LIBERTY PAPER SET

STD. 12 : Physics

Full Solution

Time : 3 Hours **ASSIGNTMENT PAPER 2**

Section A

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

Section A

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

1.

➥ (i) Electric field lines are imaginary curves drawn in such a way that the tangent to it of each point shows the direction of electric field at that point.

(ii) Field lines start from positive charges and end at negative charges. If there is a single charge, they may start or end at infinity.

(iii) In a charge-free region, electric field lines can be taken to be continuous curves without any breaks.

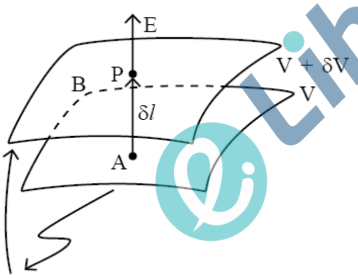
(iv) Two field lines never cross each other.

(v) Electrostatic field lines do not form any closed loops.

(vi) Distribution of electric field lines gives an idea of electric field intensity in that region.

(vii) Field lines of a uniform electric field are mutually parallel and equidistant.

2.



Equipotential surfaces

➥ As shown in the fig., two equipotential surfaces A and B are very close to each other. Magnitudes of electric potentials on them are V and V + δV respectively.

➥ Here, δV is change in electric potential in the direction of electric field $\vec{E}$.

➥ Point P is present on surface B. And the perpendicular distance from surface A to point P is δl.

➥ The amount of work done in taking a unit positive charge on the perpendicular line from surface B to surface A is equal to $|\vec{E}|\ \delta l$. This work is equal to the electric potential difference between surfaces A and B, which is $V_A - V_B$.

$\therefore\ |\vec{E}|\ \delta l = \Delta V = V_A - V_B$

$\therefore\ |\vec{E}| \cdot \delta l = V - (V + \delta V)$

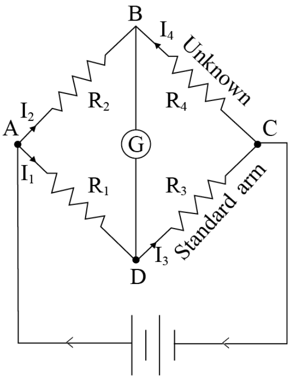
$= -\delta V$

$\therefore\ |\vec{E}| = -\dfrac{\delta V}{\delta l}$

➥ Here, δV is negative, so taking $-\delta V$ in place of δV,

$|\vec{E}| = \dfrac{\delta V}{\delta l}$

3.

➥ 

➥ The circuit shown in the figure is called the wheatstone bridge. It uses four resistors R_1, R_2, R_3 and R_4 out of them three resistors are known and one is unknown, wheatstone bridge is used to find the value of unknown resistance.

➥ As shown in the figure, across one pair of diagonally opposite points (A and C in the figure) a source is connected hence AC is called the battery arm.

➥ Between the other two vertices, B and D, a galvanomenter G is connected hence BD is called the galvanometer arm.

➥ When battery is connected, the currents flowing through the resistors R_1, R_2, R_3 and R_4 are I_1, I_2, I_3 and I_4 respectively.

➥ Here, there resistors are chosen in such a way that current flowing through galvanometer is zero ($I_g = 0$).

➥ When the current flowing through the galvanometer becomes zero, the bridge is said to be in balanced condition.

➥ From the figure, in balanced condition

$I_1 = I_3$ and $I_2 = I_4$

➥ Applying Kirchhoff's loop rule to closed loop A – D – B – A

$$-I_1R_1 + 0 + I_2R_2 = 0$$

$$\therefore I_1R_1 = I_2R_2 \quad ... (1)$$

➥ Applying similarly, for closed loop C – B – D – C

$$I_4R_4 + 0 - I_3R_3 = 0$$

$$\therefore I_3R_3 = I_4R_4 \quad ... (2)$$

➥ Taking ratio of equation (1) and (2)

$$\therefore \frac{I_1R_1}{I_3R_3} = \frac{I_2R_2}{I_4R_4}$$

But $I_1 = I_3$ and $I_2 = I_4$

$$\therefore \frac{R_1}{R_3} = \frac{R_2}{R_4} \text{ OR } \frac{R_1}{R_2} = \frac{R_3}{R_4} \quad ... (3)$$

➥ which is a condition for the whetstone bridge to be in balanced condition.

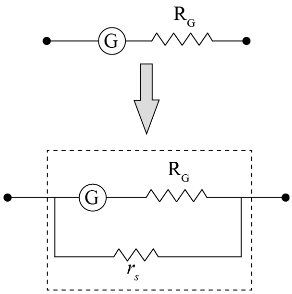
➥ If three resistors R_1, R_2 and R_3 are known then unknown resistence of R_4 is given by

$$R_4 = R_3 \cdot \frac{R_2}{R_1} \quad ... (4)$$

➥ A practical device using this principle is called the meter bridge.

4.

➥ There are two reasons why a galvanometer cannot be used directly as an ammeter.



Ammeter

(i) Galvanometer is a very sensitive device. It also shows the full scale deflection for a current of the order of μA.

(ii) To measure current, a galvanometer has to be connected in series but its resistance is high, so that it changes the value of the current flowing in the circuit.

➥ To overcome these difficulties, a small resistance called a shunt is connected to the galvanometer.

➥ The shunt is connected in parallel with the galvanometer. Due to this, most of the current passes through the shunt.

➥ The resistance of this arrangement is = $\frac{R_G r_S}{R_G + r_S}$

But $R_G >> r_S$

So, we can neglect r_S as compared to R_G

So, $\frac{R_G r_S}{R_G} \approx r_S$

➥ Since, the value of r_S very small, the original current does not change and the true value of current can be measured.

5.

➥ m = 0.48 J/T

$r = 10 \text{ cm} = 0.1 \text{ m} = 10^{-1} \text{ m}$

(a) Magnetic field on the axis of magnet at distance '*r*'

$B_1 = \frac{\mu_0}{4\pi} \cdot \frac{2m}{r^3}$

$B_1 = \frac{10^{-7} \times 2 \times 0.48}{10^{-3}}$

$B_1 = 0.96 \times 10^{-4}$ T

= 0.96 G

➠ Direction of this magnetic field will be in the direction of magnetic moment of the magnet. (Which will be from S to N)

(b) Magnetic field at distance '*r*' on the equatorial line of magnet,

$B_2 = \frac{\mu_0}{4\pi} \cdot \frac{m}{r^3}$

$B_2 = \frac{10^{-7} \times 0.48}{10^{-3}}$

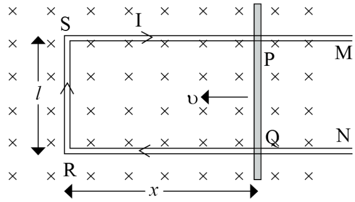
$B_2 = 0.48 \times 10^{-4}$ T

= 0.48 G

➠ Direction of this magnetic field will be in the direction opposite to the magnetic moment (Which will be from N to S direction.)

6.

➥ *"The induced* emf *arising due to some motion is called Motional* emf.*"*



As shown in figure, a rectangular conductor PQRS is placed in a time independent, uniform magnetic field. If θ is the angle between $\vec{B}$ and area vector $\vec{A}$ of coil, then here (θ = 0). Here, rod PQ is free to do frictionless motion. Its effective length is *l*.

➥ On moving conductor PQ with uniform velocity $\vec{\upsilon}$ as shown in figure, area enclosed by closed circuit PQRS changes with time.

➥ Suppose, at any instant,

RQ = *x* & RS = *l* then

Magnetic flux linked with closed loop PQRS is

$\varphi_B = B\,l\,x$ ($\because$ υ = 0 → *cos* θ = 1)... (1)

➥ Distance *x* changes with time, as a result, time rate of change of φ_B induces *emf*.

$\therefore \varepsilon = -\frac{d\phi_B}{dt} = -\frac{d}{dt}(B\,l\,x)$ [From eq. (1)]

$\therefore \varepsilon = -Bl\frac{dx}{dt}$ But $\frac{dx}{dt} = -\upsilon$

Where υ is speed of conductor PQ

$\therefore \varepsilon = B\,l\,\upsilon$ ... (2)

Equation (2) is formula for motional *emf*.

➥ Note : Motion of free electrons in closed path is shown in figure.

7.

➥ $I = C\frac{dV}{dt}$

where I = Electric Current (A)

C = Capacitance (F)

$\frac{dV}{dt}$ = Rate of change in electrical condition (Volts Per Second)

$C = 80\ pF = 80 \times 10^{-2}\ F$

I = 0.15 A

$\frac{dV}{dt}$ is Multiplication of,

$0.15 = 80 \times 10^{-12} \times \frac{dV}{dt}$

$\frac{dV}{dt} = \frac{0.15}{80 \times 10^{-12}} = \frac{0.15}{80 \times 10^{-11}}$

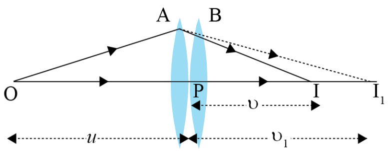
$= 1.875 \times 10^{9}$ V/S

displacement $= \varepsilon_0 \cdot A \cdot \frac{dE}{dt}$

displacement (Id displacement) and I is changing in displacement and electrice current

$I_{displacement} = I = 0.15\ A$

8.



- As shown in figure two lenses A and B are arranges so that their principal axis is the same. The focal lengths of these are f_1 and f_2 respectively. Here we will assume that since both the lenses are thin, their optical centre converge on each other. Let the centre be the point P.
- Let the object be placed at point O beyond the focus of the first lens A. The first lens produces an image at I_1. This image I_1 serves as a virtual object for the second lens. B producing the final image at I.
- For the image formed by the first lens A,

$$\frac{1}{υ_1} - \frac{1}{u} = \frac{1}{f_1} \quad ...(1)$$

- For the image formed by the second lens B,

$$\frac{1}{υ} - \frac{1}{υ_1} = \frac{1}{f_2} \quad ...(2)$$

- Adding equations (1) and (2),

$$\frac{1}{υ} - \frac{1}{u} = \frac{1}{f_1} + \frac{1}{f_2} \quad ...(3)$$

- If the two lens-system is regarded as equivalent to a single lens of focal length f.

$$\therefore \frac{1}{υ} - \frac{1}{u} = \frac{1}{f} \quad ...(4)$$

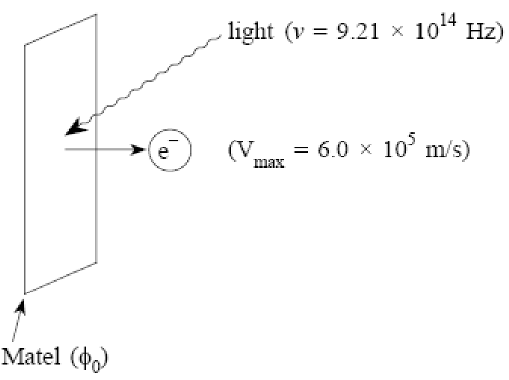
- Comparing equations (3) and (4),

$$\therefore \frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$$

- The derivation is valid for any number of thin lenses, in contact. If several thin lenses of focal length f_1, f_2, f_3, ... are in contact, the effective focal length of their combination is given by $\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} + \frac{1}{f_3} + ...$

9.

- $\nu = 9.21 \times 10^{14}$ Hz
- $v_{max} = 6.0 \times 10^5$ m/s
- $\nu_0 = ?$



- According to Einstein's equation,

$$K_{max} = h\nu - \phi_0$$

$$\therefore \frac{1}{2} mv^2_{max} = h\nu - \phi_0 \quad (\because K_{max} = \frac{1}{2} mv^2_{max})$$

$$\therefore \phi_0 = h\nu - \frac{1}{2} mv^2_{max}$$

$$\therefore h\nu_0 = h\nu - \frac{1}{2} mv^2_{max} \quad (\because \phi_0 = h\nu_0)$$

$$\therefore \nu_0 = \nu - \frac{mV^2_{max}}{2h}$$

$$\therefore \nu_0 = (9.21 \times 10^{14}) - \left(\frac{9.1 \times 10^{-31} \times (6.0 \times 10^5)^2}{2 \times 6.625 \times 10^{-34}}\right)$$

$$\nu_0 = (9.21 \times 10^{14}) - (2.472 \times 10^{14})$$

$$\nu_0 = 6.78 \times 10^{14} \text{ Hz}$$

10.

➥ $n = 4$

$\lambda = ?$

$\nu = ?$

➥ Total energy of electron

$E_n = -\frac{13.6}{n^2}$ eV ... (1)

➥ For ground state, $n = 1$

$E_1 = -\frac{13.6}{1^2}$ eV

$= -13.6$ eV

➥ Using $n = 4$ in equation (1)

$E_4 = -\frac{-13.6}{(4)^2}$ eV

$= \frac{-13.6}{16}$ eV

$E_4 = -0.85$ eV

➥ Energy of incident photon

$E_4 - E_1 = -0.85 - (-13.6)$

$E_4 - E_1 = 12.75$ eV

But, $E_i - E_f = h\nu$

$h\nu = 12.75$ eV

$\therefore \nu = \frac{12.75 \times 1.6 \times 10^{-19}}{6.625 \times 10^{-34}}$

$\therefore \nu = 3.08 \times 10^{15}$ Hz

➥ Wavelength of incident radiation

$\lambda = \frac{c}{\nu} = \frac{3 \times 10^8}{3.08 \times 10^{15}}$

$\therefore \lambda = 0.974 \times 10^{-7}$ m

$\therefore \lambda = 97.4$ nm

11.

- The nucleus is made up of neutrons and protons. Therefore, it may be expected that the mass of the nucleus is equal to the total mass of its individual protons and neutrons.
- But the nuclear mass M is found to be always less than the total mass of its individual protons and neutrons.
- For example :

  ${}_{8}O^{16}$, a nucleus which has 8 neutrons and 8 protons.

  Mass of 8 neutrons = $8 \cdot 1.00866\ u$

  Mass of 8 protons = $8 \cdot 1.00727\ u$

  Mass of 8 electrons = $8 \cdot 0.00055\ u$

- Therefore, the expected mass of ${}_{8}O^{16}$ nucleus

  $= (8 \cdot 1.00866 + 8 \cdot 1.00727)$

  $= 8(1.00866 + 1.00727)$

  $= 8 \cdot 2.01593\ u$

  $= 16.12744\ u$

- The atomic mass of ${}_{8}O^{16}$ found from mass spectroscopy experiments is seen to be $15.99493\ u$.
- Subtracting the mass of 8 electrons

  $(8 \cdot 0.00055\ u = 0.0044\ u)$ from this we get the experimental mass of ${}_{8}O^{16}$ nucleus to be $15.99053\ u$.

- Thus, the mass of the ${}_{8}O^{16}$ nucleus is less than the total mass of its constituents by

  $(16.12744 - 15.99053) = 0.13691\ u$.

- *"The difference in mass of a nucleus and its constituents, ΔM is called the mass defect"* and is given by

  $\Delta M = [Zm_p + (A - Z)m_n] - M$

  Where, Z = number of protons

  A – Z = N = neutron number

  m_p - mass of proton

  m_n - mass of neutron

  M - mass of a nucleus

- The energy equivalent to this mass defect is called the binding energy of nucleus.

  $\therefore$ Binding energy $E_b = \Delta M c^2$

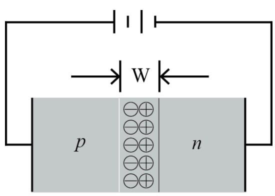
- Binding energy per nucleon is the binding energy divided by the total number of nucleons.

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

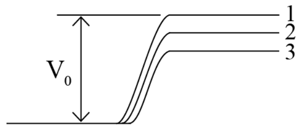
- The binding energy per nucleon gives a measure of the stability of the nucleus.
- A nucleus for which the value of E_{bn} is comparatively higher is said to be more stable and for a nucleus for which the value of E_{bn} is comparatively less is said to be less stable.

12.

- When an external voltage V is applied across a semi-conductor diode such that *p*-side is connected to the positive terminal of the battery and the *n*-side to the negative terminal (fig. (a)), it is said to be forward biased.

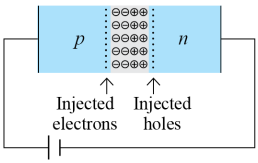


(a)



(b)

- Here, the voltage applied to the diode across the two terminals of the depletion region and the direction of the applied voltage (V) is opposite to the built-in potential (V).
- As a result, the depletion layer width decreases and the barrier height is reduced (Fig. (b)). The effective barrier height under forward bias is $(V_0 - V)$.
- If the applied voltage is small, the barrier potential will be reduced only slightly below the equilibrium value and only a small number of carriers in the material - those that happen to be in the uppermost energy levels - will possess enough energy to cross the junction. So the current will be small.
- If we increase the applied voltage significantly, the height of the barrier potential reduces, and more number of charge carriers gain enough energy to cross the depletion region, due to which the current also increases.
- *"Due to the applied voltage, electrons from the* n*-side cross the depletion region and reach* p*-side (Where they are minority carriers). Similarly, holes from the* p*-side cross the junction and reach the* n*-side. (Where they are minority carriers.) This process under forward bias is known as minority carrier injection."*
- At the junction boundary, on each side, the minority carrier concentration increases significantly compared to the locations far from the junction.
- Due to this concentration gradient, the injected electrons on *p*-side diffuse from the junction edge of *p*-side to the other end of *p*-side. Likewise, the injected holes on *n*-side diffuse from the junction edge of *n*-side to the other end of *n*-side. This is shown in fig. below.

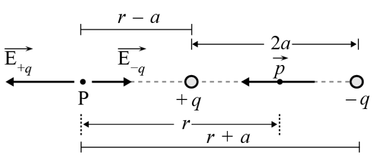


- This motion of charged carriers on either side gives rise to current. The total diode forward current is sum of hole diffusion current and conventional current due to electron diffusion. The magnitude of this current is usually in *m*A.

Section B

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

13.



- As shown in Fig., suppose point P is on the axis of dipole, at distance 'r' from its midpoint.
- We want to find electric field at point P.
- Electric field due to $+q$ charge of point P.

$$\vec{E}_{+q} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{(r-a)^2} \cdot \hat{p} \quad \dots (1)$$

Where $\hat{p}$ is unit vector in the direction of dipole moment.

- Electric field due to charge - q of point P,

$$\vec{E}_{-q} = -\frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{(r+a)^2} \cdot \hat{p} \quad \dots (2)$$

➥ The total field at P is

$$\vec{E} = \vec{E}_{+q} + \vec{E}_{-q}$$

$$\therefore \vec{E} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{(r-a)^2} \cdot \hat{p} - \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{(r+a)^2} \cdot \hat{p}$$

$$\therefore \vec{E} = \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{(r-a)^2} - \frac{1}{(r+a)^2}\right]\hat{p}$$

$$\therefore \vec{E} = \frac{q}{4\pi\varepsilon_0}\left[\frac{(r+a)^2-(r-a)^2}{(r-a)^2\,(r+a)^2}\right]\hat{p}$$

$$\therefore \vec{E} = \frac{q}{4\pi\varepsilon_0}\left[\frac{r^2+2ra+a^2-r^2+2ra-a^2}{(r^2-a^2)^2}\right]\hat{p}$$

$$\therefore \vec{E} = \frac{q}{4\pi\varepsilon_0}\left[\frac{4ra}{(r^2-a^2)^2}\right]\hat{p}$$

$$\therefore \vec{E} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{(2aq)\,(2r)}{(r^2-a^2)^2} \cdot \hat{p}$$

$$\therefore \vec{E} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{2pr}{(r^2-a^2)^2} \cdot \hat{p} \quad (\because 2aq = \text{P electric dipole moment})$$

➥ Suppose, point P is very far away As a result $r >> a$, so a^2 can be ignored compared to r^2

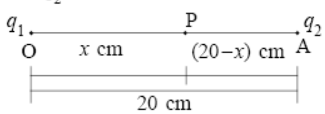
$$\therefore \vec{E} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{2pr}{r^4} \cdot \hat{p}$$

$$\therefore \vec{E} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{2p}{r^3} \cdot \hat{p}$$

14.

➥ (a) $q_1 = 5 \times 10^{-8}$ C

$q_2 = -3 \times 10^{-8}$ C



➥ Suppose, here the positive charge 'q_1' is on the origin and negative charge 'q_2' is on the X-axis, towards the RHS of the origin.

➥ Suppose, electric potential at point P is zero. Point P is x cm away from charge q_1.

$$\therefore \frac{k\,q_1}{x\times10^{-2}} + \frac{k\,q_2}{(20-x)\times10^{-2}} = 0$$

$$\therefore \frac{k\,(5\times10^{-8})}{x\times10^{-2}} - \frac{k\,(3\times10^{-8})}{(20-x)\times10^{-2}} = 0$$

$$\therefore \frac{k\,(5\times10^{-8})}{x\times10^{-2}} = \frac{k\,(3\times10^{-8})}{(20-x)\times10^{-2}}$$

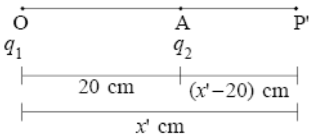
$$\therefore \frac{5}{x} = \frac{3}{20-x}$$

$\therefore$ $100 - 5x = 3x$

$\therefore$ $100 = 8x$

$\therefore$ $x = 12.5$ cm

(b)



➥ As shown in fig, electric potential at point P' is zero.

$$\therefore \quad \frac{k\,q_1}{x' \times 10^{-2}} + \frac{k\,q_2}{(x'-20)\times 10^{-2}} = 0$$

$$\therefore \quad \frac{k\,(5\times10^{-8})}{x'\times10^{-2}} - \frac{k\,(3\times10^{-8})}{(x'-20)\times10^{-2}} = 0$$

$$\therefore \quad \frac{k\,(5\times10^{-8})}{x'\times10^{-2}} = \frac{k\,(3\times10^{-8})}{(x'-20)\times10^{-2}}$$

$$\therefore \quad \frac{5}{x'} = \frac{3}{x'-20}$$

$\therefore \; 5x' - 100 = 3x'$

$\therefore \; 5x' - 3x' = 100$

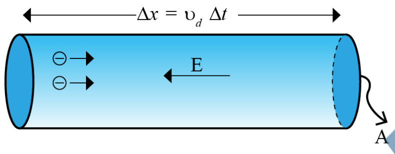
$\therefore \; 2x' = 100$

$\therefore \; x' = 50$ cm

➥ Hence, electric potential will be zero at distance 12.5 cm from q_1 (positive charge) and at 50 cm from q_1.

15.

➥



➥ A conductor of cross- sectional area $\vec{A}$ is shown in the figure. The electric field inside the conductor is $\vec{E}$.

➥ Due to this electric field, there will be net flow of charges across any area of the conductor.

➥ Because of the drift, distance travelled by electron in time Δt is $|\vec{\upsilon}_d|\,\Delta t$.

➥ Suppose the number of free electrons per unit volume in metal is n, then the number of electrons passing through the area A is N $= nA\,|\vec{\upsilon}_d|\,\Delta t$.

➥ The total charge flowing through the cross - sectional area in time Δt is $-neA\,|\vec{\upsilon}_d|\,\Delta t$ ... (1)

➥ Here, electric field $\vec{E}$ is directed towards the left as a result the total electric charge passing through the surface in the direction of $\vec{E}$, will be equal to the negative value of above equation (1).

$\therefore q = -(-ne\,A\,|\vec{\upsilon}_d|\,\Delta t)$ ... (2)

$\therefore q = ne\,A\,|\vec{\upsilon}_d|\,\Delta t$

➥ The amount of charge crossing the area $\vec{A}$ in time Δt is by definition I Δt (where I is the magnitude of the current).

➥ Hence,

$\therefore \mathrm{I}\,\Delta t = ne\,A\,|\vec{\upsilon}_d|\,\Delta t$

$\therefore \mathrm{I} = ne\,A\,|\vec{\upsilon}_d|$ ... (3)

➥ but current density $j = \frac{\mathrm{I}}{\mathrm{A}}$

$\mathrm{I} = j\mathrm{A}$

$\therefore j\mathrm{A} = ne\,A\,|\vec{\upsilon}_d|$ ($\because$ from eq^n (3))

$\therefore j = ne \left|\vec{\upsilon}_d\right|$ ... (4)

$\therefore j = ne\left(\frac{eE}{m}\right) \cdot \tau \; (\because \left|\vec{\upsilon}_d\right| = \frac{eE}{m}\tau)$

$\therefore j = \frac{ne^2E}{m}\tau$ ... (5)

➥ Writing above equation (5) in vector form

$$\vec{j} = \frac{ne^2\tau}{m} \cdot \vec{E}$$

➥ Now comparing above equation with $\vec{j} = \sigma\vec{E}$

we get

$\therefore \sigma\vec{E} = \frac{ne^2\tau}{m} \cdot \vec{E}$

$\therefore \sigma = \frac{ne^2\tau}{m}$ ... (6)

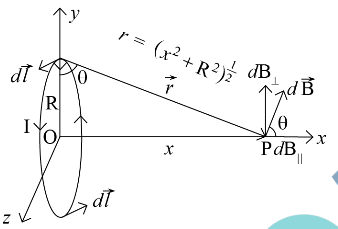
➥ Resistivity of conductor is reciprocal of conductivity

$\varrho = \frac{1}{\sigma}$

$\therefore \varrho = \frac{m}{ne^2\tau}$ ... (7)

16.

➥ As shown in the figure, a steady current I is flowing through a conducting loop of radius R.



➥ The loop is placed in such a way that it lies in the y-z plane and the X-axis passing through its axis.

➥ A point P lies at a distance x on the X-axis from its origin. We want to calculate the magnetic field at the point P.

➥ Consider a current element $I\,d\vec{l}$ from the loop shown in figure. The magnitude of the magnetic field due to this element is,

$dB = \frac{\mu_0}{4\pi} \cdot \frac{\left|I d\vec{l} \times \vec{r}\right|}{r^3}$ ... (1)

➥ But $I\,d\vec{l} \perp \vec{r}$ because $I\,d\vec{l}$ is in the yz plane and the position vector ($\vec{r}$) is in xy plane.

$\therefore dB = \frac{\mu_0}{4\pi} \cdot \frac{Idlr\,sin\,90}{r^3}$

$\therefore dB = \frac{\mu_0}{4\pi} \cdot \frac{Idl}{r^2}$ ... (2)

➥ From the figure, $r^2 = R^2 + x^2$. Hence,

$dB = \frac{\mu_0}{4\pi} \cdot \frac{Idl}{(R^2 + x^2)}$ ... (3)

➥ The magnetic field has two components at point P

(i) Perpendicular component ($dB_\perp = dB\,sin\,\theta$)

➥ When the perpendicular components are summed to get the net magnetic field, they cancel each other and the result is zero

(ii) Parallel component ($dB_{||} = dB\cos\theta$)

- The parallel components are summed up to get the net magnetic field, so it can be obtained by integrating $dB_x = dB\cos\theta$ over the loop.
- $dB(x) = dB\cos\theta$

$$\therefore dB(x) = \frac{\mu_0}{4\pi} \cdot \frac{Idl}{R^2 + x^2} \cdot \cos\theta \text{ ... (4) } (\because \text{ from equation (3)})$$

- From the figure,

$$\cos\theta = \frac{R}{(x^2 + R^2)^{\frac{1}{2}}}$$

$$\therefore dB(x) = \frac{\mu_0}{4\pi} \cdot \frac{Idl}{R^2 + x^2} \cdot \frac{R}{(R^2 + x^2)^{\frac{1}{2}}}$$

$$\therefore dB(x) = \frac{\mu_0}{4\pi} \cdot \frac{Idl \cdot R}{(R^2 + x^2)^{\frac{3}{2}}}$$

- The resultant magnetic field.

$$B = \oint dB(x) = \frac{\mu_0 IR}{4\pi(R^2 + x^2)^{\frac{3}{2}}} \oint dl$$

$$\therefore B = \frac{\mu_0 IR}{4\pi(R^2 + x^2)^{\frac{3}{2}}} (2\pi R) \left(\because \oint dl = 2\pi R\right)$$

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

- In vector form,

$$\vec{B} = \frac{\mu_0 IR^2}{2(R^2 + x^2)^{\frac{3}{2}}} \cdot \hat{i}$$

- To obtain the magnetic field at the centre of the loop $x = 0$

$$\therefore B = \frac{\mu_0 IR^2}{2R^3} = \frac{\mu_0 I}{2R}$$

- If there are N turns, then

$$\vec{B} = \frac{\mu_0 NIR^2}{2(R^2 + x^2)^{\frac{3}{2}}} \cdot \hat{i}$$

17.

- $V_m = 283$ V

  R = 3 Ω

  C = 796 ∝F

  $v = 50$ Hz

  L = 25.48 mH

- (a) Impedence of the circuit (Z),
  - Inductive reactance (X_L)

    $X_L = \omega L = 2\pi v L$

    $\therefore X_L = 2 \times 3.14 \times 50 \times 25.48 \times 10^{-3}$

    $\therefore X_L = 8000.72 \times 10^{-3}$

    $\therefore X_L = 8\ \Omega$
  - Capacitive reactance (X_C)

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

$$\therefore X_C = \frac{1}{2 \times 3.14 \times 50 \times 796 \times 10^{-6}}$$

$$\therefore X_C = \frac{1000000}{249944}$$

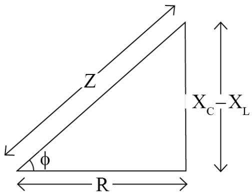
$$\therefore X_C = 4\ \Omega$$

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

$$\therefore Z = \sqrt{3^2 + (4-8)^2}$$

$$\therefore Z = 5\ \Omega$$

(b) Phase difference (φ)



(impedance diagram)

$$\tan\varphi = \frac{X_C - X_L}{R}$$

$$\tan\varphi = \frac{4-8}{3}$$

$$\tan\varphi = -\frac{4}{3}$$

$$\tan\varphi = -1.3333$$

$$\varphi = -53.1^\circ$$

$(\because \tan(-\theta) = -\tan\theta)$

Note : Here φ is negative. So the current in the circuit is lagging behind the voltage between two terminals of the source.

(c) Power dissipated in the circuit :

$$P = I^2 R$$

$$\text{But } I = \frac{I_m}{\sqrt{2}}$$

$$\therefore I = \frac{V_m}{Z\sqrt{2}}$$

$$\therefore P = \frac{V_m^2}{Z^2(2)} \cdot R$$

$$\therefore P = \frac{(283)^2 \times 3}{25 \times 2}$$

$$\therefore P = 4800\ W$$

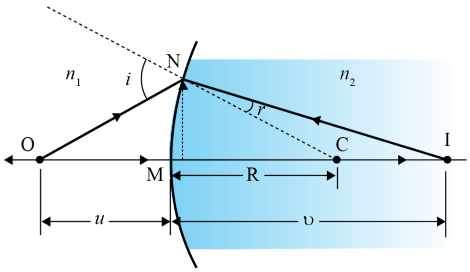
(d) Power factor,

$\cos\varphi = \cos(-53.1^\circ)$ $(\because \cos(-\theta) = \cos\theta)$

$= \cos 53.1^\circ$

$= 0.6$

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,

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

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

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

➥ 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, $\angle$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.

➥ $\varphi_0 = 2.14\ eV$

$V_0 = 0.60\ V$

$v_0 = ?$

$\lambda = ?$

➥ (a) The cut off or threshold frequency

$\varphi_0 = hv_0$

$$\therefore v_0 = \frac{\phi_0}{h}$$

$$= \frac{2.14 \times 1.6 \times 10^{-19}}{6.625 \times 10^{-34}}$$

$v_0 = 0.5163 \times 10^{15}$ Hz

$v_0 = 5.16 \times 10^{14}$ Hz

➥ (b) Einstein's photoelectric equation is

$K_{max} = hv - \varphi_0$

but $K_{max} = eV_0$

$$\therefore eV_0 = \frac{hc}{\lambda} - \varphi_0\ (C = v\lambda)$$

$$\therefore \frac{hc}{\lambda} = eV_0 + \varphi_0$$

$$\therefore \frac{hc}{\lambda} = (1.6 \times 10^{-19} \times 0.60) + (2.14 \times 1.6 \times 10^{-19})$$

$$\therefore \frac{hc}{\lambda} = 1.6 \times 10^{-19}\ (0.60 + 2.14)$$

$$\therefore \frac{hc}{\lambda} = 4.384 \times 10^{-19}$$

$$\therefore \lambda = \frac{6.625 \times 10^{-34} \times 3 \times 10^{8}}{4.384 \times 10^{-19}}$$

$\therefore \lambda = 4.54 \times 10^{-7}$ m

$= 454 \times 10^{-9}$ m

$\lambda = 454$ nm

20.

➥ Nucleus of copper contains 29 protons and number of neutrons $N = A - Z$

$= 34$

➥ Mass Defect $\Delta M = [Zm_p + Nm_n] - m({}^{63}_{29}Cu)$

$\therefore \Delta M = [29 \cdot 1.007825 + 34 \cdot 1.008665] - 62.92960$

$\therefore \Delta M = [29.226925 + 34.29461] - 62.92960$

$\therefore \Delta M = 0.591935\ u$

- Binding Energy

  $E_b = \Delta M c^2$

  $\therefore E_b = 0.591935 \times 931.5$

  $\therefore E_b = 551.39$ MeV
- An energy of 551.39 MeV is required to separate protons and neutrons in a copper nucleus.
- Number of atoms in 3 g copper coin,

  Mass of Cu Number of atoms in Cu

  63 g $6.022 \cdot 10^{23}$

  $\therefore$ 3 g (?)
- Number of atoms in coin,

  $$N = \frac{3 \times 6.022 \times 10^{23}}{63} = 2.87 \cdot 10^{22}$$
- The energy required to separate all the neutrons and protons from the copper of 3 g.

  $E = E_b \cdot N$

  $\therefore E = 551.39 \cdot 2.87 \cdot 10^{22}$ MeV

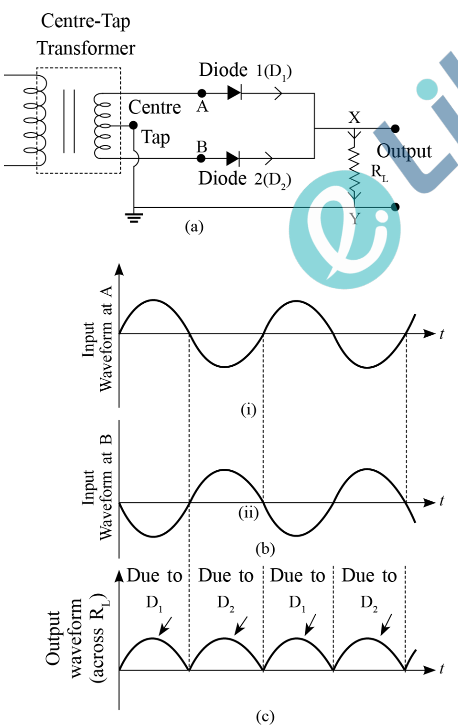
  $\therefore E = 1582.4893 \cdot 10^{22}$ MeV

  $\therefore E = 1582.4893 \cdot 10^{22} \cdot 10^{6} \cdot 1.6 \cdot 10^{-19}$ J

  $\therefore E = 2531.98 \cdot 10^{9}$ J

  $\therefore E = 2.53 \cdot 10^{9}$ J

21.

- 

- The circuit diagram of the full-wave rectifier is shown in the figure. In full wave rectifier, two *p* - *n* junction diodes are used.
- In this type of rectifier, the rectified output voltage is obtained during both the positive as well as negative half of ac cycle. Hence, it is known as full-wave rectifier.

- As shown in fig., the *p*-side of the two diodes are connected to the ends of the secondary of the transformer. The *n*-side of the diodes are connected together and the output is taken between this common point of diodes and the mid-point of the secondary of the transformer. So for a full wave rectifier the secondary of the transformer is provided with a centre tapping and so it is called centre-tap transformer.
- As can be seen from fig. (c), the voltage rectified by each diode is only half the total secondary voltage. Each diode rectifies only for half the cycle, but the two do so for alternate cycles. Thus the output between their common terminals and the centre tap of the transformer becomes a full-wave rectifier output.
- Suppose the input voltage to A with respect to centre tap at any instant is positive. At that instant, voltage B being out of phase should be negative. In this case, diode D_1 gets forward biased and conducts, while D_2 gets reverse biased and does not conduct. Hence, as shown in fig. c, output current is obtained between two terminals of R_L during this half-cycle.
- During the other half-cycle, voltage at A is negative and voltage at B is positive. In this case diode D_1 is in reverse bias condition and D_2 is in forward bias. Hence, in this part of cycle, D_2 conducts and output voltage is obtained.
- Thus, we get output voltage during both positive as well as negative half of the cycle.

Section C

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

22.

- $E_x = \alpha x^{\frac{1}{2}}$ $E_y = 0$ $E_z = 0$

  $\alpha = 800$ N/C $m^{\frac{1}{2}}$ $a = 0.1$ m

  (a) Here, the electric field is only in the direction of X-axis. Hence, for all the unshaded faces in the fig., the angle between electric field $\vec{E}$ and area vector $\Delta \vec{S}$ becomes $90° \left(\frac{\pi}{2}\right)$,

  therefore flux associated with those surfaces becomes zero.
- The magnitude of electric field at the left face is,

  From, $E_L = \alpha x^{\frac{1}{2}}$

  $E_L = \alpha a^{\frac{1}{2}}$ (For the left side $x = a$)
- The magnitude of electric field at the right face is,

  From, $E_R = \alpha x^{\frac{1}{2}}$

  $E_R = \alpha (2a)^{\frac{1}{2}}$ (For the right face $x = 2a$)
- Total electric (Net) flux through the cube,

  $\varphi = \varphi_L + \varphi_R$

  $\therefore \varphi = \vec{E}_L \cdot \vec{S} + \vec{E}_R \cdot \vec{S}$

  $\therefore \varphi = E_L S \cos \pi + E_R S \cos 0$

  $\therefore \varphi = \left(\alpha a^{\frac{1}{2}}\right)(a^2) \cos \pi + \left(\alpha (2a)^{\frac{1}{2}}\right)(a^2) \cos 0$

  $\therefore \varphi = -\alpha a^{\frac{5}{2}} + \sqrt{2}\, \alpha a^{\frac{5}{2}}$

  $\therefore \varphi = \alpha a^{\frac{5}{2}} (-1 + \sqrt{2})$

  $\therefore \varphi = (800)\, (0.1)^{\frac{5}{2}}\, (-1 + 1.414)$

  $\therefore \varphi = 1.05 \frac{Nm^2}{C}$

  (b) Total (Net) electric charge in the cube,

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

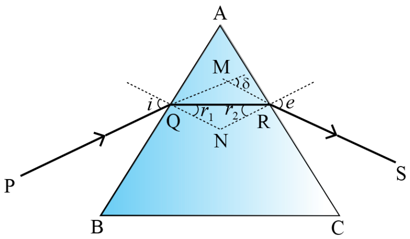
$$\therefore q = \varphi\, \varepsilon_0$$

$$= 1.05 \cdot 8.85 \cdot 10^{-12}$$

$$\therefore q = 9.29 \cdot 10^{-12}\ \text{C}$$

23.

21. Derive $i + e = A + \delta$ for a triangular glass prism. Also write the condition for the angle of minimum deviation. Derive the formula for the refractive index of the material of the prism.

➥ 

➥ Figure shows the cross section of a prism.

➥ The path of a light passing through this prism is PQRS.

➥ The angle of incidence is i and the angle of refraction is r at the first side AB.

➥ The angle incidence is r_2 and the angle of emergence (angle of refraction) is e.

➥ Angle between the direction of emergent ray RS and incident ray PQ is called angle of deviation (δ).

➥ In □AQNR m∠AQN = m∠ARN = 90°.

➥ The sum of remaining two angles is 180°.

$\therefore \angle A + \angle QNR = 180° \ ... (1)$

➥ For ΔQNR,

$r_1 + r_2 + \angle QNR = 180° \ ... (2)$

➥ Comparing equation (1) and (2),

$\therefore \angle A + \angle QNR = r_1 + r_2 + \angle QNR$

$\therefore A = r_1 + r_2 \ ... (3)$

➥ For ΔQMR, δ is the exterior angle.

$\therefore \delta = \angle MQR + \angle MRQ \ ... (4)$

but $i = r_1 + \angle MQR$

$\therefore \angle MQR = i - r_1$

and same way $\angle MRQ = e - r_2$.

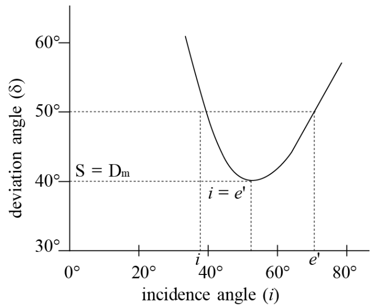
➥ Substituting these two values in equation (4),

$\therefore \delta = i - r_1 + e - r_2$

$\therefore \delta = i + e - (r_1 + r_2)$

➥ From equation (3),

$\therefore \delta = i + e - A$

➥ 

➥ The graph of deviation angle versus incidence angle is shown in figure.

➥ The graph shows that for a single value of deviation angle (δ) there are two values of incidence angle i and hence also of e.

➥ From the symmetry it can be said that angle of deviation δ remains the same if angle of incidence i and angle of emergent e are interchanged. Even if the path of ray can be traced back, resulting in the same angle of deviation.

➥ From the graph, for a particular value of $i = e$ the angle of incidence, a single value of deviation is obtained. At the minimum deviation, D_m, the refracted ray becomes parallel to its base.

➥ So when $\delta = D_m$ and $i = e$, then $r_1 = r_2$.

➥ For prism, $A = r_1 + r_2$

$\therefore A = 2r_1$

$\therefore r_1 = \frac{A}{2}$ ... (1)

➥ and from $\delta = i + e - A$,

$D_m = 2i - A$

$2i = D_m + A$

$i = \frac{A + D_m}{2}$ ... (2)

➥ Applying Snell's law at incident point Q,

$n_1 \sin i = n_2 \sin r_1$

➥ Substituting value of r_1 and i from equation (1) and (2),

$$\therefore n_1 \sin\left(\frac{A + D_m}{2}\right) = n_2 \sin\left(\frac{A}{2}\right)$$

$$\therefore \frac{n_2}{n_1} = \frac{\sin\left(\frac{A + D_m}{2}\right)}{\sin\frac{A}{2}}$$

$$\therefore n_{21} = \frac{\sin\left(\frac{A + D_m}{2}\right)}{\sin\frac{A}{2}}$$

➥ which is the formula to find the refractive index of the material of the prism.

22. A beam of light consisting of two wavelengths 6000 Å and 4000 Å, is used to obtain interference fringes in a Young's double-slit experiment.
a) Find the distance of the third dark fringe on the screen from the central maximum for wavelength 6000 Å.
b) What is the least distance from the central maximum where bright fringes due to both the wavelengths coincide?
(Distance between two slits = 0.1 mm. Take D = 100 cm)

➥ Self Practice

23. Explain the process of thermonuclear fusion as a source of energy in the Sun.

➥ Sun continuously emits energy due to thermonuclear fusion. The interior of the Sun has a temperature of $1.5 \cdot 10^7$ K.

➥ The thermonuclear fusion process in the Sun is known as proton-proton cycle.

➥ This process is a multi-step process in which the hydrogen is burned into helium. Thus the fuel in the Sun is the hydrogen in its core.

➥ The proton-proton cycle is represented by the following sets of reactions :

${}^1_1H + {}^1_1H \rightarrow {}^2_1H + e^+ + \nu + 0.42$ MeV ...(i)

$e^+ + e^- \rightarrow \gamma + \gamma + 1.02$ MeV ...(ii)

${}^2_1H + {}^1_1H \rightarrow {}^3_2He + \gamma + 5.49$ MeV ...(iii)

${}^3_2He + {}^3_2He \rightarrow {}^4_2He + {}^1_1H + {}^1_1H + 12.86$ MeV ...(iv)

➥ In this reaction, the first three reactions must occur twice and in the fourth reaction two light helium nuclei unite to form ordinary helium nucleus.

➥ If we consider the combination

2(i) + 2(ii) + 2(iii) + (iv), the net effect is

$4\,{}_1H^1 + 2e^- \longrightarrow {}_2He^4 + 2\nu + 6\gamma + 26.7$ MeV

OR

$$4\,{}_1H^1 + 4e^- \rightarrow [{}_2He^4 + 2e^-] + 2\nu + 6\gamma + 26.7\ MeV$$

➥ Thus four hydrogen atoms combine to form an ${}_2He^4$ atom with a release of 26.7 MeV of energy.