पु●ना International School

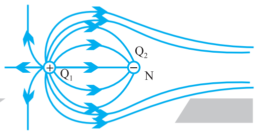
Shree Swaminarayan Gurukul, Zundal

Class – XII

Physics

Specimen Copy

Year-2022-23



Unit I and II

Section - 1

KEY POINTS

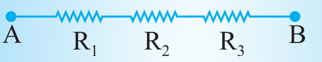
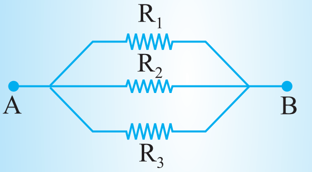
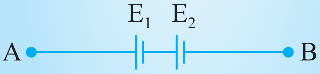
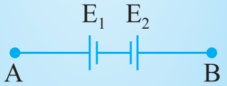
Physical Quantity	Formulae Used	SI Unit
Quantization of charge	$q = \pm ne$	C
Coulomb's force	$\lvert F \rvert = \frac{kq_1q_2}{r^2}$	N
In vector form	$\vec{F}_{12} = \frac{kq_1q_2}{r_{21}^3}\vec{r}_{21} = \frac{kq_1q_2}{r_{21}^2}.\hat{r}_{21}$	
Dielectric constant (or relative permitivity)	$K_D = \in_r = \frac{F_0}{F_m} = \frac{\in_m}{\in_0} = \frac{C_m}{C_0} = \frac{\phi_0}{\phi_m} = \frac{E_0}{E_m}$	Unit less
Hence $F_0 \geq F_m$ as free space has minimum permitivity		
Linear charge density	$\lambda = \frac{q}{L}$	Cm^{-1}
Surface charge density	$\sigma = \frac{q}{A}$	Cm^{-2}
Volume charge density	$\rho = \frac{q}{V}$	Cm^{-3}
Electric field due to a point charge	$\vec{E} = \underset{q_0 \to 0}{\text{Lt}} \frac{\vec{F}}{q_0}$ (theoretical) $\left(\text{In numerical, we use } E = \frac{kq_1}{r^2}\right)$	

The components of electric field,	$E_x = \frac{1}{4\pi\epsilon_0}\frac{q\hat{x}}{r^3}, E_y = \frac{1}{4\pi\epsilon_0}\frac{q\hat{y}}{r^3},$ $E_z = \frac{1}{4\pi\epsilon_0}\frac{q\hat{z}}{r^3}$	NC^{-1}
Torque on a dipole in a uniform electric field	$\vec{\tau} = \vec{p} \times \vec{E}$ (or $\tau = pE \sin\theta$)	Nm
Electric dipole moment	$\vec{p} = q \cdot (2\vec{a})$ or $\lvert\vec{p}\rvert = q(2a)$	Cm
Potential energy of a dipole in a uniform electric field	$U = -\vec{p} \cdot \vec{E}$ (or $U = -pE\cos\theta$)	J
Electric field on axial line of an electric dipole	$E_{axial} = \frac{1}{4\pi\epsilon_0}\frac{2pr}{(r^2 - a^2)^2}$ When $2a << r$, $E_{axial} = \frac{1}{4\pi\epsilon_0}\frac{2p}{r^3}$	NC^{-1}
Electric field on equatorial line of an electric dipole	$E_{equatorial} = \frac{1}{4\pi\epsilon_0}\frac{q2a}{(r^2 + a^2)^{\frac{3}{2}}}$ When $2a << r$, $E_{equatorial}$ $= \frac{1}{4\pi\epsilon_0}\frac{p}{r^3}$	
Electric field as a gradient of potential	$E = -\frac{dV}{dr}$ or $\vec{E} \cdot d\vec{r} = -dV$	
Electric potential differences between ponts A & B	$V_A - V_B = -\frac{W_{AB}}{q_0}$	Volts (or JC^{-1})
Electric potential at a point	$V_A = \frac{1}{4\pi\epsilon_0}\frac{q}{r_A} = \frac{W_{A\infty}}{q}$	

Common potential	$V = \dfrac{C_1V_1 + C_2V_2}{C_1 + C_2}$	
Electric potential due to a system of charges	$V = \dfrac{1}{4\pi \epsilon_0} \sum_{i=1}^{n} \dfrac{q_i}{r_i}$	
Electric potential at any point due to an electric dipole	$V = \dfrac{1}{4\pi \varepsilon_0} \dfrac{p\cos\theta}{(r^2 - a^2\cos^2\theta)}$ When, $\theta = 0°$ or $\theta = 180°$, $V = \dfrac{\pm 1}{4\pi \epsilon_0} \dfrac{p}{(r^2 - a^2)}$ If $r >> a$, $V = \dfrac{1}{4\pi \epsilon_0} \dfrac{p}{r^2}$ When, $\theta = 90°$, $V_{equi} = 0$	
Total electric flux through a closed surface S	$\phi_e = \oint \vec{E} . d\vec{S} = \dfrac{q_{net}}{\epsilon_0}$ q_{net} = Net charge enclosed by a ⇒ Gaussian surface	Nm^2C^{-1}
Electric field due to line charge	$E = \dfrac{1}{2\pi\epsilon_0} \dfrac{\lambda}{r}$	NC^{-1} (or V/m)
Electric field due to an infinite plane sheet of charge	$E = \dfrac{\sigma}{2\epsilon_0}$	
Electric field between two infinitely charged plane parallel sheets having change density +s and –s	$E = \dfrac{\sigma}{\epsilon_0}$	
Electric field due to a uniformly charged spherical shell	$E = \dfrac{\sigma}{\epsilon_0} \dfrac{R^2}{r^2}$ When $r = R$, $E_0 = \dfrac{\sigma}{\epsilon_0}$ When $r < R$, $E \times 4\pi r^2 = 0$ $\therefore E = 0$	

Loss of energy (in Parallel compinaton of two capacitors	$\Delta U = \frac{1}{2}\frac{C_1C_2}{(C_1+C_2)}(V_1-V_2)^2$	
Electrical capacitance	$C = \frac{q}{V}$	F(SI Unit)
Capacitance of an isolated sphere	$C_0 = 4\pi\epsilon_0 r$	
Capacitance of a parallel plate	$C = \frac{A\epsilon_0}{d}$	
Capacitors in series	$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$	
Capacitors in parallel	$C = C_1 + C_2 + C_3$	
Capacitance of a parallel plate capacitor with dielectric slab between plates	$C = \frac{\epsilon_0 A}{d - t\left(1 - \frac{1}{K_D}\right)}$	
Capacitance of a parallel plate capacitor with conducting slab between plates	$C = \frac{C_0}{\left(1 - \frac{t}{d}\right)}$	
Energy stored in a charged capacitor	$U = \frac{q^2}{2C} = \frac{1}{2}CV^2 = \frac{1}{2}qV$	J
Resultant electric field in a polarised dielectric slab	$\vec{E} = \vec{E}_0 - \vec{E}_p$, where $\bar{E}_0$ = Applied electric field and $\bar{E}_p$ = Electric field due to	Cm^{-1}
polarization		
Polarization density	$P = \epsilon_0 \chi E$	Vm^{-1} or Nc^{-1}
Dielectric constant (in terms of electric susceptibility or atomic polarisability)	$K_D = 1 + \chi$ Where K is dieletric Contant	

CURRENT ELECTRICITY
IMPORTANT FORMULA

1.	Drift Velocity	$\vec{v}_d = -\frac{e\vec{E}}{m}\tau$	$\vec{E}$ – electric fluid
2.	Relation b/w current and Drift Velocity	$I = neA\upsilon_d$	τ = Relaxation time e = charge on electrons. m = mass of electron 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	$\rho = \frac{RA}{l} = \frac{m}{ne^2\tau}$	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 Combination	$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$	
9.	Temperature Dependance of Resistance	$R_t = R_0(1 + \alpha t)$	R_t = Resistance at t°C a = Cofficent of temprature t = Temperature
10.	Internal Resistance of a cell	$r = \left(\frac{E}{V} - 1\right)R$	R_o = Resistance at 0°C
11.	Power	$P = VI = I^2R = \frac{V^2}{R}$	
12.	Cells in Series	$Eeq = E_1 + E_2$	
	Equivalent emf	$Eeq = E_1 - E_2$	$E_1 > E_2$ 
	Equivalent Internal Resistance	$r_{eq} = r_1 + r_2$	E_1 & E_2 are emf of two cells
	Mobility (μ)	$\frac{v_d}{E}$	CGS unit → $Cm^2s^{-1}v^{-1}$ SI unit → $M^2s^{-1}s^{-}v^{-1}$

		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) $\Sigma iR = \Sigma E$ or $\Sigma iR = 0$ (in a closed loop)	i = Current R = Resistance E = e.m.f.
15. Wheatstone Bridge (balanced condition)	$\frac{P}{Q} = \frac{R}{S}$	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 potentiometer wire for cells E_1 and E_2
Internal Resistance	$r = \left(\frac{l_1 - l_2}{l_2}\right) R = \left(\frac{E}{V} - 1\right) R$	l_1 and l_2 are balancing lengths on potentiometer wire for emt E and Pot. diff. V across R.

UNIT–I & UNIT–II

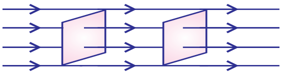
ELECTROSTATICS AND CURRENT ELECTRICITY

QUESTIONS

VERY SHORT ANSWER QUESTIONS (1 MARK)

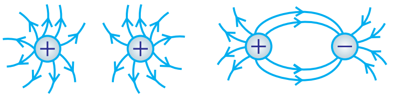
1. Draw schematically an equipotential surface of a uniform electrostatic field along x-axis.

Ans.



2. Sketch field lines due to (i) two equal positive charges near each other (ii) a dipole.

Ans.



3. Name the physical quantity whose SI unit is volt/meter. Is it a scalar or a vector quantity ?

Ans. Electric field intensity. It is a vector quantity.

4. Two point charges repel each other with a force F when placed in water of dielectric constant 81. What will be the force between them when placed the same distance apart in air ?

Ans. $\in_r = \dfrac{F_0}{F_m} \Rightarrow F_0 = \in_r F_m \Rightarrow F_0 = 81 F_m$

5. Electric dipole moment of $CuSO_4$ molecule is 3.2×10^{-28} Cm. Find the separation between copper and sulphate ions.

Ans. $p = q(2a) \Rightarrow$ Length of dipole $a = \dfrac{3.2 \times 10^{-28}}{2 \times 1.6 \times 10^{-19}} = 10^{-9}$ cm

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.

$$C_p = 12\mu f \Rightarrow C = \frac{12}{3} = 4\mu F.$$

$$C_p = C_1 + C_2 = 8\mu F$$

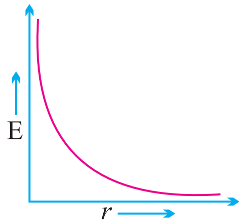
$$C_s = \frac{C_1C_2}{C_1+C_2} = \frac{16}{8} = 2\mu F$$

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.

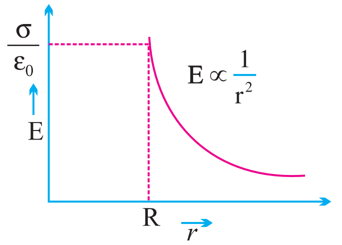
Ans.
$$\phi = \frac{q}{\epsilon_0}$$
$$\phi' = \frac{\phi}{2} = \frac{q}{2\epsilon_0}$$

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

Ans.



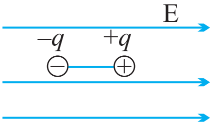
Linear Charge



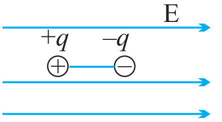
Charged conducting spherical shall

9. Diagrammatically represent the position of a dipole in (i) stable (ii) unstable equilibrium when placed in a uniform electric field.

Ans.



Stable equilibrium



Unstable equilibrium

10. A charge Q is distribution over a metal sphere of radius R. What is the electric field and electric potential at the centre ? **Ans.** $E = 0$, $V = kQ/R$

Ans. Electric field inside conductor $E = 0$

$$E = \frac{dV}{dr} = 0 \Rightarrow V = \text{Constant} = \frac{Q}{4\pi\epsilon_0 R} = k\frac{Q}{R}$$

11. If a body contains n_1 electrons and n_2 protons then what is the total charge on the body ?

Ans. $Q = q_1 + q_2 + ... + q_n$. (Additive property of charge)

$Q = (n_2 - n_1)e$

12. What is the total positive or negative charge present in 1 molecule of water.

Ans. H_2O has 10 electrons (2 of hydrogen and 8 of oxygen)

Total charge = $10e$

13. How does the energy of dipole change when it is rotated from unstable equilibrium to stable equilibrium in a uniform electric field.

Ans. Work done $= pE(\cos 180° - \cos 0°)$

$= -2pE$

i.e., energy decreases.

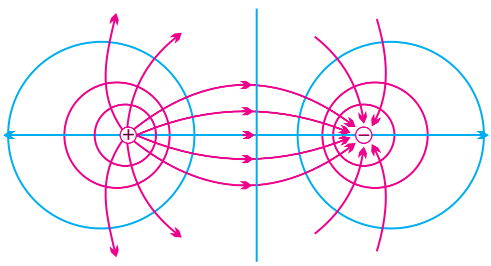
14. Write the ratio of electric field intensity due to a dipole at a point on the equatorial line to the field at a point on the axial line, when the points are at the same distance from the centre of dipole.

Ans. $E_{axial} = \dfrac{2kp}{r^3}$ $E_{equatorial} = \dfrac{kp}{r^3}$

$\therefore$ $E_{axial} = 2E_{equatorial}$

15. Draw equipotential surface for a dipole.

Ans.



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. Total charge = $0 + q = q$ remains same.

P. D. decreases due to induced charge on A.

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. $V_A - V_B > 0$ for $Q > 0$ and $V_A - V_B < 0$ for $Q < 0$

As electric field lines are in the direction of decreasing potential.

18. An electron and proton are released from rest in a uniform electrostatic field. Which of them will have larger acceleration ?

Ans. acceleration $= \dfrac{\text{force}}{\text{mass}}$, $m_p > m_e$

$$a_p < a_e$$

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.
$$\frac{W_{AB}}{W_{BA}} = -1$$

$$\therefore \quad W_{AB} + W_{BA} = 0$$

$$|W_{AB}| = |-W_{BA}|$$

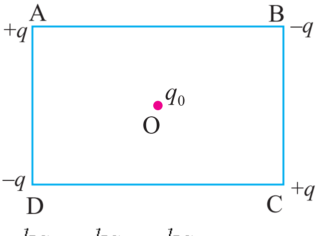
20. If a dipole having charge $\pm 2\mu C$ is placed inside a sphere of radius 2 m, what is the net flux linked with the sphere.

Ans. Net flux $= \dfrac{\text{Net charge}}{\epsilon_0} = \dfrac{+q-q}{\epsilon_0} = 0$

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.

Here, OA = OB = OC = OD

& q_0 = Test charge



Ans.
$$V_0 = \frac{kq}{AO} + \frac{kq}{OC} - \frac{kq}{OB} - \frac{kq}{OD} = 0$$

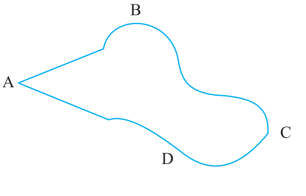
$$W = q_0 \times V_0 = 0$$

22. Calculate electric flux linked with a sphere of radius 1m and charge of 1C at its centre.

Ans. Electric flux linked with the sphere (closed surface)

$$\phi_e = \frac{q}{\epsilon_0} = \frac{1}{\epsilon_0}$$

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. Charge leaks from A first as surface charge density (σ) at A (sharp ends) is more.

24. What is dielectric strength ? Write the value of dielectric strength of air.

Ans. Maximum electric field which can be safely applied across a dielectric before its break down is called dielectric strength.

Dielectric strength of air = 3×10^6 V/m.

25. Two charges $-q$ 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. $W = \vec{F} \cdot \vec{dr} = q\vec{E} \cdot \vec{dr} = q\, E dr \cos 90° = 0$

∴ E along equitorial line of dipole is anti-parallel to dipole moment, hence perpendicular to displacement or $W = 20 \times q_0 \times V_{equatorial} = q_0 \times 0 = 0$ J.

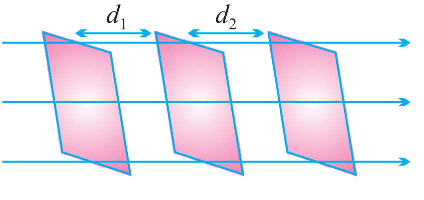
26. If an electron is accelerated by a Potential difference of 1 Volt, Calculate the gain in energy in Joule and electron volt.

Ans. Gain in Energy = eV = $1.6 \times 10^{-19} \times 1 = 1.6 \times 10^{-19}$ J

or $\Delta KE = 1e \times 1 \text{ volt} = 1.6 \times 10^{-19} \text{ C} \times 1 \text{ volt} = 1.6 \times 10^{-19}$J

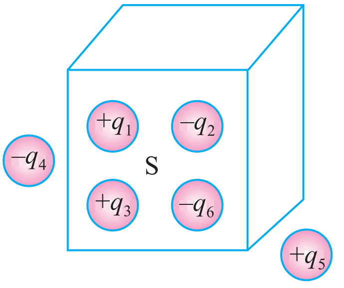
27. Draw schematically the equipotential surface corresponding to a field that uniformly increases in magnitude but remains in a constant (say z) direction.

Ans.



E increases therefore, equipotential surface are closer *i.e.*, $d_1 > d_2$.

28. Figure shows six charged lumps of plastic coin. The cross-section of a Guassian surface S is indicated. What is the net electric flux through the surface ?



Ans. $$\phi = \frac{+q_1}{\in_0}\frac{-q_2}{\in_0}\frac{+q_3}{\in_0} - \frac{q_4}{\in_0}.$$

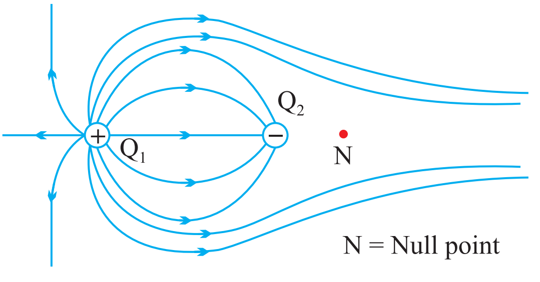
29. Without referring to the formula C = $\in_0$ A/d. Explain why the capacitance of a parallel plate capacitor reduces on increasing the separation between the plates ?

Ans. $$\text{P. D.} = V = E \times d$$

'*d*' increases hence V increases.

as $C = \frac{Q}{V}$, $\therefore$ C decreases.

30. 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.



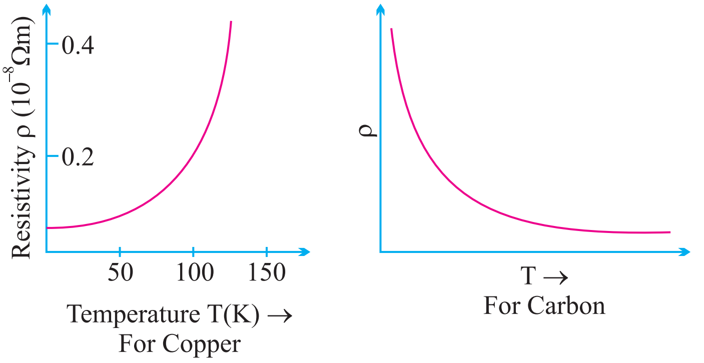
Ans. $|Q_1| > |Q_2|$, N is the neutral point.

31. How does the relaxation time of electron in the conductor change when temperature of the conductor decreases.

Ans. When temperature of the conductor decreases, ionic vibration in the conductor decreases so relaxation time increases.

32. Sketch a graph showing variation of resistivity with temperature of (i) Copper (ii) Carbon.

Ans.



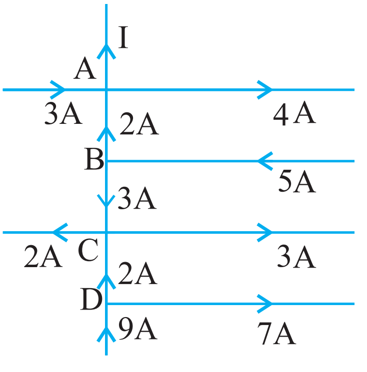
33. The emf of the driver cell (Auxiliary battery) in the potentiometer experiment should be greater than emf of the cell to be determined. Why ?

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

34. You are required to select a carbon resistor of resistance $47k\Omega \pm 10\%$ from a large collection. What should be the sequence of color bands used to code it ?

Ans. Yellow, Violet, Orange, Silver.

35. Find the value of *i* in the given circuit :



Ans. On applying Kirchoff current law on junction A, at junction A

$$2 + 3 = I + 4$$

so, $$I = + 1A$$

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

Ans. $R = \rho_c \frac{l_c}{A_c} = \rho_m \frac{l_m}{A_m} \Rightarrow \frac{\rho_c}{\rho_m} = \frac{A_c}{A_m} < 1$

$\therefore$ Manganin is thicker.

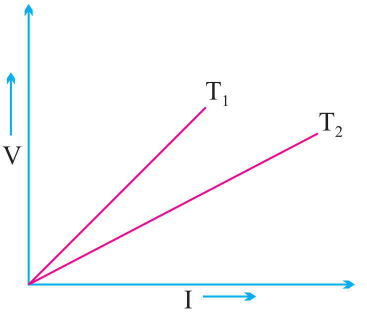
37. You are given three constants wires P, Q and R of length and area of cross-section (L, A), $\left(2L, \frac{A}{2}\right), \left(\frac{L}{2}, 2A\right)$ respectively. Which has highest resistance ?

Ans. $R_P = \rho\frac{L}{A}, \; R_Q = \frac{\rho(2L)}{\frac{A}{2}} = \frac{4\rho L}{A}$

$\Rightarrow R_R = \frac{\rho L}{4A} \Rightarrow R_Q = 4R_P, R_R = \frac{1}{4}R_P$

Q has the highest resistance,

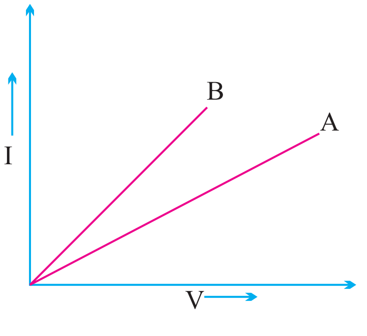
38. V – I graph for a metallic wire at two different temperatures T_1 and T_2 is as shown in the figure. Which of the two temperatures is higher and why ?



Ans. Slope of T_1 is large, so T_1 represents higher temperature as resistance increases with temperature for a conductor

$$R = \frac{V}{I} = \text{slope.}$$

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



Ans. The resistance for parallel combination in lesser than for series combination for a given set of resistors. Hence B represents parallel combination sinc $\frac{I}{V}$ is more. Hence Resistance = $\frac{V}{I}$ is less.

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

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

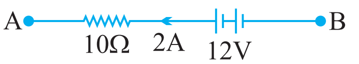
41. How can a given 4 wires potentiometer be made more sensitive ?

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

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

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

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



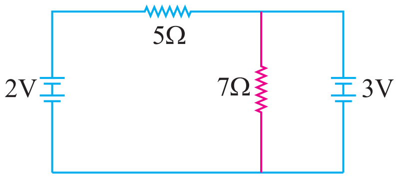
Ans. $V_A - V_B = -8$ volt.

44. 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 ?

Ans. $$R' = n^2R$$

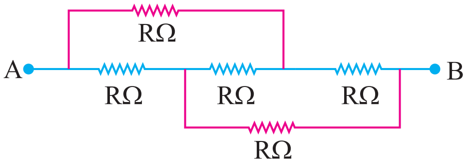
$$\therefore \quad R' = \rho\frac{nL}{A/n} = \rho n^2\frac{I}{A} = n^2R$$

45. Two resistance 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

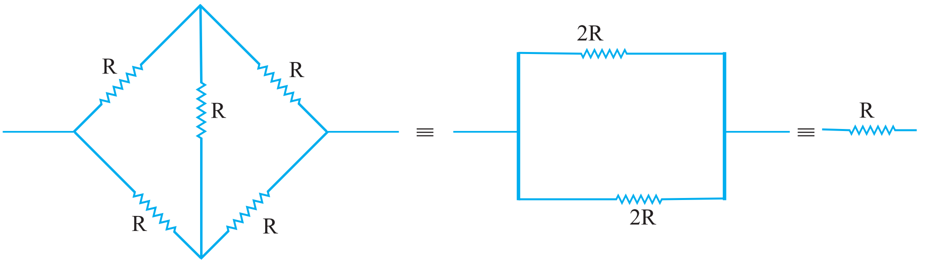


Ans. $I = \frac{2}{5}A.$

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



Ans. We obtain using wheatstone bridge balencing condition.



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

Ans. $P = \dfrac{V^2}{R}, V^2 = P\,R = 1 \times 196 = 196$

$$V = 14 \text{ Volt.}$$

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

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

(ii) When the cell is discharged, then $V < E$

$$V = E - I\,r$$

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

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

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

Ans. As $R = \dfrac{V^2}{P}$, 220 V, 60 W lamp has higher resistance.

51. Resistors of high value are made up of carbon. Why ?

Ans. High resistivity and low temperature Coefficient of resistance.

52. Draw graph showing the variation of electronic field & electronic potential with distances 'r' due to a point change.

53. Net capacitance of three identical capacitors in series is 1μF. What will be their net capacitance if connected in parallel. Find the raio of energy stored in two combinations connected across the same battery.

54. Distinguish with the help of a suitable diagram,the difference in the behaviour of conductor and a dielectric substance placed in an external electric field. How does the polarised dielectric modifies the external field.

55. A parallel plate capacitor of capacitance C is charged to a potential of V volt. It is then connected across another uncharged capacitor of same capacitance .Find the ratio of initial energy of single capacitor to the final energy combination . **[Ans -2:1]**

56. An infinite large plane thin charged sheet has surface charge density σ. Obtain an expression for work done in carrying a point charge q from finity to a point at a distance

57. A proton and a alpha particle are accelerated from rest through a potential difference of 100 volt. Find (i) Their KE in eV and Joule (ii) which particle will move faster.

[Ans: (1) 100 eV, 200 eV, 1.6 x 10^{-17}J, 3.2x 10^{-17}J (ii) Proton]

58. An electron starting from rest takes 14×10^{-9} sec to reach from one plate to other of a capacitor placed 2 cm apart. If charge to mass ratio of electron is 1.8×10^{11} *CI* kg. Then find the potential difference between the plates.

[Ans: V = 2400 Volt]

59. An alpha particle of charge $3.2\times10\text{-}^{19}$ cm/sec and mass 6.8×10^{-27}Kg is initially moving at speed 10^7 when it is at far distance from another fixed point charge 112×10^{-19}C. Find the distance of closest approach.

[Ans: r = 9.4×10-15 m]

60. If the dielectric strength of air is 3×10^6 V/m, what will be the maximum potential at the surface of a metal sphere of radius 1m.

[**Ans:** V = 3×106 Volt]

61. Two point charge each +3 μC are placed along the diameter of a circle of radius 15 cm. Calculate the ectric potential at the ends of perpendicular diameter [**Ans:** V = 2.52×10^5 Volt]

62. An electric dipole of dipole moment 40×10^{-6}C-m is enclosed by a closed surface. What is the net flux coming out of the surface? [**Ans:** zero]

63. Does the charge given to a metallic sphere depend on whether it is solid or hollow .Give reason.

[Ans: Charge comes on the outer surface only, like charges repel and conductor allows flow of charge]

64. A and B are two conducting spheres of the same radius, A being solid and B hollow. Both have same field on their surface. What will be the relation between the charges on the two spheres? **[Ans: Same]**

65. How does the electric flux due to a point charge enclosed by a spherical gaussian surface is affected ,if radius is increased

[Ans: remains same as it does not depend upon shape and size of Gaussian surface]

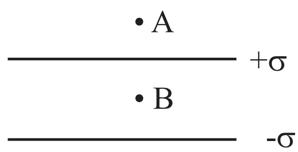
66. How does the Coulomb force between two point charges depend upon the dielectric constant of the intervening medium?

[Ans: It decreases with increasing dielectric constant of medium]

67. The distance of the field point, on the equatorial plane of a small electric dipole, is halved. By what factor will the electric field, due to the dipole, change? [**Ans:** As E oc $1/r^3$, 8 times]

68. Two plane sheets of charge densities $+\sigma$ and $-\sigma$ are kept in air as shown in figure.What are the electric field intensities at points A and B?

[Ans: zero, σ/ε_0]



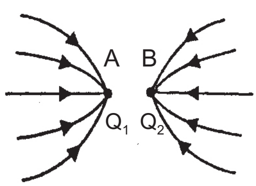
69. Why does the electric field inside a dielectric decrease when it is `aced in an external electric field?

[Ans: Due to induced field is opposite direction]

70. A charge Q is uniformly distributed over a ring of radius a.Obtain an expression for electric field intensity at a point on the axis of ring. show that at far point ring behaves as a point charge.

71. Figure shows electric lines of force due to two point charges q_1 and q_2 placed at points A and B respectively. Write the nature of charge on them.

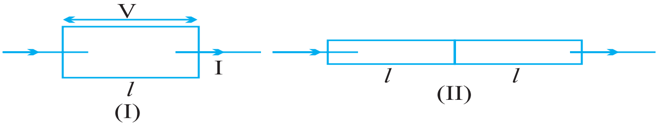
[Ans: $Q_1 < 0$, $Q_2 < 0$]



72. Two points charges q_1 and q_2 are placed close to each other. What is the nature of force between the charges when $q_1 < 0, q_2 > 0$, $q_1 < 0, q_2 < 0$

[Ans: Attractive, repulsive]

73. A metal rod of square cross-section area A having length l has current I flowing through it, when a potential difference of V volt is applied across its ends (figure I). Now the rod is cut parallel to its length in two Identical pieces and joined as shown in (figure-II). What potential difference must be maintained across the length $2l$ so that the current in the rod is still remains I ?



Ans.

$$R_1 = \rho\frac{l}{A}$$

$$R_2 = \rho\frac{2l}{A/2} = 4R_1$$

$$I = \frac{V}{R_1} = \frac{V_2}{R_2}$$

$$\frac{V}{R_1} = \frac{V_2}{4R_1}$$

$$V_2 = 4V$$

74. (a) Define torque acting on a dipole moment $\vec{p}$ Placed in a uniform electric field $\vec{E}$. Express it in the vector form and point out the direction along which it acts.

(b) What happens if the electric field is non-uniform ?

(c) What would happen if the external field $\vec{E}$ is increasing (i) Parallel to $\vec{p}$ (ii) anti-parallel to $\vec{p}$?

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

Ans. When battery is in open circuit *i.e.* when no current is being drawn from the cell. V_{open} = emf of cell or battery

76. State the condition for maximum current to be drawn from a cell.

Ans. $I = \frac{E}{R + r}$ for I maximum R = 0 *i.e.*, for maximum current the terminals of a cell must be short circuited.

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 = mg/Q, downward

2. Draw E and V versus *r* on the same graph for a point charge.

3. Find position around dipole at which electric potential due to dipole is zero but has non zero electric field intensity.

Ans. Equitorial position, V = 0, $\vec{E} = \frac{-1}{4\pi \epsilon_0} \frac{\vec{p}}{r^3}$ (a << *r*)

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. A electrostatic field line can not be discontinuous.Why ?

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. 72×10^5 N/C

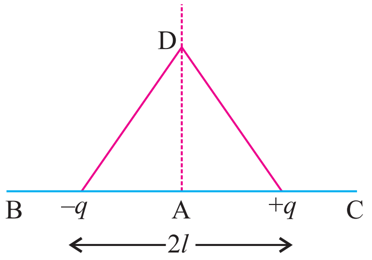
7. What is the ratio of electric field intensity at a point on the equatorial line to the field at a point on axial line when the points are at the same distance from the centre of the dipole ? **Ans.** 1 : 2

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.** $\frac{1}{16\pi\epsilon_0} \frac{q_A^2}{d^2}$

10. An electron and a proton travel through equal distances in the same uniform electric field E. Compare their time of travel. (Neglect gravity)

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

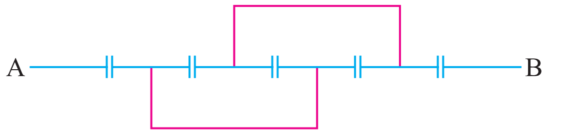


12. The electric potential V at any point in space is given $V = 20x^3$ volt, where x is in meter. Calculate the electric intensity at point P (1, 0, 2).

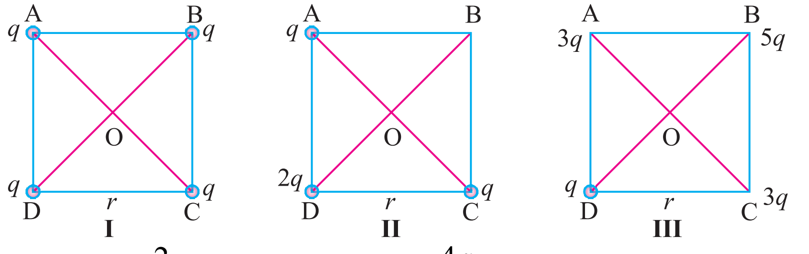
Ans. 60 NC^{-1}

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) $\frac{2q}{4\pi\varepsilon_0 r^2}$ along OB (iii) $\frac{4q}{4\pi\varepsilon_0}$ r^2 along OD

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 2 cm 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 be change in (i) charge on the plates (ii) potential difference across the plates (iii) electric 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.

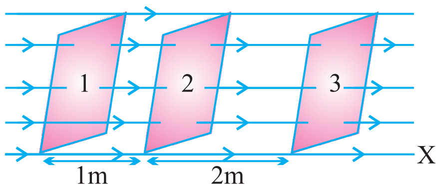
Ans. No, charge resides on the surface of conductor.

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 electric field due to electric dipole at any point on the equatorial line.

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



22. Calculate the work required to separate two charges 5μ*c* and – 2μ*c* placed at (– 3 cm, 0, 0) and (+ 3 cm, 0, 0) infinitely away from each other.

Ans. 1.5 J

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

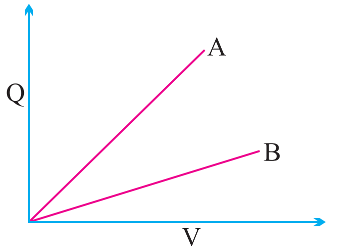
______________ 150 V

(i) ______________ – 50 V

Ans. $E_0 = 10^4\ NC^{-1}$, $E = \frac{10^4}{k}\ NC^{-1}$

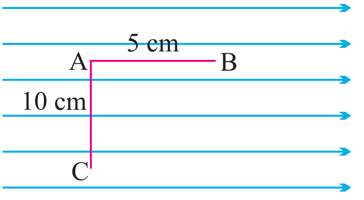
24. A RAM (Random access Memory) chip a storage device like parallel plate capacitor has a capacity of 55pF. If the capacitor is charged to 5.3V, how may excess electrons are on its negative plate ? **Ans.** 1.8×10^9

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. $W_{AC} = 0$J

27. 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 at a point A is – 500 V and that at another point B is + 500 V. What is the work done by external agent to take 2 units (S.I.) of negative charge from B to A. $W_{BA} = 2000$ J

29. How does the (i) Potential energy of 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 that Farad is a very large unit of capacitance.

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

32. 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.

33. An electric dipole of dipole moment p, is held perpendicular to an electric field. If the dipole is released does it have (a) only rotational motion

(b) only translatory motion (c) both translatory and rotatory motion explain?

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

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

36. There are two large parallel metallic plates S_1 and S_2 carrying surface charge densities σ_1 and σ_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 S_1 and S_2 along a line making an angle $\pi/4$ with the normal to the plates.

37. 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 ?

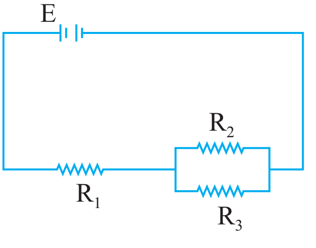
38. On what factor does potential gradient of a potentiometer wire depend ?

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

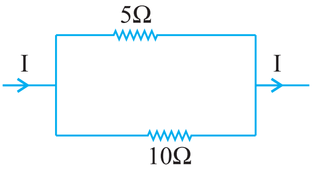
40. Two copper wires with their lengths in the ratio 1 : 2 and resistances in the ratio 1 : 2 are connected (i) in series (ii) in parallel with a battery. What will be the ratio of drift velocities of free electrons in two wires in (i) and (ii) ? **Ans.** (1 : 1, 2 : 1)

41. 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.

42. 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)



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

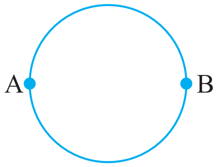


44. A 100W and a 200 W domestic bulbs joined in series are connected to the mains. Which bulb will glow more brightly ? Justify. (100W)

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

46. 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.

47. 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]

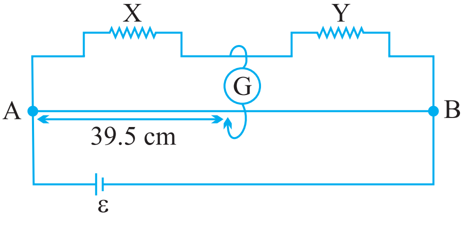


48. In a potentiometer arrangement, a cell of emf 1.25V gives a balance point at 35 cm length of the wire. If the cell is replaced by another cell, then the balance point shifts to 63 cm. What is the emf of the second cell ?

[Ans. 2.25V]

49. 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]



50. 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.]

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

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

53. Given any two limitations of Ohm's law.

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

55. 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.

56. If the electron drift speed is so small (~ 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.

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

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

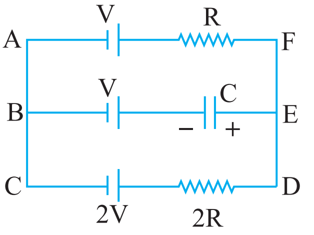
59. What is meant by the sensitivity of a potentiometer of any given length ?

60. 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]

61. 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*.

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



63. 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'.

64. Winding of rheostat wire are quite close to each other why do not they get short circuted ?

Ans. The wire has a coating of insulating oxide over it which insulate the winding from each other.

65. Why is it necessary to obtain the balance point in the middle of bridge wire ? Explain.

66. What are the possible cause of one side deflection in Galvanometer while performing potentiometer experiment ?

Ans. (i) Either +ve terminals of all the cells are not connected to same end of potentiometer.

or

(ii) The total potential drop across wire is less than the emf to be measured.

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.

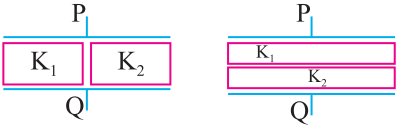
4. Using Gauss's theorem in electrostatics, deduce an expression for electric field intensity due to a charged spherical shell at a point (i) inside (ii) on its surface (iii) outside it. Graphically show the variation of electric field intensity with distance from the centre of shell.

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.

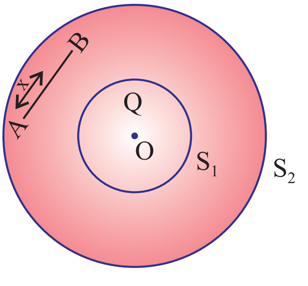
8. You are given an air filled parallel plate capacitor. Two slabs of dielectric constants K_1 and K_2 having been filled in between the two plates of the capacitor as shown in Fig. What will be the capacitance of the capacitor of initial area was A distance between plates d ?



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

$$C_2 = \frac{K_1K_2C_0}{(K_1 + K_2)}$$

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 of length l has a liner charge density λ given $\lambda = kx$ where x is the distance measured along the wire from end A.



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

By Gauss's theorem.

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

Total flux 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.

11. Derive an expression for total work done in rotating an electric dipole through an angle θ 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 f 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, what will be the flux 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

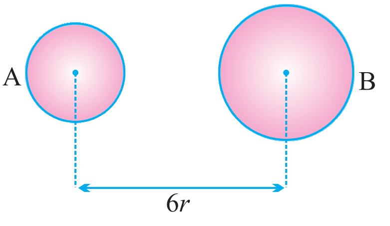
(i) Isolated point charge

(ii) Uniform electric field

(iii) Dipole

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

17. 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 V_1 and V_2. Find the ratio of V_1/V_2. 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 ?



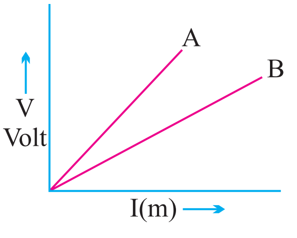
18. Define specific resistance. Write its SI unit. Derive an expression for resistivity of a wire in terms of its material's parameters, number density of free electrons and relaxation time.

19. 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.

20. 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

21. Define potential gradient. How can potential gradient of a potentiometers 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 ?

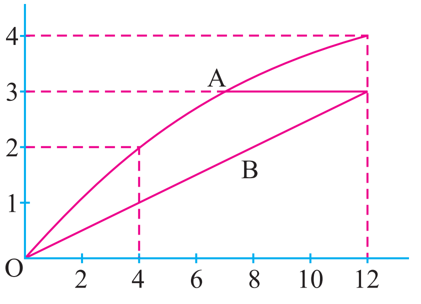


22. Define conductivity of a substance. Give its SI units. How does it vary with temperature for (i) Copper (ii) Silicon ?

23. Two cells of emf E_1 and E_2 having internal resistance r_1 and r_2 are connected in parallel. Calculate Eeq and req for the combination.

24. The graph A and B shows how the current varies wiht applied potential difference across a filament lamp and nichrome wire respectively. 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 resistance in (i) and (ii).

25. 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.

26. Give three differences between e.m.f. and terminal potential difference of a cell.

27. 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.

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

29. 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 ?

30. 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. Two charged capacitors are connected by a conducting wire. Calculate common potential of capacitors (ii) ratio of their charges at common potential. Show that energy is lost in this process.
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 θ 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 negative charge) 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 moment 3.6×10^{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 (a) 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 5×10^{-8} Cm^{-2} with the separation between plates being 4 mm.
8. Define current density. Give its SI unit. Whether it is vector or scalar ? How does it vary when (i) potential difference across wire increases (ii) length of wire increases (iii) temperature of wire increases (iv) Area of cross-section of wire increases justify your answer.

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 any four important results regarding electro statics of conductors.

11. State Kirchhoffs'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 ? Write the formula used.

12. 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.

13. For three cells of emf E_1, E_2 and E_3 with internal resistance 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 ?

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

15. 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 ?

16. Explain how does the conductivity of a :

(i) Metallic conductor

(ii) Semi conductor and

(iii) Insulator varies with the rise of temperature.

17. 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.

18. 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. What should be the position of charge $q = 5\mu C$ for it to be in equilibrium on the line joining two charges $q_1 = -4\ \mu C$ and $q_2 = 16\ \mu C$ 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,– 100μC 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 ?

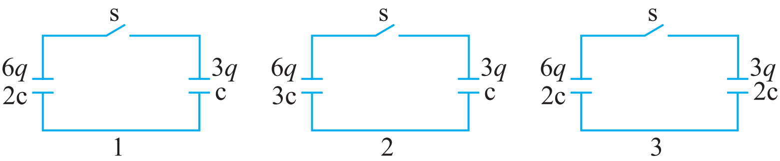
   $(90\sqrt{2} \times 10^3\ N)$
6. A point charge of 2 μC is kept fixed at the origin. Another point charge of 4 μC is brought from a far point to a distance of 50 cm from origin. (a) Calculate the electrostatic potential energy of the two charge system. Another charge of 11 μC is brought to a point 100 cm from each of the two charges. What is the work done ? (a) 144×10^{-3} J
7. A 5 MeV α 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 $\mu C/m^2$. $(1.13 \times 10^4 V)$

9. A slab of material of dielectric constant K has the same area as the plates of parallel plate capacitor but its thickness is $\frac{3d}{4}$, where d is separation between plates, How does the capacitance change when the slab is inserted between the plates ?

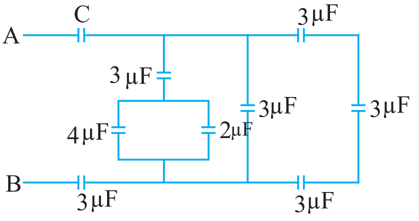
10. A point charge developes an electric field of 40 N/C and a potential difference of 10 J/C at a point. Calculate the magnitude of the charge and the distance from the point charge. $(2.9 \times 10^{-10}$ C, 25 cm)

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

13. A pendulum bob of mass 80 mg and carrying charge of 3×10^{-8} C is placed in an horizontal electric field. It comes to equilibrium position at an angle of 37° with the vertical. Calculate the intensity of electric field. (g = $10 m/s^2$) $(2 \times 10^4$ N/C)

14. Eight charged water droplets each of radius 1 mm and charge 10×10^{-10} C coalesce to form a single drop. Calculate the potential of the bigger drop.

(3600 V)

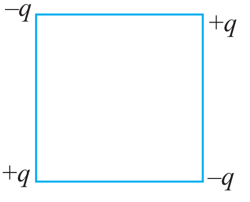
15. What potential difference must be applied to produce an electric field that can accelerate an electron to 1/10 of velocity of light. $(2.6 \times 10^3$ V)

16. 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 ?

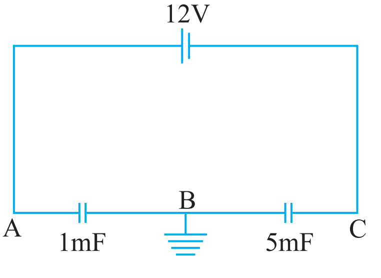
17. Three concentric spherical metallic shells A < B < C of radii *a, b, c* ($a < b < c$) have surface densities σ, – σ and σ respectively. Find the potential of three shells A, B and C (ii). If shells A and C are at the same potential obtain relation between *a, b, c*.

18. 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.

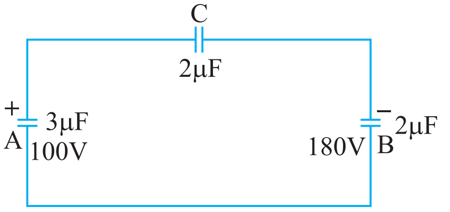
$$\left[\frac{kq^2}{a}(\sqrt{2} - 4)\right] \text{J}$$



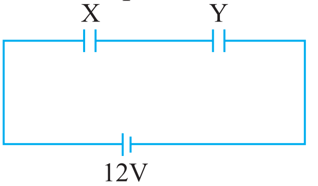
19. Find the potential at A and C in the following circuit :



20. Two capacitors A and B with capacitances 3 μF and 2 μF are charged 100 V and 180 V respectively. The capapitors 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.



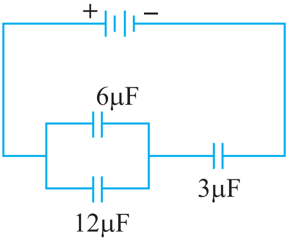
21. Fig. shows two parallel plate capacitors X and Y having same area of plates and same separation between them : X has air while Y has dielectric of constant 4 as medium between plates



(a) calculate capacitance of each capacitor, if equivalent capacitance of combination is 4μF (b) calculate potential difference between plate X and Y (c) what is the ratio of electrostatic energy stored in X & Y.

Ans. (a) 5μF, 20μF, (b) 9.6V, 2.4V (c) 4

22.



In the following arrangement of capacitors, the energy stored in the 6μF capacitor is E.

Find :

(i) Energy stored in 12 μF capacitors.

(ii) Energy stored in 3μF capacitor.

(iii) Total energy drawn from the battery.

Ans. (i) $E = \frac{1}{2}CV^2 = \frac{6}{2} \times 10^{-6}\ V^2 = 3 \times 10^{-6}\ V^2$

$$V^2 = \frac{E}{3 \times 10^{-6}}$$

Energy stored in 12μF capacitor = $\frac{1}{2}CV^2$

$$= \frac{1}{2} \times 12 \times 10^{-6} \times \frac{E}{3 \times 10^{-7}}$$

$$= 2E$$

(ii) Charge on 6μF capacitor $\left[\because E = \frac{1}{2}\frac{Q^2}{C}\right]$

$$Q_1 = \sqrt{2EC}$$
$$= 2\sqrt{3}\,E \times 10^{-3}\,C$$

Charge on 12μF capacitor

$$Q_2 = 2\sqrt{2CE}$$
$$= \sqrt{2 \times 12 \times 10^{-6} \times 2E}$$
$$= 4\sqrt{3E} \times 10^{-3}\,C$$

Charge on 3μF capacitor $Q = Q_1 + Q_2$

$$= 6\sqrt{3E} \times 10^{-3}$$

Energy stored in 3μF capacitor

$$= \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2} \times \frac{36 \times 3E \times 10^{-6}}{3 \times 10^{-6}}$$

$$= 18E$$

(ii) Capacitance of parallel combination = 18μF

Charge on parallel combination Q = CV

$$= 18 \times 10^{-6}\,V$$

$$\text{Charge on } 3\mu F = Q = 3 \times 10^{-6}\,V_1$$

$$18 \times 10^{-6}\,V = 3 \times 10^{-6}\,V_1$$

$$V_1 = 6V$$

Energy stored in 3μF capacitor = $\frac{1}{2}CV_1^2$

$$= \frac{1}{2} \times 3 \times 10^{-6} \times \frac{E \times 36}{3 \times 10^{-6}}$$

$$= 18E$$

(iii) Total eEnergy drawn = E + 2E + 18E = 21E

23. 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

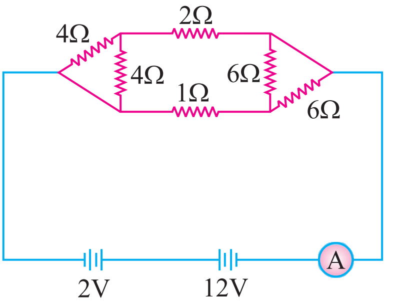
24. The resistance of a platinum wire at a point 0°C is 5.00 ohm and its resistance at steam point is 5.40Ω. When the wire is immersed in a hot oil bath, the resistance becomes 5.80Ω. Calculate the temperature of the oil bath and temperature coefficient of resistance of platinum.

Ans. a = 0.004°C; T = 200°C

25. 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.

Ans. I = 0.75; V = 5.55 V

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



27. A storage battery of emf 12V and internal resistance of 1.5Ω is being charged by a 12V 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 = 16.5 Ω

28. Three cells 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 4V and if their internal resistance are 4Ω, 3Ω and 2 Ω respectively, find the current through each cell. $\left[\textbf{Ans.}\ I_1 = \frac{-2}{13}A, I_2 = \frac{-7}{13}A,\ I_3 = \frac{9}{13}A\right]$

29. 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

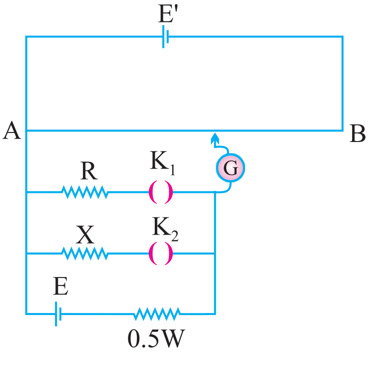
30. A length of uniform 'heating wire' made of nichrome has a resistance 72 Ω. At what rate is the energy dissipated if a potential difference of 120V is applied across (a) full length of wire (b) half the length of wire (wire is cut into two). Why is it not advisable to use the half length of wire ?

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

31. 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 15 cm. Find the value of X from these observations.

Ans. 8/3 Ω

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



33. In a potentiometer, a standard cell of emf 5V of negligible internal resistance maintains a steady current through Potentiometer wire of length 5m. Two primary cells of emf E_1 and E_2 are joined in series with (i) same polarity (ii) opposite polarity. The balancing point are found at length 350 cm and 50 cm in two cases respectively.

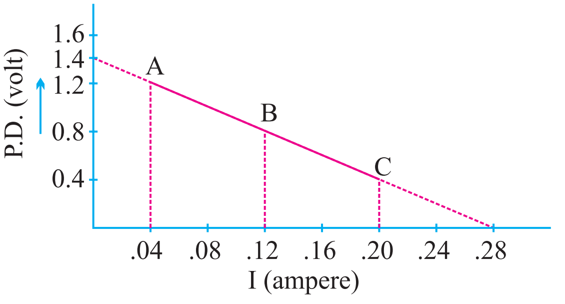
(i) Draw necessary circuit diagram

(ii) Find the value of emf E_1 and E_2 of the two cells (if $E_1 > E_2$)

Ans. $E_1 = 2V, E_2 = 1.5V$

34. 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. $r = 5\Omega$ emf = 1.4V

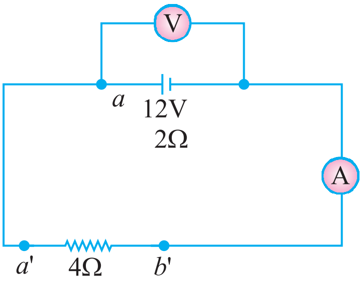


35. Four cells each of internal resistance 0.8Ω and emf 1.4V, *d* are connected (i) in series (ii) in parallel. The terminals of the battery are joined to the lamp of resistance 10Ω. Find the current through the lamp and each cell in both the cases.

Ans. $I_s = 0.424$A, $I_p = 0.137$A current through each cell is 0.03A

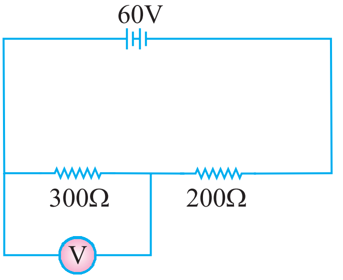
36. In the figure, an ammeter A and a resistor of resistance R = 4Ω have been connected to the terminals of the source to form a complete circuit. The emf of the source is 12V having an internal resistance of 2Ω. Calculate voltmeter and ammeter reading.

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

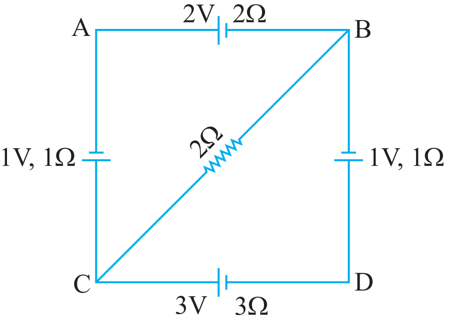


37. In the circuit shown, the reading of voltmeter is 20V. Calculate resistance of voltmeter. What will be the reading of voltmeter if this is put across 200Ω resistance ?

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

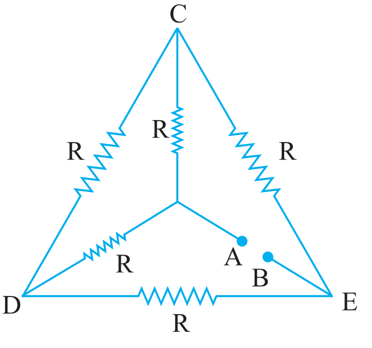


38. For the circuit given below, find the potential difference b/w points B and D. **Ans.** 1.46 Volts

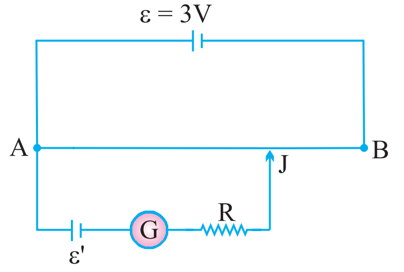


39. (i) Calculate Equivalent Resistance of the given electrical network *b/w* points A and B.

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



40. 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 80 cm. :



(i) Calculate unknown emf of ε′ the cell.

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

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

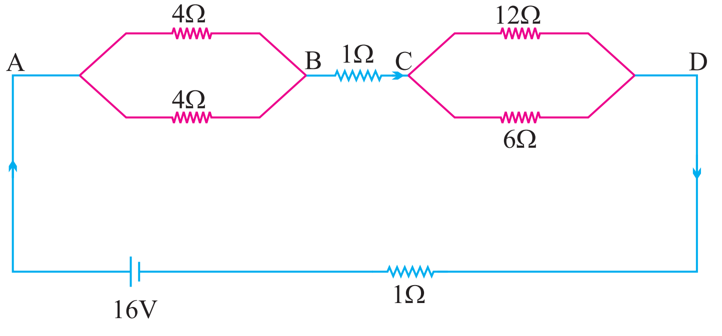
41. A battery of emf 10V and internal resistance 3Ω is connected to a resistor. If the current in the circuit is 0.5A, what is the resistance of the resistor ? What is the terminal voltage of the battery when the circuit is closed ?

42. A network of resistance is connected to a 16V battery with internal resistance of 1Ω as shown in Fig. on next page.

(i) Compute the equivalent resistance of the network.

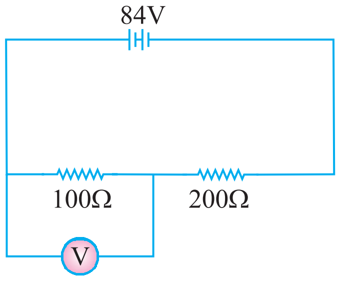
(ii) Obtain the current in each resistor.

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

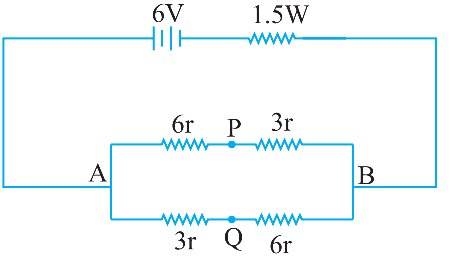


43. The number density of conduction electrons in a Copper Conductor estimated to be 8.5×10^{28} m^{-3}. How long does an electron take to drift from one end of a wire 3.0 m long to its other end ? The area of cross section of the wire is 2.0×10^{-6} m^2 and it is carrying a current of 3.0 A.

44. 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.



45. Find magnitude of current supplied by battery. Also find potential difference between points P and Q in the given fig. **Ans.** 1A, 1.5V

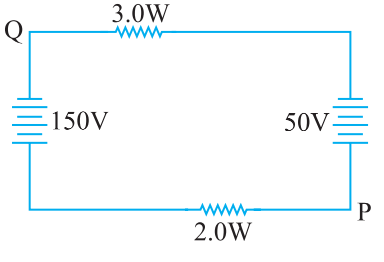


46. A copper wire of length 3 m and radius r is nickel plated till its radius becomes $2r$. What would be the effective resistance of the wire, if specific resistance of copper and nickel are ρ_c and ρ_n respectively.

[Hint : $P_c = P_e \frac{I}{\pi r^2}$; $R_n = In \frac{I}{\pi(2r)^2 - \pi r^2}$

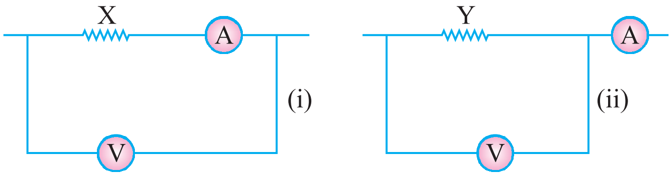
$R = \frac{R_C R_n}{R_C + R_n}$. $\left[\textbf{Ans.}\ R = \frac{3\rho_n \rho_c}{\pi r^2 (3\rho_c + \rho_n)}\right]$

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



Ans. – 10V

48. 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 ?

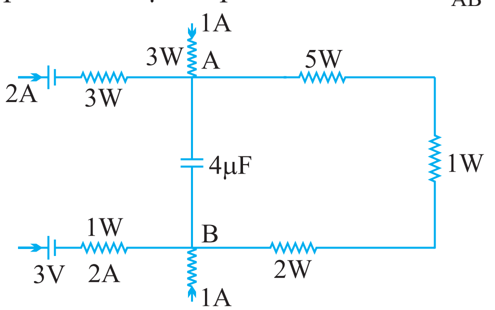


Ans. Small resistance : X will be preferred; large resistance : Y will be preferred

49. 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 = 1.5 V, I = 1.5A

50. 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.** $V_{AB} = 20V$, $U = 8 \times 10^{-4}$ J

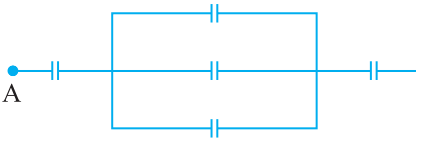


51. With two resistance wires in two gaps of a meter bridge, balance point was found to be 1/3m from zero end, when a 6Ω coil is connected in series with smaller of two resistances the balance point shifted to 2/3m from the same end. Find resistances of two wires. **Ans.** 2Ω, 4Ω

52. 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%

HINTS FOR 2 MARKS QUESTIONS

10.
14. $\frac{t_e}{e_p} = \sqrt{\frac{2s\,m_e}{eE}} \Big/ \sqrt{\frac{2s\,m_p}{eE}} = \sqrt{\frac{m_e}{m_p}}$



$$\frac{1}{Cs} = \frac{1}{2} + \frac{1}{6} + \frac{1}{2} = \frac{1}{6}$$

$$Cs = \frac{6}{7}\text{ecf}$$

21. $\varphi = \overline{E}.\overline{ds} = 2x\,\hat{i}.ds\,\hat{i} = 2x.ds$

$\varphi_1 = 0,\ \varphi_2 = 50$ Vm, $\varphi_3 = 150$ Vm

28. $W_{BA} = 90\,(V_B - V_A) = 2 \times 1000 = 2000$ J

40. $\frac{R_1}{R_2} = \frac{l I_1}{A_1} \times \frac{A_2}{l I_2} \Rightarrow \frac{I_1 A_2}{A_1 I_2} \Rightarrow \frac{1}{2}, \frac{I_1}{I_2} = \frac{1}{2} \therefore \frac{A_2}{A_1} = 1$

(i) in series neA, $(V_d) = neA_2(V_d)_2 \Rightarrow \frac{(V_d)_1}{(V_d)_2} = 1$

(ii) $i_1 R_1 = i_2 R_2 \Rightarrow \frac{(V_d)_1}{(V_d)_2} = \frac{2}{1}$

43. Current through 5Ω $= \left(\frac{10}{5+10}\right) I = \frac{2I}{3}$

64. Sensitivity of Wheatstone Bridge is maximum when resistance of all its four arms are nearly of same order, so the accuracy of result of the experiment will be highest, if balance point is in the middle of wire.

32. 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 emf radiations.

35. 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 $\frac{q}{2\varepsilon_0}$. Therefore the flux through one cube will be equal to $\frac{q}{2\varepsilon_0}$.

36. Work done = $fd \cos\theta = qEd\cos\theta = \frac{q(\sigma_1 - \sigma_2)}{\varepsilon_0}\frac{a}{\sqrt{2}}$

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

$$= \frac{ev}{2\pi r}$$

$$= \frac{ee^2me^2}{n2\pi n^2} = \frac{me^5}{2\pi n^3}$$

62. 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

$$-V_C - V + 2V - 1\,(2R) = 0$$

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

51. If e.m.f. decreases $\Rightarrow \frac{V}{l}$ decreases $\Rightarrow$ position of zero deflection increases.

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

54. 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 $\Rightarrow$ Resistance increases.

55. Temperature, Material Blue, Red, Orange, Gold

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

57.
$$V = E + ir$$
$$= 2 + 0.15$$
$$= 2.15V$$

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

59. A potentiometer is said to be sensitive if :

(i) It can measure very small potential differences.

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

HINTS FOR NUMERICALS

9.
$$V = E_o\left(\frac{d}{4}\right) + \frac{E_o}{K}\left(\frac{3d}{4}\right) = E_o\, d\left(\frac{K+3}{4K}\right)$$

$$V = V_o\left(\frac{K+3}{4K}\right)$$

$$C = \frac{Q_o}{V} = \frac{4K}{K+3}\frac{Q_o}{V_o} = \frac{4K}{K+3}Co$$

14.
$$r = 1 \text{ mm}$$

$$\frac{4}{3}\pi R^3 = 8\cdot\frac{4}{3}\pi r^3 \Rightarrow R = 2 \text{ mm}$$

$$Q = 8q = 8 \times 10 \times 10^{-10} \text{ C}$$

$$V = \frac{1}{4\pi\varepsilon_0}\frac{Q}{R}$$

$$= \frac{9 \times 10^9 \times 8 \times 10^{-9}}{2 \times 10^{-3}} = 36000 \text{ Volt}$$

21.
$$C_x = C,\ C_y = KC = 4C$$

$$\frac{C_x C_y}{C_x + C_y} = \frac{4}{5}C = 4 \Rightarrow C = 5\mu f$$

(a)
$$Ceq = C_x = 5\mu f$$
$$C_y = 20\mu f$$

(b)
$$V + \frac{V}{4} = 12 \ (V_x = V,\ V_y = \frac{V}{4} \text{ as } q \text{ constant})$$

$$V = 9.6 \text{ Volt},\ V_x = 9.6 \text{ Volt},\ V_y = 2.4 \text{ Volt}$$

(c) $$\frac{U_x}{U_y} = \frac{\frac{1}{2}C_x V_x{}^2}{\frac{1}{2}C_y (V_y)^2} = 4$$

31. $$\frac{X}{8} = \frac{l}{100 - l} \qquad ...(1)$$

$$\frac{1}{R_p} = \frac{1}{8} + \frac{1}{8} = \frac{1}{4} \Rightarrow R_p = 4,$$

$$\frac{X}{4} = \frac{1 + 15}{100 - (1 + 15)} \qquad ...(2)$$

$\Rightarrow$ u sing (1) & (2)

$$l^2 - 85l + 1500 = 0$$

$$l = 25 \text{ cm or } l = 60 \text{ cm}$$

At $l = 60$ cm using (1) $X = \frac{8}{3}\Omega$

$l = 60$ cm using (1) $X = 12\Omega$.

32. $$i_x = \frac{E}{x + 0.5}, i_R = \frac{E}{10 + 0.5} = \frac{E}{10.5}$$

$$\frac{V_R}{V_x} = \frac{160}{134.4} = \frac{i_R.R}{i_x x} = \frac{10}{10.5}\frac{(x + 0.5)}{x} \Rightarrow x = 2\ \Omega.$$

HINTS FOR 3 MARKS QUESTIONS

16. 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′ = QE/2

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

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

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

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

Charge transferred equal to

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

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

28. $$R_1 = \frac{V_1}{I_1} = \frac{50}{2\times10^{-3}} = 25{,}000\Omega$$

$$R_2 = \frac{V_2}{I_2} = \frac{60}{3\times10^{-3}} = 20{,}000\Omega.$$

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

29. Rate of production of heat, $P = I^2R$, for given l, $P \times R$, $\therefore$ $\rho_{nichrome} > \rho_{cu}$ $\therefore R_{Nichrome} > R_{cu}$ of same length and area of cross section.

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

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

NUMERICALS

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

$$= k\,4\pi a\sigma - k4\pi b\sigma + k4\pi c\sigma$$

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

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

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

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

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

When $V_A = V_C$

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

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

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

$$c=a+b$$

19. $$Q=CV$$

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 $V_B = 0$, $V_A = 10V$ and $V_C = -2V$.

21. 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

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

$$E'_B=\frac{Q^2}{2C}=\frac{(CV)^2}{2\times 3C}$$

$$=\frac{1}{3}\left(\frac{1}{2}CV^2\right),$$

$$E'=E'_A+E'_B$$

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

33. Pot. gradient $k=\frac{5}{5}=1Vm^{-1}$

$$l_1=350 \text{ cm}=3.5 \text{ m}$$

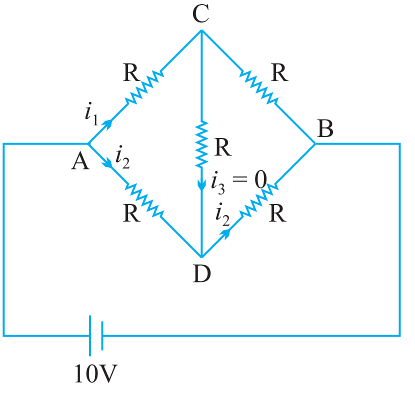
$$E_1+E_2=kl_1=3.5 \qquad ...(1)$$

$$E_1 - E_2 = 0.5 \quad ...(2)$$

$$E_1 = 2V, E_2 = 1.5 \text{ Volt}$$

39. $$R_{AB} = 2\Omega$$

$$I_{CD} = 0, I_{ACB} = \frac{V}{2R} = \frac{10}{2 \times 2} = 2.5A$$



40. (i) $\frac{E_2}{E_1} = \frac{I_2}{I_1} \Rightarrow E_2 = \frac{I_2}{I_1} E_1 = \frac{80}{60} \times 1.5 = 2.0V$

(ii) The circuit will not work if emf of driven cell is IV,/total Voltage across AB is 1 V, 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.

41. $$E = I(R + r)$$

$$10 = 0.5(R + 3)$$

$$R = 17\Omega$$

$$V = E - Ir = 10 - 0.5 \times 3 = 8.5V$$

42. $$Req = 7W$$

$$I_{4\Omega} = 1A, I_{1\Omega} = 2A, I_{12\Omega} = \frac{2}{3}A, I_{6\Omega} = \frac{4}{3}A,$$

$$V_{AB} = 4V, V_{BC} = 2V, V_{CD} = 8V$$

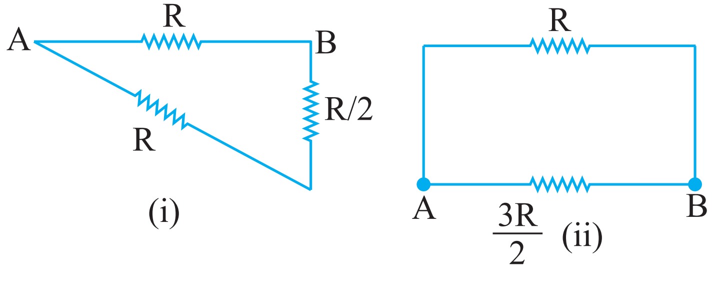
43. $$I = enAV_d = \frac{l}{t}$$

$$t = \frac{en\,Al}{1} = 2.7 \times 10^4 \text{ s}$$

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

P.d. across voltmeter & 100Ω combination

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



When, $I << r$,

45. $$R_{AB} = 4.5\Omega$$

$$i = \frac{E}{R_{AB} + 1.5} = \frac{6}{6} = 1A.$$

$$i_{AP} = i_{AQ} = 0.5A, V_{AP} = 3 \Rightarrow V_p = 3 \text{ Volt}$$

$$V_{AQ} = 1.5\ V_Q = 4.5 \text{ Volt}$$

$$V_Q - V_P = 1.5 \text{ Volt}$$

51. For two resistor P and Q

$$\frac{P}{Q} = \frac{I}{100 - I} = \frac{\frac{1}{3}}{1 - \frac{1}{3}} = \frac{1}{2} \qquad ...(i)$$

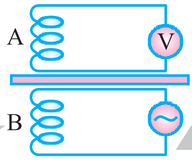
$$Q = 2P, P < Q$$

Now, $P' = P + 6$, $I' = 2/3$

$$\frac{P^1}{Q} = \frac{I'}{(100 - I')} = \frac{\frac{2}{3}}{\frac{1}{3}} = \frac{2}{1}$$

$$\frac{P + 6}{Q} = \frac{2}{1} \qquad ...(ii)$$

On solving (i) & (ii), $P = 2\Omega$, $Q = 4\Omega$.



Unit III and IV

Section - 2

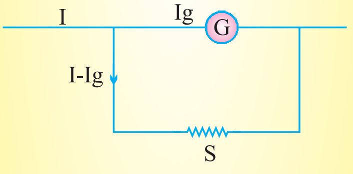
KEY POINTS

Physical Quantity	Formulae	SI Unit
Biot-Savart's Law	$d\vec{B} = \frac{\mu_0}{4\pi}\frac{Id\vec{l}\times\vec{r}}{r^3}$ $\lvert d\vec{B}\rvert = \frac{\mu_0}{4\pi}\frac{Idl\sin\theta}{r^2}$	Tesla (T); 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	$B = \frac{\mu_0 I}{2a}$ $B = \frac{\mu_0 nI}{2a}$ (For n loops)	T
Magnetic Field at a Point on the Axis of a current carrying loop	$B = \frac{\mu_0 I}{4\pi}\frac{2\pi a^2}{\left(a^2+x^2\right)^{\frac{3}{2}}}$ When, $x = 0$, $B = \frac{\mu_0 I}{2a}$ For $a << x$, $B = \frac{\mu_0 I a^2}{2x^3}$ For n loops, $B = \frac{\mu_0 n I a}{2x^3}$	T
Ampere's Circuital Law	$\oint \vec{B}.d\vec{l} = \mu_0 I$	$T - m$

Magnetic field due to a long straight solenoid	$B = \mu_0 n I$ At the end of solenoid, $B = \frac{1}{2}\mu_0 n I$ If solenoid is filled with material having magnetic permeability μr $B = \mu_0 \mu_r nI$	T
Magnetic field due to a toroidal solenoid	$B = \mu_0 nI$	T
Motion of a charged particle inside electric field	$y = \frac{qE}{2m}\left(\frac{x}{v_x}\right)^2$	m
Megnetic force on a moving charge	$\vec{F} = q\left(\overline{v} \times \vec{B}\right)$ Or $F = qv\,B\sin\theta$	N
Lorentz Force (Electric and Magnetic)	$\vec{F} = q\vec{E} + q\left(\overline{v} \times \vec{B}\right)$	N
The Cyclotron		
Radius of circular path	$r = \frac{mv}{Bq}$	
The period of circular motion	$T = \frac{2\pi m}{Bq}$	
The cyclotron frequency	$v = \frac{1}{T} = \frac{Bq}{2\pi m}$	
Maximum energy of the positive ions	$\frac{1}{2}mv_{max}^2 = \frac{B^2q^2r^2}{2m} = qV = qV$	
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 θ	$r = \frac{mv \sin\theta}{qB}$	
Force on a current carrying conductor placed in a magnetic field	$\vec{F} = I\left(\vec{l} \times \vec{B}\right)$	N
Force per unit length betwen two 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	$\vec{\tau} = \vec{M} \times \vec{B}$ $\Rightarrow \tau = MB \sin\alpha$ If coil has n turns, $\tau = n\,B\,I\,A \sin\alpha$ $\alpha \rightarrow$ angle between normal 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	$U = -\vec{M}\cdot\vec{B} = -MB\cos\theta$	
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	$I_s = \frac{\theta}{I} - \frac{nBA}{k} = \frac{1}{G}$	rad A^{-1}
Voltage sensitivity	$V_s = \frac{\theta}{V} = \frac{nBA}{kR} = \frac{1}{GR}$	rad V^{-1}
The current loop as a magnetic dipole on axis at very large distance from the centre	$B = \frac{\mu_0}{4\pi}\frac{2M}{x^3}$ T	
Gyromagnetic ratio	$\frac{\mu_e}{L} = \frac{e}{2m_e} = 8.8 \times 10^{10} \frac{C}{kg}$ → Angular momentum	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	$\vec{M} = m\left(2\vec{l}\right)$	JT^{-1} or Am^2
Magnetic field on axial line of a bar magnet	$B_{axial} = \frac{\mu_0}{4\pi}\left[\frac{2Mr}{(r^2 - l^2)^2}\right]$ When, $l << r$, $B_{eq} = \frac{\mu_0}{4\pi}\frac{M}{r^3}$	T
Gauss's Law in magnetism	$\oint_S \vec{B}.d\vec{S} = 0$	Tm^2 or weber
Magnetic inclination (or Dip)	$\tan\delta = \frac{B_V}{B_H}$, δ→ angle of dip	
Magnetic intensity (or Magnetic field strength)	$H = \frac{B_0}{\mu_0} = nI$ n is the no. of	Am^{-1} terms/length
Intensity of magnetization	$I_m = \frac{M}{V}$	Am^{-1}

Magnetic flux	$\phi = \vec{B}.\Delta\vec{S}$	Weber or Tm^2
Magnetic induction (or Magnetic flux density or Magnetic field)	$B = B_0 + \mu_0 I_m$ $= \mu_0 (H + I_m)$	T
Magnetic susceptibility	$\chi_m = \frac{I_m}{H}$ —	
Magnetic permeability	$\mu = \frac{B}{H}$ TmA^{-1} (or NA^{-2})	
Relative permeability (μ)	$\frac{\mu}{\mu_0} = \mu_r = (1 + \chi_m)$	
Curie's Law	$\chi_m = \frac{C}{T}$, C → curie constant	
Conversion of a Galvanometer into Ammeter 	$IgG = (I - Ig)S$ $Ig(G+S) = SI$ $Ig = \left(\frac{S}{G+S}\right)I$ S → shunt resistance	
Conversion of a Galvanometer into voltmeter  $R = \frac{V}{Ig} - G$	G → Galvanometer resistance	

UNIT–III & UNIT–IV

MAGNETIC EFFECTS OF CURRENT AND MAGNETISM & E.M.I. AND ALTERNATING CURRENT

QUESTIONS

VERY SHORT ANSWER QUESTIONS (1 Mark)

1. Must every magnetic field configuration have a north pole and a south pole? What about the field due to a toroid?

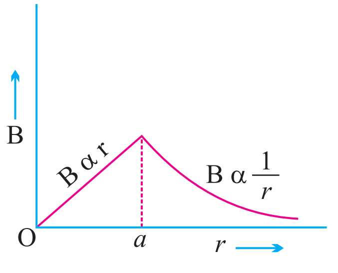
Ans. No, pole exists only when the source has some net magnetic moment. There is no pole in toroid. Magnetic field due to a toroid $B = \mu_0 nI$

2. How are the figure of merit and current sensitivity of galvanometer related with each other ?

Ans. Reciprocal.

3. Show graphically the variation of magnetic field due to a straight conductor of uniform cross-section or radius '*a*' and carrying steady currently as a function of distance *r* (*a* > *r*) from the axis of the conductor.

Ans.



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?

Ans. $F = \dfrac{\mu_w I_1 I_2}{2\pi r}$

$$F = \frac{\mu_0 (3I_1)(3I_2)}{2\pi r} = 9 \text{ times}$$

5. How does the angle of dip vary from equator to poles?

Ans. 0º to 90º

6. What is the effect on the current measuring range of a galvanometer when it is shunted?

Ans. Increased.

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.

Ans.

(i) Going into the plane of the paper.

(ii) Going out of the plane of paper.

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

Ans. By using a ferromagnetic case. Put an iron ring in the magnetic field inside the ring field will be zero.

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

Ans. To increase magnetic flux linked and sensitivity.

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

Ans. At equator.

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

Ans. 1%.

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

Ans. (i) Am

(ii) Am^2

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) ?

Ans. 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 at 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 do you understand by figure of merit ?

Ans. Figure of merit is defined as the current required per division of deflection derivation

$$K = \frac{I}{\theta}, \text{ SI unit A/div}$$

in observation for half deflection method

$$i_g = K\theta, \; i_g = \frac{E}{R+G}$$

$$k = \frac{1}{\theta}\left[\frac{E}{R+G}\right]$$

It enables us to find current required for full scale deflection.

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. Does a charge Particle gain K.E. when passed through magnetic field region? Justify.

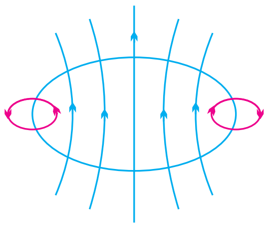
Ans. No, as the magnetic force acting on the charge particle is always perpendicular to the velocity, hence

$$\frac{d\omega}{dt} = \vec{f}\cdot\vec{v} = f\,v\cos 90° = 0$$

∴ there is no gain in KE of particle.

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

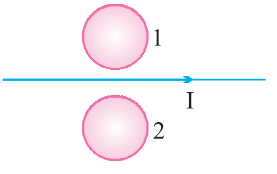
Ans.



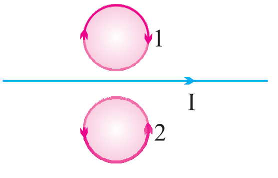
21. Why core of a transformer is laminated ?

Ans. To reduce loss due to eddy currents.

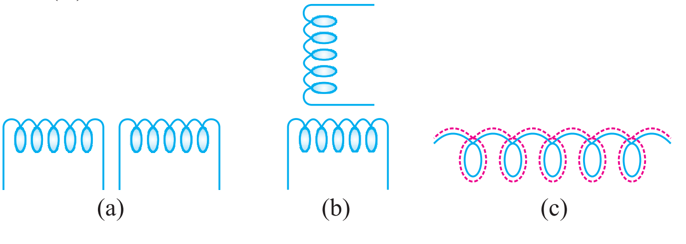
22. What is the direction of induced currents in metal rings 1 and 2 seen from the top when current I in the wire is increasing steadily ?



Ans.



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



Ans. (i) b (ii) c

24. 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?

Ans. (i) $\frac{\pi}{2}$ (ii) π

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

Ans. In steady current no induction phenomenon will take place.

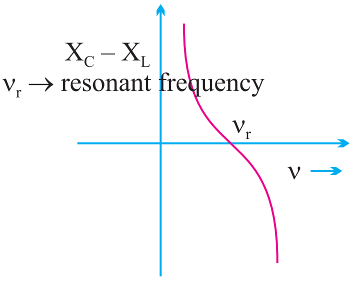
26. In an a.c. circuit, instantaneous voltage and current are V = 200 sin 300 *t* volt and *i* = 8 cos 300*t* ampere respectively. What is the average power dissipated in the circuit?

Ans. As the phase difference between current and voltage is $\frac{\pi}{2}$.

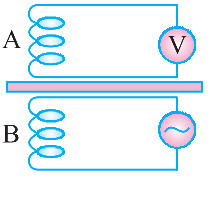
$\therefore\ P_{av} = I_{vEv} \cos \frac{\pi}{2} = 0$

27. Sketch a graph that shows change in reactance with frequency of a series LCR circuit. (x) (ν)

Ans.



28. A coil A is connected to an A.C. ammeter and another coil B to A source of alternaing e.m.f. How will the reading of ammeter change if a copper plate is introduced between the coils as shown.



Ans. Reading of ammeter will decrease due to eddy currents.

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

Ans. $i = 12 \sin \left(314t + \frac{\pi}{2}\right)$

i.e. Current is ahead the voltage by a phase difference of $\frac{\pi}{2}$. Hence circuit is a capacitive circuit.

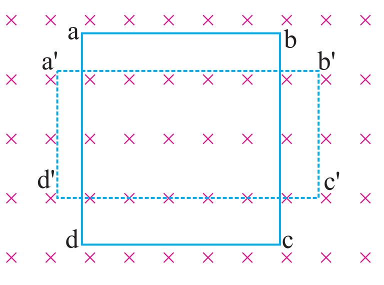
30. In a series L–C–R circuit $V_L = V_C \neq V_R$. What is the value of power factor?

Ans. At Resonance cos ϕ = 1.

31. 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?

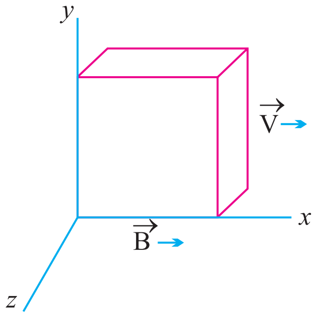
Ans. $U_L \propto I^2 \Rightarrow U' = \frac{U}{4}$

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



Ans. Clockwise.

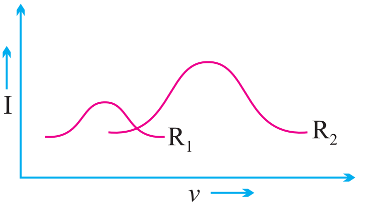
33. Twelve wires of equal lengths are connected in the form of a skeleton of a cube, which is moving with a velocity $\vec{V}$ in the direction of magnetic field $\vec{B}$. Find the emf in each arm of the cube.



Ans. emf in each branch will be zero since V & B are parallel for all arms.

$$\therefore \vec{F} = q\left(\vec{V} \times \vec{B}\right) = 0$$

34. Current versus frequency (I – v) 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?



Ans. $R_1 > R_2$ as I is smaller in larger resistance.

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

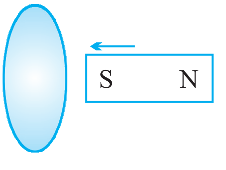
Ans. Corrosion free and small expansion on heating maintains proper contact.

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

Ans. $X_C = \infty$ for dc $\upsilon = 0$ $X_C = \dfrac{1}{\omega_c} = \dfrac{1}{2\pi\upsilon c} = \infty$

$$X_L = 0 \quad \& \quad X_L = \omega L = 2\pi\upsilon L = 0$$

37. 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.

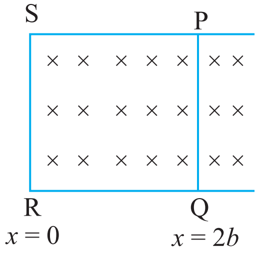


Ans. If observer is situated at the side from which bar magnet enters the loop. The direction of current is clockwise when magnet moves towards the loop and direction of current is anticlockwise when magnet moves away from the loop.

38. In figure, the arm PQ is moved from $x = 0$ 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.

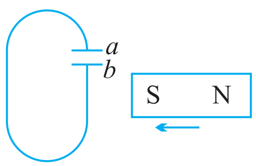


39. A wire moves with some speed perpendicular to a magnetic field. Why is emf induced across the rod?

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

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

Ans. Plate *a* will be positive with respect to '*b*'. When the observer is looking from the side of moving bar magnet.



41. A circular coil rotates about its vertical diameter in a uniform horizontal magnetic field. What is the average emf induced in the coil?

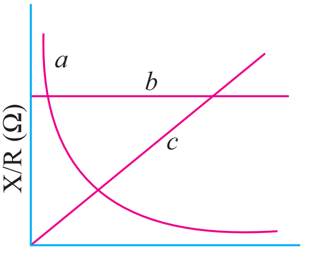
Ans. Zero

42. Define RMS Value of Current.

Ans. RMS value of ac is defined as that value of direct current which produces the same heating effect in a given resistor as is produced by the given alternating current when passed for the same time.

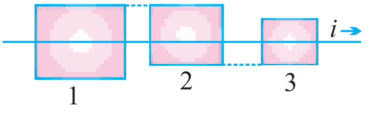
$$I_{rms} = \frac{I_0}{\sqrt{2}} = 0.707\ I_0$$

43. In given figure three curves *a, b* and *c* shows variation of resistance, (R) capacitive reactance (x_c) and inductive (x_L) reactance with frequency. Identify the respective curves for these.



Frequency in Hz

44. A long straight wire with current *i* passes (without touching) three square wire loops with edge lengths 2L, 1.5L and L. The loops are widely spaced (so as do 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.



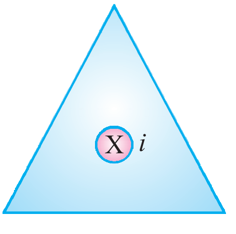
Ans. (a) No induced current

(b) Current will be induced only in loop 2.

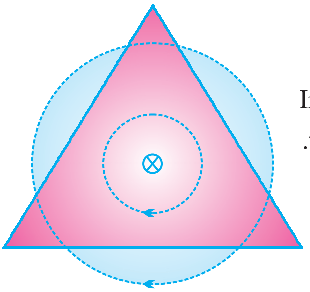
45. In an L–C circuit, current is oscillating with frequency 4×10^6 Hz. What is the frequency with which magnetic energy is oscillating?

Ans. $\upsilon_m = 2\upsilon = 8 \times 10^6$ Hz.

46. A current carrying wire (straight) passes inside a triangular coil as shown in figure. The current in the wire is perpendicular to paper inwards. Find the direction of induced current in the loop if current in the wire is increasing with time.



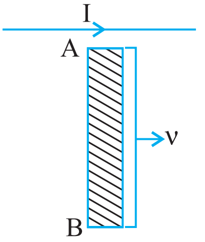
Ans. Magnetic field line are tangential to the triangular plane $\theta = 90°$ so $\phi = 0$



Induced emf = 0

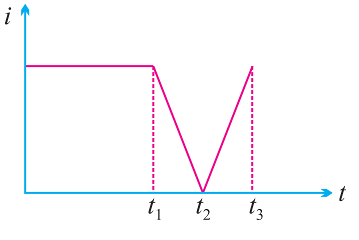
$\therefore$ Induced current = 0

47. Wire carrying a study current and rod AB are in the same plane the rod move parallel to wire with velocity v then which end of the rod is at higher potential.



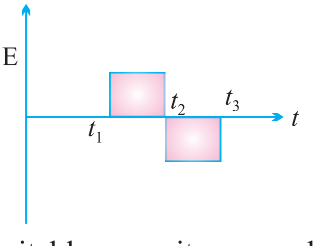
Ans. End A will be at higher potential.

48. The current i in an induction coil varies with time t according to the graph



Draw the graph of induced e.m.f. with time.

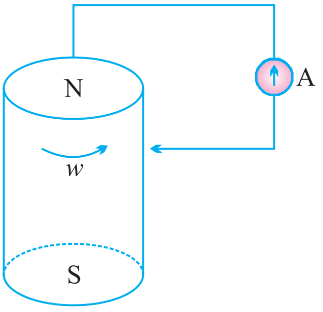
Ans.



49. Can a capacitor of suitable capacitance replace an inductor in an AC circuit?

Ans. Yes, because average power consumed in both is least while controlling an AC.

50. In the given figure,

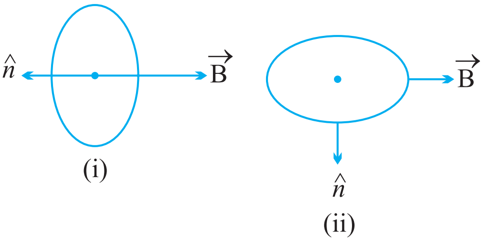


a cylinderical bar magnet is rotated about its axis. A wire is connected from the axis and is made to touch the cylinderical surface through a contact. Then, current in the Ammeter is.....

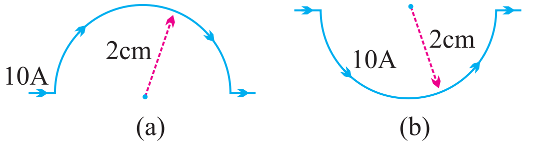
Ans. When cylinderical bar magnet is rotated about its axis, no change in magnetic flux linked with the circuit take place hence no e.m.f. is induced hence no current flows through the ammeter (A)

SHORT ANSWERS QUESTIONS (2 MARKS)

1. Write the four measures that can be taken to increase the sensitivity of 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 2 cm 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) ?



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. Why does the susceptibility of dimagnetic substance independent of temperature ?

Ans. As there is no permanent dipoles in dimagnetic substance, so, there is no meaning of randomness of dipoles on increasing temp.

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

Ans. Low retentivity, low coercivity

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.

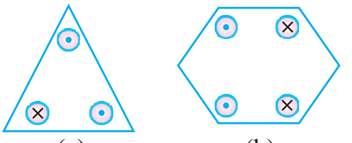
12. A coil of N turns and radius R carries a current I. It is unwound and rewound to make another coil of radius R/2, current remaining the same. Calculate the ratio of the magnetic moment of the new coil and original coil.

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 in terms of G?

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

16. Each of conductors shown in figure carries 2A of current into or out of page. Two paths are indicated for the line integral $\oint \vec{B}.d\vec{l}$. 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 9×10^{-31} kg and charge 1.6×10^{-19} C) moving at a speed of 3×10^7 m/s in a magnetic field of 6×10^{-4} T perpendicular to it? What is its frequency? Calculate its energy in keV. (1 eV = 1.6×10^{-19} J).

Ans. Radius, $r = mv/(qB)$

$= 9.1 \times 10^{-31}$ kg $\times 3 \times 10^7$ ms^{-1}/(1.6×10^{-19} C $\times 6 \times 10^{-4}$ T) = 20 cm

$\nu = v/(2\pi r) = 1.7 \times 10^7$ Hz

$E = (1/2)mv^2 = (1/2)\ 9 \times 10^{-31}$ 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. Why is it necessary for voltmeter to have a higher resistance?

Ans. Since voltmeter is to be connected across two points in parallel, if it has low resistance, a part of current will pass through it which will decrease actual potential difference to be measured.

19. Can d.c. ammeter use for measurement of alternating current?

Ans. No, it is based on the principle of torque. When ac is passing through it (of freq. 50 Hz). It will not respond to frequent change in direction due to inertia hence would show zero deflection.

20. Define the term magnetic dipole moment of a current loop. Write the expression for the magnetic moment when an electron revolves 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

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

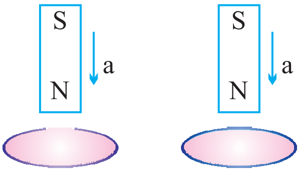
21. An ac source of rms voltage V is put across a series combination of an inductor L, capacitor C and a resistor R. If V_L, V_C and V_R are the rms voltage across L, C and R respectively then why is $V \neq V_L + V_C + V_R$? Write correct relation among V_L, V_C and V_R.

Ans. Hint :

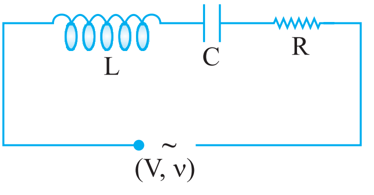
V_L, V_C and V_R are not in the same phase

$V_L + V_C + V_R > V$

22. 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?



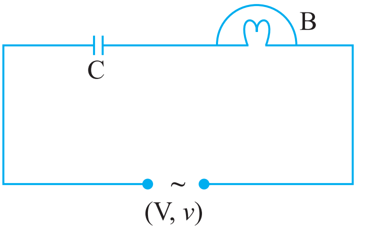
23. The series L–C–R circuit shown in fig. is in resonance state. What is the voltage across the inductor?



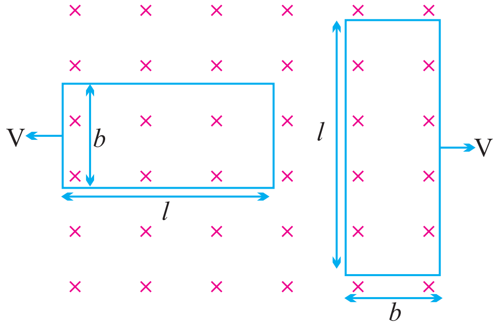
Ans. [Hint $V_L = I\,X_L$ where $I = \frac{V}{R}$]

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

25. Circuit shown here uses an air filled 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.



26. 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.



27. An electron moving through magnetic field does not experience mgnetic force, under what conditions is this possible ?

Ans. when electron moving parallel to magnetic field.

28. 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.

29. 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?

30. A galvanometer needs 50mV for full scale deflection of 50 Divisions. Find it voltage sensitivity. What must be its resistance if its current sensitivity is 1 Div/A.

Ans. $V_s = \frac{\theta}{V} = \frac{50\text{Div}}{50\text{mv}} = 10^3 \text{ div}/\, v$ $\qquad I_s \rightarrow$ Current sensitivity

$R_g = \frac{I_S}{V_S} = 10^{-3}\text{w}$ $\qquad V_S \rightarrow$ Voltage sensitivity

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

32. An electric bulb is connected in series with an inductor and an AC source. When switch is closed. 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.

33. 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 : $U = \frac{1}{2}LI^2 + \frac{1}{2}\frac{q^2}{c}$

34. 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 $= IX_C$

$\Rightarrow \quad V = IX_L - IX_C$

at resonance $X_L = X_C$

$\Rightarrow \quad V = O.$

34. When a large amount of current is passing through solenoid, it contract, explain why ?

Ans. Current in two consecutive turns being in same direction make them to form unlike poles together hence, they attract each other.

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

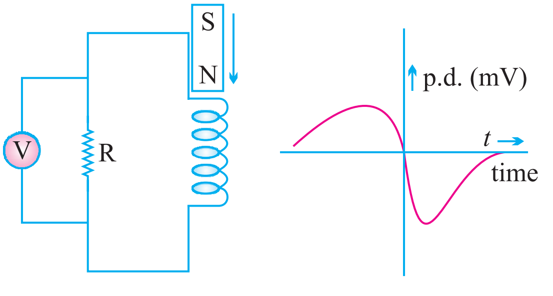
$\therefore \quad P = VI \cos\theta$

$$I = \frac{P}{V\cos\theta}$$

If $\cos\phi$ is low I will be high $\Rightarrow$ Large power loss.

36. 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.

37. 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 ?

Ans. (i) When the bar magnet moves towards the coil magnetic flux passing through the coil increases as velocity of magnet increases in downward direction, e.m.f. induced also increases, due to formation of similar pole repulsive force decreases the rate of increase of flux.

(ii) once the magnet has passed through the coil, flux decreases in downward direction but $\frac{d\phi}{dt}$ increases as self induced e.m.f. in the coil maintains its flux in the same direction. Thus due to the addition of self induced e.m.f. in same direction according to Lenz's law.

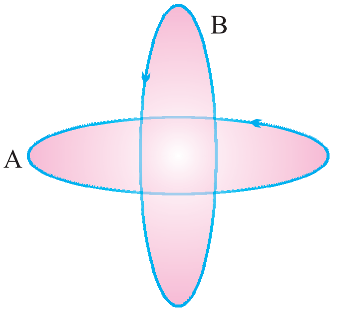
38. What is the significance of Q-factor in a series LCR resonant circuit ?

39. 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?

40. 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,



41. What is a radial magnetic field? Why is it required in a galvanometer ?

Ans. Using concave shaped pole of magnet and placing soft iron cylinderical core, A magnetic field, having field lines along radii is called as radial magnetic field.

To make Torque independent of 'θ' (constant) radial magnetic field is required $\tau = NIAB \sin \theta$

for radial Magnetic Field $\theta = 90°$

$\tau = NIAB$. (independent of θ)

42. The hysterisis loop of material depends not only on the nature of material but also on the history of its magnetization cycles. Suggest a use of this property of material.

Ans. The value of magnetization is record/memory of its cycles of magnetisation. If information bits can be made correspond to these cycles, the system displaying such hysterisis loop can act as a device for storing information's.

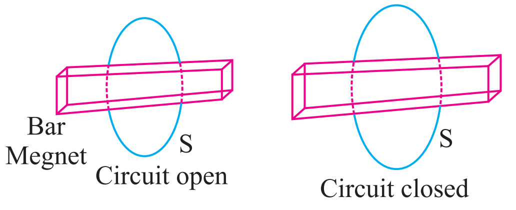
43. A wire in the form of a tightly wound Solenoid is connected to a DC source, and carries a current. If the coil is stretched so that there are gaps between successive elements of the spiral coil, will the current increase or decrease ? Explain ?

Ans. When the coil is stretched so that there are gaps between successive elements of the spiral coil *i.e.* the wires are pulled apart which lead to the flux leak through the gaps. According to Lenz's law, the e.m.f. produced must oppose this decrease, which can be done by an increase in current. So, the current will increase.

44. Show that the induced charge does not depend upon rate of change of flux.

Ans.
$$|E| = N\frac{d\phi}{dt}$$
$$i = \frac{E}{R} = \frac{N}{R}\frac{d\phi}{dt}$$
$$\frac{dq}{dt} = \frac{N}{R}\frac{d\phi}{dt}$$
$$\therefore \quad dq = \frac{N}{R}d\phi$$

45. Consider a magnet surrounded by a wire with an on/off switch S (figure). If the switch is thrown from the 'off' position (open circuit) to the 'on' position (Closed circuit) will a current flow in the circuit ? Explain.



Ans. ϕ = BA cos θ so flux linked will change only when either B or A or the angle between B and A change.

When switch is thrown from off position to the on position, then neither B nor A nor the angle between A and B change. Thus there is no change in magnetic flux linked with the coil, hence no electromotive force (e.m.f.) is produced and consequently no current will flow in the circuit.

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) Hysterisis (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 θ ($0^\circ < \theta < 90^\circ$).
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 the magnetic moment change when :
   (i) the frequency of revolution is doubled?
   (ii) the orbital radius is halved?
7. State Ampere, circuital law. Use the 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,

$$B = \frac{\mu_0 I}{2a}$$

$$2\pi a' \times n = 2\pi a \Rightarrow a' = a/n$$

The magnetic field at its centre, $B_1 = \frac{\mu_0 n I}{2a/n} = \frac{\mu_0 n^2 I}{2a} = n^2 B$

The ratio is, $B_1/B = n^2$

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

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

16. 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?

Ans. [Hint : $X_L = \omega L$, $X_C = \frac{1}{\omega C}$, R independent]

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

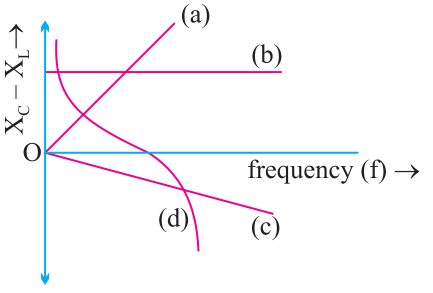
18. In a series L–R circuit, $X_L = R$ and power factor of the circuit is P_1. When capacitor with capacitance C such that $X_L = X_C$ is put in series, the power factor becomes P_2. Find P_1/P_2.

Ans. [Hint $P = \cos\theta = \frac{R}{Z}$]

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

20. 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?

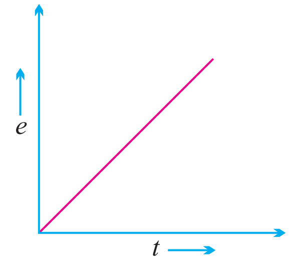
21. Which of the following curves may represent the reactance of a series LC combination.



22. A sinusoidal e.m.f. device operates at amplitude E_0 and frequency ν 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?

23. A conducting rod held horizontally along East-West direction is dropped from rest at certain height near Earth's surface. Why should there be an induced e.m.f. across the ends of the rod? Draw a graph showing the variation of e.m.f. as a function of time from the instant it begins to fall.

Ans. Hint : $e = Blv$ and $v = gt$



24. In an LC circuit, resistance of the circuit is negligible. If time period of oscillation is T then :

(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) $t = 0, T/2, 3T/2, \ldots\ldots$

(ii) $t = T/4, 3T/4, 5T/4 \ldots\ldots$

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

25. An alternating voltage of frequency f is applied across a series LCR circuit. Let f_r 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) $f > f_r$ (ii) $f < f_r$ (iii) $f = f_r$? Explain your answer in each case.

Ans. (i) Current will lag because.

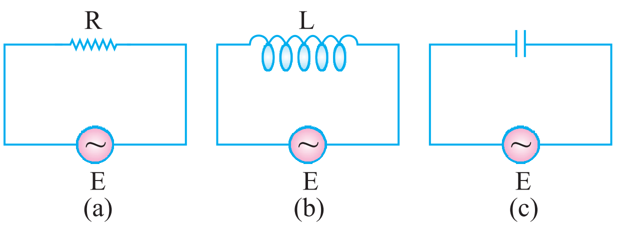
$V_L < V_C$ Hence $V_L - V_C > O$

(ii) Current will lead, because.

$V_L < V_C$ Hence $V_L - V_C < O$

(iii) In phase

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

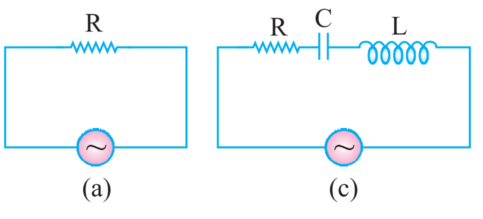


Ans. (i) No effect, R is not affected by frequency.

(ii) Current will decrease as X_L increase.

(iii) Current will increase as X_C decrease.

27. Study the circuit (a) and (b) shown in the figure and answer the following questions.



(a) Under which condition the rms current in the two circuits to be the same?

(b) Can the r.m.s. current in circuit (b) larger than that of in (a) ?

Ans. $I_{rms(a)} = \frac{V_{rms}}{R} = \frac{V}{R}$ $I_{rms(b)} = \frac{V_{rms}}{Z} = \frac{V}{\sqrt{R^2 + (X_L - X_C)^2}}$

(a) $I_{rms(a)} = I_{rms(b)}$

when $X_L = X_c$ (resonance condition)

$$\frac{I_{rms(a)}}{I_{rms(b)}} = \frac{Z}{R} = 1$$

(b) As $z \geq R$

$$I_{rms(a)} \geq I_{rms(b)}$$

No, the rms current in circuit (b), cannot be larger than that in (a).

28. Can the instantaneous power output of an AC source ever be negative ? Can average power output be negative ? Justify your answer.

Ans. Yes, Instantaneous power output of an AC source can be negative.

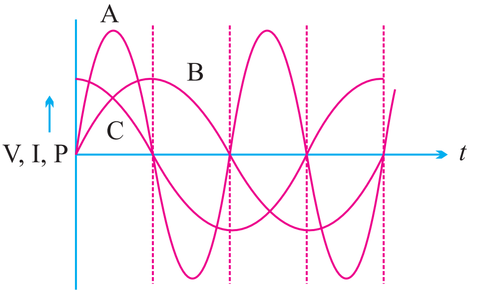
Instantaneous power output $P = EI = \frac{E.I.}{2}[\cos\phi - \cos(2\omega t + \phi)]$

No, $P_{avc} = V_{rms} I_{rms} \cos f$

$P_{avc} > 0$

$$\cos\phi = \frac{R}{Z} > 0$$

29. A device 'X' is connected to an AC source. The variation of voltage, current and power in one complete cycle is shown in fig.



(a) Which curves shows power consumption over a full cycle?

(b) What is the average power consumption over a cycle?

(c) Identify the device X if curve B shows voltage.

Ans. (a) A (a curve of power have a max. Amplitude of V and I)

(b) Zero.

(c) as average power is zero the device is a capacitor.

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 $\sqrt{3a}$.
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 a 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?

5. 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?
6. Explain, with the help of a neat and labelled diagram, the principle, construction and working of a transformer.
7. 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 the 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?

8. 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 $\omega = \frac{1}{\sqrt{LC}}$.

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

2. A charge particle of mass m and charge q entered into magnetic field B normally after accelerating by potential difference V. Calculate radius of its circular path. **[Ans.** $r = \frac{1}{B}\sqrt{\frac{2mv}{q}}$**]**

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 0.12 m from the centre of the coil (ii) at the centre of the coil.
[Ans. (i) 5.0×10^{-3} Tesla; (ii) 8.8×10^{-2} Tesla**]**

4. An electron of kinetic energy 10 keV moves perpendicular to the direction of a uniform magnetic field of 0.8 milli tesla. Calculate the time period of rotation of the electron in the magnetic field.
[Ans. 4.467×10^{-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 circular loop. For the same current passed in both the cases compare the magnetic field induction at their centres.

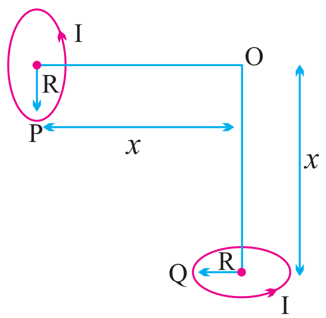
[Ans. Increased 4 times**]**

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 1.5 m below it?

[**Ans.** 1.2×10^{-5} T South ward**]**

8. A galvanometer with a coil of resistance 90Ω shows full scale deflection for a potential difference 25mV. What should be the value of resistance to convert the galvanometer into a voltmeter of range 0V to 5V. How should it be converted? **[Ans.** 1910 Ω 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.



$\tan\theta = \dfrac{B_2}{B_1} = 1,\ \theta = \pi/4.$ [**Ans.** $\dfrac{\mu_0 I R^2\sqrt{2}}{2(R^2+x^2)^{3/2}}$]

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 60 cm ? 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 = 1.6×10^{-13} J].

[Ans. B = 0.656T, E_{max} = 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 torque

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) 4.69×10^{-4} A; (ii) 1.56×10^{-6} A**]**

12. A voltmeter reads 5V 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 ΩV^{-1}? Will you prefer this voltmeter to one that is graded as 2000 ΩV^{-1}? **[Ans.** 7.5×10^4 Ω**]**

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 4 cm at a distance of 40 cm from its mid point? The magnetic moment of the bar magnet is a $0.5Am^2$.

[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?

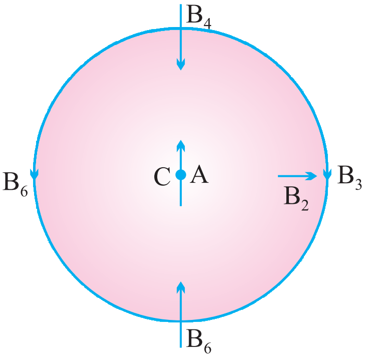
16. Two moving coil galvanometers, M_1 and M_2 have the following specifications.

$R_1 = 10\Omega$, $N_1 = 30$, $A_1 = 3.6 \times 10^{-3}m^2$, $B_1 = 0.25T$

$R_2 = 14\Omega$, $N_2 = 42$, $A_2 = 1.8 \times 10^{-3}m^2$, $B_2 = 0.50T$

Given that the spring constants are the same for the two galvanometers, determine the ratio of (a) current sensitivity (b) voltage sensitivity of M_1 & M_2. **[Ans.** (a) 5/7 (b) 1:1**]**

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.



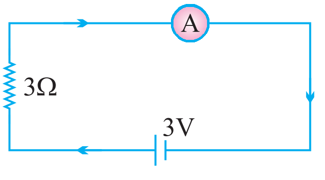
(a) In which configuration is the systems not in equilibrium?

(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 :

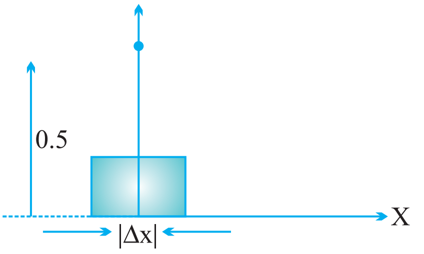


(a) is a galvanometer with a resistance $R_G = 60\ \Omega$,

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

(c) is an ideal ammeter with zero resistance?

19. An element $\Delta I = \Delta x \cdot \hat{i}$ 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 0.5 m. Δx = 1 cm.



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

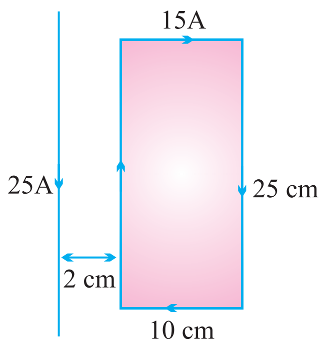
21. A rectangular loop of sides 25 cm and 10 cm carrying current of 15A is placed with its longer side parallel to a long straight conductor 2.0 cm apart carrying a current of 25A. What is the new force on the loop ? **[Ans.** 7.82×10^{-4} N towards the conductor**]**

Hint :

$$F_1 = \frac{\mu_0}{4\pi}\frac{2I_1I_2}{r_1} \times \ell = \frac{10^{-7} \times 2 \times 25 \times 15 \times 0.25}{0.02} = 9{\cdot}38 \times 10^{-4} \text{ N attractive}$$

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

Net $F = F_1 - F_2 = 7.82 \times 10^{-4}$ 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 4.8×10^6 ms^{-1} normal to the field. Explain why the path of electron is a circle.

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

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

Hint : (a) $r = \frac{m_e v}{eB} = \frac{9.1 \times 10^{-31} \times 4.8 \times 10^6}{1.6 \times 10^{-19} \times 6.5 \times 10^{-4}} = 4.2$ cm

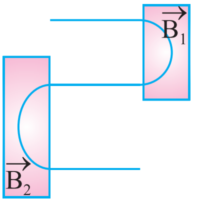
(b) frequency $v = \frac{1}{T} = \frac{eB}{2\pi m_e} = \frac{1.6 \times 10^{-19} \times 6.5 \times 10^{-4}}{2 \times 3.14 \times 9.1 \times 10^{-31}} = 18$ MHz

23. The horizontal and vertical components of earth's magnetic field at a place are 0.22G and 0.38G respectively. Calculate the angle of dip and resultant intensity of earth's field.

Hint : $\tan\delta = \frac{B_V}{B_H} = \frac{0.38}{0.22} = 1.73 = 60°$, $B = \sqrt{B_H^2 + B_V^2} = 0.44$ G

24. 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]



25. 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 ?

26. Magnetic flux linked with each turn of a 25 turns coil is 6 milliweber. The flux is reduced to 1 mWb in 0.5s. Find induced emf in the coil.

27. 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.

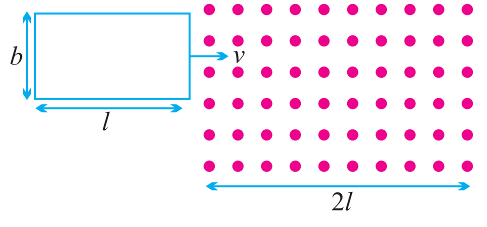
28. A power transmission line feeds input power at 2400 V to a step down ideal transformer having 4000 turns in its primary. What should be number of turns in its secondary to get power output at 240V?

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

30. A capacitor, a resistor and 4 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.

31. 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.

32. 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 versus time

(ii) Induced emf versus times

(iii) Power versus time

Resistance of the loop is R.

33. 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?

34. 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.

35. 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 emf if the field changes with 10^{-3} Tesla/cm along negative *z*-direction.

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

Ans. (i) Rate of change of flux = induced emf

$$= (0.12)^2 \times 10^{-3} \times 8$$

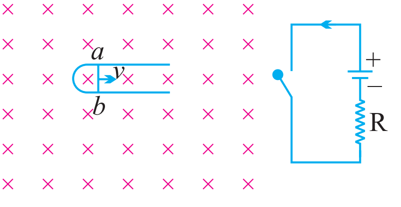
$$= 11.52 \times 10^{-5} \text{ Wb/s in } +z \text{ direction.}$$

(ii) Rate of change of flux = induced emf

$$= (0.12)^2 \times 10^{-3} \times 8$$

$$= 11.52 \times 10^{-5} \text{ Wb/s in } -z \text{ direction.}$$

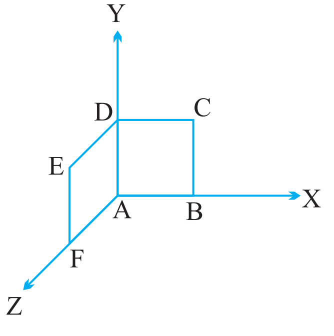
36. Figure shows a wire *ab* of length *l* which can slide on a U-shaped rail of negligible resistance. The resistance of the wire is R. The wire is pulled to the right with a constant speed *v*. Draw an equivalent circuit diagram representing the induced emf by a battery. Find the current in the wire.



$\varepsilon = Bvl$

$I = \varepsilon / r = \dfrac{Bvl}{R}$

37. A loop, made of straight edges has six corners at A(0, 0, 0), B(1, 0, 0), C(1, 1, 0), D(0, 1, 0), E(0, 1, 1) and F(0, 0, 1) a magnetic field $B = B_0\ (\hat{i} + \hat{k})$ T is present in the region. Find the flux passing through the loop ABCDEFA?



Ans. Loop ABCDA lie in *x-y* plane whose area vector $A_1 = L^2\hat{k}$ where ADEFA lie in *y-z* plane where are vector $A_2 = L^2\hat{i}$

$\phi = B.A, \quad A = A_1 + A_2 = (L^2\hat{k} + L^2\hat{i})$

$B = B_0\ (\hat{i}+\hat{k})(L^2\hat{k}+L^2\hat{i}) = 2\ B_0L^2$ Wb.

38. A coil of 0.01 H inductance and 1Ω resistance is connected to 200V, 50 Hz AC supply. Find the impendence and time lag between maximum alternating voltage and current.

Ans. $$Z = \sqrt{R^2 + X_L^2} = \sqrt{R^2 + (2\pi f L)^2} = 3.3\Omega$$

$$\tan\phi = \frac{\omega L}{R} = \frac{2nfL}{R} = 3.14$$

$$\phi \cong 72^o$$

$$\text{Phase diff. } \phi = \frac{72\times\pi}{180}\text{rad.}$$

$$\omega = \frac{\Delta\phi}{\Delta t}, \text{ time lag } \Delta t = \frac{\phi}{\omega}$$

$$= \frac{72\pi}{180\times 2\pi\times 50} = \frac{1}{250}\ \text{s}$$

39. An electrical device draws 2 KW power from AC mains (Voltage = 223V, $V_{rms} = \sqrt{50000V}$). The current differ (lags) in phase by $\phi\left(\tan\phi = \frac{-3}{4}\right)$ as compared to voltage. Find

(a) R

(b) $X_C - X_L$

(c) I_m

Ans. P = 2KW = 2000W ; $\tan\phi = \frac{-3}{4}$; $I_m = I_0$? R = ? $X_C - X_L$ = ?

$$V_{rms} = V = 223V$$

$$Z = \frac{V^2}{P} = 25\Omega$$

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

$$625 = R^2 + (X_L - X_C)^2$$

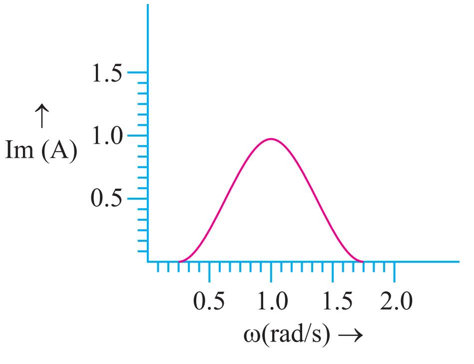
Again $$\tan\phi = \frac{X_L - X_C}{R} = \frac{3}{4}$$

$$X_L - X_C = \frac{3R}{4}$$

using this $R = 20\Omega$; $X_L - X_C = 15\Omega$, $I = \dfrac{V}{Z} = \dfrac{223}{25} = 8{\cdot}92$ A,

$$I_m = \sqrt{2}\ I = 12.6A$$

40. In a LCR circuit, the plot of I_{max} versus ω is shown in figure. Find the bandwith ?



Ans. $I_{rms} = \dfrac{I_{max}}{\sqrt{2}} = \dfrac{1}{\sqrt{2}} = 0.7$ At

from diagram $\omega_1 = 0.8$ rad/s

$\omega_2 = 1.2$ rad/s

$\Delta w = 1.2 - 0.8 = 0.4$ rad/s

41. An inductor of unknown value, a capacitor of 100μF and a resistor of 10Ω are connected in series to a 200V, 50Hz ac source. It is found that the power factor of the circuit is unity. Calculate the inductance of the inductor and the current amplitude.

Ans. $L = 0.10$ H, $I_0 = 28.3A$

42. A 100 turn coil of area 0.1 m^2 rotates at half a revolution per second. It is placed in a magnetic field of 0.01 T perpendicular to the axis of rotation of the coil. Calculate max. e.m.f. generated in the coil.

Ans. ε_0 = 0.314 Volt.

43. The magnetic flux linked with a large circular coil of radius R is 0.5 × 10^{-3} W*b*, when current of 0.5A flows through a small neighbouring coil of radius *r*. Calculate the coefficient of mutual inductance for the given pair of coils.

If the current through the small coil suddenly falls to zero, what would be the effect in the larger coil.

Ans. M = 1*m*H.

If the current through small coil suddenly falls to zero, [as, $e_2 = -M \dfrac{di_1}{dt}$] so initially large current is induced in larger coil, which soon becomes zero.

2 MARKS QUESTIONS

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

3. (i) $-mB$ (ii) zero

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

(ii) B = 5p × 10^{-5} T (inwards).

5. $r_p = \dfrac{mv}{qB}$ and $r_\alpha = \dfrac{4mv}{(2q)B} = 2r_\alpha \Rightarrow \dfrac{r_p}{r_\alpha} = \dfrac{1}{2}.$

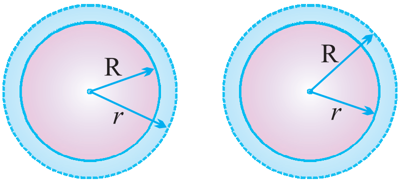
7. Low Retentivity and high permeability.

8. Minimum potential = – MB when θ = 0 (most stable position)

Maximum potential = MB when θ = 180º (most unstable position).

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

(b) Pole strength half; magnetic moment half.



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

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

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

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

11. $M_1 = NI\pi R^2$; $M_2 = NIa^2 \quad \therefore \quad \frac{M_2}{M_1} = \frac{a^2}{R^2}$

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

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

12. $$\frac{m_{new}}{m_{original}} = \frac{2I \times \pi\left(\frac{r}{2}\right)^2}{I \times \pi R^2} = \frac{1}{2} \quad (\text{As } N_2 = 2N_1)$$

13. 2B, $B\sqrt{3}$.

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

(b) zero

22. (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.

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

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

24. A.C. ammeter works on the principle of heating effect H α I^2.

25. Brightness of bulb depends on current. P α I^2 and

$$I = \frac{V}{Z} \text{ where } Z = \sqrt{X_c^2 + R^2} \text{ and}$$

$$X_C = \frac{1}{\omega C} = \frac{1}{2\pi\nu C}$$

$X_C \; \alpha \; \frac{1}{C}$, when mica sheet is introduced capacitance C increases

$\left(C = \frac{K \in_0 A}{d}\right)$,

X_C decreases, current increases and therefore brightness increases.

26. Current I = ε/R

In coil P, $I_1 = E_1/R = \frac{B\nu b}{R}$

In coil Q, $I_2 = E_2/R = \frac{B\nu l}{R}$ $\qquad I_2/I_2 = \frac{b}{l}$.

27. Electro magnetic energy is conserved.

$$\mu_E(\max) = \mu_B(\max)$$

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

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

28. 10^{-6} F.

40. No current is induced in coil A since angle is 90.

ANSWER FOR NUMERICALS

15. Force experienced by current carrying conductor in magnetic field.

$$F = \vec{IL} \times \vec{B} = IBL \sin\theta$$

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

$= 8 \times 0.15 \times 1/2 = 0.6\ Nm^{-1}$

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

Ratio of current Sensitivity $= \left(\frac{N_1B_1A_1}{K}\right) / \left(\frac{N_2B_2A_2}{K}\right)$

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

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

Ratio of voltage sensitivity $= \left(\frac{N_1B_1A_1}{kR_1}\right) / \left(\frac{N_2B_2A_2}{kR_2}\right)$

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

17. (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 0º, *i.e*, U = – MB Example : AB_6.

18. (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 $R = 0.02\Omega + 3\Omega = 3.02\Omega$

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

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

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

$dI = \Delta x = 1 \text{ cm} = 10^{-2}$ m, I = 10A, $r = y = 0.5$ m

$\mu_0/4\pi = 10^{-7}$ Tm/A, $\theta = 90^\circ$ so $\sin\theta = 1$

$$|\overrightarrow{dB}| = \frac{10^{-7} \times 10 \times 10^{-2}}{25 \times 10^{-2}} = 4 \times 10^{-8} \text{ T along + z axis}$$

20. Force experienced by wire $F_m = BIl$ (due to map field)

The force due to gravity, $F_g = mg$

$$mg = BIl \Rightarrow B = mg/Il = \frac{0.2 \times 9.8}{2 \times 1.5} = 0.657 \text{ T}$$

[Earth's mag. field 4×10^{-5} T is negligible]

25. (i) $V_0 = 110$ volt

(ii) $V_{av1/2} = \dfrac{2V_0}{\pi} = \dfrac{2 \times 110 \times 7}{22} = 70$ volt.

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

27. (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.

28. In ideal transformer $P_{in} = P_0$

$$V_P I_P = V_S I_S$$

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

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

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

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

where $\phi = 5t^2 - 4t + 2$ and $R = 8\Omega$

$\therefore$ $I = -\frac{.146}{8} A = -.018A$

30. When V and I in phase

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

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

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

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

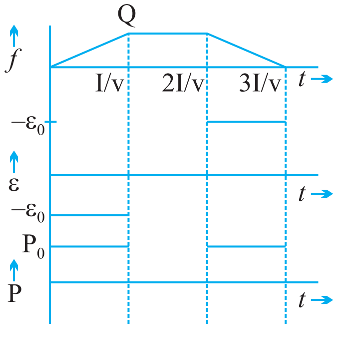
When $Z = \sqrt{X_C^2 + R^2}$, $X_C = \frac{1}{\omega C} = \frac{1}{2\pi\nu C}$

Then total voltage across capacitor and resistor.

$V_C = iX_C$, $V_R = IR$.

(ii) $\tan\phi = \frac{X_C}{R}$ [V lags current]

32.



(i) $\phi = Blb$

(ii) $\varepsilon_0 = B\nu b$

(iii) $P_0 = \frac{\varepsilon_0^2}{R}$

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

33. (i) Frequency of current oscillations

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

(ii) Frequency of electrical energy oscillation $v_c = 2v$

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

(iv) Magnetic energy in the inductor when charge on capacitor is 4*m*C.

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

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

34. Current in the circuit :

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

(ii) RMS voltage across L and R

$$V_L = I \cdot X_L; \qquad V_R = IR$$

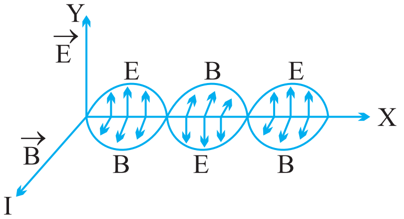
(iii) $(V_L + V_R) > V$ because V_L and V_R are not in same phase.

❑❑

Unit V & VI
ELECTROMAGNETIC WAVES AND OPTICS

KEY POINTS

1. EM waves are produced by accelerated (only by the change in speed) charged particles.
2. $\vec{E}$ and $\vec{B}$ vectors oscillate with the frequency of oscillating charged particles.
3. Propagation of wave along *x*-direction.



4. Properties of em waves :
   (i) Transverse nature
   (ii) Can travel though vacuum.
   (iii) $\frac{E_0}{B_0} = \frac{E}{B} = \lambda v = C$ C → Speed of EM waves.
   (iv) Speed of em wave C = 3 × 10^8 m/s in vacuum and

$$C = \frac{1}{\sqrt{\mu_0 \varepsilon_0}} = 3 \times 10^8 \text{ m/sec (in vaccum)}$$

(v) In any medium $V = \frac{1}{\sqrt{\mu\varepsilon}}$

Where $\mu = \mu_r \mu_0$ $\varepsilon = \varepsilon_r \varepsilon_o$

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

Also $V = \frac{c}{n}$

(vi) A material medium is not required for the propagation of e.m. waves.

(vii) Wave intensity equals average of Pointing vector $I = |\vec{S}|_{av} \frac{B_0 E_0}{2\mu_0}$.

(viii) Average electric and average magnetic energy densities are equal.

$U_E = \frac{1}{2}\varepsilon_0 E^2$ and $U_B = \frac{1}{2}\frac{B^2}{\mu_0}$

(ix) The electric vecotr is responsible for optical effects due to electro magnetic wave. For this reason, electric vector is called light vector.

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

$$E_y = E_0 \cos(\omega t - kx)$$

$$B_z = B_0 \cos(\omega t - kx)$$

$$\omega = \frac{2\pi}{T} = 2\pi v$$

$$\frac{\omega}{k} = \lambda v = V = C \text{ wave speed}$$

$$k = \frac{2\pi}{\lambda} = 2\pi\bar{v}$$

$v \rightarrow$ frequency

$\bar{v} = \frac{1}{\lambda}$ wave number.

Electromagnetic Soectrum

Name	Wavelength range	Production	Uses
Gamma Rays	$< 10^{-12}$ m	Gamma rays produced in radio active decay of nucleus	in treatment of cancer and to carry out nuclear reactions.
x-rays	10^{-9} m to 10^{-12} m	*x*-ray tubes or inner shell electrons	used as diagnostic tool in medical to find out fractures in bones. to find crack, flaws in metal part of machine
UV rays	4×10^{-7} to 10^{-9} m	by very hot bodies like sun and by UV lamps	in water purifier in detection of forged documents, in food preservation.
Visible light	7×10^{-7} m to 4×10^{-7}m	by accelerated tiny (electrons) charge particles	to see every thing around us
IR rays	10^{-3} m to 7×10^{-7} m	due to vibration of atoms	in green houses to keep plant warm to reveal secret writings on walls in photography during fog and smoke
Microwaves	10^{-1} m to 10^{-3} m	produced in klystron Valve and magnetron Valve	in RADAR in microwave ovens
Radio waves	> 0.1 m	by accelerated charged particles excited electrical circuits excited	in radio telecommunication system in radio astrology

Displacement Current—Current produced due to time varying electric field or electric flux.

$$I_D = \varepsilon_0 \frac{d\phi_e}{dt}, , \quad \phi_e \text{ is electric flux}$$

Modified Ampere's Circuital law by Maxwell

$$\oint \vec{B} . d\vec{l} = \mu_0 \left(I_C + \varepsilon_0 \frac{d\phi_e}{dt} \right)$$

$$I_c \rightarrow \text{Conduction current}$$

$$I_C = I_D$$

OPTICS
RAY OPTICS

GIST

1. REFLECTION BY CONVEX AND CONCAVE MIRRORS

a. Mirror formula $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$ where u is the object distance, v is the image distance and f is the focal length.

b. Magnification $m=-\frac{v}{u}=\frac{f-v}{f}=\frac{f}{f-u}$ m is $-ve$ for real images and $+ve$ for virtual images.

c. Focal length of a mirror depends up only on the curvature of the mirror $\left(f=\frac{R}{2}\right)$. It does not depend on the material of the mirror or on wave length of light.

2. REFRACTION

d. Ray of light bends when it enters from one medium to the other, having different optical densities.
When light wave travels from one medium to another, the wave length and velocity changes but frequency of light wave remains the same.

e. Sun can be seen before actual sunrise and after actual sun set due to Atmospheric refraction.

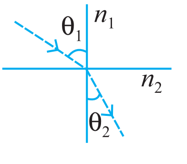
f. An object under water (any medium) appears to be raised due to refraction when observed obliquely.

$$n=\frac{\text{Real depth}}{\text{apparent depth}}$$ n ° refractive index

and normal shift in the position (apparent) of object is

$x=t\left\{1-\frac{1}{n}\right\}$ where t is the actual depth of the medium.

g. Snell's law states that for a given colour of light, the ratio of sine of the angle of incidence to sine of angle of refraction is a constant, when light travels from one medium to another.



$$n_1 \sin q_1 = n_2 \sin q_2$$

h. Absolute refractive index is the ratio between the velocities of light in vacuum to velocity of light in medium. For air regractive index is 1.003 for practical uses taken to be 1

$$n = \frac{c}{v}$$

3. T.I.R.

i. When a ray of light travels from denser to rarer medium and if the angle of incidence is greater than critical angle, the ray of light is refiected back to the denser medium. This phenomenon is called total internal refiection. (T.I.R.)

$$\sin C = \frac{n_R}{n_D}$$

Essential conditions for T.I.R.

1. Light should travel from denser to rarer medium.
2. Angle of incidence must be greater than critical angle $(i > i_C)$

j. Diamond has a high refractive index, resulting with a low critical angle $(C = 24.4^0)$. This promotes a multiple total internal reflection causing its brilliance and luster. Working of an optical fibre and formation of mirage are the examples of T.I.R.

4. When light falls on a convex refracting surface, the relation among, *u*, *v* and R is given by $\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}$.

5. Lens maker formula for thin lens formula is given by

$$\frac{1}{f} = \left(\frac{n_2 - n_1}{n_1}\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

For Convex Lens R_1 + ve; R_2 – ve and Concave lens R_1 –ve; R_2 + ve. The way in which a lens behaves as converging or diverging depends upon the values of n_2 and n_1.

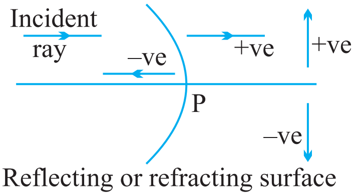
6. When two lenses are kept in contact the equivalent focal length is given by

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{x}{f_1 f_2} \text{ and Power } P = P_1 + P_2$$

Magnification $m = m_1 \times m_2$

7. The lens formula is given by $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

Sign convention for mirrors and lenses → Distances in the direction of incident ray are taken as positive. All the mesurement is done from pole (P).

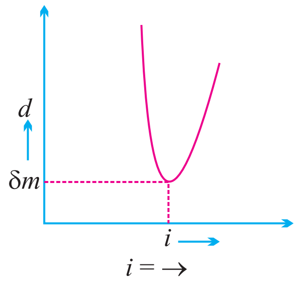


8. When ray of light passes through a glass prism it undergoes refraction, then A + δ = i + e and, the expression of refractive index of glass prism

$$n = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

As the angle of incidence increses, the angle of deviation decreases, reaches a minimum value and then increases. This minimum value of angle of deviation is called angle of minimum deviation "δ_m".

9.



Where d is minimum, $i = e$, refracted ray lies parallel to the base. For a small angled prism d min = $(n - 1)$A.

10. When white light is passed through a glass prism, it splits up into its constituent colours (Monochromatic). This phenomenon is called Dispersion.

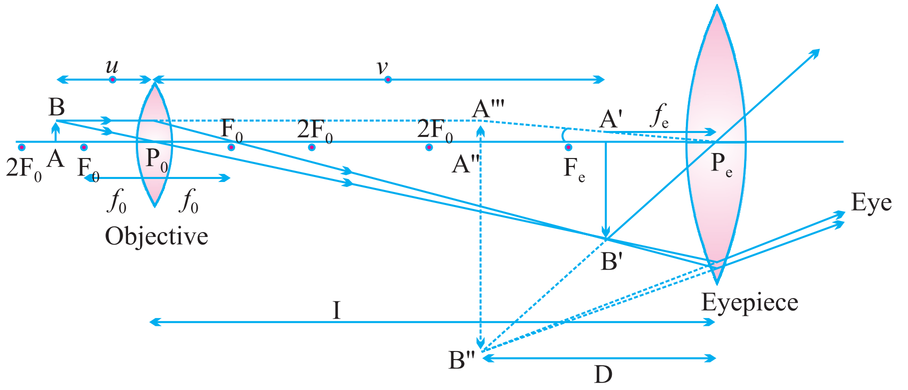
11. Scattering of light takes place when size of the particle is very small as compared to the wavelength of light.

Intensity of scattered light is $I \alpha \frac{1}{\lambda^4}$

The following properties or phenomena can be explained by scattering.

(i) Sky is blue.
(ii) Sun looks reddish at the time of sunrise and sunset.
(iii) Red light used in danger mark.
(iv) Clouds are white.

Compound Microscope :



Objective : The converging lens nearer to the object.

Eyepiece : The converging lens through which the final image is seen.

Both are of short length. Focal length of eyepiece is slightly greater than that of the objective.

4. Angular Magnification or Magnifying Power (M) :

$$\mathbf{M = M_e \times M_o}$$

(a) When final is formed atleast distance of distinct vision.

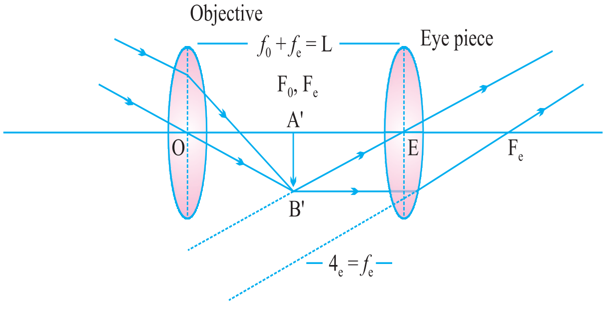
$$\boxed{M=\frac{v_o}{-u_o}\left(1+\frac{D}{f_e}\right)} \qquad \boxed{M=\frac{-L}{f_o}\left(1+\frac{D}{f_e}\right)}$$

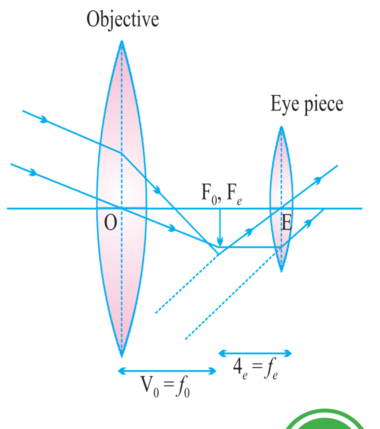
(b) When final image is formed at infinity $M=\dfrac{-L}{f_o}\,\dfrac{D}{f_e}$

(Normal adjustment *i.e.* image at infinity) Length of tube

$$L = |v_o| + |u_e|$$

5. Formation of Image by Astronomical Telescope : at infinity Normal Adjustment Position)





Focal length of the objective is much greater than that of the eyepiece. A perture of the objective is also large to allow more light to pass through it.

6. Angular magnification or Magnifying power of a telescope.

(a) When final image is formed at infinity (Normal adjustment)

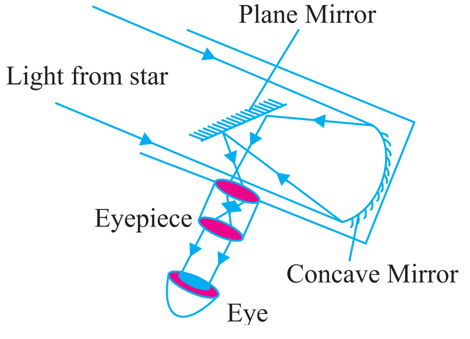
$$M = \frac{\beta}{\alpha} \qquad M = \frac{-f_o}{f_e}$$

($f_o + f_e$ = L is called the length of the telescope in normal adjustment).

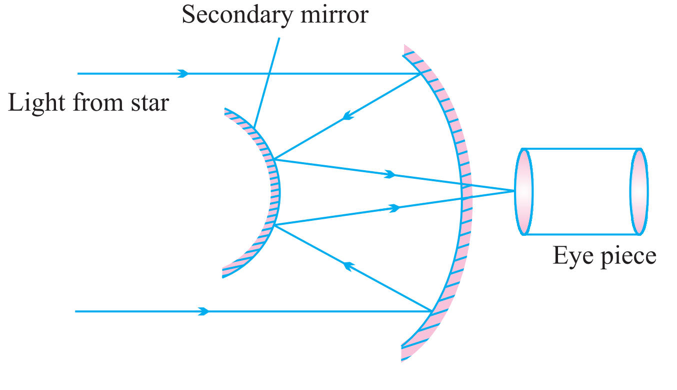
(b) When final image is formed at least distance of distinct vision.

$$m = \frac{-f_o}{f_e}\left(1 + \frac{f_o}{D}\right) \text{ and } L = f_o + |u_e|$$

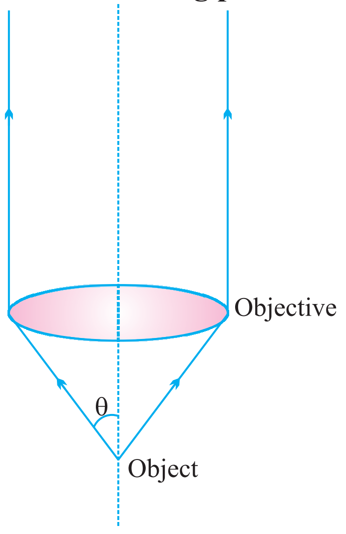
7. Newtonian Telescope : (Reflecting Type)



8. Cassegrain telescope refer



Limit of resolution and resolving power Compound Microscope



Limit of resolution $\Delta d = \dfrac{\lambda}{2\mu \sin\theta}$

$$\text{Resolving Power} = \frac{1}{\Delta d} = \boxed{\frac{2\mu\sin\theta}{\lambda}}$$

Resolving power depends on (i) wavelength λ, (ii) refractive Index of the medium between the object and the objective and (iii) half angle of the cone of light from one of the objects θ.

Telescope : Limit of resolution $d\theta = \dfrac{1.22\lambda}{D}$

$$\text{Resolving Power} = \frac{1}{d\theta} = \boxed{\frac{D}{1.22\lambda}}$$

D → diameter of objective.

Resolving power depends on (i) wavelength λ, (ii) diameter of the objective D.

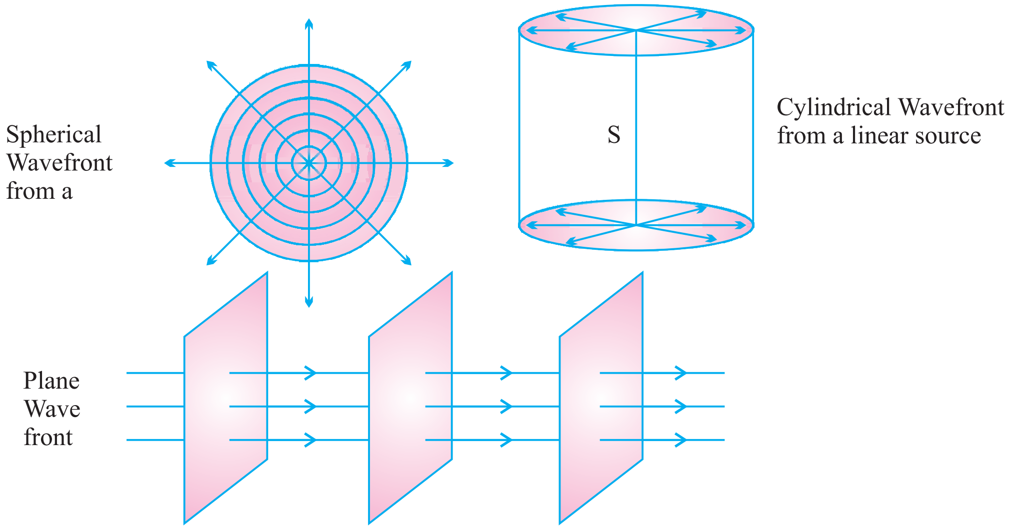
WAVE OPTICS

Wave front :

A wavelet is the point of disturbance due to propagation of light.

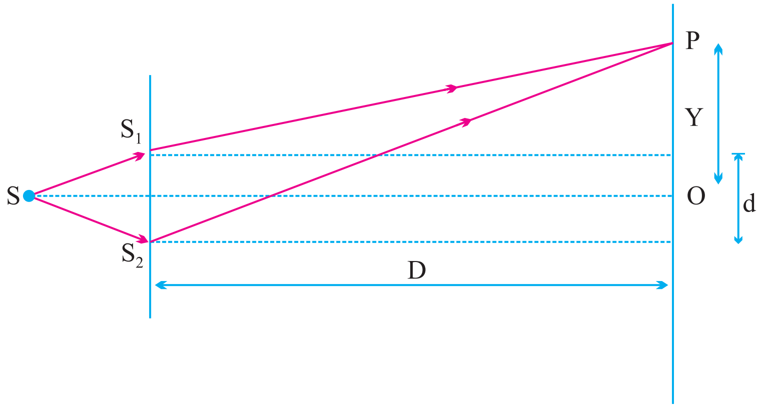
A wavefront is the locus of points (wavelets) having the same phase of oscillations.

A perpendicular to a wavefront in forward direction is called a ray.



INTERFERENCE OF WAVES

Young's Double Slit Experiment



The waves from S_1 and S_2 reach the point P with some phase difference and hence path difference

$$\Delta = S_2P - S_1P$$

$$S_2P^2 - S_1P^2 = \left[D^2 + \left\{y + \left(\frac{d}{2}\right)\right\}^2\right] - \left[D^2 + \left\{y - \left(\frac{d}{2}\right)\right\}^2\right]$$

$$(S_2P - S_1P)\,(S_2P + S_1P) = 2\,yd \qquad S_2P \approx S_1P \approx D$$

$$\Delta\,(2D) = 2\,yd$$

$$\Delta = \frac{yd}{D}$$

Interference phenomenon

1. Resultant intensity at a point on screen

$$I_R = R\,(a_1^2 + a_2^2 + 2a_1a_2 \cos f)$$

$$I_R = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\phi \qquad \text{Where } I_1 = ka_1^2,\quad I_2 = ka_2^2$$

$$\text{If } I_1 = I_2 = I_o, \text{ then } I_R = 4I_o \cos^2\left(\frac{\phi}{2}\right)$$

2. $I_{max} = \left(\sqrt{I_1} + \sqrt{I_2}\right)^2$ If $I_1 = I_2 = I_0$, $I_{max} = 4I_0$

$I_{min} = \left(\sqrt{I_1} - \sqrt{I_1}\right)^2$ If $I_1 = I_2 = I_0$, $I_{max} = 0$

3. $$\frac{I_{max}}{I_{min}} = \frac{\left(\sqrt{I_1} + \sqrt{I_2}\right)^2}{\left(\sqrt{I_1} - \sqrt{I_2}\right)^2}$$

4. $$\frac{I_{max}}{I_{min}} = \frac{(a_1 + a_2)^2}{(a_1 - a_2)^2}$$

5. $\frac{I_1}{I_2} = \frac{a_1^2}{a_2^2} = \frac{w_1}{w_2}$, w_1 and w_2 are widths of two slits

6. Constructive interference

Phase difference, $\phi = 2n\pi$

Path difference, $x = n\lambda$

Destructive interference

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

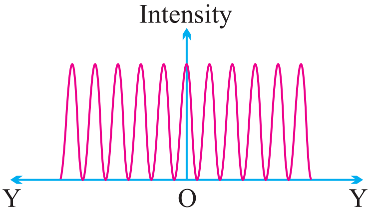
Path difference $x = (2n+1)\frac{\lambda}{2}$

Where $n = 0, 1, 2, 3, \ldots\ldots.$

7. Fringe width (dark or bright) $\beta = \frac{\lambda D}{d}$

Angular width of fringe $\Delta\theta = \frac{\beta}{D} = \frac{\lambda}{d}$

Distribution of Intensity



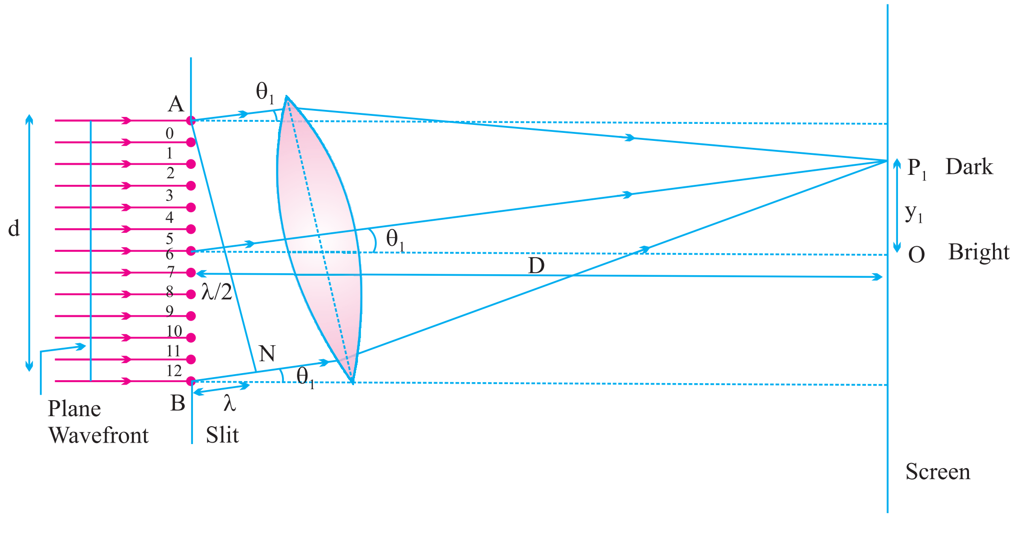
Conditions for Sustained Interference :

1. The two sources must be coherent.
2. The two interfering wave trains must have the same plane of polarisation.
3. The two sources must be very close to each other and the pattern must be observed at a large distance to have sufficient width of the fringe

   $b = \frac{\lambda D}{d}$ Angnlar width $a = l/d$
4. The sources must be monochromatic. Otherwise, the fringes of different colours will overlap.
5. The two waves must be having same amplitude for better contrast between bright and dark fringes.

DIFFRACTION OF LIGHT AT A SINGLE SLIT :

Width of Central Maximum :



$$y_1 = \frac{D\lambda}{d}$$

Since the Central Maximum is spread on either side of O, the width is

$$\boxed{\beta_0 = \frac{2D\lambda}{d}}$$

Fresnel's Distance :

$$y_1 = \frac{D\lambda}{d}$$

At Fresnel's distance, $y_1 = d$ and $D = D_F$

So, $$\frac{D_F \lambda}{d} = d \text{ or } D_F = \frac{d^2}{\lambda}$$

POLARISATION OF LIGHT WAVES :

Malus' Law : When a beam of plane polarised light is incident on an analyser, the intensity I of light transmitted from the analyser varies directly as the square of the cosine of the angle θ between the planes of transmission of analyser and polariser.

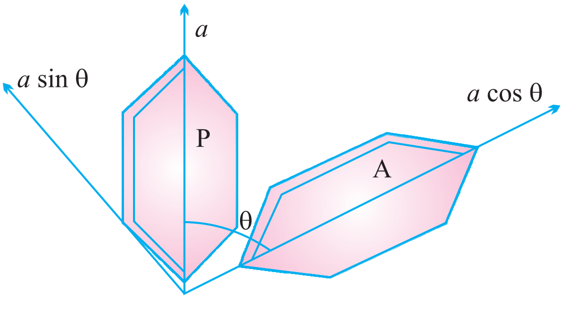
Intensity of transmitted light from the analyser is

$$\boxed{I \alpha \cos^2 \theta}$$

$$I = k\,(a \cos \theta)^2$$

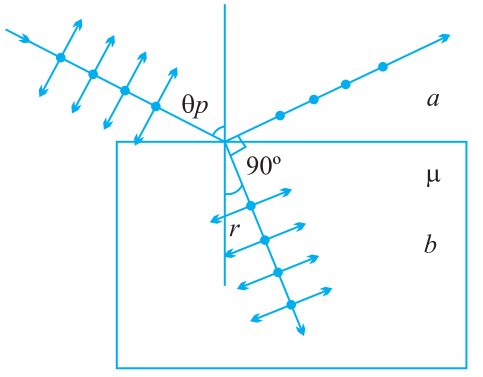
or $$I = k\,a^2 \cos^2 \theta$$

$$\boxed{I = I_0 \cos^2 \theta}$$



(where $I_0 = ka^2$ is the intensity of light transmitted from the polariser)

Polarisation by Reflection and Brewster's Law :



$$\theta_P + r = 90^\circ \text{ or } r = 90^\circ - \theta_P$$

$$_a\mu_b = \frac{\sin\theta_P}{\sin r}$$

$$_a\mu_b = \frac{\sin\theta_P}{\sin 90^\circ - \theta_P}$$

$$\boxed{_a\mu_b = \tan\theta_P}$$

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.

Ans. Electric field vector and Magnetic field vector.

2. What is the phase difference between electric and magnetic field vectors in an em wave?

Ans. $\frac{\pi}{2}$

3. Name em radiations used for detecting fake currency notes.

Ans. U.V. Radiation.

4. Give any two uses of microwaves.

Ans. Radar, Microwave ovens

5. Name the phenomenon which justifies the transverse nature of em waves.

Ans. Polarization.

6. Arrange the following em waves in descending order of wavelengths : γ ray, microwaves UV radiations.

Ans. Microwave, U V radiation, γ-rays

7. Which component $\vec{E}$ or $\vec{B}$ of an em wave is responsible for visible effect?

Ans. $\vec{E}$

8. Write expression for speed of em waves in a medium of electrical permittivity $\in$ and magnetic permeability μ.

Ans.
$$V = \frac{1}{\sqrt{\mu \in}}$$

9. Which of the following has longest penetration power?
UV radiation, X-ray, Microwaves.

Ans. X-rays

10. Which of the following has least frequency ?
IR radiations, visible radiation, radio waves.

Ans. Radiowaves.

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

Ans. Speed.

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

Ans. Energy and pressure.

13. Name the physical quantity with unit same as that of

$\left|\in_0 \frac{d\phi_e}{dt}\right|$ where $\phi_e \rightarrow$ electric flux.

Ans. Current.

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

Ans. Oscillating/accelerated charge.

15. A plane mirror is turned through 15°. Through what angle will the reflected ray be turned ?

Ans. 30°

16. Name the device used for producing microwaves.

Ans. Klystron valve and magnetron valve

17. Relative electric permittivity of a medium is 9 and relative permeability close to unity. What is the speed of em waves in the medium.

Ans. $$V = \frac{1}{\sqrt{\mu \in}} = \frac{1}{\sqrt{(\mu_0\mu_r)(\in_0\in_r)}} = \frac{1}{\sqrt{(\mu_0\varepsilon_r)(\mu_r\varepsilon_r)}}$$

$$V = \frac{C}{\sqrt{9}} = \frac{C}{3}$$

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

(i) 10^{-1} m

(ii) 10^{-12} m

Ans. Microwave, γ-ray

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

Ans. Microwave $\rightarrow$ microwave oven.

20. Which of the following act as a source of electromagnetic waves?

(i) A charge moving with a constant velocity.

(ii) A charge moving in a circular orbit with time varyinng speed.

(iii) A charge at rest.

Ans. A charge moving in a circular orbit

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

Ans. E_x and B_y

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

Ans. Remain same $I_C = I_D$

23. Give the ratio of velocities of light waves of wavelengths 4000A° and 8000A° in Vacuum.

24. Which physical quantity has the same value for waves belonging to the different parts of the electromagnetic spectrum?

Ans. Speed

25. Write the value of angle of reflection for a ray of light falling normally on a mirror.

Ans. Zero.

26. How does the dispersive power of glass prism change when it is dipped in water?

Ans. Decreases.

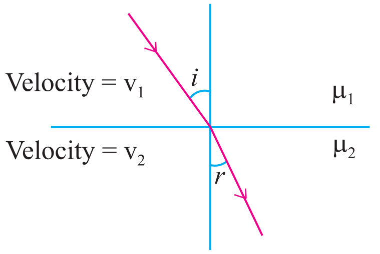
27. Light travels from glass to air. Find the angle of incidence for which the angle of refraction is 90° if refractive index of glass is $\sqrt{2}$.

Ans. 45°

28. Name the phenomenon due to which one cannot see through fog.

Ans. Scattering of light.

29. What is the ratio of sin *i* and sin *r* in terms of velocities in the given figure.

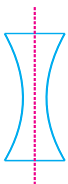


Ans. v_1/v_2

30. What is the shape of fringes in Youngs double slit experiment ?

Ans. Hyperbolic.

31. A equiconcave lens of focal length 15 cm is cut into two equal havles along dotted lines as shown in figure. What will be new focal length of each half.



Ans. 30 cm.

32. 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?

Ans. A

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

Ans. Zero.

34. What is the 'power' of plane glass plate ?

Ans. Zero.

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

Ans. Decreases,

36. 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.

37. An air bubble is formed inside water. Does it act as converging lens or a diverging lens?

Ans. Diverging lens

38. A water tank is 4 meter deep. A candle flame is kept 6 meter above the level μ for water is 4/3. Where will the image of the candle be formed?

Ans. 6 m. below the water level.

39. What is the ratio of contribution made by the electric field and magnetic field components to the intensity of an EM wave is ?

Ans. 1 : 1.

40. An EM wave of intensity 'I' falls on a surface kept in vacuum. What is the radiation pressure if wave is totally reflected?

Ans. $\frac{2I}{c}, c \rightarrow$ Speed of light

41. In a single slit diffraction pattern, how does the angular width of central maxima change when (i) slit width is decreased (ii) distance between slit & screen is increased and (iii) light of smaller visible wavelength is used ? Justify your answer.

Ans. Angular width of central maxima $\theta = \frac{\beta_0}{D} = \frac{2\lambda}{d}$

(i) If $d \rightarrow$ decreases Angular width increases.
(ii) Angular width remain same on increasing D
(iii) If λ decreases, angular width decreases.

SHORT ANSWER QUESTIONS (1 Marks)

1. It the angle between the pass axis of polorizer and analyser is 450, writhe the ratio of intensilies of orginal light an the transmitted light after passing trough anlyser [**Ans.** → 2]

2. Light of wave lenght 600nm is incident normally on a slit of with 3mm. Calculate the angular width of central maximum on a screen kept 3m away from the steb. [**Ans.** 4×10^{-4} rad]

3. If the polarising angle for air glass interface is 56.3°, lohat is the angle of refraction in glass? [**Ans.** 33.7°]

4. How does magnifying power changes with change in length of tube for a given telescope? [Ans Decreases with increase in length]

5. The magnifying power of an artronomical telescope in normal adjustment is 100 and distance between objective and eye lens in 101cm. Find the focal lenght of objective and eye piece.
[Ans fo = 100 cm, fe = 1 cm.]

SHORT ANSWER QUESTIONS (2 Marks)

1. Give one use of each of the following
(i) UV ray (ii) γ-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 λ 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).

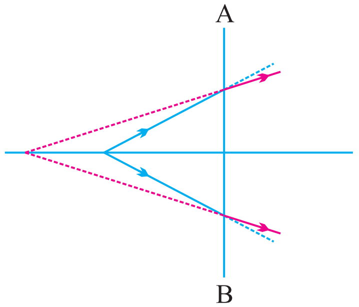
5. State two applications of infrared radiations.

6. State two applications of radio waves.

7. State two applications of x-rays.

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

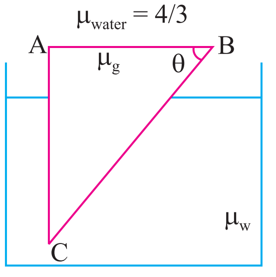
9. The line AB in the ray diagram represents a lens. State whether the lens is convex or concave.



10. Use mirror equation to deduce that an object placed between the pole and focus of a concave mirror produces a virtual and enlarged image.

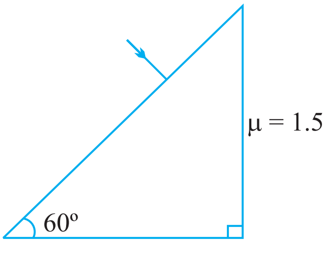
11. Calculate the value of θ, for which light incident normally on face AB grazes along the face BC.

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



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

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

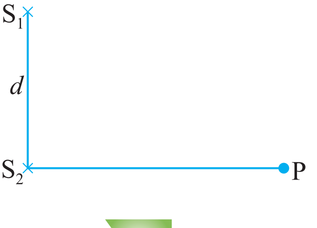


14. Define diffraction. What should be the order of the size of the aperture to observe diffraction.

15. 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.

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

17. 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?



18. 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 towards jogger.

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.

19. Define Brewstre's angle. Show that the Brewster's angle i_B for a given pair of media is related to critical angle i_c through the relation

$$i_c = \sin^{-1}(\cot i_B)$$

20. If angle between the pass axes of polariser & analyser is 45°. Write the ratio of the intersities of original light and transmitted light after passing through the analyser.

21. 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 convering to a point behind the mirror are reflected to a point on a screen.

22. 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.

23. Draw a diagram to show the advance sunrise and delayed sunset due to atmospheric refraction.

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

25. 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 focal length of the lens required.

Ans. For fixed distance 's' between object and screen, for the lens equation to give real solution for $u = v = 2f$, 'f' should not be greater than $4f = s$.

$$\therefore \quad f = s/4$$

26. 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.

27. Obtain relation between focal length and radius of curvature, of (i) concave mirror (ii) convex mirror using proper ray diagram.

28. Two independent light sources cannot act as coherent sources. Why?

29. 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.

30. 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.

31. You are provided with four convex lenses of focal length 1cm, 3cm, 10 cm and 100 cm. Which two would you prefer for a microscope and which two for a telescope.

32. Give reasons for the following

(i) Sun looks reddish at sunset

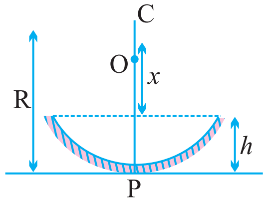
(ii) clouds are generally white

33. Using Huygens Principle draw ray diagram for the following :

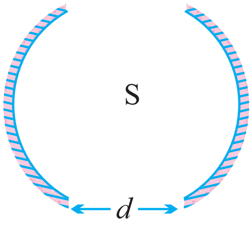
(i) Refraction of a plane wave front incident on a rarer medium

(ii) Refraction of a plane wave front incident on a denser medium.

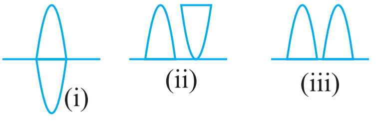
34. Water (refractive index μ) is poured into a concave mirror of radius of curvature 'R' up to a height *h* as shown in figure. What should be the value of *x* so that the image of object 'O' is formed on itself?



35. 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.

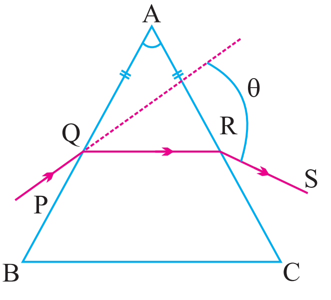


36. A thin double convex lens of focal length f is broken into two equal halves at the axis. The two halves are combined as shown in figure. What is the focal length of combination in (ii) and (iii).



37. 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. $({}_a\mu_\omega = 4/3.)$

38. 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. Name EM radiations used

(i) in the treatment of cancer.

(ii) For detecting flow 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 5×10^{19} Hz in free space. Give its two applications.

5. 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.

6. Obtain the formula for combined focal length of two thin lenses in contact, taking one divergent and the other convergent.

7. Derive Snell's law on the basis of Huygen's wave theory.

8. 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.

9. Define total internal reflection. State its two conditions. With a ray diagram show how does optical fibres transmit light.

10. 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.

11. 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) aperture of objective lens is increased.

12. Derive Mirror formula for a concave mirror forming real Image.

13. Two narrow slits are illuminated by a single monochromatic sources.

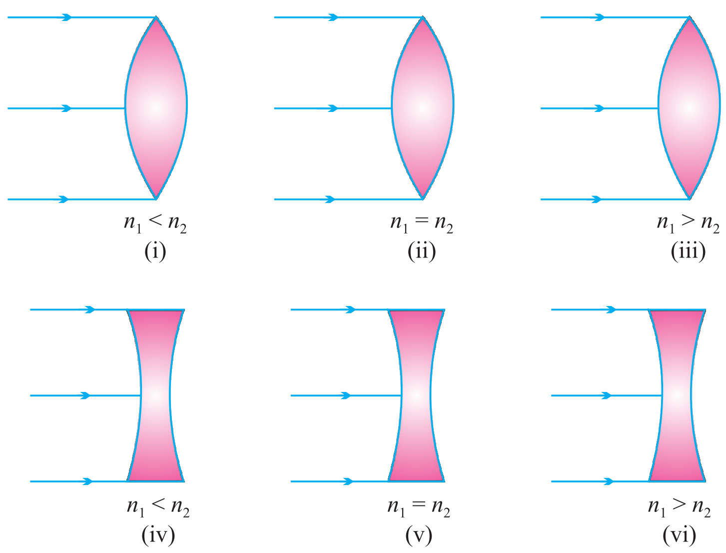
(a) Draw the intensity pattern and name the phenomenon

(b) One of the slits is now completely covered. Draw the intensity pattern now obtained.

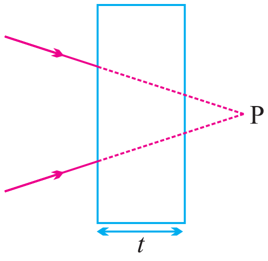
14. Explain (i) sparkling of diamond (ii) use of optical fibre in communication.

15. Using appropriate ray diagram obtain relation for refractive index of water in terms of real and apparent depth.

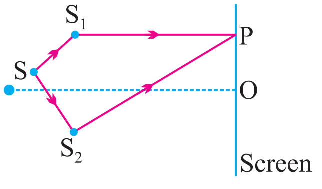
16. Complete the ray diagram in the following figure where, n_1 is refractive index of medium and n_2 is refractive index of material of lens.



17. 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 shiffted? Illustrate the answer.



18. 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.



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 if final image is formed at leat distance of distant vision.

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. Explain the following :

(a) Sometimes distant radio stations can be heard while nearby stations are not heard.

(b) If one of the slits in Youngs Double Slit Experiment is covered, what change would occur in the intensity of light at the centre of the screen?

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. When final image is formed at least distance of distinct vision.

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 prism 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. Also draw the intensity pattern with angular position.

12. How will the interference pattern in Youngs double slit experiment change, when

    (i) distance between the slits S_1 and S_2 are reduced and

    (ii) the entire set up is immersed in water ?

    Justify your answer in each case.

Ans. Fringe width $\beta = \frac{\lambda D}{d}$

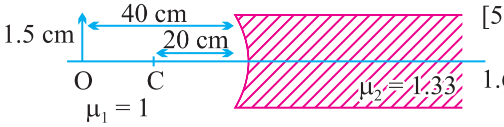
(i) If d decreases, fringe width $\beta \propto \frac{1}{d}$ increases

(ii) When apparatus is immersed in water, wavelength reduces to $\frac{\lambda}{\mu_\omega}$. Therefore, fringe width $\beta \propto \lambda$ decreases.

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 vacuum. Amplitude of the electric field vector is 5×10^4 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 $v = 50.0$ MHz.
   (a) Determine B_0, ω, κ and λ,
   (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.
7. An object of length 2.5 cm is placed at a distance of 1.5 f 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? [5 cm, Inverted]

8. Find the size of image formed in the situation shown in figure.



[5 cm, Inverted]

1.6 cm approx.

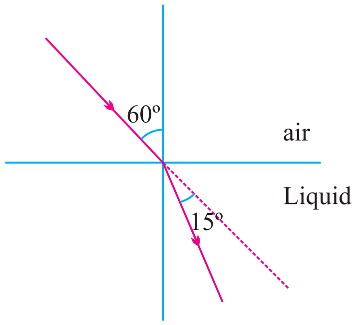
[1.2 cm, approx.]

9. 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.

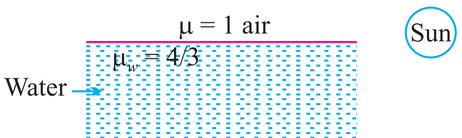
[Ans. : 30°]

10. 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. [$i_p = \tan^{-1} 2$]

11. A light ray passes from air into a liquid as shown in figure. Find refractive index of liquid. [${}^{air}\mu_{Liquid} = \sqrt{3/2}$]



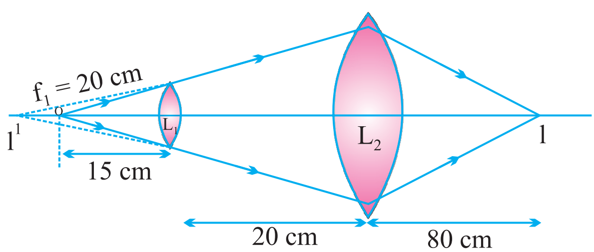
12. At what angle with the water surface does fish in figure see the setting sun ?



[C = $\sin^{-1}$ (0.7518)]

[At critical angle, fish will see the sun.]

13. In the following diagram, find the focal length of lens L_2. [40 cm]



14. Three immiscible liquids of densities $d_1 > d_2 > d_3$ and refractive indices $\mu_1 > \mu_2 > \mu_3$ are put in a beaker. The height of each liquid is $\frac{h}{3}$. A dot is made at the bottom of the beaker. For near normal vision, find the apparent depth of the dot.

Ans. (Hint : the image formed by first medium act as an object for second medium) Let the apparent depth be O_1 for the object seen from

$O_1 = \frac{\mu_2}{\mu_1} \cdot \frac{h}{3}$ image formed by medium 1, O acts as an object for medium 2. It is seen from M_3, the apparent depth is O_2.

Similarly, the image found by medium 2, O_2 act as an object for medium 3

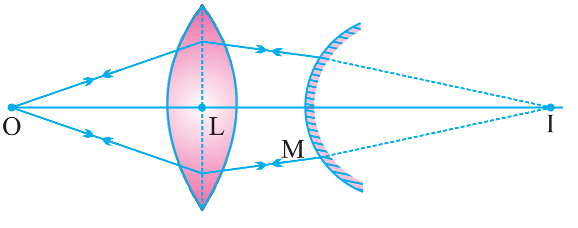
$$O_2 = \frac{\mu_3}{\mu_2}\left(\frac{h}{3} + O_1\right)$$

$$O_3 = \mu_3\left(\frac{h}{3} + O_2\right) \qquad \text{putting value of } O_2 \text{ and } O_1$$

$$O_3 = \frac{h}{3}\left(\frac{1}{\mu_1} + \frac{1}{\mu_2} + \frac{1}{\mu_3}\right)$$

15. A point object O is kept at a distance of 30 cm from a convex lens of power + 4D towards its left. It is observed that when a convex mirror is kept on right side at 50 cm from the lens, the image of object O formed by lens-mirror combination coincides with object itself. Calculate focal length of mirror.

Ans. Image formed by combination coincides with the object itself. It implies that I is the centre of curvature of convex mirror.



For lens

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$$

$$\frac{1}{25} = \frac{1}{v} + \frac{1}{30}$$

$$v = 150 \text{ cm}$$

$$\text{MI} = \text{LI} - \text{LM} = 150 - 50 = 100 \text{ cm}$$

$$f_m = \frac{\text{MI}}{2} = \frac{100}{2} = 50 \text{ cm}$$

16. 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, lens 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.

17. Two thin converging lens of focal lengths 15 cm and 30 cm respectively are held in contact with each other. Calculate power and focal length of the combination.

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}$$

$$= \frac{1}{15} + \frac{1}{30} = \frac{1}{10}$$

$$F = 10 \text{ cm}$$

$$P = 10\text{D}$$

18. An object is placed in front of a concave mirror of focal length 20 cm. The image is formed three times the size of the object. Calculate two possible distances of the object from the mirror.

Ans.

$$m = \pm 3$$

$$m = \frac{-v}{u} = +3 \text{ for virtual image}$$

$$v = -3u$$

$$\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$$

$$\frac{1}{-34} + \frac{1}{u} = -\frac{1}{20}$$

$$u = -\frac{40}{3}\text{cm}$$

$$m = \frac{-v}{u} = -3 \text{ for real image}$$

$$v = 3u$$

$$\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$$

$$\frac{1}{3u} + \frac{1}{u} = -\frac{1}{20}$$

$$u = -\frac{80}{3}\text{cm.}$$

1 MARKS QUESTIONS

1. Which part of the electromagnetic spectrum is used in RADAR? Give its frequency range.

2. How is the equation for Ampere's circuital law modified in the presence of displacement current?

3. How are electromagnetic waves produced by oscillating charges? What is the source of the energy associated with the em waves?

4. Name the radiation of the electromagnetic spectrum which is used for the following:

(a) (i) Radar (ii) Eye surgery

(b) To photograph internal parts of human body

(c) For taking photographs of the sky during night and foggy conditions

Give the frequency range in each case.

5. Two polaroids A and B are kept in crossed position. How should a third polaroid C be placed between them so that the intensity of polarised light transmitted by polaroid B reduces to $1/8^{th}$ of the intensity of unpolarised light incident on A. [Hint $I = I_0\cos^2\theta$]

Ans. 45°.

6. In young's double slit experiment using monochromatic light of wavelength λ, the intensity of light at a point on the screen where path difference is λ is "K" units. Find the intensity of light at a point where path difference is $\frac{\lambda}{3}$.

$$\text{Phase iff.} = \frac{2\pi}{\lambda} \times \frac{\lambda}{3} = \frac{2\pi}{3} = 120°$$

and $$I = I_0 \cos^2 \frac{\phi}{2} = \frac{K}{4}$$

$$\left[\text{Hint} \quad I = I_1 + I_2 + 2\sqrt{I_1 I_2} \cos\phi\right]$$

7. Two nicole polariods are so oriented that the maximum amount of light is transmitted. To what fraction of its maximum value is the intensity of transmitted light reduced when the analyser is rotated through (i) 30° (ii) 60°?

Ans. (i) 75% of max. intensity (ii) 25% of max. intensity

8. In young's double slit experiment, a light of wavelength 630 nm produces an interference pattern where bright fringes are separated by 8.1 mm. Another light produces the interference pattern. Where the bright fringes are separated by 72 mm. Calculate the wavelength of second light.

$$\left[\text{Hint} \quad \beta = \frac{\lambda D}{d}\right]$$

Ans. 560 nm

9. A beam of light consisting of two wavelength 800 nm and 600 nm is used to obtain the interference pattern in young's double slit experiment on a screen placed 1.4 m away. If the separation between two slits in 0.28 mm. Calculate the least distance from the central bright maximum, where the bright fringes of two wavelength coincide.

Ans. $$x = n\lambda_1 \frac{D}{d} = (n+1)\lambda_2 \frac{D}{d}$$

$\therefore$ $$n \times 800 = (n+1)\lambda_2 \frac{D}{d}$$

$\therefore \qquad n = 3$

$$\therefore \qquad x = n\lambda_1 \frac{D}{d} = 3\times 800\times \frac{10^{-9}\times 1.4}{0.28\times 10^{-3}} = 12 \text{ mm}$$

Numericals

1. The focal lengths of objective and eye peace of a microscope are 1.25 cm and 5 cm respectively find the position of the object relative to the objective in order to obtain an angular magnification of 30 in normal adjustment.

Ans. In normal adjustment

$$m_e = \frac{d}{f_e} = \frac{25}{5} = 5$$

$$m = m_0\, m_e$$

$$\therefore \qquad m_0 = \frac{m}{m_e} = \frac{30}{5} = 6$$

$$\text{and} \qquad m_0 = \frac{V_0}{u_0} = -6$$

$$\therefore \qquad V_0 = -6u_0$$

$$\therefore \qquad \frac{1}{v_0} - \frac{1}{u_0} = \frac{1}{f_0}$$

$$\frac{1}{-6u_0} - \frac{1}{u_0} = \frac{1}{f_0}$$

here $\qquad f_0 = 1.25$ cm

$u_0 = -1.46$ cm

2. An small telescope has an objective lens of focal length 150 cm and an eye piece of focal length 5 cm. If his telescope is used to view a 100 m high tower 3 km away find the height of the final image when it find the height of the final image when it is formed 25 cm away from the eye pieces.

Ans. $$\tan\alpha = \frac{100}{3000} = \frac{1}{30} \text{ radian}$$

again $$\tan\alpha = \frac{h}{f_0}$$

$$\therefore \quad \frac{1}{30} = \frac{h}{150}$$

$$h = 5 \text{ cm}$$

h height of image of tower

$$\therefore \quad m_e = \left(1 + \frac{\alpha}{f_e}\right) = \left(1 + \frac{25}{5}\right) = 6$$

and $$m_e = \frac{h'}{h}$$

$$\therefore \quad h' = 5 \times 6 = 30 \text{ cm}$$

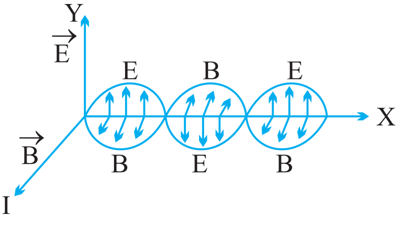
h' height of final image.

ANSWER OF 2 MARKS QUESTIONS

1. UV ray – In water purifier.

γ ray – In treatment of cancer

2.



3. An accelerated charge produces oscillating electric field in space, which produces an oscillating magnetic field, which in turn, is a source of oscillating electric field and so on. The oscillating electric & magnetic fields produces each other & give rise to e.m. waves.

4. In vacuum $$C = \frac{E_0}{B_0}$$

If electric field become $\frac{3}{4}E_0$, magnetic field will be $\frac{3}{4}B_0$.

5. (i) In green houses to keep plants warm.

(ii) In reading secret writings on ancient walls.

6. (i) In radio & tele communication systems.

(ii) In radio astronomy.

7. (i) In medical to diagnose fractures in bones.

(ii) In engineering for detecting cracks, flaws & holes in metal parts of a machine.

8.

$$\mu_E = \frac{1}{2}\varepsilon_0 E^2 \quad \& \quad u_B = \frac{1}{2}\frac{B^2}{\mu_0}$$

$$\mu_E = \frac{1}{2}\varepsilon_0 E^2 = \frac{1}{2}\varepsilon_0 (CB)^2 \qquad \text{As } c = \frac{E}{B}$$

$$= \frac{1}{2}\varepsilon_0 \frac{B^2}{\mu_0 \varepsilon_0} \qquad c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$$

$$= \frac{B^2}{2\mu_0}$$

$$= \mu_B$$

10. For concave mirror

$$f < 0 \quad \text{and} \quad u < 0$$

$$f < u < 0$$

$$\frac{1}{f} > \frac{1}{u} \quad \text{or} \quad \frac{1}{f} - \frac{1}{u} > 0$$

$$\text{or} \quad \frac{1}{v} > 0$$

Virtual image is formed.

Also $\frac{1}{v} < \frac{1}{|u|}$ or $v > |u|$

$$m = \frac{v}{|u|} > 1$$

magnified image.

11. $\theta = \sin^{-1}(8/9)$

12. Speed and frequency

13. $\sin^{-1}(3/4)$

16. 4 m pole

17. Minimum path difference is zero (when p is at infinity).

Maximum path difference = d.

29. 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

30. (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 cause overlapping of different colours.

31. f_0 = 1 cm and f_e = 3 cm for Microscope and

f_0 = 100 cm and f_e = 1 cm for a Telescope

33. N.C.E.R.T. Fig. 10.5; Fig. 10.4.

34. Distance of object from p should be equal to radius of curvature.

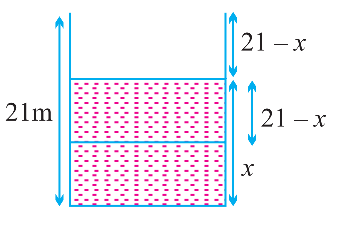
$$R = \mu x + h \Rightarrow \quad x = \frac{R - h}{\mu}$$

35. Distance between mirror will be $2f$ or $4f$.

36. (i) Focal length of combination is infinite,

(ii) $f/2$

37.



$$\frac{\text{Real depth}}{\text{Apparent depth}} = \mu$$

$$\frac{x}{21-x} = \frac{4}{3} \quad \Rightarrow \quad x = 12 \text{ cm}$$

38. This is a case of min. deviation $\theta = 60°$.

ANSWERS OF 3 MARKS QUESTIONS

11. R.P. of a compound Microscope

$$= \frac{2\mu\sin\theta}{\lambda} = 2\mu\sin\theta\frac{v}{c}$$

(i) When frequency v increases, R.P. increases

(ii) R.P. does not change with change in focal length of objective lens.

(iii) When aperture increases, θ increases

$\therefore$ R.P. increases.

17. $x = \left(1-\frac{1}{\mu}\right)t$

18. Path difference :

$$(SS_2 + S_2P) - (SS_1 + S_1P) = (SS_2 - SS_1) + (SS_2P - S_1P)$$

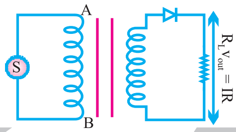
$$= (0.25\lambda + S_2P - S_1P)$$

For maxima, path difference = $n\lambda$

So, $S_2P - S_1P = n\lambda - 0.25\lambda = (n - 0.25)\lambda$

For minima, path difference = $(2n+1)\frac{\lambda}{2}$

So, $S_2P - S_1P = (2n + 0.5)\ \lambda/2$.



Unit VII Dual Nature of Matter **And Radiation**

Unit VII

DUAL NATURE OF MATTER AND RADIATION

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 = $h(\nu - \nu_0)$ Here ν_0 is the frequency below which no photoelectron is emitted and is called threshold frequency.
- If 'V' is the stopping potential of photoclectron emission, then max. kinetic energy of photo electron $E_K = qV$

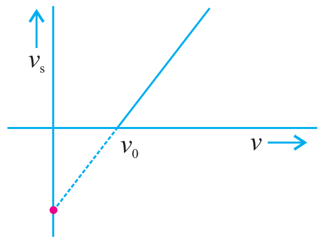
- Wavelength associated with the charge particle accelerated through a potential of g volt.

$$l = \frac{h}{\sqrt{2mqv}}$$

- Wavelength associated with electron accelerated through a potential difference

$$l_e = \frac{12.27}{\sqrt{V}} A^\circ$$

- Stopping potential versus frequency graph



$v_0 \rightarrow$ thershold frequency

slop of the curve gives $\frac{h}{e}$

The intercept on v_s axis gives $\frac{\phi}{e}$ i.e. $\frac{\text{Work function}}{e}$

- A moving body behaves in a certain way as though it has a wave nature having wavelength,

$$\lambda = \frac{h}{mv} = \frac{h}{p} = \frac{h}{\sqrt{2m E_k}}$$

where E_K is kinetic energy of movign particle

- Einestein's Photoelectric equation

$$\frac{1}{2} mv_{max}^2 = h\nu - h\nu_0$$

or $$eV_0 = h\nu - h\nu_0$$

Unit VIII

ATOMS AND NUCLEI

KEY POINTS

- Gieger-Marsden α-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 $hv = E_f - E_i$. 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

$$r_n = \left(\frac{n^2}{m}\right)\left(\frac{h}{2\pi}\right)^2 \frac{4\pi\varepsilon_0}{e^2} = \frac{n^2h^2\varepsilon_0}{\pi me^2}$$

$$\Rightarrow \qquad r_n \propto n^2$$

  The total energy is also quantised : $E_n = \dfrac{-me^4}{8n^2\varepsilon_0^2h^2} = -13.6\text{eV}/n^2$

  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.**

$$\Delta M = [Zm_p + (A - Z)m_n] - M$$

and $$\Delta E_b = (\Delta M)c^2$$

The energy ΔE_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 λ is called decay constant. It is defined as the reciprocal of the mean time during which the number of atoms of a radioactive substance decreases to $\frac{1}{e}$ 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.

$$T_{1/2} = \frac{\ln 2}{\lambda} = \ln 2 \times \text{mean life}$$

or $$0.693/\lambda = \frac{0.693}{\lambda}$$

Here λ= decay constant = $\frac{1}{\text{mean life}}$

- Radius r of the nucleus of an atom is proportional to the cube root of its mass number thereby implying that the nuclear density is the same. (Almost) for all substances/nuclei.
- α-decay : ${}_{Z}X^{A} \rightarrow {}_{Z-2}Y^{A-4} + {}_{2}He^{4} + Q$

β-decay : ${}_{Z}X^{A} \rightarrow {}_{Z+1}Y^{A} + {}_{-1}e^{0} + \overline{\nu} + Q$

γ-decay : When α or β-decay, the nucleus in excited state; the nucleus goes to lower energy state or ground state by the emission of γ-ray(s).

QUESTIONS

VERY SHORT ANSWER QUESTIONS (1 Mark)

1. What is the rest mass of photon?

Ans. Zero

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.

Ans. (b) Total no. of reflected photons decreases by 20%.

3. Why in a photocell the cathode is coated with alkali metals ?

Ans. Lower work function, sensitive to visible light.

4. Name the phenomenon which shows quantum nature of electromagnetic radiation.

Ans. Photoelectric effect.

5. Write Einstein's photoelectric equations and specify each term.

Ans. $\frac{1}{2}mv_{\max}^2 = h\upsilon - h\upsilon_0$

Max. K.E. of Photoelectrons = Energy of incident light – work function.

6. The Stopping potential in an experiment on photo electric effect is 1.5V : What is the maximum K.E. of photoelectrons emitted.

Ans.

$$eV_0 = (K.E)\ max$$

$$\Rightarrow \quad (K.E.)max = 1.6 \times 10^{-19} \times 1.5$$

$$= 2.4 \times 10^{-19} J$$

7. A metal emits photoelectrons when red light falls on it. Will this metal emit photoelectrons when blue light falls on it? Why?

Ans. Yes, blue light has higher frequency hence possess higher energy.

8. What is the value of impact parameter for a head on collision?

Ans. Zero

9. The photoelectric cut off voltage in a certain photoelectric experiment is 1.5V. What is the max. kinetic energy of photoelectrons emitted?

Ans. K.E = eV, \ K.E = 1.5 e Joule

$= 1.5 \times 1.6 \times 10^{-19}$J

$= 2.4 \times 10^{-19}$J

10. What is the de-Broglie wavelength of a 3 kg object moving with a speed of 2m/s?

Ans. $\lambda = \frac{h}{mv} = \frac{6.6\times10^{-34}}{3\times2} = 1.1 \times 10^{-34}$m.

11. What factors determine the maximum velocity of the photoelectrons from a surface?

Ans. (a) frequency of incident radiation

(b) work function of surface.

12. How will you justify that the rest mass of photons is zero ?

Ans. $m = \frac{m_0}{\sqrt{1-\frac{v^2}{c^2}}}$, rest mass for $m_0 = \sqrt{1-\frac{v^2}{c^2}}$ photon $v = c \Rightarrow m_0 = 0$.

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, $\phi_0 = hv_0 = h\frac{c}{\lambda_0}$ or $\lambda_0 \;\alpha \frac{1}{\phi_0}$

Hence caesium has a higher threshold wavelength for photoelectric emission.

14. What is the de-Broglie wavelength of a neutron at absolute temperature T K ?

Ans. $\lambda = \frac{h}{\sqrt{2m_n E_k}} = \frac{h}{\sqrt{2m_n \frac{3}{2} k_B T}} = \frac{h}{\sqrt{3m_n k_B T}}$, $K_B \rightarrow$ Boltzmann's Constant

15. Define atomic mass unit. Write its energy equivalent in MeV.

Ans. 1 a.m.u is $\frac{1}{12}$ of the mass of a carbon isotope

$^{12}C_6$ 1 u = 931 MeV

16. What was the drawback of Rutherford's model of atom?

Ans. Rutherford's model of atom failed to explain the stability of atom.

17. What are the number of electrons and neutrons in $^{236}_{92}U$ atom?

Ans. No. of electrons 92

No. of neutrons 236 – 92 = 144.

18. Name the series of hydrogen spectrum which has least wavelength.

Ans. Lyman series

19. Any two protons repel each other, then how is this possible for them to remain together in a nucleus.

Ans. Nuclear force between two protons is 100 times stronger than the electrostatic force.

20. Define radioactive decay constant.

Ans. 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.

21. You are given reaction : $_1H^2 + {}_1H^2 \rightarrow {}_2He^4$ + 24 MeV. What type of nuclear reaction is this?

Ans. Nuclear Fusion.

22. After losing two electrons, to which particle does a helium atom get transformed into?

Ans. α particle.

23. What is the ratio of velocities of electron in I, II and III Bohr Orbits ?

Ans. $\frac{1}{1}:\frac{1}{2}:\frac{1}{3}$ or 6 : 3 : 2

24. Which atomic part was discovered by Rutherford ?

Ans. Nucleus

25. In nuclear reaction $^1_1\text{H} \rightarrow {}^1_0n + {}^P_Qx$ find P, Q and hence identify X.

Ans. P = 0, Q = 1

X is $_1e^0$ a positron.

26. Binding energies of deutron $\left({}^2_1\text{H}\right)$ and α-particle ($_2He^4$) are 1.25 MeV/nucleon and 7.2 MeV/nucleon respectively. Which nucleus is more stable?

Ans. Binding energy of $_2He^4$ is more than deutron $_1H^2$. Hence $_2He^4$ is more stable.

27. α-particles are incident on a thin gold foil. For what angle of deviation will the number of deflected α-particles be minimum?

Ans. 180°

28. 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?

Ans. Four times $\because$ R = – λN

29. An electron jumps from fourth to first orbit in an atom. How many maximum number of spectral lines can be emitted by the atom?

Ans. Possible transitions are

$n_i = 4$ to $n_f = 3, 2, 1$

$n_i = 3$ to $n_f = 2.1$

$n_i = 2$ to $n_f = 1$

Total transitions = 6

For many electron system.

$$\left[\text{Max number of spectral lines} = \frac{n(n-1)}{2} = \frac{4 \times 3}{2} = 6\right]$$

30. Under what conditions of electronic transition will the emitted light be monochromatic?

Ans. Only fixed two orbits are involved and therefore single energy evolve.

31. Why does only a slow neutron (.03eV energy) cause the fission in the uranium nucleus and not the fast one?

Ans. Slow neutron stays in the nucleus for required optimum time and disturbs the configuration of nucleus.

32. Write the relation for distance of closest approach.

Ans. $\gamma_0 = \dfrac{(Ze)(2e)}{4\pi \in_0 \left(\frac{1}{2} mv^2\right)}$.

33. 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 revolving electron is bound to the nucleus.

34. Name the physical quantity whose dimensions are same as Planck's constant.

Ans. Angular momentum

35. Define ionisation potential.

Ans. The minimum accelerated potential which would provide an electron sufficient energy to escape from the outermost orbit.

36. The ionisation potential of hellium atom is 24.6 V. How much energy will be required to ionise it?

Ans. 24.6 eV

37. What is the energy possessed by an electron whose principal quantum number is infinite?

Ans. Zero $n = \infty$

$$\because \quad E_n = -\frac{13.6}{n^2} \text{ eV} = 0.$$

38. What is the SI unit of work function?

Ans. Joule

39. Name the spectral series of hydrogen atom which lie in *uv* region.

Ans. Lyman Series

40. Name two series of hydrogen spectrum lying in the infra red region.

Ans. Paschan & P fund series

41. What is the order of velocity of electron in a hydrogen atom in ground state.

Ans. 10^6 ms^{-1}

42. Write a relation for the wavelength in Paschan series lines of hydrogen spectrum.

Ans. $\frac{1}{\lambda} = R\left(\frac{1}{3^2} - \frac{1}{n^2}\right), \quad n = 4, 5...$

43. Arrange radioactive radiation in the increasing order of penetrating power.

Ans. α, β, γ

44. Write a relation between average life and decay constant.

Ans. $\tau = \frac{1}{\lambda}$ = average life

45. Write two units for activity of radioactive element and relate them with number of disintegration per second.

Ans.

1 Curie (Ci) = 3.7×10^{10} decay/s

1 becquerel (Bq) = 1 decay/s

46. 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?

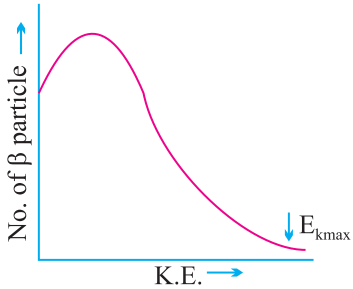
Ans. $T_A = \tau_B = 1.44T_B$

$\therefore$ $T_A > T_B$

$\therefore$ $\lambda_A < \lambda_B$

Therefore B decay faster than A.

47. Draw the graph showing the distribution of kinetic energy of electrons emitted during β decay.



48. Compare radii of two nuclei of mass numbers 1 and 27 respectively.

Ans. $$\frac{R_1}{R_2} = \left(\frac{1}{27}\right)^{1/3} = \frac{1}{3}$$

$$R_1 : R_2 = 1 : 3$$

49. Which element has highest value of Binding Energy per nucleon.

Ans. $^{56}Fe_{26}$

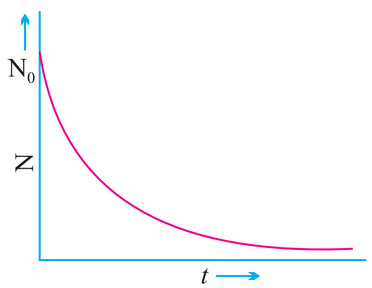
50. Mention the range of mass number for which the Binding energy curve is almost horizontal.

Ans. For A = 30 to 120 (A is mass number)

51. What is the ratio of nuclear densities of the two nuclei having mass numbers in the ratio 1 : 4?

Ans. 1 : 1 Because nuclear density is independent of mass number.

52. Draw a graph of number of undecayed nuclei to the time, for a radioactive nuclei.



53. Write an equation to represent α decay.

Ans. ${}^{A}_{Z}X \rightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}He + Q$

Atoms and Nuclie

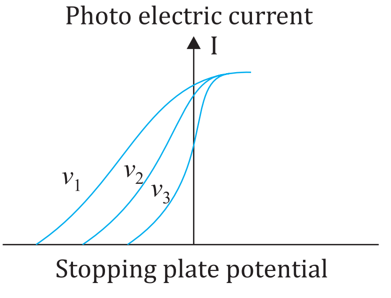
1. If a nucleus has mass defect 0.2 g. What will be its binding energy.
2. The Binding energy of helium nucleus is 28.17 max. Find its binding energy per nucleon.
3. Binding energy per nucleon for an element is 7.14 Mev. If the binding energy of the element is 28.6+ MeV. Calculate the no. of nucleons in the nucleus.
4. Calculate the mass defect of a helium nucleus. If its actual mass (atomic) is 4.001624 amu. The mass of one portion and one neutron together is 2.015941 amu.

VERY SHORT ANSWER QUESTIONS (1 Mark)

1. Illustrate by giving suitable examples, how you can show that electromagnetic waves carry both energy and momentum.
2. Define the term "threshold frequency", in the context of photoelectric emission.
3. Define the term "intensity" in photon picture of light.
4. Define intensity of radiation based on photon picture of light.
5. Plot a graph showing the variation of photoelectric current versus intensity of light.
6. Plot a graph of stopping potential (V_0) versus the frequency (v) of incident radiation in photoelectric emission.
7. Plot a graph of the de-Broglie wavelength associated with a photon versus its momentum.
8. Plot a graph of the de-Broglie wavelength associated with electron as a function of accelerating potential.
9. A proton is accelerated through a potential difference V, subjected to a uniform magnetic field acting normal to the velocity of the proton. If

the potential differences is doubled, how will the radius of the circular path described by the proton in the magnetic field change?

10. On the basis of the graphs shown in the figure, answer the following questions:

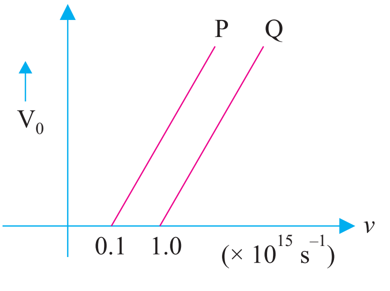


(*a*) Which physical parameter is kept constant for the three curves?

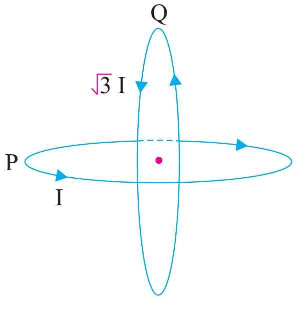
(*b*) Which is the highest frequency among, v_1, v_2 and v_3?

11. In the photoelectric emission, when the frequency of incident radiation is doubled, will the maximum kinetic energy of photoelectrons also be doubled? Justify your answer.

12. The figure shows the variation of stopping potential V_0 with the frequency v of the incident radiations for two photosensitive metals P and Q. Which metal has smaller threshold wavelength? Justify your answer.



13. Plot a graph of de-Broglie wavelength associated with electron as a function of its kinetic energy.



SHORT ANSWER QUESTIONS (2 Marks)

1. Write one similarity and one difference between matter wave and an electromagnetic wave.

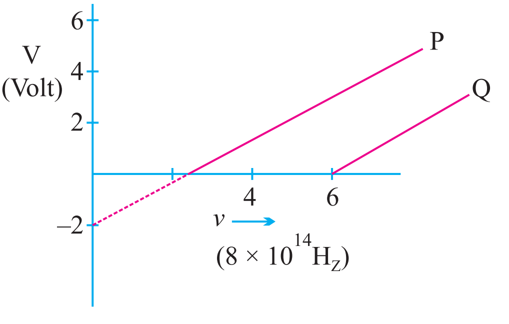
2. Does a photon have a de-Broglie wavelength? Explain.

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. Represent graphically Variation of the de-Broglie wavelength with linear momentum of a particle.

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. Explain the terms stopping potential and threshold frequency.

11. How does the maximum kinetic energy of emitted electrons vary with the increase in work function of metals?

12. Define distance of the closest approach. An α-particle of kinetic energy 'K' is bombarded on a thin gold foil. The distance of the closest approach is '*r*'. What will be the distance of closest approach for an α-particle of double the kinetic energy?

13. An a particle and a proton are accelerated by same potential. Find ratio fo their de Broglie wavelengths. **Ans.** $[1:2\sqrt{2}]$

14. Which of the following radiations α, β and γ are :
    (i) similar to x-rays?
    (ii) easily absorbed by matter
    (iii) travel with greatest speed?
    (iv) similar to the nature of cathode rays?

15. Some scientist have predicted that a global nuclear war on earth would be followed by 'Nuclear winter'. What could cause nuclear winter?

16. 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?

17. In the ground state of hydrogen atom orbital radius is 5.3×10^{-11} m. The atom is excited such that atomic radius becomes 21.2×10^{-11} m. What is the principal quantum number of the excited state of atom?

18. Calculate the percentage of any radioactive substance left undecayed after half of half life.

19. Why is the density of the nucleus more than that of atom?

20. 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?

21. What is the effect on neutron to proton ratio in a nucleus when β^- particle is emitted ? Explain your answer with the help of a suitable nuclear reaction.

22. Why must heavy stable nucleus contain more neutrons than protons?

23. 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 = – Nλ.

24. What is a nuclear fusion reaction? Why is nuclear fusion difficult to carry out for peaceful purpose?

25. Write two characteristic features of nuclear forces which distinguish them from coulomb force.

26. 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'?

27. Derive $mvr = \frac{nh}{2\pi}$ using de-Broglie equation.

28. Draw graph of number of scattered particles to scattering angle in Ratherford's experiment.

29. If the energy of a photon is 25 eV and work function of the material is 7eV, find the value of slopping potential.

30. What is the shortest wavelength present in the (i) Paschen series (ii) Balmer series of spectral lines?

Ans. (i) 820nm, (ii) 365 nm

31. 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. [**Hint:** $r = n^2 r_0$)

32. The ground state energy of hydrogen atom is –13.6 eV. What are the kinetic and potential energies of the electron in this state?

[**Hint :** K.E = – (T.E), P.E. = 2T.E]

33. Why is the wave nature of matter not more apparent to our daily observations ?

34. 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 $= \frac{\text{Mass of nucleus}}{\text{Volume of nucleus}}$

$$= \frac{mA}{\frac{4}{3}\pi R^3} = \frac{mA}{\frac{4}{3}\pi R_0^3 A}$$

$$= \frac{m}{\frac{4}{3}\pi R_0^3} = 2.3 \times 10^{17}\ \text{kg / m}^3$$

$$= \text{Constant}$$

35. Find the energy equivalent of one atomic mass unit in joules and then in MeV.

Ans. E = Δmc^2 $\Delta m = 1.6605 \times 10^{-27}$ kg

$$= 1.6605 \times 10^{-27} \times (3 \times 10^8)^2$$

$$= 1.4924 \times 10^{-4} \text{J}$$

$$= \frac{1.4924 \times 10^{-10}}{1.6 \times 10^{-19}} eV$$

$$= 0.9315 \times 10^9 \text{ eV}$$

$$= 931.5 \text{ MeV}$$

36. Write four properties of nuclear force.

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. Light of intensity I and frequency v is incident on a photosensitive surface and causes photoelectric emission. Justify with the help of graph, the effect on photoelectric current when

(i) the intensity of light is gradually increased

(ii) the frequency of incident radiation is increased

(iii) the anode potential is increased

In each case, all other factors remain the same.

5. Write Einstein's photoelectric equation. State Clearly the three salient features observed in photoelectric effect which can be explained on the basis of the above equation.

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 λ 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 $\sqrt{\frac{h\lambda}{2mc}}$.

Ans. $E = \frac{hc}{\lambda} = \frac{P^2}{2m} \therefore P = \sqrt{\frac{2mnc}{\lambda}}, \lambda_e = \frac{h}{P} = \sqrt{\frac{h\lambda}{2mc}}$

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

9. Give one example of a nuclear reaction. Also define the Q-value of the reaction. What does $Q > 0$ signify?

10. 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.

11. Define the term half life period and decay constant. Derive the relation between these terms.

12. State the law of radioactive decay. Deduce the relation $N = N_0 e^{-\lambda t}$, where symbols have their usual meaning.

13. Give the properties of α-particles, β-particles and γ-rays.

14. With the help of one example, explain how the neutron to proton ratio changes during alpha decay of a nucleus.

15. Distinguish between nuclear fusion and fission. Give an example of each.

16. A radioactive nucleus A undergoes a series of decays according to following scheme

$$A \xrightarrow{\alpha} A_1 \xrightarrow{-\beta} A_2 \xrightarrow{\alpha} A_3 \xrightarrow{\gamma} A_4$$

The mass number and atomic number of A_4 are 172 and 69 respectively. What are these numbers for A ?

Ans. Mass no. of A = 180, Atomic no. of A = 72

17. 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.

$$E = \frac{-e^2}{8\pi\varepsilon_0 r}$$

18. Draw energy level diagram for hydrogen atom and show the various line spectra originating due to transition between energy levels.

19. 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.

(ii) When P.E. at ∞ is + 0.5 eV, P.E. of first excited state will be – 3.4 – (– 0.5) = – 2.9 eV.

20. What is beta decay? Write an equation to represent β^- and β^+ decay. Explain the energy distribution curve is β decay.

21. Using energy level diagram show emission of γ rays by ${}^{60}_{27}\mathrm{Co}$ nucleus and subsequent β decay to obtain ${}^{60}_{28}\mathrm{Ni}$.

LONG ANSWER QUESTIONS (5 Marks)

1. State Bohr's postulates. Using these postulates, derive 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. What is meant by nuclear fission and fusion. Draw Binding Energy Vs Mass Number curve and explain four important features of this curve.

5. Briefly explain Rutherford's experiment for scattering of α particle with the help of a diagram. Write the conclusion made and draw the model suggested.

NUMERICALS

1. Ultraviolet light of wavelength 350 nm and intensity 1 W/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.

$$E_{Kmax} = 1.3\ \text{eV};\ n = 8.8\times10^{11}\,\frac{\text{photo electron}}{\text{second}}\ \text{or}\ {}_r = \frac{Nh\nu}{t} = nh\nu$$

2. A metal surface illuminated by 8.5 × 10^{14} Hz light emits electrons whose maximum energy is 0.52 eV the same surface is illuminated by 12.0 × 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 × 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 × 10^6 m/s; (b) 5.92 × 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)

Long Answer Question :

6. (A) Why wave theory of light could not explain the photoelectric effect? State two reasons. Draw graph between

(i) frequency ν vs stopping potential V_0.

(ii) Intensity vs photoelectric current.

(iii) anode potential vs photoelectric current.

6.(B) A proton is accelerated through a potential difference V. Find the percentage increase or decrease in its de-Broglie 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 5.6×10^{-10}m?

Ans.

$$\sqrt{2m_n \times \text{K.E.}} = \frac{h}{\lambda}$$

$$\Rightarrow \quad \text{K.E.} = \left(\frac{h}{\lambda}\right)^2 \frac{1}{2m_n}$$

$$= \left(\frac{6.625 \times 10^{-34}}{5.6 \times 10^{-10}}\right)^2 \frac{1}{2 \times 1.67 \times 10^{-27}}$$

$$= 3.35 \times 10^{-21}\text{J}$$

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,

$$\frac{M}{3}v_1 + \frac{2M}{3}v_2 = 0$$

or

$$\left|\frac{M}{3}v_1\right| = \left|\frac{2M}{3}v_2\right|$$

$$\lambda = \frac{h}{mv} \Rightarrow \left|\frac{\lambda_1}{\lambda_2}\right| = \left|\frac{2\frac{M}{3}v_2}{\frac{M}{3}v_1}\right| = 1$$

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.

$$E_e = \frac{1}{2}m_e v_e^2$$

and

$$E_p = \frac{1}{2}m_p v_p^2$$

$$\Rightarrow \quad m_e v_e = \sqrt{2E_e m_e} \text{ and } m_p v_p = \sqrt{2E_p m_p}$$

But, $E_e = E_p \Rightarrow \frac{\lambda_e}{\lambda_p} = \sqrt{\frac{m_p}{m_e}} > 1$

$\therefore \quad \lambda_e > \lambda_p.$

10. The electron in a given Bohr orbit has a total energy of –1.51 eV. Calculate the wavelength of radiation emitted, when this electon makes a transition to the ground state.

Ans. 1028 A°

11. Calculate the radius of the third Bohr orbit of hydrogen atom and energy of electron in third Bohr orbit of hydrogen atom.

Ans. (–1.51 eV)

12. Calculate the longest and shortest wavelength in the Balmer series of Hydrogen atom. Rydberg constant = $1.0987 \times 10^7\ m^{-1}$.

Ans. λ_l = 6553 A°, λ_s = 3640A°

13. What will be the distance of closest approach of a 5 MeV a-particle as it approaches a gold nucleus? (given Atomic no. of gold = 79)

Ans. 4.55×10^{-14}m

14. A 12.5 MeV alpha – particle approaching a gold nucleus is deflected 180°. What is the closest distance to which it approaches the nucleus?

Ans. 1.82×10^{-14}m

15. Determine the speed of the electron in $n = 3$ orbit of hydrogen atom.

Ans. $7.29 \times 10^5 ms^{-1}$

16. 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. 4×10^6

17. The half life of a radioactive substance is 5 hours. In how much time will 15/16 of the material decay?

Ans. 20 hours

18. At a given instant, there are 25% undecayed radioactive nuclei in a sample. After 10 seconds, the number of undecayed nuclei reduces 12.5%. Calculate the mean life of nuclei.

Ans. 14.43

19. 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.

20. 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

21. Is the fission of iron ($_{26}Fe^{56}$) into ($_{13}Al^{28}$) as given below possible?

$_{26}Fe^{56} \rightarrow {}_{13}Al^{28} + {}_{13}Al^{28} + Q$

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

22. Find the maximum energy that β-particle may have in the following decay :

$_8O^{19} \rightarrow {}_9F^{19} + {}_{-1}e^0 + \vec{v}$

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

23. The value of wavelength in the lyman series is given as

$$\lambda = \frac{913.4n_i^2}{n_i^2 - 1} \text{ Å}$$

Calculate the wavelength corresponding to transition from energy level 2, 3 and 4. Does wavelength decreases or increase.

Ans.

$$\lambda_{21} = \frac{913.4 \times 2^2}{2^2 - 1} = 1218 \text{ Å}$$

$$\lambda_{31} = \frac{913.4 \times 3^2}{3^2 - 1} = 1028 \text{ Å}$$

$$\lambda_{41} = \frac{913.4 \times 4^2}{4^2 - 1} = 974.3 \text{ Å}$$

$\lambda_{41} < \lambda_{31} < \lambda_{21}$

24. The half life of $^{238}_{92}U$ undergoing α decay is 4.5×10^9 years what is the activity of 1g. sample of $^{238}_{92}U$.

Ans.

$$T_{1/2} = 4.5 \times 10^9 \; y$$
$$= 4.5 \times 10^9 \times 3.16 \times 10^7 s$$
$$= 1.42 \times 10^{17} \; s$$

$$1g \text{ of } ^{238}_{92}U \text{ contains} = \frac{1}{238} \times 6.025 \times 10^{23} \text{ atom}$$
$$= 25.3 \times 10^{20} \text{ atoms}$$

$\therefore$

$$\text{decay rate} = R = \lambda N = \frac{0.693}{T} \times N$$
$$= \frac{0.693 \times 25.3 \times 10^{20}}{1.42 \times 10^{17}} s^{-1}$$
$$= 1.23 \times 10^4 \text{ bq.}$$

Answer to 2 Marks Question

1. Similarity : Both follow wave equation (partial differential equation)
dissimilarity : Matter waves
(a) cannot be radiated in empty space.
(b) are associated with the particles, not emitted by it

2. Yes, $\lambda = \frac{hc}{E}$

3. $\lambda = \frac{h}{p}$ for photon $P = \frac{E}{C}$ and $\lambda = \frac{hc}{E}$ for electron $P = \sqrt{2M\;E}$

$\lambda_{photon} = 2.4 \times 10^{-8}$m, $\lambda_{electron} = 3.6 \times 10^{-10}$m

4. $\lambda = 3300A^o$, $E = \frac{hc}{\lambda} = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{3300 \times 10^{-10} \times 1.6 \times 10^{-19}} eV \approx 3.8$ eV

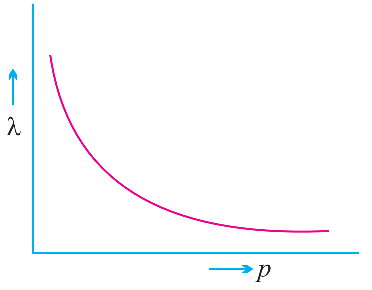
Work function of M_o & Ni > 3.8 eV hence no photoelectron emission from M_o and Ni.

5.

$$\lambda = \frac{h}{p}$$

$\Rightarrow$

$$\lambda \; \alpha \; \frac{1}{p}$$



6. Q

K.E.$_{max}$ ≈ 1.3 eV   As $\frac{h\nu_0}{e} = -2V$

7. $E = mc^2$, $h\nu = mc^2$, $m = \frac{h\nu}{c^2}$, no, it depends upon frequency.

8. $KE = h\nu - h\nu_0$. The electrons in the atom of metal occupy different energy levels, thus have different minimum energy required to be 'ejected' from the atom. So the e^- with higher energy will have higher kinetic energy.

9. Decreases, $\lambda = \frac{1}{\sqrt{V}} \therefore \frac{\lambda_1}{\lambda_2} = \frac{2\sqrt{2}}{1}$

11. $KE_{max} = h\nu - w_0 \Rightarrow KE_{max}$ decreases with increase in w_0.

12. Distance of closest approach is defined as the minimum distance between the charged particle and the nucleus at which initial kinetic energy of the particle is equal to electrostatic potential energy.

for α particle, $\frac{K\,Ze(2e)}{r} = \frac{1}{2} m v_\alpha^2$

$$r \propto \frac{1}{\text{K.E.}}$$

∴ r will be halved.

14. (i) Similar to x-rays — γ-rays.

(ii) α-particle.

(iii) γ-rays.

(iv) β-particle.

15. Nuclear radioactive waste will hang like a cloud in the earth atmosphere and will absorb sun radiations.

16. The total binding energy of nuclei on two sides need not be equal. The difference in energy appears as the energy released or absorbed.

17. $n = 2$ as $r_n \alpha\ n^2$

18. From relation $\frac{N}{N_0} = \left(\frac{1}{2}\right)^{t/T}$ when $t = T/2$

$$\frac{N}{N_0} = \left(-\right)^{1/2}$$

or $$\frac{N}{N_0} = \frac{1}{\sqrt{2}} = \frac{100}{\sqrt{2}} = 70.9\ \%$$

19. Because radius of atom is very large than radius of nucleus.

20. Due to mass defect or different binding energies.

21. Decreases as number of neutrons decreases and number of protons increases. $N \rightarrow P + {}_{-1}e^0$

22. To counter repulsive coulomb forces, strong nuclear force required between neutron-neutron, neutron-proton and proton-proton.

23. $N = N_0 e^{-\lambda t}$ differentiating both sides we get $\frac{dN}{dt} = -\lambda N_0 e^{-\lambda t} = -\lambda N$ *i.e.*, decay rate

$$R = -\frac{dN}{dt} = \lambda N$$

24. 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.

25. Nuclear forces are short range forces (within the nucleus) and do not obey inverse square law while coulomb forces are long range (infinite) and obey inverse square law.

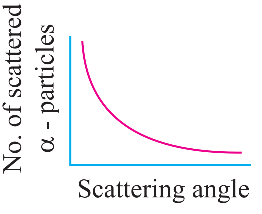
26. $$\left(\frac{A}{8A}\right) = \left(\frac{1}{2}\right)^{t/T_{1/2}}$$

or $$\left(\frac{1}{2}\right)^{3} = \left(\frac{1}{2}\right)^{t/3}$$

or $$3 = \frac{t}{3}$$

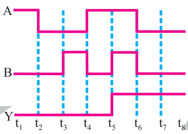
$\Rightarrow$ $$t = 9 \text{ days.}$$

28.



29. $$V_0 = (E - \phi_0)/e = \frac{(25-7)eV}{e} = 18V.$$

❑❑



Unit IX

Electronic Devices

Unit IX
ELECTRONIC DEVICES

KEY POINTS

ELECTRONIC DEVICES

1. Solids are classified on the basis of

(i) **Electrical conductivity**	**Resistivity**	**Conductivity**
Metals	$\rho(\Omega m)$	$\sigma(Sm^{-1})$
	$10^{-2} - 10^{-8}$	$10^{2} - 10^{8}$
Semi-conductors	$10^{-5} - 10^{6}$	$10^{-6} - 10^{5}$
Insulators	$10^{11} - 10^{19}$	$10^{-19} - 10^{-11}$

(ii) Energy Bands **(a) Metals →**

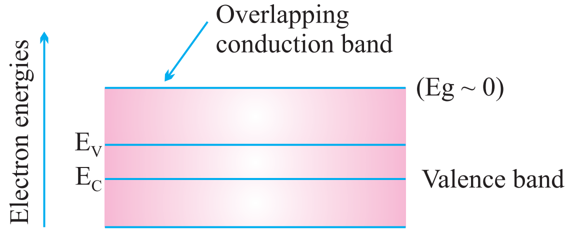


Fig. (*a*)

(b) Insulators →

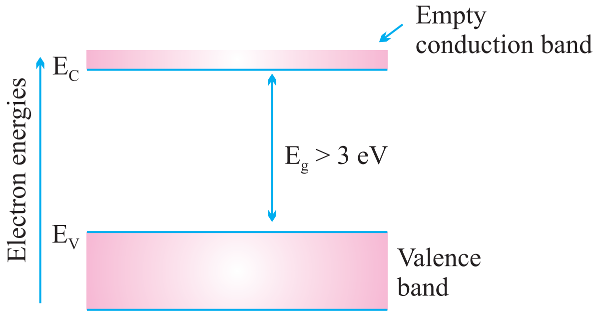


Fig (*b*)

(c) Semiconductors →

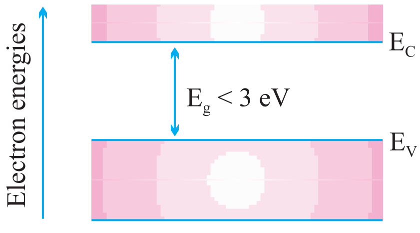


Fig (*c*)

2. Types of Semi-conductors

2 Types of semi-conductors

- Elemental: Si, Ge
- 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 (accestor) atom (In, Ga, Ag, etc) doped with Si or Ge give *p*-type semiconductor. In *n*-type semiconductor electrons are the majority charge carriers & in *p*-type holes are the majority charge carriers.

6. Net charge in *p*-type or *n*-type semiconductor remains zero.

7. Diffusion and drift are the two processes that occur during formation of *p-n* junction.

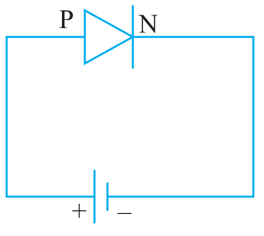
8. Diffusion current is due to concentration gradient and drift current is due to electric field.

9. In depletion region movement of electrons and holes depleted it of its free charges.

10. *p-n* Junction is the most important semiconductor device 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.

Differences between FB and RB junction diodes :

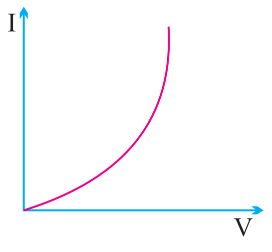
Forward Bias



Depletion layer is decreased

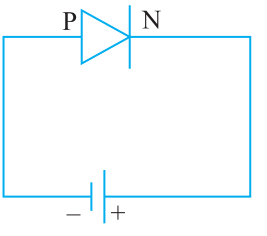
Lower resistance

$R \rightarrow 0$ ideal diode



Current due to majority charge carrier.

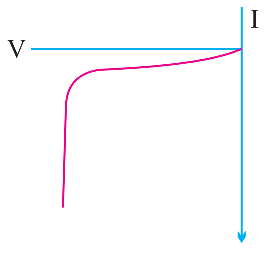
Reverse Bias



Depletion layer is increased

Higher resistance

$R \rightarrow \infty$ ideal diods

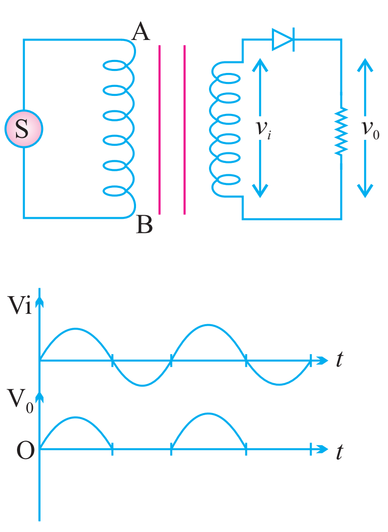


Current due to minority charge carrier.

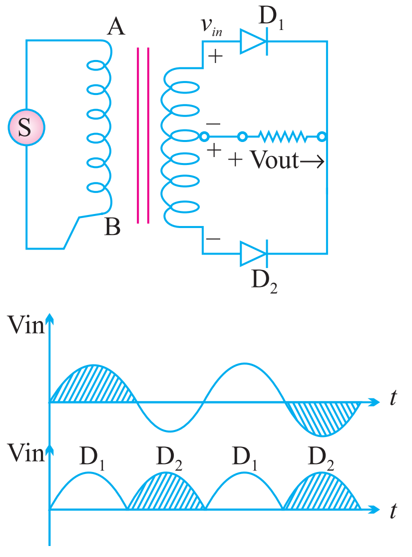
11. In half wave rectifier frequency output pulse is same as that of input and in full wave rectifier frequency of output is double of input.

Rectifier p-n junction diode

Half Wave Rectifier



Full Wave Rectifier



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.

QUESTIONS

VERY SHORT ANSWER QUESTIONS

1. Name the process involved in the formation of *p-n* junction diode. [Drift and Diffusion]
2. Name three processes involved in the formation of solar cell. [generation, separation and collection]
3. Distinguish between intrisic and extrinsic semiconductors on the basis of energy band diagrams.
4. How does energy gap in intrinsic semiconductor vary when it is doped with a(i) pentavalent impurity (ii) trivalent impurity?
5. Which type of extrinsic semiconductor has more mobility and why?

6. Name the factors which determines (i) frequency and (ii) intensity of light emitted by LED. [(i) Bandgap (ii) doping]

7. How does the width of depletion region of a *p-n* junction diode change with decrease in reverse bias?

8. What is the direction of diffusion current in a function diode? [*p-n*]

9. Zener diode has higher dopant density as compared to ordinary *p-n* function diode. How does it effect (i) width of deflection layer and (ii) function field.

[(i) ↓ (ii) ↑ as $E_\beta = \frac{V_B}{d}$]

10. How does the height of potential barrier vary with increase in temp. [↑]

11. Write the relation between number density of holes and number density of free electrons in an intrinsic semiconductor.

Ans. $n_e = n_h$

12. Write the value of resistance offered by an ideal diode when (i) forward based (ii) reverse biased.

Ans. (i) Zero (ii) infinite

13. Write any one use of (i) photodiode (ii) LED.

Ans. (i) Use of Photodiode
- (a) In detection of optical signal
- (b) In demodulation of optical signal
- (c) In light operated switches
- (d) In electronic counters

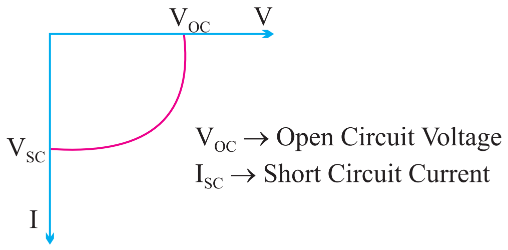
(ii) Use of LED
- (a) Infrared LEDs are used in burglar alarm
- (b) In optical communication
- (c) LED's are used as indicator lamps in radio receivers
- (d) In remote controls

14. A semiconductor is damaged when strong current passes through it. Why ?

Ans. Because bonds break up, crystal lattice breakdown takes place and crystal lattice becomes useless.

15. Draw I–V characteristic of a solar cell.

Ans.



16. What is the direction of diffusion current in a junction diode ?

Ans. The direction of diffusion current is from P to N in a semiconductor junction diode.

17. Draw a circuit diagram showing the biasing of a photodiode.

18. Name the semiconductor device that can be used to regulate an unregulated dc power supply.

Ans. Zener diode

19. Name the *p-n* junction diode which emits spontaneous radiation when forward biased.

Ans. Light emitting diode (LED)

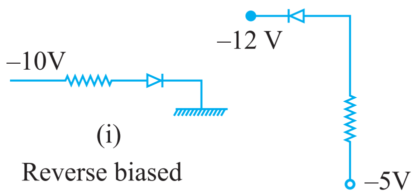
20. Name the material used to make a light emitting diode.

Ans. GaAs and GaP

21. 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.

Ans. P–N junction
(Junction Diode)

22. In the following diagram write which of the diode is forward biased and which is reverse biased ?



(i)
Reverse biased

(ii)
Forward biased

23. How does the energy gap in semiconductor vary, when doped, with a pentavalent impurity ?

Ans. The energy gap decreases.

19. What is the order of energy gap in a conductor, semiconductor and insulator.

Ans. Conductor–no energy gap

Semiconductor < 3 eV

Insulator > 3 eV

20. 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.

Ans. $\frac{n_e}{n_h} = 1 \Rightarrow n_e = n_h$ $\therefore$ Intrinsic semiconductor

$\frac{n_e}{n_h} < 1 \Rightarrow n_e < n_h$ $\therefore$ *p* type extrinsic semiconductor

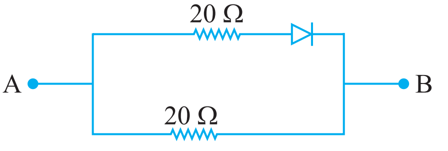
SHORT ANSWER QUESTIONS (2 MARKS)

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

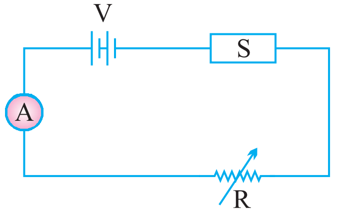


3. Potential barrier of *p-n.* junction cannot be measured by connecting a sensitive voltmeter across its terminals. Why ?

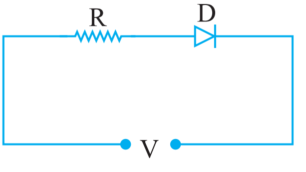
4. Diode is a non linear device. Explain it with the help of a graph.

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. 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 ?

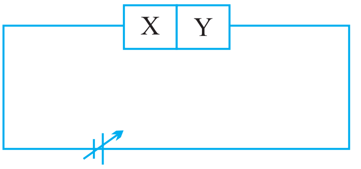


8. What are the characteristics to be taken care of while doping a semiconductor ? Justify your answer.

Ans. (a) The size of the dopent atom should be such that it do not distort the pure semiconductor labtice.
(b) It can easily contribute a charge carrier on forming covalent bond with pere Si or Ge.

9. 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.
10. Show the donor energy level in energy band diagram of *n*-type semiconductor.
11. Show the acceptor energy level in energy band diagram of *p*-type semiconductor.
12. What is the value of knee voltage in
    (a) Ge junction diode.
    (b) Si junction diode.
13. Describe the working principle of a solar cell. Mention three basic processes involved in the generation of emf.
14. Two semiconductor materials X and Y shown in the given figure, are made by doping germanium crystal with indium and arsenic respectively. The two

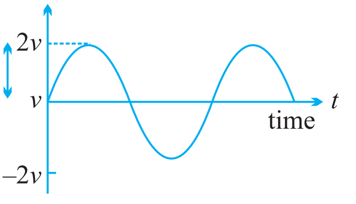
are joined at lattice level and connected to a battery as shown.



(i) Will the junction be forward biased or reversed biased ?

(ii) Sketch a V-I graph for this arrangement.

15. Following voltage waveform is fed into half wave rectifier that uses a silicon diode with a threshold voltage of 0.7 V. Draw the output voltage waveform.



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. What is rectification ? With the help of labelled circuit diagram explain half wave rectification using a junction diode.

3. With the help of a circuit diagram explain the V–I graph of a *p-n* junction in forward and reverse biasing.

4. What is *p-n* junction ? How is *p-n* junction made ? How is potential barrier developed in a *p-n* junction.

5. Give three differences between forward bias and reverse bias.

6. Show the biasing of a photodiode with the help of a circuit diagram. Draw graphs to show variations in reverse bias currents for different illumination intensities.

7. Write three differences between *n*-type semiconductor and *p*-type semiconductor.

LONG ANSWER QUESTIONS (5 MARKS)

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.

NUMERICALS

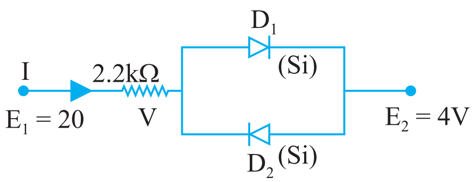
1. In a *p-n* junction, width of depletion region is 300 nm and electric field of 7×10^5 V/m exists in it.

(i) Find the height of potential barrier.

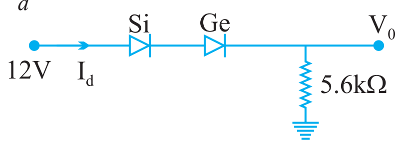
(ii) What should be the minimum kinetic energy of a conduction electron which can diffuse from the *n*-side to the *p*-side ?

2. 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 ? [**Ans.** $\lambda = 6.54 \times 10^{-7}$ m]

3. Determine the current I for the network. (Barrier voltage for Si diode is 0.7 volt).



4. Determine V_0 and I_d for the network.

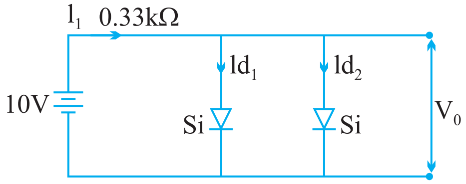


5. A *p-n* junction is fabricated from a semiconductor with a band gap of 2.8 eV. Can it detect a wavelength of 600 nm ? Justify your answer.

Ans. Eneryg of photon of wavelength 600 *n m* = 2.07 eV .... working condition of photodiode $h\nu$ £ Eg but Eg > $h\nu$ so photodio can not detecthe given wavelength

6. Determine V_0, I_{d1} and I_{d2} for the given network. Where D_1 and D_2 are made of silicon.

$$\left(I_{d_1} = I_{d_2} = \frac{I_1}{2} = 14.09 \text{ mA}\right)$$



Ans. $V_0 = V_{si} = 0.7V$

$$I_1 = \frac{10 - 0.7}{.33 \times 10^3}$$

$$= 28.18 \text{ mA}$$

$$\therefore \quad I_{d_1} = I_{d_2} = \frac{28.18}{2}$$

$$= 14.09 \ mA$$

7. 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. :** $5 \times 10^9 \ m^{-3}$]

8. 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.

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, As diode is forward biased

(ii) 20Ω, diode is reverse biased

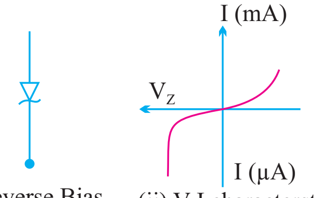
3. Because there is no free charge carrier in depletion region.

6. On heating S, resistance of semiconductors S is decreased so to compensate the value of resistance in the circuit R is increased.

9. In this case diode is sensitive and it is easier to observe fractional change in current with change in intensity.

16. (a) V (b) Zero

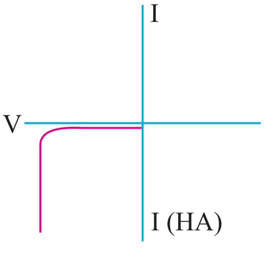
21. Zener diode



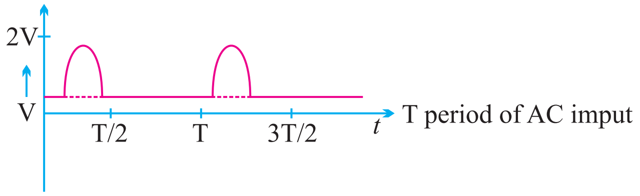
(i) Reverse Bias (ii) V-I characterstic

26. Ge ~ 0.3 V
Si ~ 0.7 V

29. (i) Reverse bias
(ii)



31. Output waveform is :



NUMERICALS

1. (i) $V = Ed = 7 \times 10^5 \times 300 \times 10^{-9} = 0.21$ V

(ii) Kinetic energy = eV = 0.21 eV

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. $V_0 = E - V_{si} - V_{Ge} = 12 - 0.7 - 1.1 = 12 - 1.8 = 10.2$ V

$$I_d = \frac{V_0}{R} = \frac{10.2}{5.6 \times 10^3} = 1.82 \text{ mA.} \quad V_0 = 12 - 0.7 - 0.3 = 11 \text{ V}$$

$$I_d = \frac{11}{5.6 \times 10^3} = 1.96 \text{ mA}$$