LIBERTY PAPER SET

STD. 12 : Physics

Full Solution

Time : 3 Hours **ASSIGNTMENT PAPER 15**

Section A

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

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.

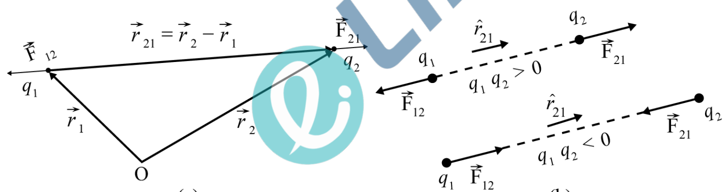
(vi) Distribution of electric field lines gives an idea of electric field intensity in that region.

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

2.

➥ The electric force (Coulomb force) between two point stationary charges is proportional to the product of the values of the charges and inversely proportional to the square of the distance between them. The direction of this force is in the direction of the line joining the two charges.

➥ Let the position vectors of charges q_1 and q_2 be $\vec{r}_1$ and $\vec{r}_2$ respectively [see Fig. (a)].



(a) (b)

➥ We denote force on q_1 due to q_2 by $\vec{F}_{12}$ and force on q_2 due to q_1 by $\vec{F}_{21}$. The two point charges q_1 and q_2 have been numbered 1 and 2 for convenience and the vector leading from 1 to 2 is denoted by $\vec{r}_{21}$:

$$\vec{r}_{21} = \vec{r}_2 - \vec{r}_1$$

➥ In the same way, the vector leading from 2 to 1 is denoted by $\vec{r}_{12}$:

$$\vec{r}_{12} = \vec{r}_1 - \vec{r}_2 = -\vec{r}_{21}$$

➥ The magnitude of the vectors $\vec{r}_{21}$ and $\vec{r}_{12}$ is denoted by r_{21} and r_{12}, respectively ($r_{12} = r_{21}$).

➥ The direction of a vector is specified by a unit vector along the vector. To denote the direction from 1 to 2 (or from 2 to 1), we define the unit vectors :

$$\hat{r}_{21} = \frac{\vec{r}_{21}}{r_{21}}, \quad \hat{r}_{12} = \frac{\vec{r}_{12}}{r_{12}}, \quad \hat{r}_{21} = -\hat{r}_{12}$$

➥ Coulomb's force law between two point charges q_1 and q_2 located at $\vec{r}_1$ and $\vec{r}_2$, respectively is then expressed as

$$\vec{F}_{21} = \frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2}{r_{21}^2} \hat{r}_{21} \quad \text{... (1)}$$

➥ Equation is valid for any sign of q_1 and q_2 whether positive or negative.

➥ If q_1 and q_2 are of the same sign (either both positive or both negative), F_{21} is along $\hat{r}_{21}$, which denotes repulsion, as it should be for like charges.

➥ If q_1 and q_2 are of opposite signs, F_{21} is along $-\hat{r}_{21} = \hat{r}_{12}$, which denotes attraction, as expected for unlike charges.

➥ The force $\vec{F}_{12}$ on charge q_1 due to charge q_2 is obtained from Eq. by simply interchanging 1 and 2, i.e.,

$$\vec{F}_{12} = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r_{12}^2}\hat{r}_{12} = -\vec{F}_{21}$$

➥ Thus, Coulomb's law agrees with Newton's third law.

3.

➥ The statements of Kirchhoff''s laws are as follows :

(1) Junction rule : *"At any junction, the sum of the currents entering the junction is equal to the sum of currents leaving the junction."*

(2) Loop rule : *"The algebraic sum of changes in potential around any closed loop involving resistors and cells in the loop is zero."*

➥ Kirchhoff's junction rule works on the law of conservation of charge and loop rule works on the law of conservation of energy.

4.

➥ Magnetisation : *"The net magnetic dipole moment per unit volume in a substance is called magnetisation."*

➥ Magnetisation $\vec{M} = \frac{\vec{m}_{net}}{V}$

➥ Magnetisation is a vector quantity and its direction is taken in the direction of magnetic dipole moment.

➥ Its unit is $\frac{A}{m}$ (or $A.m^{-1}$) and dimensional formula is $L^{-1} A^{1}$.

➥ Consider a long solenoid of n turns per unit length and carrying current I.

➥ The magnetic field in the interior of the solenoid,

$B_0 = \propto_0 n I$ ... (1)

➥ If the interior of the solenoid is filled with a material having non-zero magnetisation, magnetic field (B_m) is generated due to this core material inside the solenoid.

Therefore, the net field in the interior of the solenoid is equal to the vector addition of both the magnetic fields.

$\therefore \vec{B} = \vec{B}_0 + \vec{B}_m$ ... (2)

Where $\vec{B}_m$ is the field contributed by magnetic core.

➥ This additional field $\vec{B}_m$ is proportional to the magnetisation ($\vec{M}$) of the material.

$\therefore \vec{B}_m \ \alpha \ \vec{M}$

$\therefore \vec{B}_m = \propto_0 \vec{M}$ ... (3)

➥ Substituting the value of $\vec{B}_m$ from eq. (3) into eq. (2),

$\therefore \vec{B} = \vec{B}_0 + \propto_0 \vec{M}$

➥ dividing the equation by $\propto_0$,

$\therefore \frac{\vec{B}}{\mu_0} = \frac{\vec{B}_0}{\mu_0} + \vec{M}$

but $\frac{\vec{B}_0}{\mu_0} = \vec{H}$ – Which is a vector quantity called magnetic intensity.

$\therefore \frac{\vec{B}}{\mu_0} = \vec{H} + \vec{M}$

$\therefore \vec{B} = \propto_0(\vec{H} + \vec{M})$

➥ Magnetic intensity ($\vec{H}$) has same dimensions as $\vec{M}$ and its unit is $\frac{A}{m}$ (or $A.m^{-1}$).

5.

➥ When electric current through an isolated conducting coil is changed, magnetic flux linked with it changes. As a result, induced *emf* is produced in the coil. This phenomenon is called self induction.

➥ Here, induced *emf* is called self induced *emf*.

➥ Suppose, electric current passing through an isolated coil having N turns is I.

➥ Total magnetic flux linked with coil,

$N\varphi_B \propto I$

$\therefore N\varphi_B = L I$ ... (1)

➥ Proportionality constant L in equation (1) is called self inductance.

➥ On changing current with time, magnetic flux linked changes. As a result, induced *emf* is produced.

$\therefore N \dfrac{d\phi_B}{dt} = L \dfrac{dI}{dt}$ ... (2)

➥ According to Faraday's law,

$\varepsilon = -N \dfrac{d\phi_B}{dt}$ ... (3)

From equation (2) and (3),

$\varepsilon = -L \dfrac{dI}{dt}$ ... (4)

Equation (4) is expression for self induced *emf*.

6.

➥ Voltage of the AC source,

$\upsilon = \upsilon_m \sin \omega t$

➥ Electric current in the circuit having only inductor,

$i = i_m \sin\left(\omega t - \dfrac{\pi}{2}\right)$

Where, $i_m = \dfrac{\upsilon_m}{\omega L}$ Amplitude of electric current

➥ The instantaneous power supplied to the inductor is.

$p = \upsilon i$

$\therefore\ p = \upsilon_m i_m \sin \omega t \sin\left(\omega t - \dfrac{\pi}{2}\right)$

$\therefore\ p = -\upsilon_m i_m \sin \omega t \cos \omega t$

$\therefore\ p = -\dfrac{\upsilon_m i_m}{2} (2 \sin \omega t \cos \omega t)$

➥ But $2 \sin \omega t \cos \omega t = \sin 2\omega t$

$\therefore\ p = -\dfrac{\upsilon_m i_m}{2} \sin 2\omega t$

➥ The average power over a complete cycle is

$P = \overline{p} = \left\langle -\dfrac{\upsilon_m i_m}{2} \sin 2\omega t \right\rangle$

$P = -\dfrac{i_m \upsilon_m}{2} \langle \sin 2\omega t \rangle$

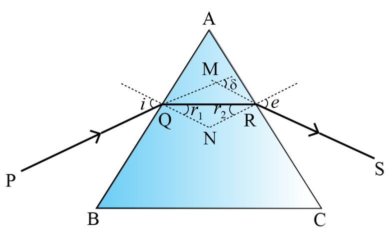
But $\langle \sin 2\omega t \rangle = 0$

$\therefore\ P = 0$

➥ Thus, the average power supplied to an inductor over one complete cycle is zero.

7.

➥



- 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 $\square$AQNR m$\angle$AQN = m$\angle$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),

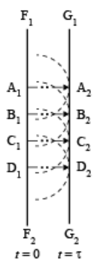
  $\therefore \delta = i - r_1 + e - r_2$

  $\therefore \delta = i + e - (r_1 + r_2)$
- From equation (3),

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

8.

- **Huygen's principle :**
- "Every point or particle of a wavefront behaves as an independent secondary source, emits by itself secondary spherical waves. After a very small time interval the surface tangential to all such secondary spherical wavelets gives the position and shape of the new wavefront."



- A plane wavefront F_1F_2 is shown in the fig. at time $t = 0$.
- To determine the shape of the wavefront at time $t = \tau$, we draw spheres of radius $\upsilon\tau$, from each point (points A_1, B_1, C_1 .... etc.) on the wavefront. (Where υ is the speed of waves in the medium.)
- A tangent common to all such points is drawn, which gives the position and shape of the new wavefront at time $t = \tau$.

9.

➥ (i) During the interaction of radiation with matter, the radiation behaves as if it is made up of particles called photons.

(ii) The energy of each photon is

$E = hv = \frac{hc}{\lambda}$ and

momentum $p = \frac{hv}{c}$

(iii) If the frequency v and wave lenght λ of a radiation are constant,

its energy $E = hv = \frac{hc}{\lambda}$ and momentum

$p = \frac{hv}{c}$ remains constant.

➠ If the intensity of the radiation is changed, the number of photons emitted (or incident) per unit time changes, but the energy remains constant.

(iv) Photons are electrically neutral and are not affected by electric or magnetic fields.

(v) Energy and momentum are conserved during photon-particle collision, but the number of photons is not conserved.

➠ During the collision the number of photons may decrease such that in photoelectric emission the number of photons decreases and an electron is emitted.

➠ The number of photons can also increase during the collision. For example, x-rays (photons) are emitted from high-energy electrons striking a metal such as Mo (molybdenum).

10.

➥ From Bohr's second postulate, the formula for the radius of n^{th} orbit for hydrogen atom is.

$$r_n = \frac{n^2 h^2 \varepsilon_0}{\pi m e^2} \quad \text{... (1)}$$

➥ The total energy of the electron in the stationary states of the hydrogen atom is

$$E_n = -\frac{1}{8\pi\varepsilon_0} \frac{e^2}{r_n} \quad \text{... (2)}$$

➥ Using equation (1) and equation (2)

$$E_n = -\frac{1}{8\pi\varepsilon_0} \frac{e^2}{\left(\frac{n^2 h^2 \varepsilon_0}{\pi m e^2}\right)}$$

$$\therefore E_n = -\frac{me^4}{8\varepsilon_0^2 n^2 h^2}$$

➥ Substituting $m = 9.1 \times 10^{-31}$ kg

$e = 1.6 \times 10^{-19}$ C

$\varepsilon_0 = 8.85 \times 10^{-12} \frac{C^2}{Nm^2}$

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

➥ Simplifying equation,

$$E_n = -\frac{2.18 \times 10^{-18}}{n^2} \text{ J}$$

➥ Atomic energies are often expressed in electron volts (eV).

$$\therefore E_n = -\frac{2.18 \times 10^{-18}}{n^2 \times 1.6 \times 10^{-19}} \; eV$$

$$\therefore E_n = -\frac{13.6}{n^2} \; eV$$

- The negative sign of the total energy of an electron moving in an orbit means that the electron is bound with the nucleus.
- Thus, energy will be required to remove the electron from the hydrogen atom to a distance infinitely far away from its nucleus.

11.

- 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 :

$${}_1^1\mathrm{H} + {}_1^1\mathrm{H} \rightarrow {}_1^2\mathrm{H} + e^+ + \nu + 0.42\ \mathrm{MeV} \ ...(\mathrm{i})$$

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

$${}_1^2\mathrm{H} + {}_1^1\mathrm{H} \rightarrow {}_2^3He + \gamma + 5.49\ \mathrm{M}e\mathrm{V} \ ...(\mathrm{iii})$$

$${}_2^3He + {}_2^3He \rightarrow {}_2^4He + {}_1^1\mathrm{H} + {}_1^1\mathrm{H} + 12.86\ \mathrm{M}e\mathrm{V} \ ...(\mathrm{iv})$$

- 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

$$4\,{}_1\mathrm{H}^1 + 2e^- \rightarrow {}_2\mathrm{H}e^4 + 2\nu + 6\gamma + 26.7\ \mathrm{M}e\mathrm{V}$$

OR

$$4\,{}_1\mathrm{H}^1 + 4e^- \rightarrow [{}_2\mathrm{H}e^4 + 2e^-] + 2\nu + 6\gamma + 26.7\ \mathrm{M}e\mathrm{V}$$

- Thus four hydrogen atoms combine to form an ${}_2\mathrm{He}^4$ atom with a release of 26.7 MeV of energy.

12.

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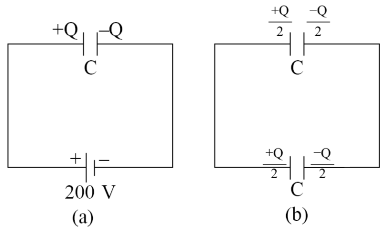
Forward Bias	Reverse Bias
p - type semiconductor of p - n junction is connected to positive terminal and n - type is connected with negative terminal of battery. Such a biasing is called forward biasing.	p - type semiconductor of p - n junction is connected to negative terminal and n - type is connected with positive terminal of battery. Such a biasing is called reverse biasing.
In forward bias, the current is due to majority charge carriers.	In Reverse bias, the current is due to minority charge carriers.
Current obtained in forward bias is of the order of mA.	Current obtained in Reverse bias is of the order of $\propto$A.
When diode is connected in forward bias, width of its depletion layer and height of potential barrier reduces.	When diode is connected in reverse bias, width of its depletion layer and height of potential barrier increases.
Resistance is of the order of 10 Ω to 100 Ω.	Resistance is of the order of 10 MΩ.

Section B

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

13.

➥ 

➥ C = 600 pF

V = 200 V

➥ Energy stored in the capacitor initially,

$$U_1 = \frac{1}{2} CV^2$$

$$U_1 = \frac{1}{2} \times 600 \times 10^{-12} \times (200)^2$$

$$U_1 = 12 \times 10^{-6} \text{ J}$$

➥ Charge on the capacitor,

$$Q = CV$$

$$\therefore Q = 600 \times 10^{-12} \times 200$$

$$\therefore Q = 12 \times 10^{-8} \text{ C}$$

➥ As shown in fig. (b), after removal of the battery, when a new uncharged capacitor is connected, the charge is distributed equally, on both the capacitors.

➥ Hence, the charge on each capacitor becomes $\frac{Q}{2}$ but the total charge Q remains constant.

➥ As shown in fig.(b), for the parallel connection, equivalent capacitance will be C' = 2C.

➥ Energy stored in the system in the final condition,

$$U' = \frac{Q^2}{2C'} = \frac{Q^2}{2(2C)}$$

$$\therefore U' = \frac{(12 \times 10^{-8})^2}{4 \times 600 \times 10^{-12}}$$

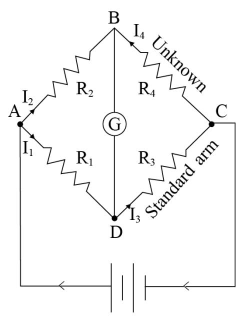
$$\therefore U' = 6 \times 10^{-6} \text{ J}$$

➥ Energy loss (/ lost) during the process,

$$\Delta U = U - U' = 12 \times 10^{-6} - 6 \times 10^{-6}$$

$$\Delta U = 6 \times 10^{-6} \text{ J}$$

14.

➥ 

- 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

  $-I_1R_1 + 0 + I_2R_2 = 0$

  $\therefore I_1R_1 = I_2R_2$ ... (1)
- Applying similarly, for closed loop C – B – D – C

  $I_4R_4 + 0 - I_3R_3 = 0$

  $\therefore I_3R_3 = I_4R_4$ ... (2)
- Taking ratio of equation (1) and (2)

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

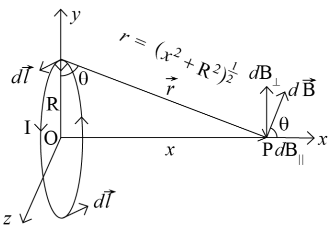
  But $I_1 = I_3$ and $I_2 = I_4$

  $\therefore \frac{R_1}{R_3} = \frac{R_2}{R_4}$ OR $\frac{R_1}{R_2} = \frac{R_3}{R_4}$ ... (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

  $R_4 = R_3 \cdot \frac{R_2}{R_1}$ ... (4)
- A practical device using this principle is called the meter bridge.

15.

- 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,

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

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

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

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

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

➥ 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.

➠ $dB(x) = dB \cos\theta$

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

➠ 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.

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

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

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

➥ 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

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

16.

➥ (a) Magnetic energy stored in solenoid

$$U_B = \frac{1}{2} LI^2$$

$= \frac{1}{2} L \left(\frac{B}{\mu_0 n}\right)^2$

$(\because$ for solenoid, $B = \propto_0 nI \Rightarrow I = \frac{B}{\mu_0 n})$

$= \frac{1}{2} (\propto_0 n^2 Al) \left(\frac{B}{\mu_0 n}\right)^2$

$(\because$ Self inductance of solenoid $L = \propto_0 n^2 Al)$

$= \frac{1}{2} \propto_0 n^2 Al \times \frac{B^2}{\mu_0^2 n^2}$

$U_B = \frac{1}{2\mu_0} (B^2 Al) \ldots (1)$

(b) Magnetic energy per unit volume

$\rho_B = \frac{U_B}{V}$ $(\because V = \text{Volume})$

$= \frac{U_B}{Al}$ $(\because$ Volume $V = Al)$

$= \frac{1}{2\mu_0} \frac{B^2 Al}{Al}$ (from eq. 1)

$\rho_B = \frac{B^2}{2\mu_0} \ldots (2)$

- Electrostatic energy stored per unit volume in parallel plate capacitor.

  $\rho_E = \frac{1}{2} \varepsilon_0 E^2 \ldots (3)$

- From equation (2) & (3), energy is directly proportional to square of field intensity in both cases.

17.

- $V_m = 283$ V

  $R = 3\ \Omega$

  $C = 796\ \mu F$

  $v = 50$ 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)

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

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

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

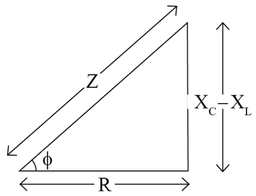
  $\therefore X_C = 4\ \Omega$

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

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

  $\therefore Z = 5\ \Omega$

(b) Phase difference (φ)



(impedance diagram)

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

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

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

$\tan \varphi = -1.3333$

$\varphi = -53.1°$

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

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 :

$P = I^2 R$

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

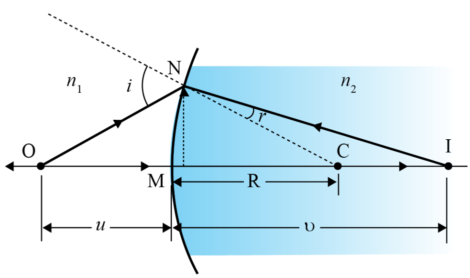
(d) Power factor,

$\cos \varphi = \cos(-53.1°)$ $(\because \cos(-\theta) = \cos\theta)$

$= \cos 53.1°$

$= 0.6$

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,

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

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

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

- For ΔNOC, i is the exterior angle.

  Therefore,

  $i = \angle NOM + \angle NCM$

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

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

- From figure for ΔNIC, $\angle NCM$ is the exterior angle.

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

  $r = \angle NCM - \angle NIM$

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

- 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.

- The resultant intensity at any point on the screen in the Young's Double slit Experiment is given by the following formula :

$$I = 4 I_0 \cos^2 \frac{\phi}{2} \quad \ldots (1)$$

  where, φ - Phase difference

- Phase difference at the P on the screen where the path difference is λ

Phase difference = $\frac{2\pi}{\lambda}$ × Path difference

$\therefore \varphi = \frac{2\pi}{\lambda} \times \lambda$

$\therefore \varphi = 2\pi$

➥ Putting I = K and $\varphi = 2\pi$ in equation (1),

$\therefore K = 4\, I_0\, cos^2 \frac{2\pi}{2}$

$\therefore K = 4\, I_0\, cos^2\, \pi$

$\therefore K = 4\, I_0$ ... (2) ($\because$ $cos^2\, \pi = (-1)^2 = 1$)

➥ Phase difference at the point on the screen where the path difference is $\frac{\lambda}{3}$,

Phase difference = $\frac{2\pi}{\lambda}$ × Path difference

$\therefore \varphi' = \frac{2\pi}{\lambda} \times \frac{\lambda}{3}$

$\therefore \varphi' = \frac{2\pi}{3}$

➥ Intensity is this point is I'.

➥ From equation (1),

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

$\therefore I' = 4\, I_0\, cos^2 \left(\frac{2\pi}{3 \times 2}\right)$

$\therefore I' = 4\, I_0\, cos^2 \left(\frac{\pi}{3}\right)$

$\therefore I' = 4\, I_0 \left(\frac{1}{2}\right)^2$

$\therefore I' = I_0$ ... (3)

➥ Taking the ratio of equation (3) and (2),

$\therefore \frac{I'}{K} = \frac{I_0}{4\, I_0}$

$\therefore I' = \frac{K}{4}$

20.

➥ In 1905, Einstien gave a historical explanation of the photoelectric effect. For which he was awarded the Nobel prize in physics in 1921.

➥ Einstein accepted Max Planck's concept of radiation.

➥ According to this concept, the energy of radiation is not continuous. Radiation is composed of discrete units of energy, (Bundles of energy) These units of energy are called quanta or photons.

Each quantum (photon) has energy $E = h\nu$.

Where, h = Planck's constant

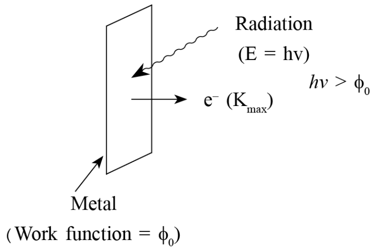
$h = 6.625 \times 10^{-34}$ J s

ν = Frequency of radiation

➥ When radiation is incident on a metal surface, the electrons in the metal interact with the quanta of the radiation. If the energy of quantum ($h\nu$) is greater than the work function (φ_0) of a given metal, the electron absorbs this quantum. i.e. the full energy of the quantum ($h\nu$) is absorbed and is emitted from the metal with a maximum kinetic energy K_{max}.

➥ Thus, $K_{max} = h\nu - \varphi_0$

➥ This equation is called Einstein's equation of photoelectric effect.



➥ If a photon interacts with an strongly bound electron than electron requires more energy to be ejected. So it is emitted with less energy than K_{max}.

21.

➥ (a) The radius of electron

$$r_n = \frac{n^2 h^2 \varepsilon_0}{\pi m e^2} \quad \dots (1)$$

➠ We know $F_c = F_e$

(Centripetal force) = (Coulomb Force)

$$\frac{m\upsilon_n^2}{r_n} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{e^2}{r_n^2}$$

$$\therefore \upsilon_n^2 = \frac{1}{4\pi\varepsilon_0} \cdot \frac{e^2}{m\, r_n}$$

➠ Putting the value from equation (1)

$$\therefore \upsilon_n^2 = \frac{1}{4\pi\varepsilon_0} \cdot \frac{e^2}{m\left(\frac{n^2 h^2 \varepsilon_0}{\pi m e^2}\right)}$$

$$\therefore \upsilon_n^2 = \frac{e^4}{4h^2 \varepsilon_0^2 n^2}$$

$$\therefore \upsilon_n = \frac{e^2}{2\, h\varepsilon_0 n}$$

$$\therefore \upsilon_n = \frac{(1.6 \times 10^{-19})^2}{2 \times 6.625 \times 10^{-34} \times 8.85 \times 10^{-12} \times n}$$

$$\therefore \upsilon_n = \frac{2.18 \times 10^6}{n} \quad \dots (2)$$

➠ Taking $n = 1$ in equation (2),

$\upsilon_1 = 2.18 \times 10^6$ m/s

➠ Taking $n = 2$ in equation (2),

$$\upsilon_2 = \frac{2.18 \times 10^6}{2}$$

$\therefore \upsilon_2 = 1.09 \times 10^6$ m/s

➠ Taking $n = 3$ in equation (2),

$$\upsilon_3 = \frac{2.18 \times 10^6}{3}$$

$= 0.727 \times 10^6$ m/s

➥ (b) Time period (T)

$$T_n = \frac{2\pi r_n}{\upsilon_n}$$

- Using equation (1) and (2)

$$T_n = \frac{2\pi\left(\frac{n^2 h^2 \varepsilon_0}{\pi m e^2}\right)}{\frac{2.18 \times 10^6}{n}}$$

$$T_n = \frac{2h^2 \varepsilon_0\, n^3}{2.18 \times 10^6 \times m e^2}$$

$$T_n = \frac{2 \times (6.625 \times 10^{-34})^2 \times (8.85 \times 10^{-12}) \times n^3}{2.18 \times 10^6 \times 9.1 \times 10^{-31} \times (1.6 \times 10^{-19})^2}$$

$$T_n = 1.529 \times 10^{-16}\, n^3$$

$$T_n = 1.53 \times 10^{-16}\, n^3 \; ... (3)$$

- Taking $n = 1$ in equation (3)

$$T_1 = 1.53 \times 10^{-16} \text{ sec}$$

- Taking $n = 2$ in equation (3)

$$T_2 = 1.53 \times 10^{-16} \times (2)^3$$

$$\therefore T_2 = 1.22 \times 10^{-15} \text{ sec}$$

- Taking $n = 3$ in equation (3)

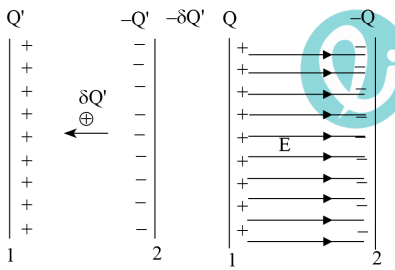
$$T_3 = 1.53 \times 10^{-16} \times (3)^3$$

$$\therefore T_3 = 4.13 \times 10^{-15} \text{ sec}$$

Section C

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

22.



- To find the energy stored in capacitor, suppose the charge on the conductor is zero, initially.
- Suppose the positive charge is taken from conductor-2 to conductor 1, bit by bit. At the end of the process, suppose the conductor 1 gets charge Q and conductor 2 has charge –Q.
- To transfer the positive charge from conductor 2 to conductor 1, work needs to be done and the energy equivalent to this work is stored in the capacitor, which is known as the energy stored in the capacitor.
- Consider the intermediate situation when the conductors 1 and 2 have charges Q' and –Q' respectively. At this stage, the p.d. V' between the conductors 1 and 2 is $\frac{Q'}{C}$ where C is the capacitance of the system.
- Now, work done to transfer a small charge δQ' from conductor 2 to conductor 1,

$$\delta W = V'\,\delta Q' = \frac{Q'}{C}\,\delta Q' \; ......(1)$$

- Total work required to be done in building (/ establishing) + Q charge on conductor 1,

$$W = \int_0^Q \frac{Q'}{C}\,\delta Q'$$

$$\therefore W = \frac{1}{C}\left(\frac{Q'^2}{2}\right)_0^Q \left[\because \int x^n dx = \frac{x^{n+1}}{n+1}\right]$$

$$\therefore W = \frac{1}{C}\left(\frac{Q^2}{2} - 0\right)$$

$$\therefore W = \frac{Q^2}{2C}$$

- Because this work is stored in capacitor in the form of energy which is called energy stored in capacitor.

$$\therefore U = \frac{Q^2}{2C}$$

- Using Q = CV in above equation, we can easily get other alternate forms of above equation.
- $$U = \frac{Q^2}{2C} = \frac{1}{2} CV^2 = \frac{1}{2} VQ$$
- Energy density : *"Energy stored per unit volume is called energy density."*
- Suppose the area of each capacitor plate is A and the distance between plates is *d*.
- Energy stored in capacitor.

$$U = \frac{Q^2}{2C}$$

but Q = σA (where σ is surface charge density)

and $C = \frac{\varepsilon_0 A}{d}$

$$\therefore U = \frac{\sigma^2 A^2}{2\left(\frac{\varepsilon_0 A}{d}\right)}$$

$$= \frac{\sigma^2 A d}{2\varepsilon_0} \quad .....(1)$$

- Electric field between two plates,

$$E = \frac{\sigma}{\varepsilon_0} \quad \therefore \sigma = E\,\varepsilon_0 \quad .....(2)$$

From eq. (1) and (2),

$$\therefore U = \frac{E^2 \varepsilon_0^2 A d}{2\varepsilon_0}$$

$$\therefore U = \frac{1}{2}\varepsilon_0 E^2 A d$$

$$\therefore \frac{U}{Ad} = \frac{1}{2}\varepsilon_0 E^2$$

but A*d* = V (Volume of the space between two plates)

$$\therefore \frac{U}{V} = \frac{1}{2}\varepsilon_0 E^2$$

$$\therefore \varrho_E = \frac{1}{2}\varepsilon_0 E^2$$

23.

➥ Applying kirchhoff's second law to closed loop B – A – D – B

$100\ I_1 - 60\ I_2 + 15\ I_g = 0$

$\therefore 20\ I_1 - 12\ I_2 + 3\ I_g = 0\ ...\ (1)$

➥ Applying Kirchhoff's second law to closed loop B – C – D – B

$-10\ (I_1 - I_g) + 5\ (I_2 + I_g) + 15\ I_g = 0$

$\therefore -2\ (I_1 - I_g) + I_2 + I_g + 3\ I_g = 0$

$\therefore -2\ I_1 + 2\ I_g + I_2 + I_g + 3\ I_g = 0$

$\therefore -2\ I_1 + I_2 + 6\ I_g = 0$

$\therefore 2\ I_1 - I_2 - 6\ I_g = 0\ ...\ (2)$

➥ Applying Kirchhoff's second law to closed loop A–D–C–ε–A

$-\ 60\ I_2 - 5(I_2 + I_g) + 10 = 0$

$\therefore -\ 60\ I_2 - 5\ I_2 - 5\ I_g + 10 = 0$

$\therefore -\ 65\ I_2 - 5\ I_g + 10 = 0$

$\therefore -\ 5\ (13\ I_2 + I_g - 2) = 0$

$\therefore 13\ I_2 + I_g = 2\ ...\ (3)$

➥ Multiplying equation (2) by 10 and subtracting from equation (1),

$$\begin{array}{rrrrl} \therefore & 20\ I_1 & -\ 12\ I_2 & +\ 3\ I_g & = 0 \\ & 20\ I_1 & -\ 10\ I_2 & -\ 60\ I_g & = 0 \\ & - & + & + & \\ \hline \end{array}$$

$-\ 2\ I_2 + 63\ I_g = 0$

$-\ 2\ I_2 = -\ 63\ I_g$

$I_2 = \frac{63}{2}\ I_g\ ...\ (4)$

➥ Using equation (4) in equation (3)

$\therefore 13\left(\frac{63}{2}\right)I_g + I_g = 2$

$\therefore \frac{819\ I_g + 2\ I_g}{2} = 2$

$\therefore 821\ I_g = 4$

$\therefore I_g = \frac{4}{821} = 4.87\ \text{mA}$

24.

➥ $V = 230\ V$

$L = 5\ H$

$C = 80\ \mu F$

$R = 40\ \Omega$

➥ (a) Source angular frequency (ω_0) which drives the circuit in resonance :

$\omega_0 = \frac{1}{\sqrt{LC}}$

$\therefore \omega_0 = \frac{1}{\sqrt{5 \times 80 \times 10^{-6}}}$

$\therefore \omega_0 = \frac{1}{20 \times 10^{-3}}$

$\therefore \omega_0 = \frac{1000}{20}$

$= 50 \ \frac{\text{rad}}{\text{s}}$

(b) At the time of resonance in the circuit,

$X_C - X_L = 0$

So, impedence Z = R

$\therefore Z = 40\ \Omega$

Amplitude of current means peak (max.) value of current (i_m)

$i_m = \sqrt{2}\ I$

$= \sqrt{2}\ \frac{V}{Z}$

$\therefore i_m = \frac{1.414 \times 230}{40}$

$\therefore i_m = 8.13$ A

(c) (i) Potential difference between two terminals of a resistor,

$V_R = I R$

$= \frac{V}{Z} \times R$

$V_R = \frac{230}{40} \times 40$

$= 230$ V

(ii) Potential difference between two terminals of an inductor,

$V_L = I X_L$

$= I \omega L$

$= \frac{V}{Z}\ \omega L$

$V_L = \frac{230}{40} \times 50 \times 5$

$V_L = 1437.5$ V

(iii) Potential difference between two terminals of a capacitor,

$V_C = I X_C$

$= \frac{V}{Z} \cdot \frac{1}{\omega C}$

$V_C = \frac{230}{40 \times 50 \times 80 \times 10^{-6}}$

$V_C = 0.0014375 \times 10^6$

$V_C = 1437.5$ V

Potential difference between two terminals of LC combination,

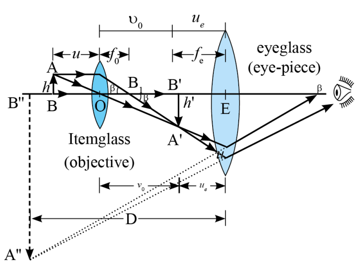
$V_{LC} = V_C - V_L$

$= 1437.5 - 1437.5$

$= 0$

(In LCR series circuit, phasors of voltage of inductor and capacitor are in mutually opposite directions.)

25.



➥ $f_0 = 2.0$ cm

$f_e = 6.25$ cm

(a) final image is at near point

➠ $\upsilon_e = -25$ cm

➠ Lens formula for eye-piece,

$$\therefore \frac{1}{\upsilon_e} - \frac{1}{u_e} = \frac{1}{f_e}$$

$$\therefore \frac{1}{\upsilon_e} - \frac{1}{f_e} = \frac{1}{u_e}$$

$$\therefore \frac{1}{u_e} = \frac{-1}{25} - \frac{1}{6.25}$$

$$\therefore \frac{1}{u_e} = \frac{-1-4}{25}$$

$\therefore u_e = -5$ cm

➠ Thus, the object distance for the eye-piece is 5 cm.

➠ The distance between two lens,

$\upsilon_0 + |u_e| = 15$ cm (which can be understood from the figure)

$\therefore \upsilon_0 + 5 = 15$

$\therefore \upsilon_0 = 10$ (image distance for objective)

➠ Applying lens formula for the objective,

$$\frac{1}{\upsilon_0} - \frac{1}{u_0} = \frac{1}{f_0}$$

$$\therefore \frac{1}{\upsilon_0} - \frac{1}{f_0} = \frac{1}{u_0}$$

$$\therefore \frac{1}{u_0} = \frac{1}{10} - \frac{1}{2}$$

$$\therefore \frac{1}{u_0} = \frac{1-5}{10}$$

$$\therefore \frac{1}{u_0} = -\frac{4}{10}$$

$\therefore u_0 = -2.5$ cm

➠ Thus, object should be kept at a distance of 2.5 cm from the objective.

➠ Magnification of microscope,

$m = m_0 \times m_e$

$$\therefore m = \frac{\upsilon_0}{|u_0|} \times \left(1 + \frac{D}{f_e}\right)$$

$$\therefore m = \frac{10}{2.5} \times \left(1 + \frac{25}{6.25}\right)$$

$\therefore m = 4(1 + 4)$

$\therefore m = 20$

(b) final image is formed at infinite distance.

$\upsilon_e = \infty \; f_e = 6.25$ cm

➠ Applying the lens formula for eye-piece,

$$\therefore \frac{1}{\upsilon_e} - \frac{1}{u_e} = \frac{1}{f_e}$$

$$\therefore \frac{1}{\upsilon_e} - \frac{1}{f_e} = \frac{1}{u_e}$$

$\therefore \frac{1}{\infty} - \frac{1}{6.25} = \frac{1}{u_e}$

$\therefore \frac{1}{u_e} = 0 - \frac{1}{6.25}$

$\therefore u_e = -6.25$ cm

- Thus, the object distance for eye-piece is 6.25 cm.
- For eye-piece :
- Distance between two lenses

$\upsilon_0 + |u_e| = 15$ cm (which can be understood from the figure)

$\therefore \upsilon_0 + 6.25 = 15$

$\therefore \upsilon_0 = 8.75$ cm (which is image distance for the objective)

- Applying lens formula for objective,

$\frac{1}{\upsilon_0} - \frac{1}{u_0} = \frac{1}{f_0}$

$\therefore \frac{1}{\upsilon_0} - \frac{1}{f_0} = \frac{1}{u_0}$

$\therefore \frac{1}{u_0} = \frac{1}{8.75} - \frac{1}{2}$

$\frac{1}{u_0} = \frac{2 - 8.75}{8.75 \times 2}$

$\therefore \frac{1}{u_0} = \frac{-6.75}{17.5}$

$\therefore u_0 = \frac{-17.5}{6.75}$

$\therefore u_0 = -2.59$ cm

- Thus, object should be kept at a distance of 2.59 cm from the objective.
- Magnification of microscope,

$m = m_0 \times m_e$

$\therefore m = \frac{\upsilon_0}{|u_0|} \times \left(\frac{D}{f_e}\right)$

$\therefore m = \frac{8.75}{2.59} \times \frac{25}{6.25} = 13.5$

26.

- atomic weight of deuteron = 2 g/mol

Mass of deuteron No. of atoms

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

$\therefore$ 2000 g (?)

- No. of atoms

$N = \frac{2000 \times 6.023 \times 10^{23}}{2}$

$\therefore N = 6.023 \cdot 10^{26}$

- When two atoms of deuteron fuse, the energy released = 3.27 MeV

$\therefore$ The energy released by fusion of N atoms

$$E = \frac{N \times 3.27}{2} \text{ MeV}$$

$$E = \frac{6.023 \times 10^{26} \times 3.27 \times 10^{6} \times 1.6 \times 10^{-19}}{2}$$

$\therefore E = 15.75 \cdot 10^{13}$ J

➥ Power of electric lamp = 100 W. It means the energy consumed by the lamp per second = 100 J

$\therefore$ time required to consumed $15.75 \cdot 10^{13}$ J

$$t = \frac{15.75 \times 10^{13}}{100}$$

$\therefore t = 15.75 \cdot 10^{11}$ s

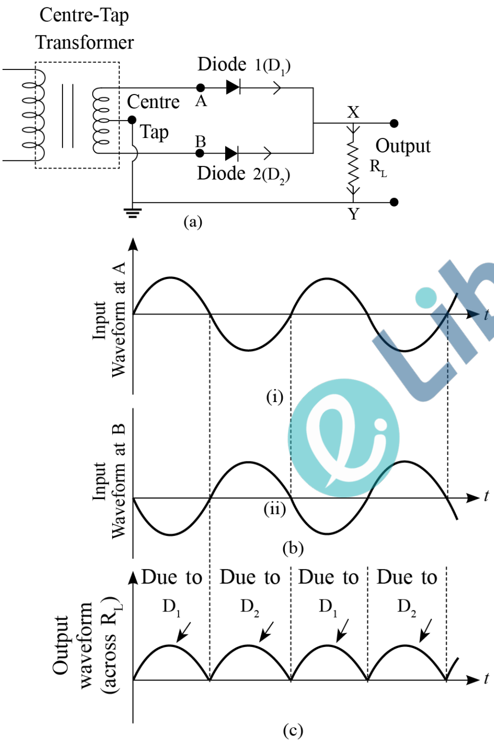
$$\therefore t = \frac{15.75 \times 10^{11}}{3.154 \times 10^{7}}$$

$\therefore t = 4.99 \cdot 10^{4}$ years

➥ Thus, an electric bulb can glow for about 50,000 years.

27.

➥



➥ 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.