# LIBERTY PAPER SET

**STD. 12 : Physics**

**Full Solution**

**Time : 3 Hours** **ASSIGNMENT PAPER 10**

## Section A

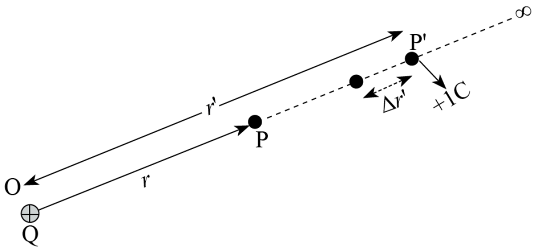
**1.** (A) **2.** (A) **3.** (D) **4.** (B) **5.** (A) **6.** (D) **7.** (C) **8.** (C) **9.** (C) **10.** (B) **11.** (B) **12.** (A) **13.** (A) **14.** (C) **15.** (D) **16.** (C) **17.** (C) **18.** (B) **19.** (D) **20.** (B) **21.** (A) **22.** (B) **23.** (A) **24.** (B) **25.** (D) **26.** (A) **27.** (D) **28.** (A) **29.** (A) **30.** (C) **31.** (D) **32.** (A) **33.** (A) **34.** (C) **35.** (C) **36.** (D) **37.** (B) **38.** (A) **39.** (D) **40.** (C) **41.** (B) **42.** (A) **43.** (A) **44.** (B) **45.** (D) **46.** (B) **47.** (A) **48.** (D) **49.** (A) **50.** (B)

**Section A**

➢ **Write the answer of the following questions : (Each carries 2 Mark)**

1.

➥




➥ As shown in fig., charge Q (Q > 0) is placed on the origin of the cartesian co-ordinates system. We want to find electric potential at some point P, having its position vector $\vec{r}$ from origin O. For this we should calculate work done by external force in bringing unit positive charge (test charge) from infinity to point P.

➥ Suppose, there is a point P' at distance $r'$ in between the path from infinity to P.

➥ Force on unit positive charge kept at point P' is

$$\vec{F'} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{Q}{r'^2} \cdot \hat{r}'$$

Where $\hat{r}'$ is the unit vector in the direction of $\overrightarrow{OP'}$.

➥ The work done against the (field) force in giving $\overrightarrow{\Delta r'}$ displacement to the unit positive charge,

$$\Delta W = -\frac{1}{4\pi\varepsilon_0} \cdot \frac{Q}{r'^2} \cdot \Delta r' \quad \dots (1)$$

➥

**Note ...**

To get the total work done by the external force, integration of all partial work(s) should be taken from $r' = \infty$ to $r' = r$.

➥ Total work

$$W = -\frac{Q}{4\pi\varepsilon_0} \int_{\infty}^{r} \frac{1}{r'^2} \cdot dr' \quad \left(\because \lim_{\Delta r \to 0}\right)$$

$$\therefore W = -\frac{Q}{4\pi\varepsilon_0} \left[\frac{r'^{-2+1}}{-2+1}\right]_{\infty}^{r}$$

$$\therefore W = -\frac{Q}{4\pi\varepsilon_0} \left[-\frac{1}{r'}\right]_{\infty}^{r}$$

$$\therefore W = -\frac{Q}{4\pi\varepsilon_0} \left(-\frac{1}{r} + \frac{1}{\infty}\right)$$

$$\therefore W = \frac{1}{4\pi\varepsilon_0} \cdot \frac{Q}{r}$$

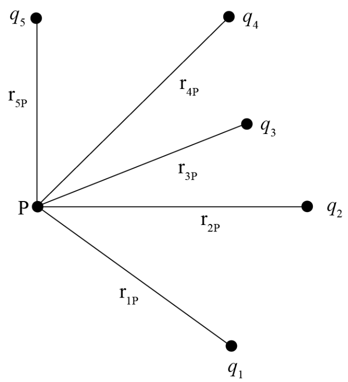
➥ As per definition, this work is called electric potential at point P due to electric charge Q.

$$V(r) = \frac{1}{4\pi\varepsilon_0} \cdot \frac{Q}{r}$$

➥ If Q < 0 is taken, V < 0 which means work done per unit negative test charge in bringing it from infinity to given point is negative.

➥ If Q > 0 is taken V > 0 which means work done per unit positive test charge in bringing it from infinity to given point is positive.

2.

➥ 


➥ A system of $n$ - electric charges is shown in the fig., with reference to the origin, their position vectors are $\vec{r_1}, \vec{r_2}, \vec{r_3} ..... \vec{r_n}$ and the electric charges are respectively $q_1, q_2, q_3 ..... q_n$.

➥ Electric potential at point $p$ due to charge $q_1$

$$V_1 = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1}{r_{1p}}$$

Where, $r_{1p}$ is the distance between $q_1$ and $p$.

➥ Similarly if potential at point $p$ due to charge $q_2$ is $V_2$ and potential at $p$ due to charge $q_3$ is $V_3$ then,

$$V_2 = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_2}{r_{2p}} \text{ and } V_3 = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_3}{r_{3p}}$$

Where, $r_{2p}$ is the distance between $q_2$ and $p$.

$r_{3p}$ is the distance between $q_3$ and $p$.

➥ Similarly we can get potential due to other electric charges

➥ So, the total (net) potential at point P as per the super position principle,

$$V = V_1 + V_2 + V_3 + ..... + V_n$$

$$V = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1}{r_{1p}} + \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_2}{r_{2p}} + \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_3}{r_{3p}} + ..... + \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_n}{r_{np}}$$

$$V = \frac{1}{4\pi\varepsilon_0}\left(\frac{q_1}{r_{1p}} + \frac{q_2}{r_{2p}} + \frac{q_3}{r_{3p}} + ..... + \frac{q_n}{r_{np}}\right)$$

$$V = \frac{1}{4\pi\varepsilon_0} \sum_{i=1}^{n} \frac{q_i}{r_{ip}}$$

3.

➥ Resistance of material

$$R = \frac{\varrho l}{A}$$

where $\varrho$ = resistivity of conductor

$$\therefore \varrho = \frac{RA}{l}$$

If we take A = 1 unit ($A = 1 m^2$) and $l$ = 1 unit ($l$ = 1 m) then $\varrho$ = R.

➥ Definition : Resistance of a conductor having unit cross- sectional area and unit length is called resistivity.

- The magnitude of resistivity depends on the type of material and temperature but it does not depend on the dimensions of material.
- The unit of resistivity is Ω m and its dimensional formula $M^1L^3T^{-3}A^{-2}$.

4.

- $m = 1.5$ J/T

  B = 0.22 T

  (a) (i) Work required to be done in aligning magnetic moment perpendicular to the magnetic field, $(W_1)$

  - Here $\theta_1 = 0$ and $\theta_2 = \frac{\pi}{2}$ rad.
  - Work required to be done in taking the magnet from angle $\theta_1$ to $\theta_2$,

  $W_1 = mB\,(\cos\theta_1 - \cos\theta_2)$

  $W_1 = (1.5) \times (0.22)\,(\cos 0 - \cos\frac{\pi}{2})$

  $W_1 = (0.33)\,(1 - 0)$

  $W_1 = 0.33$ J

  (ii) Work required to be done in aligning the magnetic moment in the direction opposite to the magnetic field $(W_2)$

  - Here, $\theta_1 = 0$ and $\theta_2 = \pi$ rad
  - Work required to be done on magnet in this case, $(W_2)$

  $W_2 = mB\,(\cos\theta_1 - \cos\theta_2)$,

  $W_2 = (1.5) \times (0.22)\,(\cos 0 - \cos\pi)$

  $W_2 = (0.33)\,(1 - (-1))$

  $W_2 = (0.33)\,(2)$

  $= 0.66$ J

  (b) (i) When the magnetic moment is arranged perpendicular to the magnetic field, torque acting on it will be,

  From, $\tau_1 = mB\sin\theta$,

  Here, $\theta = \frac{\pi}{2}$

  $\therefore \tau_1 = (1.5) \times (0.22)\sin\frac{\pi}{2}$

  $\therefore \tau_1 = (0.33)\,(1)$

  $\therefore \tau_1 = 0.33$ Nm

  (ii) Torque acting on the magnet when the dipole moment is arranged in the direction opposite to the magnetic field,

  From $\tau_2 = mB\sin\theta$,

  Here, $\theta = \pi$.

  $\therefore \tau_2 = (1.5) \times (0.22)\sin\pi$

  $\therefore \tau_2 = (0.33)\,(0)$

  $\therefore \tau_2 = 0$

5.

- $\Delta t = 0.1$ sec

  $I_1 = 5$ A $\Delta I = -5$A

$I_2 = 0$ A

$< \varepsilon > = 200$ V

L = ?

➥ Average induced *emf* for the circuit

$$< \varepsilon > = -L \frac{\Delta I}{\Delta t}$$

$$\therefore 200 = -L\left(-\frac{5}{0.1}\right)$$

$\therefore 200 = 50$ L

$\therefore L = 4$ H

6.

➥ $B_y = 2 \times 10^{-7} \sin (0.5 \times 10^3 x + 1.5 \times 10^{11} t)$ T

Comparing with $B_y = B_0 \sin (kx + \omega t)$

$$B_0 = 2 \times 10^{-7} \text{ T } k = 0.5 \times 10^3 \frac{\text{rad}}{\text{m}},$$

$$\omega = 1.5 \times 10^{11} \frac{\text{rad}}{\text{s}}$$

➥ (a) (i) Wavelength of the wave ($\lambda$)

$$k = 0.5 \times 10^3 \frac{\text{rad}}{\text{m}}$$

$$\frac{2\pi}{\lambda} = 0.5 \times 10^3$$

$$\therefore \lambda = \frac{2 \times 3.14}{0.5 \times 10^3}$$

$\therefore \lambda = 12.56 \times 10^{-3}$ m

$\therefore \lambda = 1.256$ cm

(ii) Frequency ($v$)

$$\omega = 1.5 \times 10^{11} \frac{\text{rad}}{\text{s}}$$

$\therefore 2\pi v = 1.5 \times 10^{11}$

$$\therefore v = \frac{1.5 \times 10^{11}}{2 \times 3.14}$$

$\therefore v = 0.2388 \times 10^{11}$ Hz

$\therefore v = 23.9$ GHz

(b) Amplitude of the Electric field ($E_0$)

From $\dfrac{E_0}{B_0} = c$

$E_0 = B_0 c = 2 \times 10^{-7} \times 3 \times 10^8$

$$E_0 = 60 \frac{\text{V}}{\text{m}}$$

➠ Component of electric field will be perpendicular to both the direction of wave propogation and to the magnetic field. Hence, component of given electric field will be in the direction of Z-axis.

➠ Equation of Electric Field,

$E_Z = E_0 \sin (kx + \omega t)$

$$E_Z = 60 \sin (0.5 \times 10^3 x + 1.5 \times 10^{11} t) \frac{\text{V}}{\text{m}}$$

7.

- $u = -100$ cm

  $\upsilon = ?$

  R = + 20 cm

  $n_1 = 1$

  $n_2 = 1.5$

- The formula for refraction near a refracting surface,

$$-\frac{n_1}{u} + \frac{n_2}{\upsilon} = \frac{n_2 - n_1}{R}$$

$$\therefore -\frac{1}{-100} + \frac{1.5}{\upsilon} = \frac{1.5 - 1}{20}$$

$$\therefore \frac{1}{100} + \frac{1.5}{\upsilon} = \frac{0.5}{20}$$

$$\therefore \frac{1.5}{\upsilon} = \frac{0.5}{20} - \frac{1}{100}$$

$$\therefore \frac{1.5}{\upsilon} = \frac{2.5 - 1}{100}$$

$$\therefore \frac{1.5}{\upsilon} = \frac{1.5}{100}$$

$$\therefore \upsilon = 100 \text{ cm}$$

- The image is formed at a distance of 100 cm from the glass surface in the direction of incident light.

8.

- Constructive Interference :
  - If we have two coherent sources $S_1$ and $S_2$ vibrating in phase, then for an arbitrary point P, whenever the path difference,

    $S_1P \sim S_2P = n\lambda$ ($n = 0, 1, 2, 3, ...$)

    we will have maximum intensity ($I = 4\ I_0$) at the given point, which means we will have constructive interference.

    [The sign ~ between $S_1P$ and $S_2P$ represents the difference between $S_1P$ and $S_2P$.]

- Destructive Interference :
  - When two coherent sources ($S_1$ and $S_2$) are vibrating in phase, and if the point P is such that the path difference

$$S_1P \sim S_2P = \left(n + \frac{1}{2}\right)\lambda$$

$$\left(\text{OR } S_1P \sim S_2P = (2n + 1)\frac{\lambda}{2}\right)$$

(where, $n = 0, 1, 2, 3 ...$)

We will have destructive interference and the resultant intensity will be zero.

9.

- Work function of metal $\varphi_0 = 4.2\ eV$

  wave length $\lambda = 330$ nm

- energy of photon

$$E = h\nu = \frac{hc}{\lambda}$$

$$\therefore E = \frac{6.625 \times 10^{-34} \times 3 \times 10^{8}}{330 \times 10^{-9}}$$

$$\therefore E = 0.06022 \times 10^{-17}$$

$$\therefore E = 6.022 \times 10^{-19} \text{ J}$$

$\therefore E = \dfrac{6.022 \times 10^{-19}}{1.6 \times 10^{-19}}\ eV$

$E = 3.76\ eV$

➥ But here E (3.76 $eV$) < $\varphi_0$ (4.2 $eV$).

➥ Therefore, electrons will not be emitted from the metal.

10.

➥ According to the third postulate of Bohr's model, when an atom makes a transition from the higher energy state with quantum number $n_i$ to the lower energy state with quantum number $n_f$ ($n_f < n_i$), the difference of energy is carried away by a photon of frequency $v_{if}$ such that

$h\, v_{if} = E_{ni} - E_{nf}$

➥ Since both $n_f$ and $n_i$ are integers, this shows that in transitions between different atomic levels, light is radiated in various discrete frequencies.

➥ The various lines in the atomic spectra are produced when electrons jump from higher energy state to a lower energy state and photons are emitted. These spectral lines are called emission lines.

➥ On the other hand, when an atom absorbs a photon that has the same energy needed by the electron in a lower energy state to make transitions to a higher energy state, the process is called absorption.

➥ Thus, if photons with a continuous range of frequencies pass through a rarefied gas and then are analysed with a spectrometer, a series of dark spectral absorption lines appear in the continuous spectrum. The dark lines indicate the frequencies that have been absorbed by the atoms of the gas.

11.

➥ Nucleus of $^{14}_{7}N$ has

7 protons and 14 – 7 = 7 neutrons.

➥ Mass defect $\Delta M = (Zm_p + Nm_n) - m(^{14}_{7}N)$

$\therefore \Delta M = (7 \cdot 1.007825 + 7 \cdot 1.008665) - 14.00307$

$\therefore \Delta M = [7.054775 + 7.060655 - 14.00307]$

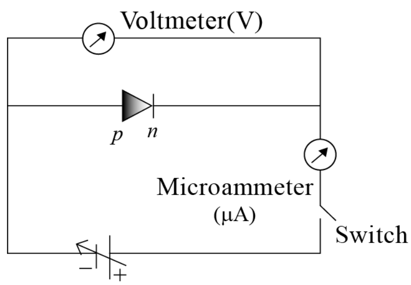
$\therefore \Delta M = 0.11236\ u$

➥ Binding energy $E_b = \Delta M\, c^2$

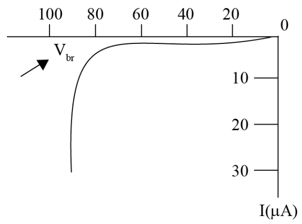
$E_b = 0.11236 \cdot 931.5$

$E_b = 104.7\ MeV$

12.




(a)




(b)

- The circuit arrangement for studying the V-I characteristics of a diode in Reverse bias is shown in the figure.
- As shown the battery is connected to the diode through a potentiometer (or rheostat) so that the applied voltage to the diode can be changed.
- For different values of voltages, the value of the current is noted, and as shown in fig (b), a graph of $V \rightarrow I$ is obtained. The current obtained in the reverse bias is of the order of micro ampere, ($\propto$A). This current is known as reverse saturation current.
- For the diode in reverse bias, the current is very small and almost remains constant (increases very slowly) with change in bias.
- Beyond a particular value of characteristic voltage, diode current changes/increases suddenly with small change in voltage. The reverse voltage, at which this phenomenon is seen is called Breakdown voltage.
- In reverse bias, after the breakdown occurs, voltage almost remains constant. Regulator circuits are prepared using this characteristic of a diode.
- In reverse bias mode, the dynamic resistance of $p$ - $n$ junction is of the order of $10^6\ \Omega$ (M$\Omega$).

## Section B

➢ **Write the answer of the following questions : (Each carries 3 Mark)**

13.

- Here, the magnitude of the attraction or repulsion force acting between any two charges will be same,

  and the value of the force will be :

$$F = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q^2}{l^2}$$

$$= |\overrightarrow{F_{12}}| = |\overrightarrow{F_{21}}| = |\overrightarrow{F_{13}}|$$

$$= |\overrightarrow{F_{31}}| = |\overrightarrow{F_{23}}| = |\overrightarrow{F_{32}}|$$

- The net force acting on charge $q$ placed at A,

$$F_1 = \sqrt{F_{12}^2 + F_{13}^2 + 2F_{12}F_{13}\cos 120°}$$

Put $F_{12} = F_{13} = F$

$$F_1 = \sqrt{F^2 + F^2 + 2F^2\left(-\frac{1}{2}\right)}$$

$$\therefore F_1 = \sqrt{F^2 + F^2 - F^2} = F$$

$$\therefore F_1 = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q^2}{l^2}$$

(The direction of this force will be parallel to B to C direction.)

- Now, the net force acting on charge $q$, placed at B,

$$F_2 = \sqrt{F_{21}^2 + F_{23}^2 + 2F_{21} \cdot F_{23}\cos 120°}$$

Put $F_{21} = F_{23} = F$

$$F_2 = \sqrt{F^2 + F^2 + 2\,F^2\left(-\frac{1}{2}\right)}$$

$$F_2 = \sqrt{F^2 + F^2 - F^2}$$

$$F_2 = F = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q^2}{l^2}$$

(The direction of this force will be parallel to A to C direction, as shown in Fig.)

- Now, the net force acting on charge $-q$, placed at C,

$$F_3 = \sqrt{F_{31}^2 + F_{32}^2 + 2F_{31} \cdot F_{32} \cos 60}$$

Put $F_{31} = F_{32} = F$

$$\therefore F_3 = \sqrt{F^2 + F^2 + 2F^2\left(\frac{1}{2}\right)}$$

$$\therefore F_3 = \sqrt{F^2 + F^2 + F^2} = \sqrt{3}\,F$$

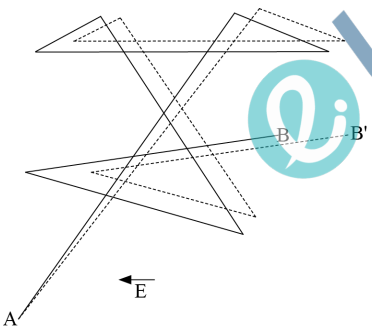
(The direction of this force will be down and perpendicular to AB)

$$\therefore F_3 = \frac{\sqrt{3}}{4\pi\varepsilon_0} \cdot \frac{q^2}{l^2}$$

14.

- A conducting material (conductor) consists of free electrons and positive ions situated at lattice points. (Free electrons cannot escape from the metals)
- The free electrons in the conductor move randomly in the space between the positive ions and during this motion they collide with ions. After collision they move in random (any) directions with same speed.
- If we consider all the electrons, due to their motion in random direction their average velocity will be zero.
- This, if there are N electrons and the velocity of the $i^{th}$ electron ($i = 1, 2, 3, \ldots N$) at a given time is $\vec{V}_i$ then

$$\frac{1}{N} \sum_{i=1}^{N} \vec{V}_i = 0 \ldots (1)$$




- Now, when an electric field is applied to a conductor, electrons will be accelerated due to this field.
- The acceleration.

$$\vec{a} = \frac{-e\vec{E}}{m} \ldots (2)$$

where $-e$ is the charge of electron $m$ is mass of an electron and $\vec{E}$ is applied electric field.

- Suppose that $t_i$ time passed after an electron collides with a positive ion.
- The velocity of an electron after collision with a positive ion is $\vec{\upsilon}_i$
- $\vec{V}_i$ the velocity of the electron at time $t_i$ is given by the following formula can be

$$\vec{V}_i = \vec{\upsilon}_i + \vec{a}\, t_i$$

$$\vec{V}_i = \vec{\upsilon}_i - \frac{-e\vec{E}}{m}\, t_i \ldots (3)$$

- But the average value of $\vec{\upsilon}_i$ is zero because the direction of electron after the collision is completely random.
- The collisions of the electrons do not occur at regular time intervals but at random times.
- The average time between two successive collisions of the electron with the ions is called relaxation time and is denoted by τ.
- Some of the electrons would have spent time more than τ and some less than τ but the average time is τ (relaxation time).
- Thus, averaging equation (3) over the N - electrons gives the drift velocity of electron.

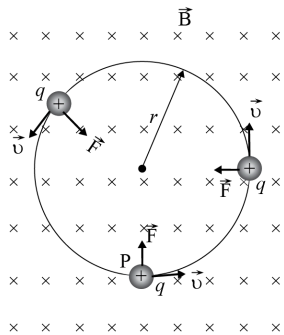
$$\vec{\upsilon}_d = \vec{V}_i \text{ (average)} = \vec{\upsilon}_i \text{ (average)} - \frac{e\vec{E}}{m} t_i \text{ (average)}$$

$$\therefore \vec{\upsilon}_d = \frac{e\vec{E}}{m} \tau \; (\because \vec{V}_i \text{ (average)} = \vec{O}) \text{ ... (4)}$$

Where $\tau = t_i$ (average) relaxation time

- The velocity $\vec{\upsilon}_d$ in equation (4) is called the drift velocity.
- Equation (4) shows that the electrons move with an average velocity which is independent of time. This phenomenon is called drift and the average velocity is called drift velocity.

15.

- 


- As shown in the figure the magnetic field is perpendicular to the plane of paper going inside.
- In this magnetic field, A charged particle is introduced perpendicular to the magnetic field with a velocity of $\vec{\upsilon}$ .
- As a result, a charged particle experiences the magnetic force according to the equation $q(\vec{\upsilon} \times \vec{B})$ This force provides a centripetal force on the particle, so that under the effect of this force the charged particle moves in a circular path. Suppose, the radius of the trajectory of the particle is $r$.
- Centripetal force = magnetic force

$$\therefore \frac{m\upsilon^2}{r} = q\upsilon B$$

$(\because \vec{\upsilon} \perp \vec{B}$ Therefore $= q\upsilon B \sin\theta$

$= q\upsilon B \sin 90 = q\upsilon B)$

$$\therefore \frac{m\upsilon}{r} = qB$$

$$\therefore r = \frac{m\upsilon}{qB} \text{ ... (1)}$$

- Equation (1) shows that the radius of the circular path of a particle is proportional to the momentum of the particle ($P = m\upsilon$)
- So, if the momentum of particle increases, then the radius of the circular path also increases.
- Suppose the angular frequency of particle is ω.
- linear velocity $\upsilon = r\omega$... ... (2)

using equation (2) in equation (1)

$$\therefore r = \frac{m(r\omega)}{qB}$$

$$\therefore 1 = \frac{m\omega}{qB}$$

$\therefore \omega = \dfrac{qB}{m}$ ... (3)

But $\omega = 2\pi v$ (where, $v$ = frequency of particle)

$\therefore 2\pi v = \dfrac{qB}{m}$

$\therefore v = \dfrac{qB}{2\pi m}$ ... (4)

➥ Time period of charged particle

$T = \dfrac{1}{v}$

$\therefore T = \dfrac{2\pi m}{qB}$ (From equation (4))... (5)

➥ From equation (1) and (4) we can say that if the linear momentum of the charged particle is increased, the radius of the circular path increases but the frequency remains constant. Cyclotron works according to this principle.

16.

➥ $l = 10$ cm $= 0.1$ m

Area $A = l^2$

$= (0.1)^2$

$= 0.01\ m^2$

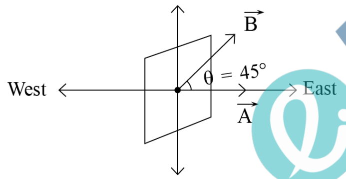
$R = 0.5\ \Omega$

$B_1 = 0.10$ T

$B_2 = 0$

$\theta = 45°$

$\Delta t = 0.70$ sec




➥ From Faraday's law, induced *emf* in loop

$|\varepsilon| = \dfrac{|\Delta\phi_B|}{\Delta t}$

$\therefore |\varepsilon| = \dfrac{|\phi_2 - \phi_1|}{\Delta t}$

$\therefore |\varepsilon| = \dfrac{|B_2 A \cos\theta - B_1 A \cos\theta|}{\Delta t}$

$\therefore |\varepsilon| = \dfrac{|-B_1 A \cos\theta|}{\Delta t}$ $(\because B_2 = 0)$

$\therefore |\varepsilon| = \dfrac{0.1 \times 10^{-2} \times \cos 45}{0.7}$

$\therefore |\varepsilon| = 0.1 \times 10^{-2}$ V

$\therefore |\varepsilon| = 1$ mV

➥ Induced current in the loop

$I = \dfrac{\varepsilon}{R}$

$\therefore I = \frac{1 \times 10^{-3}}{0.5}$

$\therefore I = 2 \times 10^{-3}$ A

$\therefore I = 2$ mA

17.

➥ V = 220 V, P = 100 W

➥ (a) Resistance of bulb (R)

$\therefore P = \frac{V^2}{R}$

$\therefore R = \frac{V^2}{P}$

$= \frac{220 \times 220}{100}$

$\therefore R = 484\ \Omega$

(b) Maximum value of source voltage ($\upsilon_m$)

$\therefore \upsilon_m = \sqrt{2}$ V

$\therefore \upsilon_m = (1.414)\ (220)$

$\therefore \upsilon_m = 311$ V

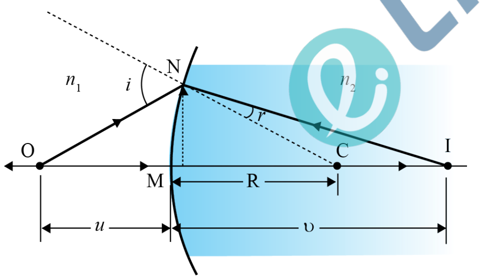
(c) rms value of current flowing through bulb,

$\therefore I = \frac{V}{R}$

$= \frac{220}{484}$

$\therefore I = 0.454$ A

18.

➥ 


➥ As shown in figure, a point like object O is placed on the principal axis of the spherical surface. A spherical surface has centre of curvature ‘C’ and radius of curvature R.

➥ Rays emerge from a medium having refractive index $n_1$. Here, OM and ON are the incident rays.

➥ They refract in a medium having refractive index $n_2$. Here NI and MI are the refractive rays. As a result, image I of the point object O is obtained.

➥ Assume that the aperture of the spherical surface is small compared to the object distance, image distance and radius of curvature, so that the angles can be taken small.

➥ Since the aperture of the surface is assumed to be small here, NM will be taken to be nearly equal to the length of the perpendicular from the point N on the principal axis.

➥ From figure,

$tan\ \angle NOM \approx \angle NOM = \frac{MN}{OM}$ ... (1)

$tan\ \angle NCM \approx \angle NCM = \frac{MN}{MC}$ ... (2)

$$\tan \angle NIM \approx \angle NIM = \frac{MN}{MI} \quad ... (3)$$

➥ For ΔNOC, $i$ is the exterior angle.

Therefore,

$i = \angle NOM + \angle NCM$

Substituting values from equation (1) and equation (2),

$$\therefore i = \frac{MN}{OM} + \frac{MN}{MC} \quad ... (4)$$

➥ From figure for ΔNIC, ∠NCM is the exterior angle.

$\therefore \angle NCM = r + \angle NIM$

$r = \angle NCM - \angle NIM$

$$\therefore r = \frac{MN}{MC} - \frac{MN}{MI} \quad ... (5)$$

➥ By applying Snell's law at point N,

$n_1 \sin i = n_2 \sin r$

But, $\sin i \approx i$

$\sin r \approx r$

$\therefore n_1 i = n_2 r$

➥ Substituting $i$ and $r$ from equation (4) and equation (5),

$$\therefore n_1\left(\frac{MN}{OM} + \frac{MN}{MC}\right) = n_2\left(\frac{MN}{MC} - \frac{MN}{MI}\right)$$

$$\therefore \frac{n_1}{OM} + \frac{n_1}{MC} = \frac{n_2}{MC} - \frac{n_2}{MI}$$

$$\therefore \frac{n_1}{OM} + \frac{n_2}{MI} = \frac{n_2}{MC} - \frac{n_1}{MC}$$

$$\therefore \frac{n_1}{OM} + \frac{n_2}{MI} = \frac{n_2 - n_1}{MC}$$

➥ But from figure, applying Cartesian sign convention,

$OM = -u$, $MI = \upsilon$ and $MC = R$

$$\therefore -\frac{n_1}{u} + \frac{n_2}{\upsilon} = \frac{n_2 - n_1}{R}$$

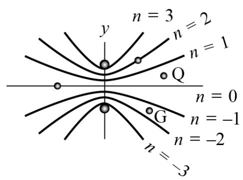
➥ Above equation gives us a relation between object and image distance in terms of refractive index of the medium and the radius of curvature of the curved spherical surface.

19.

➥ As shown in the fig., two waves emanated from two coherent sources.

$S_1$ and $S_2$ are superimposed on each other at a point G in the medium.

➥ Let, the phase difference between the two displacements be φ.




➥ Thus, if the displacement produced by $S_1$ is given by,

$y_1 = a \cos \omega t$

then the displacement produced by $S_2$ will be,

$y_2 = a \cos (\omega t + \varphi)$

where, ($a$ - Amplitude, ω - Angular frequency)

➥ As per super position principle, the resultant displacement will be given by :

$y = y_1 + y_2$

$y = a \cos \omega t + a \cos (\omega t + \varphi)$

$\therefore y = 2a \cos \left(\frac{\omega t - \omega t - \phi}{2}\right) \cos \left(\frac{\omega t + \omega t + \phi}{2}\right)$

$\therefore y = 2a \cos \left(\frac{-\phi}{2}\right) \cos \left(\frac{2\,\omega t + \phi}{2}\right)$

$\therefore y = 2a \cos \left(\frac{\phi}{2}\right) \cos \left(\omega t + \frac{\phi}{2}\right)$

$\left(\cos \text{ being an even function, } \cos \left(-\frac{\phi}{2}\right) = \cos \left(\frac{\phi}{2}\right)\right)$

- Here, $2a \cos \left(\frac{\phi}{2}\right)$ is the amplitude of the resultant displacement.
- Suppose, intensity of the original wave is $I_0$ and that of resultant wave is I, Intensity of a wave is directly proportional to the square of the amplitude.

$I_0 \,\alpha\, a^2$ and $I \,\alpha\, 4\, a^2 \cos^2 \frac{\phi}{2}$

$\frac{I}{I_0} = \frac{4a^2 \cos^2 \frac{\phi}{2}}{a^2}$

$\therefore I = 4\, I_0 \cos^2 \left(\frac{\phi}{2}\right)$

which is the formula of resultant intensity at the given point.

20.

- Some phenomena associated with light like diffraction, interference and polarisation show that light (radiation) has a wave-form.
- Similarly, the photoelectric effect, the Compton effect, show that light has a particle-form.
- Thus, radiation has dual nature.
- The first scientist named Louis de-Broglie questioned whether the universe had symmetry, so if radiation (energy) could act as a particle, then a particle could also act as radiation. If radiation can have dual nature then particle can also have dual nature.
- de-Broglie stated that when a particle (such as an electron, proton etc) moves, it moves in a wave-form.
- de-Broglie said that if a particle has mass $m$ and is moving with speed $v$, then the wave length of the wave of the particle can be given by the formula

$\lambda = \frac{h}{p} = \frac{h}{mv}$

- This wave length is called the de-Broglie wave length of the particle. The above equation is known as the de-Broglie relation.
- The wave length of a photon of radiation,

$\lambda = \frac{c}{v}$ $(\because c = v\lambda)$

$\lambda = \frac{h}{p}$ (momentum $p = \frac{hv}{c} \therefore \frac{c}{v} = \frac{h}{p}$)

Thus, the de-Broglie wave length and the wave length of a photon of radiation can be given by the same formula.

- The de-Broglie wave length $\lambda = \frac{h}{p}$.
- In this equation, the physical quantity on the left is wave form and the momentum ($p$) on the right side is the physical quantity of the particle form. Thus this equation relates the wave nature and the particle nature.
- Davisson and Germer's experiment proved de-Broglie's hypothesis experimentally.

21.

- For ${}^{239}_{94}Pu$, mass number = 239

Mass of P$u$ No. of atoms in P$u$

239 g $6.023 \cdot 10^{23}$

$\therefore$ 1000 g (?)

➥ No. of atoms in 1000 g P*u*

$$N = \frac{1000 \times 6.023 \times 10^{23}}{239}$$

$N = 2.52 \cdot 10^{24}$ atoms

➥ The energy released from fission per every atom = 180 M*e*V.

$\therefore$ energy released from fission of N atoms

$E = 180\ MeV \cdot N$

$E = 180 \cdot 2.52 \cdot 10^{24}$

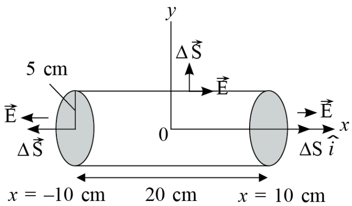
$E = 4.536 \cdot 10^{26}\ MeV$

## Section C

➢ **Write the answer of the following questions : (Each carries 4 Mark)**

22.

➥




(a) Electric flux coming out of the left flat surface,

$\therefore \varphi_L = \vec{E} \cdot \Delta \vec{S} = (-200\ \hat{i}) \cdot (-\Delta S\ \hat{i})$

$\therefore \varphi_L = 200 \cdot \pi r^2$

$\therefore \varphi_L = 200 \cdot 3.14 \cdot (5 \cdot 10^{-2})^2$

$\therefore \varphi_L = 1.57\ \frac{Nm^2}{C}$

➥ Electric flux coming out of the Right flat surface,

$\therefore \varphi_R = \vec{E} \cdot \Delta \vec{S}$

$= (+200\ \hat{i})(\Delta S\ \hat{i}) = 200 \cdot \pi r^2$

$\therefore \varphi_R = 200 \cdot 3.14 \cdot (5 \cdot 10^{-2})^2$

$\therefore \varphi_R = 1.57\ \frac{Nm^2}{C}$

➥ Flux coming out of the curved cylindrical surface,

$\therefore \varphi_S = \vec{E} \cdot \Delta \vec{S}$

but for curved surface $\vec{E} \perp \Delta \vec{S}$ $(\theta = 90°)$

$\therefore \varphi_S = E\ \Delta S\ cos\ 90$

$\therefore \varphi_S = 0$

➥ Total electric flux coming out of the cylinder,

$\therefore \varphi = \varphi_L + \varphi_R + \varphi_S$

$\therefore \varphi = 1.57 + 1.57 + 0$

$\therefore \varphi = 3.14\ \frac{Nm^2}{C}$

➥ Total charge inside the cylinder,

$$\therefore \varphi = \frac{q}{\varepsilon_0}$$

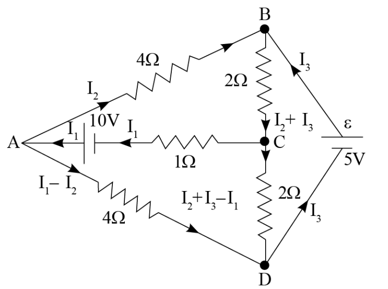
$$\therefore q = \varepsilon_0 \varphi$$

$$\therefore q = 8.85 \cdot 10^{-12} \cdot 3.14$$

$$\therefore q = 2.78 \cdot 10^{-11} \text{ C}$$

23.

- Here, each branch of network is assigned an unknown current. The distribution of currents is such that the number of these unknown currents is minimised.




- As shown in the figure, we consider three unknown currents $I_1$, $I_2$ and $I_3$.
- Applying kirchhoff's second rule for the closed loop ADCA,

$$-4(I_1 - I_2) + 2(I_2 + I_3 - I_1) - 1(I_1) + 10 = 0$$

$$\therefore -4I_1 + 4I_2 + 2I_2 + 2I_3 - 2I_1 - I_1 = -10$$

$$\therefore -7I_1 + 6I_2 + 2I_3 = -10$$

$$\therefore 7I_1 - 6I_2 - 2I_3 = 10 \text{ ... (1)}$$

- Applying Kirchhoff's second rule for the closed loop ABCA,

$$-4I_2 - 2(I_2 + I_3) - 1(I_1) + 10 = 0$$

$$\therefore -4I_2 - 2I_2 - 2I_3 - I_1 = -10$$

$$\therefore -I_1 - 6I_2 - 2I_3 = -10$$

$$\therefore I_1 + 6I_2 + 2I_3 = 10 \text{ ... (2)}$$

- Applying kirchhoff's second rule for the closed loop BCDεB,

$$-2(I_2 + I_3) - 2(I_2 + I_3 - I_1) + 5 = 0$$

$$\therefore -2I_2 - 2I_3 - 2I_2 - 2I_3 + 2I_1 = -5$$

$$\therefore 2I_1 - 4I_2 - 4I_3 = -5$$

$$\therefore I_1 - 2I_2 - 2I_3 = -2.5 \text{ ... (3)}$$

- Adding equations (1) and (2) we get,

$$\begin{array}{lrcrcrcl} \therefore & 7I_1 & - & 6I_2 & - & 2I_3 & = & 10 \\ & I_1 & + & 6I_2 & + & 2I_3 & = & 10 \\ \hline & 8I_1 & & & & & = & 20 \end{array}$$

$$\therefore I_1 = \frac{20}{8} = 2.5 \text{ A ... (4)}$$

- Now, by adding equation (2) and (3),

$$\begin{array}{lrcrcrcl} \therefore & I_1 & + & 6I_2 & + & 2I_3 & = & 10 \\ & I_1 & - & 2I_2 & - & 2I_3 & = & -2.5 \\ \hline & 2I_1 & + & 4I_2 & & & = & 7.5 \end{array}$$

$$\therefore 2(2.5) + 4I_2 = 7.5$$

$$\therefore 4I_2 = 7.5 - 5$$

$\therefore I_2 = \frac{2.5}{4} = \frac{25}{40} = \frac{5}{8}$ A ... (5)

- Putting the value of $I_1$ and $I_2$ in equation (2)
- (we can use equation (1), (2) and (3) for similar calculations)

$$\therefore 2.5 + 6\left(\frac{5}{8}\right) + 2I_3 = 10$$

$$\therefore 2I_3 = 10 - 2.5 - \frac{30}{8}$$

$$\therefore 2I_3 = 7.5 - \frac{30}{8}$$

$$\therefore 2I_3 = \frac{60 - 30}{8}$$

$$\therefore I_3 = \frac{30}{16} = \frac{15}{8} \text{ A}$$

Current flowing through the Arm AB $I_2 = \frac{5}{8}$ A

Current flowing through the Arm AC $I_1 = 2.5$ A

Current flowing through the Arm AD

$$I_1 - I_2 = \frac{5}{2} - \frac{5}{8}$$

$$= \frac{20 - 5}{8} = \frac{15}{8} \text{ A}$$

- Current in the Arm B ε D

$$I_3 = \frac{15}{8} \text{ A}$$

- Current in the Arm BC is

$$I_2 + I_3 = \frac{5}{8} + \frac{15}{8} = \frac{20}{8} = \frac{5}{2} \text{ A}$$

- Current in the Arm CD is

$$I_2 + I_3 - I_1 = \frac{5}{8} + \frac{15}{8} - \frac{5}{2} = \frac{5 + 15 - 20}{8} = 0 \text{ A}$$

24.

- $V = 220$ V

  $\nu = 50$ Hz

  $R = 200\ \Omega$

  $C = 15\ \mu F$

- Capacitive reactance,

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

$$= \frac{1}{2 \times 3.14 \times 50 \times 15 \times 10^{-6}}$$

$$X_C = 212.3\ \Omega$$

- (a) Impedence of the circuit,

$$Z = \sqrt{R^2 + X_C^2}$$

$$\therefore Z = \sqrt{(200)^2 + (212.3)^2}$$

$$\therefore Z = \sqrt{40000 + 45071.29}$$

$$\therefore Z = \sqrt{85071.29}$$

$$\therefore Z = 291.67\ \Omega$$

➠ Electric current in the circuit,

$\therefore\ I = \frac{V}{Z}$

$= \frac{220}{291.67}$

$\therefore\ I = 0.7542\ A$

(b) Voltage across two terminals of resistor ($V_R$),

$V_R = IR$

$= (0.754)\ (200)$

$= 150.8\ V$

➠ Voltage across two terminals of capacitor ($V_C$)

$V_C = I\ X_C$

$= (0.754)\ (212.3)$

$= 160.07\ V$

➠ Algebric sum of $V_R$ and $V_C$,

$V' = V_R + V_C$

$V' = 150.8 + 160.07$

$V' = 310.87\ V$

➠ which is more than the source voltage V = 220 V.

➠ Here, both the voltages $V_R$ and $V_C$ are not in same phase, hence they can not be added like normal numbers, directly.

➠ But the phase-difference between $V_R$ and $V_C$ is 90°. So, from Phythagoras theorem,

Total voltage $V_{R+C} = \sqrt{V_R^2 + V_C^2}$

$V_{R+C} \approx 220\ V$

➥ Thus, if the phase difference between the two voltages is taken in to consideration and calculation is done appropriately, the total voltage between two terminals of capacitor and resistor is found to be same as the source voltage.

25.

➥ radius of curvature R = –15 cm

focal length $f = \frac{R}{2} = -7.5$ cm

(i) object distance $u = -10$ cm

$\frac{1}{\upsilon} + \frac{1}{u} = \frac{1}{f}$

$\therefore \frac{1}{\upsilon} = \frac{1}{f} - \frac{1}{u}$

$\therefore \frac{1}{\upsilon} = \frac{-1}{7.5} + \frac{1}{10}$

$\therefore \frac{1}{\upsilon} = \frac{-10 + 7.5}{75}$

$\therefore \upsilon = \frac{-75}{2.5}$

$\therefore \upsilon = -30$ cm

➥ The image is 30 cm from the mirror on the same side as the object.

- magnification $m = -\frac{\upsilon}{u}$

  $\therefore m = -\frac{(-30)}{(-10)}$

  $\therefore m = -3$

- As $|m| > 1$ the image is magnified. Since magnification is negative, image is inverted and real.

  (ii) object distance $u = -5$ cm

- from mirror formula,

  $\frac{1}{\upsilon} + \frac{1}{u} = \frac{1}{f}$

  $\therefore \frac{1}{\upsilon} = \frac{1}{f} - \frac{1}{u}$

  $\therefore \frac{1}{\upsilon} = \frac{-1}{7.5} + \frac{1}{5}$

  $\therefore \frac{1}{\upsilon} = \frac{-2+3}{15}$

  $\therefore \upsilon = 15$ cm

- The image is formed at 15 cm behind the mirror.

- magnification $m = -\frac{\upsilon}{u}$

  $\therefore m = -\frac{15}{(-5)}$

  $\therefore m = 3$

- Since $|m| > 1$, image is larger than the object.

26.

- Bohr's second postulate :

- An electron revolves around the nucleus only in those orbits for which the angular momentum is an integral multiple of $\frac{h}{2\pi}$.

  Where, $h$ is Planck's constant

- $h = 6.625 \times 10^{-34}$ Js

- Thus the angular momentum of the electron

  $L = \frac{nh}{2\pi}$ Where, $n = 1, 2, 3$ ......

- De - Broglie's explanation :

- According to de-Broglie's hypothesis even matter particles like electrons have wave nature. Its practical explanation was given by Davisson and Germer, from which de-Broglie argued that the electron in its circular orbit must be seen as a particle wave.

- When the tensioned wire is plucked tied to a rigid support on both ends, a vast number of wavelengths are excited. However only those wavelengths survive which have nodes at the ends and form the standing wave in the string. It means standing waves are formed when the total distance travelled by a wave down the string and back is one wavelength or any integral number of wavelength.

- Waves with other wavelengths interfere with themselves upon reflection and their amplitudes rapidly drop to zero.

- For an electron moving in $n^{th}$ circular orbit of radius $r_n$, the total distance is the circumference of the orbit. Thus,

  $2\pi r_n = n\lambda$ ... (1)

  Where $n = 1, 2, 3,$ ........

- But the de-Broglie wavelength $\lambda = \frac{h}{p}$

  Where p = momentum of electron. If the speed of the electron is much less than the speed of light, the momentum is = $mv_n$

  $\therefore \lambda = \frac{h}{mv_n}$ ... (2)

- Form equation (1) and (2),

$\therefore 2\pi r_n = \frac{nh}{mv_n}$

$\therefore mv_n r_n = \frac{nh}{2\pi}$

➥ This is the quantum condition proposed by Bohr for the angular momentum of the electron.

➥ Thus, de-Broglie hypothesis provided an explanation for Bohr's second postulate for the quantisation of angular momentum of the orbiting electron.

27.

➥ (a) In nucleus of ${}^{56}_{26}Fe$

number of protons Z = 26

and number of neutrons N = 56 – 26 = 30

➠ Mass Defect

$\Delta M = (Zm_p + Nm_n) - m({}^{56}_{26}Fe)$

$\therefore \Delta M = (26 \cdot 1.007825 + 30 \cdot 1.008665) - 55.934939$

$\therefore \Delta M = 26.20345 + 30.25995 - 55.934939$

$\therefore \Delta M = 0.528461\ u$

➠ Binding Energy

$E_b = \Delta Mc^2$

$\therefore E_b = 0.528461 \cdot 931.5$

$\therefore E_b = 492.26142$ MeV

➠ Binding energy per nucleon

$E_{bn} = \frac{E_b}{A}$

$\therefore E_{bn} = \frac{492.26142}{56}$

$\therefore E_{bn} \approx 8.79$ MeV

(b) In nucleus of ${}^{209}_{83}Bi$

number of protons Z = 83

and number of neutrons N = 209 – 83 = 126

➠ Mass Defect

$\therefore \Delta M = [Zm_p + Nm_n] - m[{}^{209}_{83}Bi]$

$\therefore \Delta M = [83 \cdot 1.007825 + 126 \cdot 1.008665] - [208.980388]$

$\therefore \Delta M = [83.649475 + 127.091790] - [208.980388]$

$\therefore \Delta M = 1.760877\ u$

➠ Binding Energy

$E_b = \Delta Mc^2$

$\therefore E_b = 1.760877 \cdot 931.5$

$\therefore E_b = 1640.2569255$ MeV

➠ Binding Energy per nucleon

$E_{bn} = \frac{E_b}{A}$

$\therefore E_b = \frac{1640.2569255}{209}$

$\therefore E_{bn} = 7.84 \frac{\text{MeV}}{\text{nucleon}}$