is 30° (< $i_c$); $\therefore$ there will refractions on *OB*. Angle of refractions *r* is given below

$$\frac{\sin i}{\delta n\ r} = 1/\mu \qquad \text{(refraction is from denses to cases)}$$

$$\frac{\delta n\ \delta 0}{\delta ni\ r} = \frac{1}{\sqrt{2}}$$

$\Rightarrow$ $r = 45°$

In equiangular prism angle of prism is 60°

(i) Also $i = e = 45°$ (Given)

$\therefore$ Deviation is given by

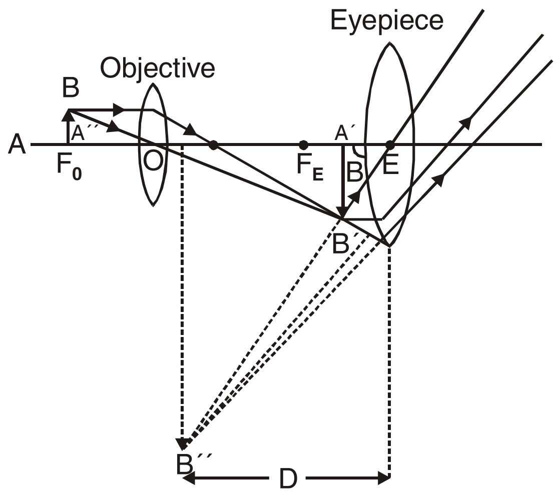
$$i + e = A + \delta$$

$$45 + 45 = 60 + \delta$$

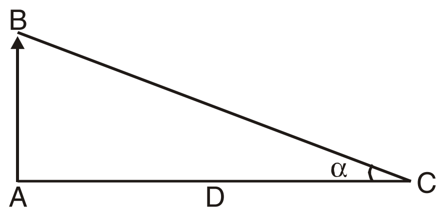
$\Rightarrow \qquad \delta = 30° = \delta_m.$

(ii) Refractive in dix of material of prism

$$\mu = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin(A/2)} = \frac{\sin\left(\frac{60+30}{2}\right)}{\sin(60/2)} = \sqrt{2}.$$



(i)



(ii)

$\alpha \rightarrow$ angle formed at the eye by the object AB held at distance D.

$\beta \rightarrow$ angle formed at the eye by the final image at near point.

Magnifying power $M = \beta/\alpha$ (1)

$$\beta \approx \frac{A''B''}{A''E} \qquad (2)$$

$$\alpha = \frac{AB}{D} \qquad (3)$$

Using (2) and (3) in (1)

$$M = \frac{\frac{A''B''}{A''E}}{\frac{AB}{D}} = \frac{A''B''}{AB} \qquad (4)\ (\because A''E = D)$$

$$= \left(\frac{A''B''}{A'B'}\right)\left(\frac{A'B'}{AB}\right)$$

$$M = m_e \, m_0 \qquad (5)$$

$$m_0 = v_0/u_0 \qquad (6) \qquad\qquad M_e = 1 + D/fe \qquad (7)$$

(Simple Microscope)

(6) and (7) is (5) given

$$\boxed{M = v_0/u_0 \, (1 + D/fe)} \qquad (8)$$

For the maximum magnifying power $u_0 \approx f_0$ and $v_0 \approx$ L (length of Microscope tube)

$$\therefore \qquad \boxed{M = \frac{L}{f_0}\left(1 + D/f_e\right)} \qquad (9)$$

(i) No effect on magnifying power of change of diameter of objective lens.

(ii) Magnifying power decreases with the increases in focal length of objects lens.

# SAMPLE PAPER – III

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

***General Instructions***

*All questions are compulsory.*

1. Draw the equipotential surfaces for two point charges each of magnitude $q > 0$ placed at some finite distance? 1

2. A bar magnet of dipole moment M is cut into two equal parts along its axis. What is the new pole strength of each part. 1

3. A rod of length L, along East-West direction is dropped from a height H. if B be the magnetic field due to earth at that place and angle of dip is $\delta$, then what is the magnitude of induced emf across two ends of the rod when the rod reaches the earth? 1

4. Which characteristic of the following electromagnetic waves (i) increases (ii) remains same as we move along $\gamma$-radiation, ultraviolet rays, microwaves and radio waves? 1

5. Two polaroids are placed with their optic axis perpendicular to each other. One of them is rotated through 45° what is the intensity of light emerging from the second polaroid if $I_0$ is the intensity of unpolarised light? 1

6. Sketch the graph showing the variation of applied voltage and photo electric current for (i) same frequency and two different intensities, and (ii) same intensity and two different frequencies. 1

7. A heavy nucleus splits into two lighter nuclei. Which one of the two – parent nucleus or the daughter nuclei have more binding energy per nucleon? 1

8. What happens to the width of depletion layer of a *p-n* junction diode when it is (i) forward biased (ii) reverse biased. 1

9. Four equal charges $+q$, $-q$ and $+q$ are placed at the vertices *P, Q* and *R* of an equilateral triangle of side '*a*'. What is the electric potential at the centre of the triangle? How will your answer change if position of charges at *P* and *Q* are interchanged? 2

10. What are ohmic and non-ohmic conductors? Give one example of each. Why can one not measure the resistance of a *p-n* junction is measured by using a voltmeter? 2

11. A charged particle enters a magnetic field perpendicular to it. The particle follows a zigzag path and comes out of it. What happens to its velocity and kinetic energy of the particle? Justify your answer. 2

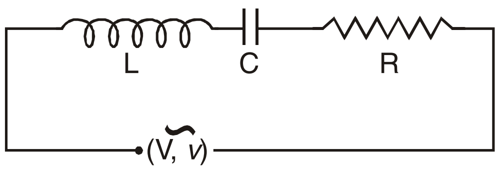
12. Two solenoids each of length L are wound over each other. $A_1$ and $A_2$ are the areas of the outer and inner solenoids and $N_1$ and $N_2$ are the no. of turns per unit length of the two solenoids. Write the expressions for the self inductances of the two solenoids and their mutual inductance. Hence show that square of the mutual inductance of the two solenoids is less than the product of the self inductances of the two solenoids. 2

13. Why two equipotential surfaces do not intersect each other? A charge $q_0$ is placed at the centre of a conducting sphere of radius R, what is the work done in moving a charge $q$ from one point to other diametrically opposite along the surface of the sphere?

14. In and LCR circuit if frequency of the supply is made 4 time, how should the values of $C$ and $L$ be changed so that there is no change in the current in the circuit. 2

**OR**

The series LCR circuit shown in figure is in resonance state. What is the voltage across the inductor?




15. Arrange the following in ascending order of frequency X-rays, green light, red light, microwaves, $\gamma$-radiation. Which characteristic of the above waves is same for all? 2

16. A ray of light travels through an equilateral triangular prism at an angle of incidence $i$ and emerges out at and angle of emergence $e$ write the expression for the angle of deviation relating $i$, $e$ and $A$ (angle of the prism). If the ray undergoes a minimum deviation of 30° then what is the refractive index of the material of the prism? 2

17. A radio active material after 10 days reduces to 6.25%. If 40 g sample is taken then in how many days only 5g of the material is left? 2

18. What is ground wave communication? Why can it not be used for long distance using high frequency? 2

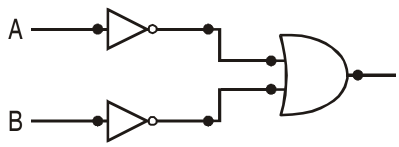
19. In young's double slig experiment the intensities of two interfering waves are $I$ and $4I$. What are the maximum and minimum intensities in the interference pattern? 2

20. An electric dipole of moment $\boldsymbol{p}$ is placed in a uniform electric field $\boldsymbol{E}$. Derive the expression for the potential energy of the dipole and show diagrammatically the orientation of the dipole in the field for which the potential energy is (i) maximum (ii) minimum. 3

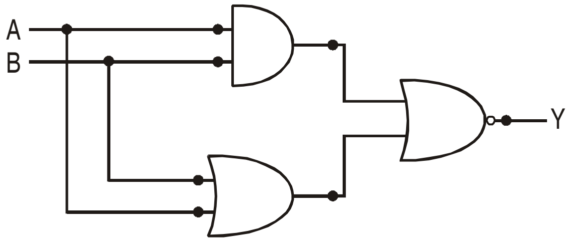
**OR**

Two capacitors $C_1$ and $C_2$ are charged to potential $V_1$ and $V_2$ respectively and then connected in parallel. Calculate (i) common potential, (ii) charge on each capacitor, (iii) electrostatic energy in the system after connection.

21. Produced the truth table for the combination of gates shown in the figure. 3




(A)




(B)

22. What are the characteristics of the objectives lens of an objective lens of and astronomical telescope? Derive the expression for the magnifying power of astronomical telescope in normal adjustment. 3

23. Calculate the de-Broglie wavelength of (i) an electron accelerated by a potential difference of 100V and (ii) a particle of mass 0.03 kg moving with a speed of $100ms^{-1}$. Hence show that wavelength of the particle is not relevant. 3

24. In a plane electromagnetic waves progressing towards –x-axis, the electric field oscillates sinusoidally at a frequency of $2.0 \times 10^{10}$ Hz and amplitude 48 $Vm^{-1}$ along –z-axis. Write the expression for the electric field and the magnetic field. 3

25. Name the series of hydrogen which does not lie in visible region?

The wavelength of first member of Lyman series is 1216 Å. Calculate the wavelength of third member of Lyman series. 3

26. The height of a transmission antenna is 600m find the area covered by the antenna in which the signal from the antenna can be received. 3

27. Draw the circuit diagram to draw the characteristics of common emitter *npn* transistor. Also draw the input and output characteristics of the transistor. 3

28. Derive the formula for the equivalent emf and internal resistance of the parallel combination of the cells of emf $E_1$ and $E_2$ and internal resistance $r_1$ and $r_2$ respectively. Two cells of emf 1V and 2V and internal resistance 2Ω and 1Ω respectively connected in (i) series (ii) parallel. What should be the value of external resistance in the circuit so that the current through the resistance be the same in the two cases? In which case more heat is generated in the cells?

**OR**

Two cells of emf 1.5V and 2.0V and internal resistance 1Ω and 2Ω respectively are connected in parallel so as to send current in the same direction through an external resistance of 5Ω. (a) Draw the circuit diagram. (b) Using Kirchhoff's laws, calculate current through each branch of the circuit and potential across the 5Ω resistance.

29. Write the principle, working of moving coil galvanometer with the help of neat labelled diagram. What is the importance of radial field and phospher bronze used in the construction of moving coil galvanometer?

**OR**

(i) A beam of alpha particular and of protons, enter a uniform magnetic field at right angles to the field lines. The particles describe circular paths. Calculate the ratio of the radii two paths if they have same (a) velocity, (b) same momentum, (c) same kinetic energy.

(ii) A beam of $\alpha$-particles and of protons of the same velocity u enters a uniform magnetic field at right angles to the fields lines. The particles describe circular paths. What is the ratio of the radii of the two circles?

30. (i) Using the relation for the refraction at a single spherical refracting surface, derive lens maker's formula for a thin convex lens.

(ii) The radius of curvature of either face of a convex lens is equal to its focal length. What is the refractive index of its material?

**OR**

(i) Deduce the relationship between the object distance, image distance and the focal length for a mirror. What is the corresponding formula for a thin lens?

(ii) Two lenses of powers +15D and –5D are in contact with each other forming a combination lens. (a) What is the focal length of this combination? (b) An object of size 3cm is placed at 30cm from this combination of lenses. Calculate the position and size of the image formed.