* Stokes theorem :- It states that line Integration of a vector field function around a closed surface is equal to surface integration of the curl of vector field function taken over an open surface bounded by closed path.

$$\boxed{\oint_C \vec{E}\cdot d\vec{l} = \iint_S (\vec{\nabla}\times\vec{E})\cdot d\vec{S}}$$

* Gauss divergence theorem :- It states that the surface integration of a vector feild function over an closed surface is equal to volume integration of the divegence of the function over the volume of the closed surface.

$$\boxed{\oiint_S \vec{E}\cdot d\vec{S} = \iiint_V (\vec{\nabla}\cdot\vec{E})\,dV}$$

Page No.
Date / 20

* Maxwell equations of integral form

(i) Gauss law for electrostatic

$$\boxed{\oiint_S \vec{E}\cdot d\vec{s} = \iiint_V \frac{\rho}{\varepsilon_0}\cdot dv}$$

(ii) Gauss law of magnetic field

$$\boxed{\oiint_S \vec{B}\cdot d\vec{s} = 0}$$

(iii) faraday's law of electro magnetic induction

$$\boxed{\oint_C \vec{E}\cdot d\vec{l} = -\frac{\partial}{\partial t}\iint_S \vec{B}\cdot d\vec{s}}$$

(iv) Ampere's law for varying currents

$$\boxed{\oint_C \vec{B}\cdot d\vec{l} = \mu_0 \iint_S \vec{J}_c\cdot d\vec{s}}$$

$\vec{J_c} \rightarrow$ Conduction current density

Page No.

Date / 20

* Maxwell's equations of differential form

(i) $\boxed{\vec{\nabla} \cdot \vec{E} = \frac{\rho}{\varepsilon_0}}$ → Gauss la e.s

(ii) $\boxed{\vec{\nabla} \cdot \vec{B} = 0}$ → Gauss Mag

(iii) $\boxed{\vec{\nabla} \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}}$ → faraday's l o em.i

(iv) $\boxed{\vec{\nabla} \times \vec{B} = \mu_0 (\vec{J_c} + \vec{J_D})}$ Ampere's law

* Maxwell equations in free space diff form

(i) $\boxed{\vec{\nabla} \cdot \vec{E} = 0}$

(ii) $\boxed{\vec{\nabla} \cdot \vec{B} = 0}$

(iii) $\boxed{\vec{\nabla} \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}}$

1) Derive Gauss law of electrostatic

$$\oiint_S \vec{E}\cdot d\vec{s} = \iiint_V \frac{\rho}{\varepsilon_0}\cdot dV$$

Applying gauss divergence theorem

$$\oiint_S E\cdot d\vec{s} = \iiint(\vec{\nabla}\cdot\vec{E})\cdot dV$$

$$\iiint \vec{\nabla}\cdot\vec{E}\cdot dV = \iiint \frac{\rho}{\varepsilon_0}\cdot dV$$

$$\iiint \vec{\nabla}\cdot\vec{E}\cdot dV - \iiint \frac{\rho}{\varepsilon_0}\cdot dV = 0$$

$$\iiint\left(\vec{\nabla}\cdot\vec{E} - \frac{\rho}{\varepsilon_0}\right)dV = 0 \qquad \boxed{dV \neq 0}$$

this integration is zero independent of the volume of the surface

$$\vec{\nabla}\cdot\vec{E} - \frac{\rho}{\varepsilon_0} = 0$$

$$\boxed{\vec{\nabla}\cdot\vec{E} = \frac{\rho}{\varepsilon_0}}$$ proofted

Page No.
Date / 20

(ii) Gauss law of Magnetic field.

$$\oiint_S \vec{B}\cdot d\vec{S} = 0$$

Applying gauss divegence theorem

$$\oiint_S \vec{B}\cdot d\vec{s} = \iiint_V (\vec{\nabla}\cdot\vec{B})\, dV$$

$$\iiint_V (\vec{\nabla}\cdot\vec{B})\, dV = 0 \qquad \boxed{dV \neq 0}$$

This integration is zero independent of the volume of the surface

$$\boxed{\vec{\nabla}\cdot\vec{B} = 0}$$ prooved

(iii) faraday's law of electro magnetic induction

$$\oint_C \vec{E}\cdot d\vec{l} = -\frac{\partial}{\partial t}\iint_S \vec{B}\cdot d\vec{S}$$

Applying stokes's theorem

$$\oint \vec{E}\cdot d\vec{l} = \iint_S (\vec{\nabla}\times\vec{E})\, d\vec{s}$$

$$\iint_S (\vec{\nabla}\times\vec{E})\, d\vec{s} = -\frac{\partial}{\partial t}\iint_S \vec{B}\cdot d\vec{s}$$

$$\iint_S (\vec{\nabla} \times \vec{E}) d\vec{s} = -\iint_S \frac{\partial B}{\partial t} \cdot d\vec{s}$$

$$\iint \left(\vec{\nabla} \times \vec{E} + \frac{\partial \vec{B}}{\partial t}\right) ds = 0 \quad \boxed{ds \neq 0}$$

This integration is zero independent of the surface.

$$\vec{\nabla} \times \vec{E} + \frac{\partial \vec{B}}{\partial t} = 0$$

$$\boxed{\vec{\nabla} \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}}$$

(iv) Ampere's circuital law of varying current
(steady current)
(~~R~~ current)

$$\oint_C \vec{B} \cdot d\vec{l} = \mu_0 \iint_S \vec{J_c} \cdot d\vec{s}$$

Applying Stokes's theorem

$$\oint_C \vec{B} \cdot d\vec{l} = \iint_S (\vec{\nabla} \times \vec{B}) \cdot d\vec{s}$$

L.H.S = R.H.S

$$\iint \vec{\nabla} \times \vec{B} \cdot ds = \mu_0 \iint_S \vec{J} \cdot d\vec{s}$$

$$\iint (\vec{\nabla} \times \vec{B} - \mu_0 \vec{J}) \, d\vec{s} = 0$$

This integration is zero independent of the surface

$$\vec{\nabla} \times \vec{B} - \mu_0 \vec{J} = 0$$

$$\vec{\nabla} \times \vec{B} = \mu_0 \vec{J}$$

$$\boxed{\vec{\nabla} \times \vec{B} = \mu_0 \vec{J}}$$

* Ampere circuital law for time varying current (समय के साथ current बदलेगा)

Taking divergence both sides

$$\vec{\nabla} \cdot (\vec{\nabla} \times \vec{B}) = \mu_0 (\vec{\nabla} \cdot \vec{J_c})$$

divergence of curl $= 0$

$$0 = \mu_0 (\vec{\nabla} \cdot \vec{J_c})$$

$\because \boxed{\mu_0 \neq 0}$

$$\vec{\nabla} \cdot \vec{J_c} = 0$$

that means some dependent term is missing on R·H·S

$$\vec{\nabla} \times \vec{B} = \mu_0 \vec{J_c} + \vec{x} \quad \text{---} (1)$$

again taking divergence both sides

$$\vec{\nabla} \cdot (\vec{\nabla} \times \vec{B}) = \mu_0 (\vec{\nabla} \cdot \vec{J_c}) + (\vec{\nabla} \cdot \vec{x})$$

$$0 = \mu_0 (\vec{\nabla} \cdot \vec{J_c}) + \vec{\nabla} \cdot \vec{x}$$

$\mu_0 \neq 0$

divide μ_0 both sides

$$0 = (\vec{\nabla} \cdot \vec{J_c}) + \frac{1}{\mu_0}(\vec{\nabla} \cdot \vec{x})$$

$$\because \vec{\nabla} \cdot \vec{J_c} + \frac{\partial \rho}{\partial t} = 0$$

$$\boxed{\vec{\nabla} \cdot \vec{J_c} = -\frac{\partial \rho}{\partial t}}$$ equation of ~~continiouty~~ continuity

$$0 = -\frac{\partial \rho}{\partial t} + \frac{1}{\mu_0}(\vec{\nabla} \cdot \vec{x})$$

$$\frac{1}{\mu_0}(\vec{\nabla} \cdot \vec{x}) = \frac{\partial \rho}{\partial t}$$

$$\vec{\nabla} \cdot \vec{x} = \mu_0 \frac{\partial \rho}{\partial t}$$

$\because$ gauss law $\vec{\nabla} \cdot \vec{E} = \frac{\rho}{\varepsilon_0}$

$$\rho = \varepsilon_0(\vec{\nabla} \cdot \vec{E})$$

$$\vec{\nabla} \cdot \vec{x} = \mu_0 \varepsilon_0 \frac{\partial (\vec{\nabla} \cdot \vec{E})}{\partial t}$$

integrate w. r. to. space

$$\vec{x} = \mu_0 \varepsilon_0 \frac{\partial E}{\partial t} \quad \text{--- (2)}$$

(2) put in (1)

$$\vec{\nabla} \times \vec{B} = \mu_0 \vec{j_c} + \mu_0 \varepsilon_0 \frac{\partial E}{\partial t}$$

$$\vec{\nabla} \times \vec{B} = \mu_0\left(\vec{J_c} + \varepsilon_0 \frac{\partial E}{\partial t}\right) \quad \left\{ \left(J_D = \varepsilon_0 \frac{\partial E}{\partial t}\right) \right.$$

$$\boxed{\vec{\nabla} \times \vec{B} = \mu_0(\vec{J_c} + \vec{J_D})}$$ prooved

Page No.
Date / 20

* significance of Maxwell equations

(1) $\vec{\nabla} \cdot \vec{E} = \frac{\rho}{\varepsilon_0}$

(i) single charge can be exist.

(ii) It is time independent.

(iii) $\nabla \cdot \vec{E}$ is scalar quantity.

(2) $\vec{\nabla} \cdot \vec{B} = 0$

(i) It tells that isolated poles does not exist.

(ii) It is a time independent.

(iii) divergence of B is always zero.

(3) $\vec{\nabla} \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$

(i) It relates electric field vector and magnetic flux density vector.

(ii) It is time independent.

(iii) It describes faraday's law of electromagnetic induction along with Lenz's law.

$\because B = \mu_0 H \; , \; H = B/\mu_0$

Page No.

Date / 20

④ $\vec{\nabla} \times \vec{B} = \mu_0 (\vec{J_c} + \vec{J_D})$ / $\vec{\nabla} \times \vec{H} = \vec{J} + \frac{\partial \vec{D}}{\partial t}$

(i) It is time dependent.

(ii) It relates magnetic field vector with displacement vector

(iii) $\vec{\nabla} \times \vec{B}$ is also called modified Ampere's law

Q) Derive Maxwell's electromagnetic wave equation for free space and show that speed of em wave in free space is 3×10^8 m/s. Also comment on the nature of em waves.

Sol^n → from faraday's law

$$\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t} \quad \text{—— (1)}$$

Taking curl both sides

$$\vec{\nabla} \times (\vec{\nabla} \times \vec{E}) = -\frac{\partial}{\partial t}(\vec{\nabla} \times \vec{B}) \quad \text{—— (2)}$$

from vector property

$$\boxed{\vec{\nabla} \times (\vec{\nabla} \times \vec{E}) = \vec{\nabla}(\vec{\nabla}\cdot\vec{E}) - \vec{\nabla}^2\vec{E}}$$

$$\vec{\nabla}(\vec{\nabla}\cdot\vec{E}) - \vec{\nabla}^2\vec{E} = -\frac{\partial}{\partial t}(\vec{\nabla} \times \vec{B})$$

$\boxed{\vec{\nabla}\cdot\vec{E} = 0}$ gauss law E.s for free space

multiply by (-1) → $0 - \vec{\nabla}^2\vec{E} = -\frac{\partial}{\partial t}(\vec{\nabla} \times \vec{B})$ ∵ $\vec{B} = \mu_0 \vec{H}$

$$\vec{\nabla}^2\vec{E} = \frac{\partial}{\partial t}(\vec{\nabla} \times \mu_0 \vec{H})$$

for free space

$\vec{\nabla} \times \vec{B} = \mu_0 (J_D)$

$\vec{\nabla} \times \vec{B} = \mu_0 \frac{\partial D}{\partial t}$

$\boxed{\vec{\nabla} \times \vec{H} = \frac{\partial D}{\partial t}}$

$$\vec{\nabla}^2\vec{E} = \mu_0 \frac{\partial}{\partial t}(\vec{\nabla} \times \vec{H})$$

$$\vec{\nabla}^2\vec{E} = \mu_0 \frac{\partial}{\partial t}\left(\frac{\partial \vec{D}}{\partial t}\right)$$

∵ $\boxed{\vec{D} = \epsilon_0 \vec{E}}$

$$\vec{\nabla}^2 \vec{E} = \mu_0 \frac{\partial}{\partial t}\left(\frac{\partial(\varepsilon_0 \vec{E})}{\partial t}\right)$$

$$\vec{\nabla}^2 \vec{E} = \mu_0 \varepsilon_0 \frac{\partial}{\partial t}\left(\frac{\partial \vec{E}}{\partial t}\right)$$

$$\boxed{\vec{\nabla}^2 \cdot \vec{E} = \mu_0 \varepsilon_0 \frac{\partial^2 \vec{E}}{\partial t^2}} \quad (3) \rightarrow \text{wave eq}^n \text{ for free space}$$

or $$\boxed{\vec{\nabla}^2 \cdot \vec{B} = \mu_0 \varepsilon_0 \frac{\partial^2 \vec{B}}{\partial t^2}}$$ where $\vec{E} = \vec{E_0} \sin(\omega t - \vec{k} \cdot \vec{r})$

$\vec{B} = \vec{B_0} \sin(\omega t - \vec{k} \cdot \vec{r})$

Speed of em waves in free space is 3×10^8 m/s

for General wave eq^n

$$\boxed{\vec{\nabla}^2 \psi = \frac{1}{v^2} \frac{\partial^2 \psi}{\partial t^2}} \quad (4)$$

by Compairing eq^n (3) and 4

$$\vec{\nabla}^2 \cdot \vec{B} = \mu_0 \varepsilon_0 \frac{\partial^2 \vec{B}}{\partial t^2}$$

$$\vec{\nabla}^2 \cdot \psi = \frac{1}{v^2} \frac{\partial^2 \psi}{\partial t^2}$$

$$\boxed{\frac{1}{v^2} = \mu_0 \varepsilon_0}$$

$$v^2 = \frac{1}{\mu_0 \varepsilon_0}$$

$$v = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$$

$\therefore$ $$\boxed{v = \frac{1}{\sqrt{\mu_0 \varepsilon_0}} = c}$$

$$\boxed{v = c}$$

$$\boxed{v = 3 \times 10^8 \text{ m/s}}$$ proved

Page No.
Date / 20

PYQ* Nature of em waves

- The electromagnetic wave has a 'transverse' nature. Electric and magnetic field vector in electromagnetic wave are perpendicular to each-other and also perpendicular to the wave's propagation direction. This type of electromagnetic wave is referred as transverse nature.

* Transverse nature of EM waves

Sol^n from maxwell 1st & second eq^n in free space

$$\vec{\nabla}\cdot\vec{E}=0 \quad \text{and} \quad \vec{\nabla}\cdot\vec{B}=0$$

∵ We know that emw wave eq^n

$$\vec{\nabla}^2\vec{E}=\mu_0\epsilon_0\frac{\partial^2\vec{E}}{\partial t^2} \quad \& \quad \vec{\nabla}^2\vec{B}=\mu_0\epsilon_0\frac{\partial^2\vec{B}}{\partial t^2}$$

so, The general solution of this equation is

$$\boxed{\vec{E}(\vec{r},t)=\vec{E_0}\,e^{i(\vec{K}\cdot\vec{r}-\omega t)}} \quad \text{(d)}$$

and $$\boxed{\vec{B}(\vec{r},t)=\vec{B_0}\,e^{i(\vec{K}\cdot\vec{r}-\omega t)}}$$

where $\vec{E_0}$ & $\vec{B_0}$ are complex amplitude, $\vec{K}$ is a wave propagation vector

Page No.
Date. / 20

$$\therefore \vec{\nabla}\cdot\vec{E} = \left(\hat{i}\frac{\partial}{\partial x} + \hat{j}\frac{\partial}{\partial y} + \hat{k}\frac{\partial}{\partial z}\right)\left(\vec{E_0}\, e^{i(\vec{k}\cdot\vec{r}-\omega t)}\right) \text{ --- (A)}$$

where $\boxed{\vec{E_0} = \hat{i}E_{0x} + \hat{j}E_{0y} + \hat{k}E_{0z}}$ --- (B)

$$\vec{k} = \hat{i}k_x + \hat{j}k_y + \hat{k}k_z$$
$$\vec{r} = \hat{i}x + \hat{j}y + \hat{k}z$$

$$\vec{k}\cdot\vec{r} = (\hat{i}k_x + \hat{j}k_y + \hat{k}k_z)(\hat{i}x + \hat{j}y + \hat{k}z)$$
$$\boxed{\vec{k}\cdot\vec{r} = k_x x + k_y y + k_z z} \text{ --- (C)}$$

Put eq^n B and C in eq (A)

$$\vec{\nabla}\cdot\vec{E} = \left(\hat{i}\frac{\partial}{\partial x} + \hat{j}\frac{\partial}{\partial y} + \hat{k}\frac{\partial}{\partial z}\right)\cdot\left(\hat{i}E_{0x} + \hat{j}E_{0y} + \hat{k}E_{0z}\right)e^{i(k_x x + k_y y + k_z z - \omega t)}$$

$$\vec{\nabla}\cdot\vec{E} = \left(\hat{i}\frac{\partial}{\partial x} + \hat{j}\frac{\partial}{\partial y} + \hat{k}\frac{\partial}{\partial z}\right)\cdot\Big(\hat{i}E_{0x}e^{i(k_x x + k_y y + k_z z - \omega t)} + \hat{j}E_{0y}e^{i(k_x x + k_y y + k_z z - \omega t)}$$
$$+ \hat{k}E_{0z}e^{i(k_x x + k_y y + k_z z - \omega t)}\Big)$$

$$\vec{\nabla}\cdot\vec{E} = \frac{\partial}{\partial x}\left(E_{0x}e^{i(k_x x + k_y y + k_z z - \omega t)}\right) + \frac{\partial}{\partial y}\left(E_{0y}e^{i(k_x x + k_y y + k_z z - \omega t)}\right)$$
$$+ \frac{\partial}{\partial z}\left(E_{0z}e^{i(k_x x + k_y y + k_z z - \omega t)}\right)$$

$$\vec{\nabla}\cdot\vec{E} = E_{0x}e^{i(k_x x + k_y y + k_z z - \omega t)}\cdot ik_x + E_{0y}e^{i(k_x x + k_y y + k_z z - \omega t)}\cdot ik_y$$
$$= E_{0z}e^{i(k_x x + k_y y + k_z z - \omega t)}\cdot ik_z$$

$$\vec{\nabla}\cdot\vec{E} = \left(ik_x E_{0x} + ik_y E_{0y} + ik_z E_{0z}\right)e^{i(k_x x + k_y y + k_z z - \omega t)}$$

$$\vec{\nabla}\cdot\vec{E} = i\left(k_x E_{0x} + k_y E_{0y} + k_z E_{0z}\right)e^{i(k_x x + k_y y + k_z z - \omega t)} \text{ --- (1)}$$

Now we calculate $\vec{k}\cdot\vec{E}$ → (put eq^n d in place of $\vec{E}$)

$$\vec{k}\cdot\vec{E} = (\hat{i}k_x + \hat{j}k_y + \hat{k}k_z)\cdot(\hat{i}E_{0x}$$

$$\vec{k}\cdot\vec{E} = (\hat{i}k_x + \hat{j}k_y + \hat{k}k_z)\cdot(\vec{E_0}\, e^{i(\vec{k}\cdot\vec{r} - \omega t)})$$

put eq^n (B) & (C) in place of $\vec{E_0}$ or $(\vec{k}\cdot\vec{r})$

$$\vec{k}\cdot\vec{E} = (\hat{i}k_x + \hat{j}k_y + \hat{k}k_z)\cdot(\hat{i}E_{0x} + \hat{j}E_{0y} + \hat{k}E_{0z})\cdot e^{i(k_x x + k_y y + k_z z - \omega t)}$$

$$\vec{k}\cdot\vec{E} = (k_x E_{0x} + k_y E_{0y} + k_z E_{0z})\, e^{i(k_x x + k_y y + k_z z - \omega t)} \longrightarrow (2)$$

put eq (2) in (1)

$$\vec{\nabla}\cdot\vec{E} = i(\vec{k}\cdot\vec{E})$$

$\because$ from maxwell eq^n

$$\vec{\nabla}\cdot\vec{E} = 0 \quad \{\text{in free space}\}$$

$$0 = i(\vec{k}\cdot\vec{E})$$

$$\vec{k}\cdot\vec{E} = 0 \quad \& \quad \vec{k}\cdot\vec{B} = 0$$

$$\vec{k} \perp \vec{E} \quad \& \quad \vec{k} \perp B$$

So hence proved electric and magnetic fields are perpendicular to the direction of propagation vector $(\vec{k})$.

This is Electromagnetic waves are transverse in nature.

and it's Significance

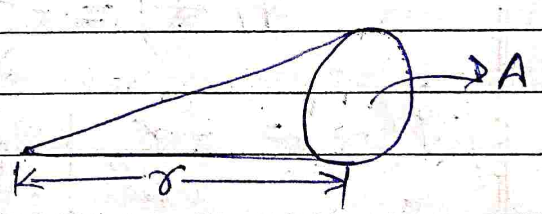
* Poynting vector :- Energy or power transformed per unit areas is called poynting vector, poynting vector is denoted by $\vec{P}$ and it's unit is watt/m^2.

$$\vec{P} = \frac{\text{Energy or power transformed}}{\text{area}}$$

इसका significance करता है। अगली

unit $\boxed{\vec{P} = \frac{watt}{m^2}}$

* Solid angle :- Solid angle is the ratio of area of the sphere and square of the distance is called solid angle, it is denoted by 'Ω' and its unit is steradian.



$$\boxed{\Omega = \frac{A}{r^2}}$$

↳ dimension less

Ω = unit steradian

other words → ~~the solid angle subtended by the~~ The surface area of a sphere subtended by ~~the line and by~~ the radius of that sphere is called solid angle

$$\boxed{\Omega = \frac{A}{r^2}}$$

Relationship between Electric field & potential.

ans ⇒ Consider a point charge +q, the electric potential $+q \overset{\leftarrow r \rightarrow}{\bullet\text{———}\bullet} P$ at a point P distance r from +q and P given.

$$\because \quad \boxed{V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}} \text{ — (A)}$$

and

$$\boxed{\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\cdot\hat{r}} \text{ — (B)}$$

we know that $\boxed{\vec{\nabla}\left(\frac{1}{r}\right) = -\frac{\vec{r}}{r^3}}$

$$\nabla\left(\frac{1}{r}\right) = -\frac{\vec{r}}{r^3} \qquad \left\{\hat{r} = \frac{\vec{r}}{|\vec{r}|}\right.$$

$$\boxed{\vec{\nabla}\left(\frac{1}{r}\right) = -\frac{\hat{r}}{r^2}} \text{ — (C)}$$

Multiplay by $\frac{q}{4\pi\varepsilon_0}$ both sides

$$\vec{\nabla}\left(\frac{1}{4\pi\varepsilon_0}\frac{q}{r}\right) = -\frac{\hat{r}}{r^2}\frac{q}{4\pi\varepsilon_0}$$

Mul by − both sides

$$-\vec{\nabla}\left(\frac{1}{4\pi\varepsilon_0}\frac{q}{r}\right) = \hat{r}\left(\frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\right)$$

from eq^n (A) & (B)

$$-\vec{\nabla}\cdot V = \vec{E}$$

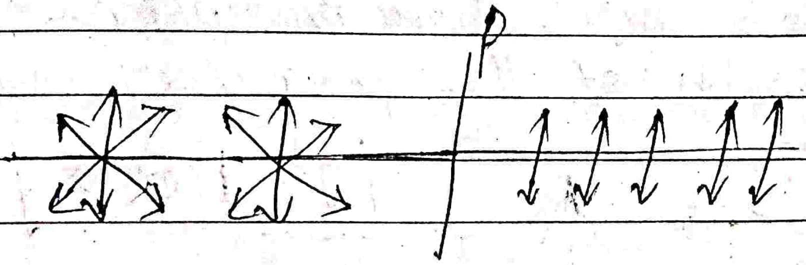
$$\boxed{\vec{E} = -\vec{\nabla}\cdot V}$$

Thus the electric field $(\vec{E})$ can be expressed as −ve of ~~proofud~~ gradient of electric potential (V).

Page No.
Date / 20

* What is polarization → short note

ans ⇒ polarization is the property of electromagnetic radiations in which the direction and magnitude of the vibrating electric fields are related in a specified way.



when electricmagnetic radiation of sunlite is to be come to earth or in a space then electric fields are oscillation in all direction perpendicularly the propagation of the em wave and when this wave passes through polariser then ~~propagation~~ oscillation of emwave in only one direction this process called polarization.

* Brewster's law :- The refractive index of a medium is equal to the tangent sine of the polar angle.

$$\boxed{\mu = \tan i_p} \text{ — (i)}$$

from Snell law $\mu = \dfrac{\sin i_p}{\sin r}$ — (ii)

from eq^n (i) & (ii)

$\tan i_p = \dfrac{\sin i_p}{\sin r}$ ⇒

$\dfrac{\cancel{\sin i_p}}{\cos i_p} = \dfrac{\cancel{\sin i_p}}{\sin r}$

$\sin r = \cos i_p$

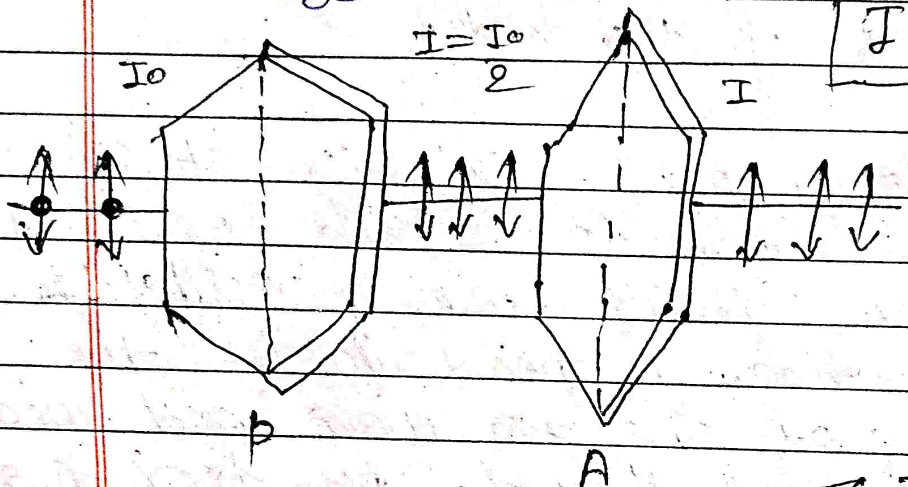
$\cancel{\sin} r = \cancel{\sin}(90 - i_p)$

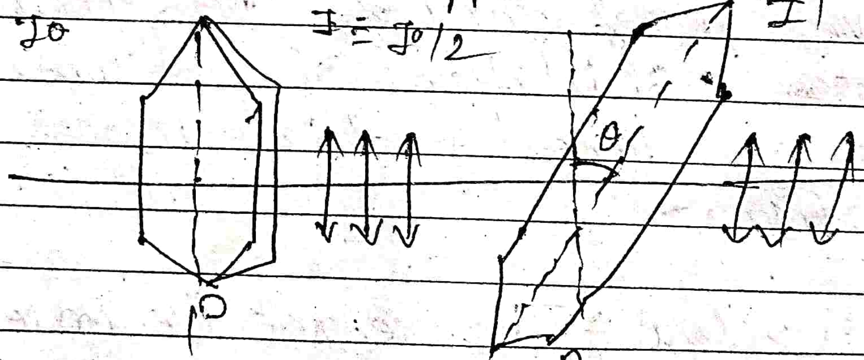
$\boxed{r + i_p = 90}$

Page No.
Date / 20

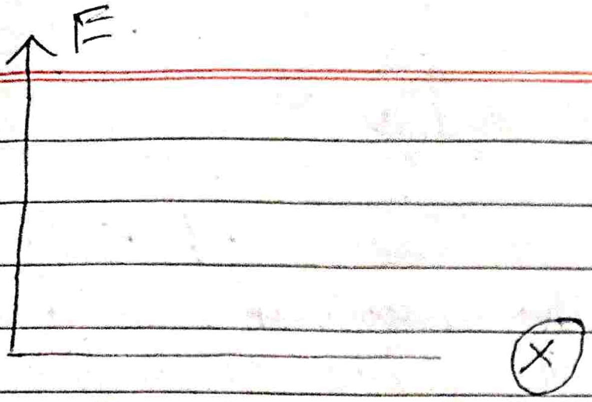
* Malus law :- It states that when a beam of plane polarised light from a polarizer is incident on analyser, the intensity of light emerging from analyser varies as the square of the cosine of angle between plane of transmission of the polarizer and analyser.

$$\boxed{I' = I\cos^2\theta}$$





PYQ What is the concept of displacement current



\# Type (1) and Type (2) Superconductor and difference

* अनुचुम्बकीय, प्रतिचुम्बकीय, लौह चुम्बकीय Property

* Concept of energy gap insulator, conductor and superconductor

* Semiconductor

* Nomericle $H(T)$; $I_c(T)$

* Nomericle based on de broglie hypothesis का Nomericle.

PYQ Define poynting vector and it's significance: Energy or power transformed per unit area is called poynting vector, poynting vector is denoted by $\vec{P}$ and it's unit is watt/m^2 $\vec{P}$ = Energy transformed / unit area = watt/m^2 (direction of $\vec{P}$ is always normal to the area.)

it's significance

(i) it represents the flow of em energy in a given direction.

(ii) it indicates the rate of transfer of energy per unit area.

(iii) it measure power per unit area transformed by emw wave.

(*) Definision of Gradient

→ Gradient is a vector that points in th direction of the maximum rate of increas of the field and its magnitude represents the rate of change of the field in that direction.

$$\boxed{\nabla f = \hat{i}\frac{\partial f}{\partial x} + \hat{j}\frac{\partial f}{\partial y} + \hat{k}\frac{\partial f}{\partial z}}$$

(*) Definition of Divergence : Divergence measures that how much the field spreads out from a point

(div $\vec{f}$) $$\boxed{\vec{\nabla}\cdot\vec{f} = \frac{\partial f_x}{\partial x} + \frac{\partial f_y}{\partial y} + \frac{\partial f_z}{\partial z}}$$

(*) Definitaion of ~~Divergence~~ curl :

→ Curl measures that the amount of local rotation of the field at a point

(curl $\vec{f}$) $$\vec{\nabla}\times\vec{f} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ f_1 & f_2 & f_3 \end{vmatrix}$$

Note → ✓ $\vec{\nabla}\cdot\vec{A} = 0$ → solenoidal $\vec{E} = -\vec{\nabla}V \Rightarrow$ lemmellar fi

✓ $\vec{\nabla}\times\vec{A} = 0$ → irrotational

✓ $\vec{\nabla}\times\vec{A} \neq 0$ → rotational

✓ $|\nabla\times\vec{B}| = 0$ → conservative field

$|\nabla\times\vec{A}| \neq 0$ → Non-conservative field

(A) Divergence ÷ Divergence of vector field at a point is defined as flux per unit volume provided the volume is taken to be as small as possible. if $\vec{A}$ is a vector field then

$$\text{divergence of } \vec{A} = \vec{\nabla}\cdot\vec{A} = \lim_{V\to 0} \frac{\text{flux}}{\text{volume}}$$

or

$$\vec{\nabla}\cdot\vec{A} = \lim_{V\to 0} \frac{\iint \vec{A}\cdot d\vec{s}}{V}$$

significance →

(1) It gives in the spreading tendency of field.

if $\vec{\nabla}\cdot\vec{A}$ is +ve so it is → source

if $\vec{\nabla}\cdot\vec{A}$ is −ve so it is → sink field

if $\vec{\nabla}\cdot\vec{A}$ is zero so it is → dipole field and the field is solenoidal.

$$\vec{\nabla}\cdot\vec{A} = \frac{\partial(A_x)}{\partial x} + \frac{\partial(A_y)}{\partial y} + \frac{\partial(A_z)}{\partial z}$$

(A) Curl ÷ curl of vector field $\vec{A}$ at a point is defined as maximum circulation per unit area, provided the area is taken to be as small as possible. Its direction is normal to the surface.

$$\text{curl } \vec{A} = \vec{\nabla}\times\vec{A} = \lim_{S\to 0} \frac{\text{max circulation}}{\text{Area}} = \lim_{S\to 0} \frac{\oint \vec{A}\cdot d\vec{l}}{S}$$

$$\text{magnitude of curl of } \vec{A} = |\vec{\nabla}\times\vec{A}| = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ \partial/\partial x & \partial/\partial y & \partial/\partial z \\ A_x & A_y & A_z \end{vmatrix}$$

if $|\vec{\nabla}\times\vec{A}| \neq 0$ Rotational field

$= 0$ irrotational field & conservative field

Significance → (1) It gives the rotational tendency of the field

(2) It measures how much a vector field rotates/circulates.

Expt. No. Page No. Date

Gradient :- gradient of scalar field ($\vec{\nabla}\phi$) is defined as maximum rate of change of scalar field with space coordinates and its direction is always normal to the surface.

$$\vec{\nabla}\phi = \left(\frac{d\phi}{d\vec{r}}\right)_{max}\hat{n} = \hat{i}\frac{\partial\phi}{\partial x} + \hat{j}\frac{\partial\phi}{\partial y} + \hat{k}\frac{\partial\phi}{\partial z}$$

significance → gradient gives the direction of maximum rate of change of scalar field.

eg. $\boxed{\vec{E} = -\vec{\nabla} V}$

Divergence : Divergence of vector field can be defined as

$$\text{divergence} = \lim_{V \to 0} \frac{\text{flux}}{\text{volume}}$$

flux per unit volum where volum $V \to 0$ divergence of a vector field is scalar for a vector ~~field~~ $\vec{A}$ divergence can be defined as

$$\vec{\nabla} \cdot \vec{A} = \frac{\partial (A_x)}{\partial x} + \frac{\partial (A_y)}{\partial y} + \frac{\partial (A_z)}{\partial z}$$

for solenoidal field divergence of vetor = 0 for example a vetor $\vec{A}$ to be solenoidal

$$\vec{\nabla} \cdot \vec{A} = 0$$

Significance of divergence

(i) the indication of the spreading of the vector from a particular point.

(ii) It measures density of charge

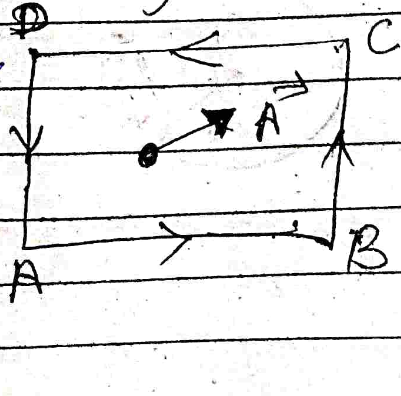
Define curl : ~~curl~~ line integral of vector field over the close loop per unit area is known as curl.

$$\text{curl}(\vec{A}) = \lim_{\text{area} \to 0} \left[\frac{1}{\text{area}} \oint \vec{A} \cdot \vec{dl} \right]$$

significance

(i) It measure how much a vector field circulates or rotates.

(ii) It measure how a fluid may rotate.



Gradient : gradient measure of the rate of change or the slope of a scalar or vector field. The gradient is often denoted by the symbol ∇ (del)

$$\boxed{\nabla f = \frac{\partial f}{\partial x} + \frac{\partial f}{\partial y} + \frac{\partial f}{\partial z}}$$

Significance → It measure rate of change of one variable with respect to another

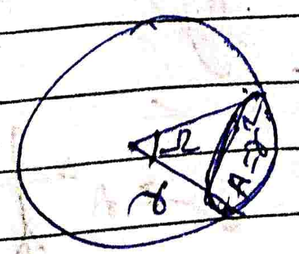
It measures magnetic field at a point.

Solid angle : Solid angle is the angle subtended by any part of a spherical surface of unit radius at its center. It is 3D angle. It's symbol is Ω and unit is steradian.

Generally $\boxed{\Omega = \frac{A}{r^2}}$

for a sphere $\Omega = \frac{4\pi r^2}{r^2}$

$\Omega = 4\pi$ steradian



Q) A vector field is given as $\vec{A} = xy\hat{i} + yz\hat{k}$, find $\vec{\nabla} \times \vec{A}$ and tell whether the field is conservative or not.

Ans) $\vec{\nabla} \times \vec{A}$

$$\begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ xy & 0 & yz \end{vmatrix}$$

$$\Rightarrow \hat{i}\left(\frac{\partial(yz)}{\partial y} - 0\right) - \hat{j}\left(\frac{\partial(yz)}{\partial x} - \frac{\partial(xy)}{\partial z}\right) + \hat{k}\left[0 - \frac{\partial(xy)}{\partial y}\right]$$

$$\Rightarrow \hat{i}z - \hat{j}(0 - 0) + \hat{k}(-x)$$

$$\Rightarrow \hat{i}z + \hat{k}(-x) \Rightarrow z\hat{i} - x\hat{k}$$

$$\Rightarrow z\hat{i} - x\hat{k}$$

non - conservative field

Q) Given $E = 3x^2\hat{i} - 6xy\hat{j} + 12z^2xy\,\hat{k}$ find divergence of the given vector field and comment on its nature whether field is converging or diverging.

Ans) $$\vec{\nabla} \cdot f = \frac{\partial f x}{\partial x} + \frac{\partial f y}{\partial y} + \frac{\partial f z}{\partial z} =$$

$$\vec{\nabla} \cdot \vec{f} = \frac{\partial(3x^2)}{\partial x} + \frac{\partial(-6xy)}{\partial y} + \frac{\partial(12z^2xy)}{\partial z}$$

$$\boxed{\vec{\nabla} \cdot \vec{f} = 6x - 6x + 24xyz}$$

$$\vec{\nabla} \cdot \vec{f} = \cancel{6x} - \cancel{6x} + 24xyz$$

$$\boxed{\vec{\nabla} \cdot \vec{f} = 24xyz}$$

because x and z positive

so vector field is diverging.

for
$+yz$
$,0)$

diverging :- if x is positive and z is positive then divergence is positive so vector field is diverging.

Converging :- if x is negative and z is positive then divergence is negative so vector field is converging.

PYQ Given $\vec{F} = x^2 y \hat{i} + y^2 x \hat{j} + z^2 y \hat{k}$. find the divergence and curl of this vector field.

(i) divergence $\vec{\nabla} \cdot \vec{F} =$

$$\Rightarrow \frac{\partial (x^2 y)}{\partial x} + \frac{\partial (y^2 x)}{\partial y} + \frac{\partial (z^2 y)}{\partial z} =$$

$$\Rightarrow 2xy + 2xy + 2yz$$

curl of $\vec{f} =$

$$\begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ \partial/\partial x & \partial/\partial y & \partial/\partial z \\ x^2 y & y^2 x & z^2 y \end{vmatrix}$$

$$\Rightarrow \hat{i}\left(\frac{\partial(z^2 y)}{\partial y} - \frac{\partial(y^2 x)}{\partial z}\right) - \hat{j}\left(\frac{\partial(z^2 y)}{\partial x} - \frac{\partial(x^2 y)}{\partial z}\right) + \hat{k}\left(\frac{\partial(y^2 x)}{\partial x} - \frac{\partial(x^2 y)}{\partial y}\right)$$

$$\Rightarrow \hat{i}((z^2) - 0) - \hat{j}(0 - 0) + \hat{k}((y^2) - (x^2))$$

$$\Rightarrow z^2 \hat{i} + \hat{k}(y^2 - x^2)$$

$$\Rightarrow \boxed{z^2 \hat{i} + y^2 \hat{k} - x^2 \hat{k}}$$

(PYQ) find divergence and curl of position vector

(Ans) $\vec{r} = x\hat{i} + y\hat{j} + z\hat{k}$

divergence $\nabla \cdot \vec{f} = \frac{\partial(x)}{\partial x} + \frac{\partial(y)}{\partial y} + \frac{\partial(z)}{\partial z}$

$\vec{\nabla} \cdot \vec{f} = 1+1+1$ $\boxed{\nabla \vec{f} = 3}$

$$\text{curl}\,\vec{f} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ \partial/\partial x & \partial/\partial y & \partial/\partial z \\ x & y & z \end{vmatrix}$$

$\hat{i}(0-0) - \hat{j}(0-0) + \hat{k}(0-0)$

$\boxed{\text{curl}\,\vec{f} = 0}$

(PYQ) The electric potential given by $V(x,y,z) = 4x^2 + 3y^2 + 9z^2$ calculate the associated electric field at point $(1,1,0)$

Sol^n → we know that $E = -\nabla V$

$E = -\left(\hat{i}\frac{\partial}{\partial x} + \hat{j}\frac{\partial}{\partial y} + \hat{k}\frac{\partial}{\partial z}\right) \cdot (4x^2 + 3y^2 + 9z^2)$

$E = -\left(\hat{i}\frac{\partial(4x^2)}{\partial x} + \hat{j}\frac{\partial(3y^2)}{\partial y} + \hat{k}\frac{\partial(9z^2)}{\partial z}\right)$

$E = -(\hat{i} \cdot 8x + \hat{j}\,6y + \hat{k}\,18z)$ at point $(1,1,0)$

$E = -(\hat{i}\,8(1) + \hat{j}\,6(1) + \hat{k}\,18(0))$

$\boxed{E = -8\hat{i} - 6\hat{j}}$

Page No.
Date / 20

Q19) The electric potential in a certain region of space is given by $V(x,y,z) = 20x^2 + 10y + 5z^3$, find the electric field intensity vector? Check the field thus obtained is (i) uniform (ii) solenoidal.

ans
$$V = 20x^2 + 10y + 5z^3$$

$$E = -\nabla V$$

$$E = -(\hat{i}(40x) + \hat{j}(10) + 15z^2\hat{k})$$

$$\boxed{E = -40x\hat{i} + 10\hat{j} + 15z^2\hat{k}}$$

(i) $$\vec{\nabla}\cdot\vec{A} = \frac{\partial(20x^2)}{\partial x} + \frac{\partial(10y)}{\partial y} + \frac{\partial(5z^3)}{\partial z}$$
$$= 40x + 10 + 15z^2$$

* Calculate the electric field at point (1,1,1) in an electric field the electric potential is given by
$V(x,y,z) = (4x^2 + 3y^2 + 9z^2)^{-1/2}$

$$\vec{E} = -\nabla V$$

$$V = \frac{1}{\sqrt{4x^2 + 3y^2 + 9z^2}}$$

$$V = \frac{1}{\sqrt{4x^2}} + \frac{1}{\sqrt{3y^2}} + \frac{1}{\sqrt{9z^2}}$$

$$V = \frac{1}{2x} + \frac{1}{\sqrt{3}y} + \frac{1}{3z}$$

~~$E = -(\hat{i}\partial$~~

$$E = -\left(\hat{i}\frac{\partial\left(\frac{1}{2x}\right)}{\partial x} + \hat{j}\frac{\partial\left(\frac{1}{\sqrt{3}y}\right)}{\partial y} + \hat{k}\frac{\partial\left(\frac{1}{3z}\right)}{\partial z}\right)$$

$$\vec{E} = -\left(\hat{i}\frac{-1}{2x^2} + \hat{j}\left(\frac{-1}{\sqrt{3}y^2}\right) + \hat{k}\frac{-1}{3z^2}\right)$$

$$\boxed{\vec{E} = \frac{1}{2x^2}\hat{i} + \frac{\hat{j}}{\sqrt{3}y^2} - \frac{\hat{k}}{3z^2}}$$

Expt. No. .... Page No. .... Date ....

Q.9) find the constants a, b and c such that the vector field.

Ans →

$$\vec{f} = (x+2y+az)\hat{i} + (bx-3y-z)\hat{j} + (4x+cy+2z)\hat{k}$$

$$(\vec{\nabla} \times \vec{F}) = 0$$

$$\begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ \partial/\partial x & \partial/\partial y & \partial/\partial z \\ (x+2y+az) & (bx-3y-z) & (4x+cy+2z) \end{vmatrix}$$

$$\hat{i}\left(\frac{\partial(4x+cy+2z)}{\partial y} - \frac{\partial(bx-3y-z)}{\partial z}\right)$$

$$-\hat{j}\left(\frac{\partial(4x+cy+2z)}{\partial x} - \frac{\partial(x+2y+az)}{\partial z}\right) + \hat{k}$$

$$\left(\frac{\partial(bx-3y-z)}{\partial x} - \frac{\partial(x+2y+az)}{\partial y}\right) = 0$$

$$\Rightarrow \hat{i}(c-0) - \hat{j}(4-a) + \hat{k}(b-2) = 0$$

$$c\hat{i} - \hat{j}(4-a) + \hat{k}(b-2) = 0\hat{i} + 0\hat{j} + 0\hat{k}$$

$$c\hat{i} = 0\hat{i}, \quad -\hat{j}(4-a) = 0\hat{j}, \quad \hat{k}(b-2) = 0\hat{k}$$

$$\boxed{c=0} \qquad -4+a=0 \qquad , \qquad b-2=0$$

$$\boxed{a=4} \qquad \boxed{b=2}$$

$$\boxed{a=4}, \boxed{b=2}, \boxed{c=0}$$

Teacher's Signature ....

Show that gravitation force field is irrotational & conservative.

(PYQ) Newton's law of universal gravitation is represented $\vec{F} = \left(\frac{GMm}{r^2}\right)r$ where f is the magnitude of the gravitational forces exerted by one object on another. M and m are the masses of the objects, and r is a distance. Find the curl of gravitational field.

$\vec{f} = \frac{GMm}{r^2}\cdot\hat{r}$, $\hat{r} = \frac{\vec{r}}{r}$

If a vector field is to be irrotational & conservative then $|\vec{\nabla}\times\vec{F}| = 0$

$\vec{f}_G = \frac{GMm\cdot\vec{r}}{r^3}$, $r = \sqrt{x^2+y^2+z^2}$

Let's find $|\vec{\nabla}\times\vec{f}_G|$

$\vec{f} = \frac{GMm}{(x^2+y^2+z^2)^{3/2}}$

$\boxed{\vec{f}_x = \frac{GMm\cdot x}{(x^2+y^2+z^2)^{3/2}}}$

$\boxed{\vec{f}_y = \frac{GMm\cdot y}{(x^2+y^2+z^2)^{3/2}}}$

$\boxed{\vec{f}_z = \frac{GMm\, z}{(x^2+y^2+z^2)^{3/2}}}$

$$\begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ \partial/\partial x & \partial/\partial y & \partial/\partial z \\ \frac{GMm\,x}{(x^2+y^2+z^2)^{3/2}} & \frac{GMm\,y}{(x^2+y^2+z^2)^{3/2}} & \frac{GMm\,z}{(x^2+y^2+z^2)^{3/2}} \end{vmatrix}$$

$$GMm\left\{\hat{i}\left[\frac{\partial}{\partial y}\left(\frac{z}{(x^2+y^2+z^2)^{3/2}}\right) - \frac{\partial}{\partial z}\left(\frac{y}{(x^2+y^2+z^2)^{3/2}}\right)\right] - \hat{j}\left[\frac{\partial}{\partial x}\left(\frac{z}{(x^2+y^2+z^2)^{3/2}}\right) - \frac{\partial}{\partial z}\left(\frac{x}{(x^2+y^2+z^2)^{3/2}}\right)\right] + \hat{k}\left[\frac{\partial}{\partial x}\left(\frac{y}{(x^2+y^2+z^2)^{3/2}}\right) - \frac{\partial}{\partial y}\left(\frac{x}{(x^2+y^2+z^2)^{3/2}}\right)\right]\right\}$$

$$= GMm\,\hat{i}\left[z\frac{\partial}{\partial y}(x^2+y^2+z^2)^{-3/2} - y\frac{\partial}{\partial z}(x^2+y^2+z^2)^{-3/2}\right] - \hat{j}\left[z\frac{\partial}{\partial x}(x^2+y^2+z^2)^{-3/2} - x\frac{\partial}{\partial z}\left[(x^2+y^2+z^2)^{-3/2}\right]\right] + \hat{k}\left[y\frac{\partial}{\partial x}(x^2+y^2+z^2)^{-3/2} - x\frac{\partial}{\partial y}(x^2+y^2+z^2)^{-3/2}\right]$$

$$\Rightarrow GMm\,\hat{i}\left(z\cdot -\frac{3}{2}(x^2+y^2+z^2)^{-5/2}\cdot 2y - y\left(-\frac{3}{2}\right)(x^2+y^2+z^2)^{-5/2}\cdot 2z\right) - \hat{j}\left(z\left(-\frac{3}{2}\right)(x^2+y^2+z^2)^{-5/2}\cdot 2x - x\left(-\frac{3}{2}\right)(x^2+y^2+z^2)^{-5/2}\cdot 2z\right] + \hat{k}\left(y\left(-\frac{3}{2}\right)(x^2+y^2+z^2)^{-5/2}\cdot 2x - x\left(-\frac{3}{2}\right)(x^2+y^2+z^2)^{-5/2}\cdot 2y\right]$$

$$\Rightarrow \frac{GMm}{(x^2+y^2+z^2)^{5/2}}\left(-\frac{3}{2}\right)\left\{\hat{i}(\cancel{2yz}-\cancel{2yz}) - \hat{j}(\cancel{2xz}-\cancel{2xz}) + \hat{k}(\cancel{2xy}-\cancel{2xy})\right]$$

$$\Rightarrow \frac{GMm}{(x^2+y^2+z^2)^{5/2}}\left(-\frac{3}{2}\right)\{0\}$$

$\boxed{|(\vec{\nabla}\times\vec{f}_G)| = 0}$ $\vec{f}_G$ is irrotational & conservative.

Expt. No. Page No. Date

(PYQ) $\vec{A} = x^2y\hat{i} + (x-y)\hat{k}$ find $\vec{\nabla}\times\vec{A}$ and $\vec{\nabla}\cdot\vec{A}$

$$\vec{\nabla}\cdot\vec{A} = \left(\hat{i}\frac{\partial}{\partial x} + \hat{j}\frac{\partial}{\partial y} + \hat{k}\frac{\partial}{\partial z}\right)\left(x^2y\hat{i} + (x-y)\hat{k}\right)$$

$$\vec{\nabla}\cdot\vec{A} = \frac{\partial(x^2y)}{\partial x} + \frac{\partial(x-y)}{\partial z}$$

$$\vec{\nabla}\cdot\vec{A} = 2xy + 0 \qquad \boxed{\vec{\nabla}\cdot\vec{A} = 2xy}$$

$$\vec{\nabla}\times\vec{A} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ \partial/\partial x & \partial/\partial y & \partial/\partial z \\ x^2y & 0 & x-y \end{vmatrix}$$

$$\hat{i}\left(\frac{\partial(x-y)}{\partial y} - 0\right) + \hat{k}\left(0 - \frac{\partial(x^2y)}{\partial y}\right)$$

$$\hat{i}(-1) + \hat{k}(0 - x^2) \Rightarrow \boxed{-\hat{i} - x^2\hat{k}}$$

Gradient of scalar field $\phi(x,y,z) = \vec{\nabla}\phi$

(Q) Given $\phi(xyz) = 3x^2 - y^3 + yz$ find gradient of $\phi(xyz)$

Ans → given → $\phi = 3x^2 - y^3 + yz$

$$\vec{\nabla}\phi = \hat{i}\frac{\partial\phi}{\partial x} + \hat{j}\frac{\partial\phi}{\partial y} + \hat{k}\frac{\partial\phi}{\partial z}$$

$$\vec{\nabla}\phi = \hat{i}\frac{\partial(3x^2-y^3+yz)}{\partial x} + \hat{j}\frac{\partial}{\partial y}(3x^2-y^3+yz) + \hat{k}\frac{\partial}{\partial z}(3x^2-y^3+yz)$$

$$\vec{\nabla}\phi = (6x)\hat{i} + \hat{j}(-3y^2) + \hat{k}(y)$$ at point $(1, 2, 3)$

$$\vec{\nabla}\phi = 6x\hat{i} - 3y^2\hat{j} + y\hat{k}$$

$$\boxed{\vec{\nabla}\phi = 6\hat{i} - 12\hat{j} + 2\hat{k}}$$

Teacher's Signature

Q given electric scalar function $V(x, y, z)$,
$V = -x^2 + xy^2z + z^3$ find electric field intensity at pt $(1, -1, 0)$

Solⁿ: $\boxed{\vec{E} = -\vec{\nabla} V}$

$$\vec{E} = -\left[\hat{i}\frac{\partial V}{\partial x} + \hat{j}\frac{\partial V}{\partial y} + \hat{k}\frac{\partial V}{\partial z}\right]$$

$$\vec{E} = -\left[\hat{i}\frac{\partial}{\partial x}(-x^2 + xy^2z + z^3) - \hat{j}\frac{\partial}{\partial y}(-x^2 + xy^2z + z^3) - \hat{k}\frac{\partial}{\partial z}(-x^2 + xy^2z + z^3)\right]$$

$$\vec{E} = -\hat{i}(-2x + y^2z) - \hat{j}(2xyz) - \hat{k}(xy^2 + 3z^2)$$

$$\vec{E}_{1,-1,0} = -\hat{i}(-2+0) - \hat{j}\cdot 0 - \hat{k}(1+0)$$

$$\boxed{\vec{E} = 2\hat{i} - 0\hat{j} - \hat{k}} \text{ V/m}$$

magnitude of $\vec{E} = \sqrt{4+0+1} = \sqrt{5}$ V/m

Page No.
Date / 20

* De broglie Numericle - $\boxed{\lambda = \frac{h}{p}}$

(i) Case (I) In terms of kinetic energy

$$\boxed{\lambda = \frac{h}{\sqrt{2mK \cdot E}}}$$

Q1 An $\bar{e}$, an α particle & a proton has same energy. Arrange them in order of decreasing in De-Broglie λ.

$$\lambda = \frac{h}{\sqrt{2mK}} \qquad \lambda \propto \frac{1}{\sqrt{m}}$$

$$\boxed{\lambda_e > \lambda_p > \lambda_\alpha}$$

mass ->

(ii) Case (2) : In terms of potential

S.C -> $\boxed{\lambda = \sqrt{\frac{150}{V}} \text{ in } (\mathring{A})}$ $\boxed{\lambda = \frac{h}{\sqrt{2mqV}}}$ $\boxed{\lambda = \frac{h}{\sqrt{2meV}}}$

$\boxed{h = 6.626 \times 10^{-34} \text{ JS}}$ $\boxed{\text{mass of } \bar{e} = 9.1 \times 10^{-31} \text{ kg}}$

Q2 find de broglie λ associated with an $\bar{e}$ accelerated at 600V.

ans -> $\lambda = \sqrt{\frac{150}{V}} \mathring{A}$ $\quad \lambda = \sqrt{\frac{150}{600}} \mathring{A}$

$$\boxed{\lambda = 0.5 \mathring{A}}$$

$$-31$$
$$-13$$
$$-\!\!-\!\!-$$
$$-8.04$$

PYQ Calculate the de-Broglie wavelength of a virus particle accelerated by a potential difference of 30,000V.

ans) $\lambda = \frac{h}{\sqrt{2m\,eV}}$ $\lambda = \frac{h}{\sqrt{2 \cdot 9.1 \times 10^{-31} \cdot 1.6 \times 10^{-19} \times 3 \times 10^{4}}}$

$\lambda = \frac{6.26 \times 10^{-34}}{\sqrt{18 \times 1.6 \times 3 \times 10^{-46}}}$ $\lambda = \frac{6.62 \times 10^{-34}}{9.29 \times 10^{-23}}$

$\lambda = \frac{6.26 \times 10^{-34}}{\sqrt{54 \times 1.6 \times 10^{-46}}}$ $\lambda = \frac{6.62}{9.29} \times 10^{-11}$

$\lambda = \frac{6.62 \times 10^{-34}}{\sqrt{86.4 \times 10^{-46}}}$ $\lambda = 0.71 \times 10^{-11}$

$\lambda = 0.071 \times 10^{-12}$

$\boxed{\lambda = 0.071\,\mathring{A}}$

Through shortcut → $\lambda = \sqrt{\frac{150}{V}}$

$\lambda = \sqrt{\frac{150}{30000}}$ $\lambda = \sqrt{\frac{15}{3000}}$

$\lambda = \sqrt{0.005}$ $\boxed{\lambda = 0.07\,\mathring{A}}$

PYQ An electron and a proton are moving with same speed of 300m/s compare the magnitude of de-broglie wavelength for these particles. Given mass of an electron 9.1×10^{-31} kg. mass of proton $= 1.67 \times 10^{-27}$ kg and plank's constant $h = 6.62 \times 10^{-34}$ Js

ans) $\lambda_e = \frac{h}{\sqrt{2mK}}$, $\lambda_e = \frac{h}{\sqrt{2m \cdot \frac{1}{2} m v^2}}$ $\lambda = \frac{h}{mv}$

Page No.
Date / 20

$$\lambda e = \frac{6.62 \times 10^{-34} Js}{9.1 \times 10^{-31} \times 300 m/s}$$

$$\lambda e = \frac{6.62}{9.1 \times 3} \times 10^{-34} \times 10^{31} \times 10^{-2}$$

$\lambda e = 0.2424 \times 10^{-5}$

$\boxed{\lambda e = 0.2424 \times 10^{-5}}$ ~~$\lambda e = 0.24 \times 10^{-9}$~~

~~$\lambda e = 2.24$ nm~~ ~~$\lambda e = 0.00000.24$ nm~~

2424 nm

$$\lambda p = \frac{6.62 \times 10^{-34}}{1.67 \times 10^{-27} \times 300} \qquad \lambda p = \frac{6.62}{1.67 \times 3} \times 10^{-34} \times 10^{27} \times 10^{-2}$$

$\lambda p = 1.3213 \times 10^{-9}$ $\boxed{\lambda p = 1.32 nm}$

So wavelength of electron is greater than wavelength of proton.

* Calculate the potential difference through which an electron should be accelerated to achieve a speed of 1600m/s and also find the wavelength of the matter waves associated with the moving electron.

$$\lambda = \sqrt{\frac{186}{V}} \qquad \boxed{V = \frac{\sqrt{186}}{\sqrt{\lambda}}}$$

$$\lambda = \frac{h}{m \cdot v} \qquad \lambda = \frac{6.62 \times 10^{-34}}{9.1 \times 10^{-31} \times 16000}$$

$$\lambda = \frac{6.62}{9.1 \times 16} \times 10^{-34} \times 10^{31} \times 10^{-3} \qquad \boxed{\lambda = 0.0454 \times 10^{-6}}$$

~~$\lambda = 4.54 \times 10^{-9}$~~ ~~$\lambda = 4.54$ nm~~

$$V = \frac{180}{6.73}$$ ~~$V = 70.42 V$~~ $\lambda = 45.4$ nm

$V = 22.28 V$

Q (pyq) An electron is accelerated with low acceleration voltage V, show that the expression for wavelength of the matter waves associated with the electron is given by $\frac{12.27}{\sqrt{V}}\mathring{A}$

Ans)

$$\lambda = \frac{h}{\sqrt{2mqV}} \quad \lambda = \frac{6.62\times10^{-34}}{\sqrt{2\cdot9.1\times10^{-31}\times1.6\times10^{-19}\times V}}$$

$$\lambda = \frac{6.62\times10^{-34}}{\sqrt{29.12\times10^{-50}}\cdot\sqrt{V}} \quad \lambda = \frac{6.62\times10^{-34}}{\times10^{-25}\sqrt{V}}$$

$$\lambda = \frac{6.62\times10^{-34}\times10^{28}}{5.39\sqrt{V}}$$

$$\lambda = \frac{1.227\times10^{-9}}{\sqrt{V}}, \quad \lambda = \frac{1.227\times10\times10^{-9}}{10}$$

$$\lambda = \frac{12.27\times10^{-9}\times10^{-1}}{\sqrt{V}} \quad \lambda = \frac{12.27\times10^{-10}}{\sqrt{V}}$$

$$\boxed{\lambda = \frac{12.27}{\sqrt{V}}\mathring{A}}$$

* Calculate the de-broglie wavelength of an e whose kinetic energy is 80 eV, given $h = 6.62\times10^{-34}$ Joule-sec $m_e = 9.1\times10^{-31}$ kg, $1\,eV = 1.6\times10^{-19}$ Joule

Ans)

$$\lambda = \frac{h}{\sqrt{2mK}} \quad \lambda = \frac{6.62\times10^{-34}}{\sqrt{2\times9.1\times10^{-31}\times50\times1.6\times10^{-19}}}$$

$$\lambda = \frac{6.62\times10^{-34}}{\sqrt{1456\times10^{-50}}} \quad \lambda = \frac{6.62\times10^{-34}}{38.15\times10^{-25}}$$

$$\lambda = 0.173\times10^{-34}\times10^{25}$$

$$\lambda = 0.17\times10^{-9} \quad \boxed{\lambda = 0.17\,nm}$$

(Q48) Calculate the velocity and de broglie wavelength of a proton energy 10^{5} eV. Given that mass of proton $= 1.66 \times 10^{-34}$ g ; plank's Constant $= 6.6 \times 10^{-34}$, and Charge on electron 4.8×10^{-10} esu.

$\lambda = \frac{h}{\sqrt{2mek}}$, $\lambda = \frac{h}{\sqrt{2 \cdot 1.66 \times 10^{-34} \times 10^{5} \times 1.6 \times 10^{-19}}}$

$\lambda = \frac{h}{\sqrt{5.312 \times 10^{-24}}}$ $\lambda = \frac{6.62 \times 10^{-34} \times 10^{24}}{2.30}$

$\lambda = 2.8782 \times 10^{-10}$

$\boxed{\lambda = 2.8 A^{\circ}}$

$\lambda = \frac{h}{\sqrt{2m \cdot \frac{1}{2} mv^2}}$ $\lambda = \frac{h}{mv}$

$v = \frac{h}{m\lambda}$

$v = \frac{6.62 \times \cancel{10^{-34}}}{1.66 \times \cancel{10^{-34}} \times 2.8 \times 10^{-10}}$ $\Rightarrow v = \frac{6.62 \times 10^{10}}{4.64}$

$\boxed{v = 1.42 \times 10^{10}\ m/s}$

Quantum mechanics

* What is de-Broglie hypothesis or Matter wave

ans ⇒ According to de-broglie hypothesis every moving particle in a medium is associated by a wave. This associated wave is called matter waves.

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

Expression for 'de broglie wavelength'

from Einstein's relation $\boxed{E = mc^2}$ — ①

for a light particle $\boxed{E = h\nu}$ — ②

Comparing ① & ② $\therefore$ $\boxed{\nu = \frac{c}{\lambda}}$

$$mc^2 = h\nu$$

$$mc^2 = \frac{hc}{\lambda}$$

$$mc\lambda = h \qquad \boxed{\lambda = \frac{h}{mc}} \qquad \because p = m \cdot v, \; p = m \cdot c$$

$$\boxed{\lambda = \frac{h}{p}} \qquad \boxed{\lambda = \frac{h}{\sqrt{2mE}}} \qquad \boxed{\lambda = \frac{h}{\sqrt{2mqV}}}$$

$\boxed{h = 6.6 \times 10^{-34}\ Js}$

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

$\boxed{e = 1.6 \times 10^{-19}}$ $\quad$ $q = ne$

* Calculate the de-broglie wavelength associated with ~~infinite~~ electrons which are accelerated by a voltage of 50kV.

ans ⇒ $\lambda = \frac{h}{\sqrt{2mqV}}$ $\qquad V = 50 \times 10^3\ V$

$$\lambda = \frac{6.66 \times 10^{-34}}{\sqrt{2 \cdot 9.16 \times 10^{-31} \times 1.6 \times 10^{-19} \times 50 \times 10^3}}$$

$$\lambda = \frac{6.66 \times 10^{-34}}{10^{-23}\sqrt{146.86}} \qquad \lambda = \frac{6.66 \times 10^{-11}}{12.10} \qquad \boxed{\lambda = 0.55 \times 10^{-11}} \qquad \lambda = 0.0055\ n

Page No.
Date / 20

PYQ* Define phase velocity and group velocity, prove that particle velocity is equal to group velocity for non-relativistic speeds.

→ Phase velocity :- That velocity in which a plane monochromatic wave moves through a medium is called phase velocity or wa... it is denoted by v_p.

Phase velocity $v_p = \nu\lambda$

according to einstein $E = mc^2$ —— (1)

Energy of photon particle $E = h\nu$ —— (2)

equate eqn (1) & (2)

$$mc^2 = h\nu$$

$$\nu = \frac{mc^2}{h}$$

Now ∵ phase velocity $v_p = \nu\lambda$

$$v_p = \frac{mc^2}{h} \times \lambda \quad \left\{ \because \lambda = \frac{h}{mv} \right.$$

$$v_p = \frac{mc^2}{\cancel{h}} \times \frac{\cancel{h}}{\cancel{m}v}$$

$$\boxed{v_p = \frac{c^2}{v}} \quad \text{where } \frac{c^2}{v} > c$$

Phase velocity can be greater than 'c'.

according to Einsentin $E = mc^2$ — (B)

Equate eqn (B) (C)

$$\boxed{E = h\nu} \text{ — (C)}$$

$$mc^2 = h\nu$$

$$\boxed{\nu = \frac{mc^2}{h}} \text{ — (d)}$$

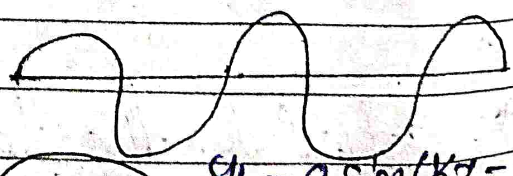
put in

∴ Phase velocity $\boxed{V_p = \nu\lambda}$ from (A) & (d)

$$V_p = \cancel{\frac{mc^2}{h}} \times \cancel{\frac{h}{mv}} \qquad \boxed{V_p = \frac{c^2}{v}}$$

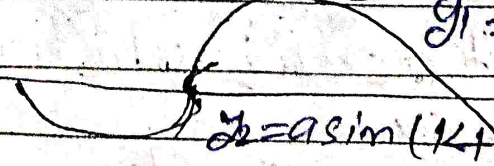
* group velocity: That velocity in which group of waves (a wave pocket) moves in a medium is called group velocity. It is represented by (V_g).

Derivation

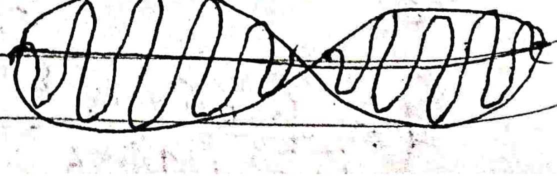


$$\boxed{V_g = \frac{\Delta\omega}{\Delta K}} = \frac{\omega_2 - \omega_1}{k_2 - k_1}$$

$y_1 = a\sin(kx - \omega t)$



$y_2 = a\sin((k_1 + dk)x - (\omega + d\omega)t)$



5/2→ Its square of the absolute value of wave funⁿ gives probability density to locate the particle at point xyz and time t.

Date / 20

Q What is wave function write its significance
wave function is mathematical way of representation of given wave
It actually represents the state of particle once completely known

- A wave function is a function which describes the behaviour of a matter wave it is a function with respect to position & time It is denoted by $\psi(\vec{r}, t) = \psi = |\psi|^2$

Significance of wave function

1. It describes the state of quantum system.
2. It helps to find probability of a particle at a given point xyz and time t.
3. It is used to calculate the energy levels of atoms.

Condition for well behaved wave funⁿ

1. the wave function must be finite.
2. wave function must be single valued.
3. wave function must be continuous.
4. wave function must be square integrable.

What is normalisation of wave function.
Total probability to locate the particle in this universe should come to be 1.

$$\boxed{\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} P\,dv = 1}, \; P \to \text{probability}$$

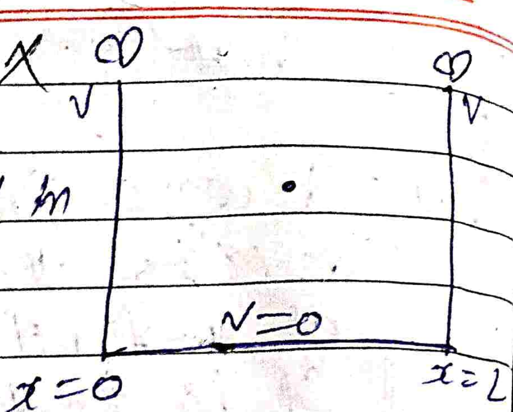
→ Normalisation of the particle

$$P \propto |\psi|^2 \to P = N|\psi|^2$$

$$\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} N|\psi|^2 \cdot dv \qquad N = 1$$

$$\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} |\psi|^2 dv = 1, \; \psi \text{ is normalise}$$

(A) Particle in one D - box



Consider a particle is moving in one D - within a box from $x=0$ to $x=L$

$$\begin{cases} V=0 & \text{for } 0<x<L \\ V=\infty & \text{for } 0>x>L \end{cases}$$

From schrodinger equation,

$$\frac{\partial^2\psi}{\partial x^2} + \frac{2m}{\hbar^2}(E-V)\psi = 0$$

$$\Rightarrow \frac{\partial^2\psi}{\partial x^2} + \frac{2m}{\hbar^2}E\psi = 0 \qquad \boxed{V=0}$$

$$\boxed{K^2 = \frac{2mE}{\hbar^2}} \quad \text{— (2)}$$

$$\boxed{\frac{\partial^2\psi}{\partial x^2} + K^2\psi = 0} \quad \text{— (A)}$$

Solⁿ of eqⁿ (A)

$$\psi = A\cos kx + B\sin kx \quad \text{— (B)}$$

at $x=0$, $\psi=0$

$$\boxed{0 = A}$$

again $\psi = A\cos kx + B\sin kx$

put $A=0$

$$\boxed{\psi = B\sin kx} \quad \text{— (C)}$$

at $x=L$ $\psi=0$

$$0 = B\sin kL$$

$$\sin kL = 0$$

$$\sin kL = \sin n\pi \quad (1,2,3,4)$$

$$\boxed{kL = n\pi}$$

$$\boxed{K = \frac{n\pi}{L}} \text{ (m)} \quad \text{put in C} \quad \boxed{\psi = B\sin\left(\frac{n\pi x}{L}\right)} \text{ — (n)}$$

from eqn (e) and (m)

$$\boxed{E = \frac{K^2\hbar^2}{2m}}$$ put eqn (m) in (e)

$K^2 = \frac{2mE}{\hbar^2}$ | $\because \hbar = \frac{h}{2\pi}$

$$E = \frac{n^2\pi^2}{L^2} \cdot \frac{\hbar^2}{2m} \qquad E = \frac{n^2 h^2 \pi^2}{L^2 4\pi^2 \cdot 2m} \qquad \boxed{E = \frac{n^2 h^2}{8mL^2}}$$

→ Energy value

$\psi = B\sin\left(\frac{n\pi x}{L}\right)$

B → Normalisition constant

$$\boxed{\int_0^L \psi\psi^* dx = 1}$$ → Normalisition Condition

$$\int_0^L B^2 \sin^2\left(\frac{n\pi x}{L}\right) \cdot dx = B^2 \int_0^L \sin^2\left(\frac{n\pi x}{L}\right) \cdot dx = 1$$

$$B^2 \int_0^L \frac{1 - \cos\left(\frac{2n\pi x}{L}\right)}{2} \cdot dx = 1$$

$$\frac{B^2}{2} \int_0^L 1 - \cos\left(\frac{2n\pi x}{L}\right) \cdot dx = 1$$

$$\Rightarrow \frac{B^2}{2}\left[x - \frac{\sin\left(\frac{2n\pi x}{L}\right)}{\left(\frac{2n\pi}{L}\right)}\right]_0^L = 1 \Rightarrow \frac{B^2}{2}\left[x - \sin\left(\frac{2n\pi x}{L}\right) \cdot \frac{L}{2n\pi}\right]_0^L = 1$$

$$\Rightarrow \frac{B^2}{2}\left[L - \sin(2n\pi) \cdot \frac{L}{2n\pi}\right] = 1 \Rightarrow \frac{B^2}{2}\left[L - 0\right] = 1$$

$$\Rightarrow \frac{B^2 L}{2} = 1, \quad B^2 L = 2$$

$$\boxed{B = \sqrt{\frac{2}{L}}}$$ — (g) put in eq eqn (h)

$$\boxed{\psi = \sqrt{\frac{2}{L}} \sin\left(\frac{n\pi x}{L}\right)}$$ — (k)

$\psi = \sqrt{\frac{2}{L}} \sin\left(\frac{n\pi x}{L}\right)$

$n=1$ Ground state

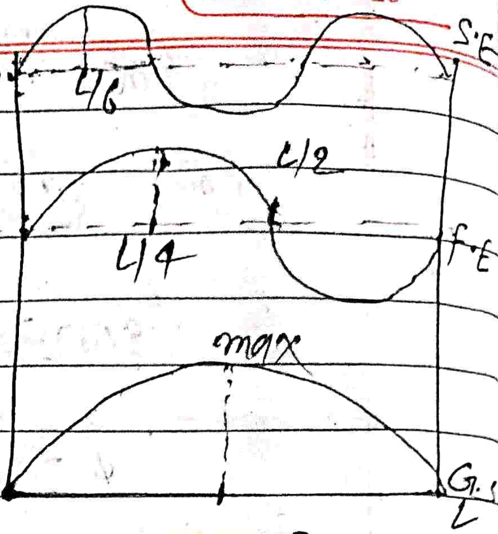
$\psi_1 = \sqrt{\frac{2}{L}} \sin\left(\frac{\pi x}{L}\right)$

for maximum value

$\cancel{\sin\left(\frac{\pi x}{L}\right) = \sin\left(\frac{\pi}{2}\right)}$

$\cancel{\frac{\pi x}{L} = \frac{\pi}{2}}$

$\boxed{x = \frac{L}{2}}$



for first ~~[illegible]~~ excited state

$n=2$

$\psi_2 = \sqrt{\frac{2}{L}} \sin\left(\frac{2\pi x}{L}\right)$

for max vale $\Rightarrow$ $\cancel{\sin\left(\frac{2\pi x}{L}\right) = \sin\left(\frac{\pi}{2}\right)}$

$\frac{2x}{L} = \frac{1}{2}$ $\boxed{x = \frac{L}{4}}$

again $\psi = \sqrt{\frac{2}{L}} \sin\left(\frac{n\pi x}{L}\right)$

for second excited state

$n=3$ $\psi = \sqrt{\frac{2}{L}} \sin\left(\frac{3\pi x}{L}\right)$

for max vale

$\cancel{\sin\left(\frac{3\pi x}{L}\right) = \sin\left(\frac{\pi}{2}\right)}$

$\frac{3x}{L} = \frac{1}{2}$ $\boxed{x = \frac{6}{L}}$

PYQ what is ~~Derive~~ dispersion relation and discuss various Cases possible of dispersion, give its mathematical expression.

श्रोडिंगर

Schrodinger wave equation for time independent

Sol^n: A general wave expression in differential form

$$\boxed{\frac{\partial^2\psi}{\partial x^2} = \frac{1}{v^2}\frac{\partial^2\psi}{\partial t^2}} \quad \text{—— (1)}$$

in 3D

$$\frac{\partial^2\psi}{\partial x^2} + \frac{\partial^2\psi}{\partial y^2} + \frac{\partial^2\psi}{\partial z^2} = \frac{1}{v^2}\frac{\partial^2\psi}{\partial t^2}$$

$$\psi\left(\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2}\right) = \frac{1}{v^2}\frac{\partial^2\psi}{\partial t^2}$$

$$\boxed{\nabla^2\psi = \frac{1}{v^2}\frac{\partial^2\psi}{\partial t^2}} \quad \text{—— (2)}$$

$$\boxed{\psi(x, y, z) = \psi_0 e^{-i\omega t}} \rightarrow (3)$$ this is the sol^n of eq (2)

diff eq (3) with respect to t

$$\frac{\partial\psi}{\partial t} = \psi_0(-i\omega)e^{-i\omega t}$$

~~again diff w.r.to t~~

$$\frac{\partial^2\psi}{\partial t^2} = \psi_0(-i\omega)(-i\omega)e^{-i\omega t}$$

$$\frac{\partial^2\psi}{\partial t^2} = \psi_0(-1)\omega^2 e^{-i\omega t} \qquad \left\{\boxed{i^2 = -1}\right\}$$

{from eq^n (3)}

$$\frac{\partial^2\psi}{\partial t^2} = \psi_0 e^{-i\omega t} \cdot -\omega^2$$

$$\boxed{\frac{\partial^2\psi}{\partial t^2} = -\psi\omega^2} \qquad \left\{\because \omega = 2\pi v \quad \boxed{\omega = \frac{2\pi v}{\lambda}}\right\} \qquad \boxed{v = \frac{v}{\lambda}}$$

$$\frac{\partial^2\psi}{\partial t^2} = -\psi\left(\frac{2\pi v}{\lambda}\right)^2$$

$$\boxed{\frac{\partial^2\psi}{\partial t^2} = -\psi\frac{4\pi^2 v^2}{\lambda^2}} \quad \left\{\lambda = \frac{h}{p}\right\} \Rightarrow \boxed{\frac{\partial^2\psi}{\partial t^2} = -\psi\frac{4\pi^2 v^2 p^2}{h^2}}$$

$$\frac{\partial^2\psi}{\partial t^2} = -\frac{\psi 4\pi^2 v^2 p^2}{h^2} \quad \left\{ \hbar = \frac{h}{2\pi} \Rightarrow \frac{2\pi}{h} = \frac{1}{\hbar} \right.$$

$$\boxed{\frac{\partial^2\psi}{\partial t^2} = \frac{-\psi v^2 p^2}{\hbar^2}} \quad \frac{\partial^2\psi}{\partial t^2} = \frac{-\psi v^2 m^2 \cdot v^2}{\hbar^2} \quad \{ p = mv \}$$

$$\boxed{\frac{\partial^2\psi}{\partial t^2} = \frac{-v^2 m^2 v^2 \cdot \psi}{\hbar^2}} \quad (4)$$

put eq^n (4) in eq^n (2)

$$\nabla^2\psi = \frac{1}{\cancel{v^2}}\left[\frac{-\cancel{v^2} m^2 v^2 \cdot \psi}{\hbar^2}\right]$$

$$\boxed{\nabla^2\psi = -\left(\frac{m^2 v^2}{\hbar^2}\right)\psi}$$

$E = K.E + V$ potential Eng

$E = \frac{1}{2} mv^2 + V_p$

$E = \frac{mv^2}{2} + V_p$

$E - V = \frac{mv^2}{2}$

$2(E-V) = mv^2$

$2m(E-V) = m^2 v^2 \quad (5)$

put in (6)

$$\nabla^2\psi = -\frac{2m(E-V)\psi}{\hbar^2} \quad (6)$$

$$\boxed{\nabla^2\psi + \frac{2m(E-V)}{\hbar^2}\psi = 0}$$ Time independent

$$\boxed{\nabla^2\psi + \frac{2m}{\hbar^2}(E-V)\psi = 0}$$

what is dispersion relation and discuss various cases posibles of dispersion give its mathematical expression.

Page No.
Date / 20

Q8 Relation between phase velocity and group velocity or prove that particle velocity is equal to group velocity :

Relationship b/w v_g & v_p is known as dispersion relation.

we know that for group velocity

$$\boxed{v_g = \frac{\Delta \omega}{\Delta K} = \frac{d\omega}{dK}} \quad \text{—— (1)}$$

from phase velocity

$$v_p = \frac{\omega}{K} \Rightarrow \omega = v_p K \quad \text{—— (2)}$$

diff w.r. to. K

$$\frac{d\omega}{dK} = v_p + K\frac{dv_p}{dK} \quad \text{—— (3)}$$

from eq^n (1)

$$\boxed{v_g = v_p + K\frac{dv_p}{dK}} \quad \left\{ \boxed{K = \frac{2\pi}{\lambda}},\ \lambda = \frac{2\pi}{K} \right. \quad \text{(6)}$$

(4) multipley by $d\lambda$ and divide in last term

$$\lambda = \frac{2\pi}{K}$$

diff w.r. to. K

$$\boxed{\frac{d\lambda}{dK} = -\frac{2\pi}{K^2}} \quad \text{—— (5)}$$

$$v_g = v_p + K\frac{dv_p}{dK} \times \frac{d\lambda}{d\lambda} \rightarrow \text{from eq}^n \text{ (8)}$$

$$v_g = v_p + \cancel{K}\frac{dv_p}{d\lambda}\left(-\frac{2\pi}{K^{\cancel{2}}}\right) \Rightarrow v_g = v_p + \frac{dv_p}{d\lambda}\left(-\frac{2\pi}{K}\right)$$

from (6)

$$v_g = v_p + \frac{dv_p}{d\lambda}(-\lambda)$$

$$\boxed{v_g = v_p - \frac{dv_p}{d\lambda}\cdot\lambda}$$

$\frac{dv_p}{d\lambda} = 0$ in when medium is independent of frequency

$$v_g = v_p - (0)\lambda \quad \boxed{v_g = v_p - \lambda\frac{dv_p}{d\lambda}}$$

Here → v_p → phase velo
v_g → group velo

$$\boxed{v_g = v_p}$$

Case (i) v_p increases with increasing λ or v_p decrease with decreasing λ, then $\frac{dv_p}{d\lambda}$ is +ve $\rightarrow$ Normal dispersion
$v_g < v_p$

(ii) v_p does not depend on λ, then $\frac{dv_p}{d\lambda} = 0$
$v_p = v_g \rightarrow$ non dispersive medium.

(iii) v_p increases with decreasing λ or vice versa then $\frac{dv_p}{d\lambda}$ is -ve $\Rightarrow v_g > v_p \rightarrow$ Anomalous dispersion.

Eigen func^n & Eigen value

If $\hat{x}$ is any operator acting on some function f and in answer we get function f itself multiplied by constant (A) then equation is known as eigen equation,

$\hat{x}$ is known as eigen operator, fun^n f is known as eigen function. and constant A is known as eigen value

Ex → $\frac{d}{dx}(e^{2x}) = 2 \cdot e^{2x}$ is an eigen eq^n.

$\frac{d}{dx}$ is eigen operator for fun^n e^{2x} and 2 is eigen value.

$\frac{d(\sin x)}{dx} = \cos x$, here $\frac{d}{dx}$ is not eigen fun^n ∴ we are not getting same fun^n in answer.

Page No.
Date / 20

What do you understand by wave packet

Ans ⇒ A wave pocket refers to the case where two or more waves exist simultaneously.

PYQ difference between phase velocity & group velocity

Phase velocity	group velocity
(i) That velocity in which plane monochromatic wave moves through a meadium.	That velocity in which group of waves moves in a meadium.
(ii) It is represented by v_p	It is represented by v_g
(iii) It's formula is $\boxed{v_p = \frac{\omega}{K}}$	It's formula is $\boxed{v_g = \frac{\Delta \omega}{\Delta K}}$
(iv) phase velocity is the characteristic of individual wave	group velocity is the characteristic of group of waves.

pyq ⊛ formation of wave pocket discuss.

* ~~eigen wave function~~ :

Nomericle on One 1D - box

*

(a) $\boxed{E = \frac{n^2 h^2}{8mL^2}}$ emergy

(b) wave function $\boxed{\psi = \sqrt{\frac{2}{L}} \sin\left(\frac{n\pi x}{L}\right)}$ $n = 1, 2, 3 \ldots$

(c) Normalization $\int_{n_1}^{n_2} \psi^* \psi \cdot dx = 1$

(d) $\boxed{\text{Probablity} = \int_{n_1}^{n_2} \psi^* \psi \, d\tau}$ $\{ \tau \rightarrow$ dतर

PYQ find the emergy of an electron in a box of width 1Å in the ground state.

ans ⇒ $E = \frac{n^2 h^2}{8mL^2}$ where $h = 6.62 \times 10^{-34}$

mass → 9.1×10^{-31} kg

L^2 = width, length

n^2 = states (ground, first

$E = \frac{n^2 (6.62 \times 10^{-34})^2}{8 \times 9.1 \times 10^{-31} \times (10^{-10} m)^2}$

$L = 1$ Å

$\boxed{L = 1 \times 10^{-10} m}$

$E = \frac{n^2 (6.62 \times 10^{-34})^2}{8 \times 9.1 \times 10^{-31} \times (10^{-10})^2}$

$E = \frac{n^2 \, 43.82 \times 10^{-68}}{72.8 \times 10^{-51}}$

$n = 1 \left(\frac{9.31}{2}\right)$

$E = n \times 0.60 \times 10^{-17}$

$E = 1 \times 0.60 \times 10^{-17}$ J

for electron volt

$E = \frac{0.60 \times 10^{-17}}{1.6 \times 10^{-19}}$

$\boxed{E = 37.5 \text{ ev}}$

Page No.
Date / 20

PYQ - Find the de broglie wavelength corresponding to the ground state energy for the particle trapped in a 1-dimensional box of length 5 nm.
particle → of electron

ans ⇒ given → $n = 1$
$l = 5\,nm$
$l = 5 \times 10^{-9} m$

$$E = \frac{n^2 h^2}{8ml^2} \qquad \cancel{E = n^2 \times 0.60 \times 10^{-17}}\ J$$

$$\cancel{E = 1 \times 0.60}$$

$$E = \frac{n^2 \times (6.62 \times 10^{-34})^2}{l^2\,(8 \times 9.1 \times 10^{-31})} \Rightarrow E = \frac{n^2}{l^2}\left(\frac{43.82 \times 10^{-37}}{72.8}\right)$$

$$E = \frac{n^2 \times 43.82 \times 10^{-37}}{72.8 \times l^2} \qquad \boxed{E = \frac{n^2}{l^2} \times 0.60 \times 10^{-37}\ J}$$

$$E = \frac{(1)^2 \times 0.60 \times 10^{-37}}{25 \times 10^{-18}}$$

$$E = \frac{0.60 \times 10^{-37} \times 10^{+18}}{25}$$

$$\boxed{E = 0.024 \times 10^{-19}\ J}$$

$$\because E = \frac{hc}{\lambda}$$

$$\boxed{\lambda = \frac{hc}{E}}$$

$$\lambda = \frac{6.62 \times 10^{-34} \times 3 \times 10^{8}}{0.024 \times 10^{-19}}$$

$$\lambda = \frac{19.86 \times 10^{-26} \times 10^{19}}{0.024}$$

$$\boxed{\lambda = 827.5 \times 10^{-7} m}$$

1.12.21

Date

Expt. No. Page No.

PYQ) An electron is confined to a one-dimensional potential box of length 0.1nm. Calculate the difference in energies corresponding to the ground state and first excited state in eV, given me.

ans

$l = 0.1nm$ $\boxed{l = 0.1 \times 10^{-9} m}$

find energy at ground & first exicited state

$mass_e = 9.1 \times 10^{-31} kg$ $E = \frac{n^2 h^2}{8mL^2}$

$E = \frac{n^2}{l^2} \times 0.60 \times 10^{-37} J$

at ground state $n=1$

$E = \frac{1 \times 0.60 \times 10^{-37}}{0.1 \times 10^{-9}} \Rightarrow \boxed{E = 6 \times 10^{-28} J}$

$E = \frac{6 \times 10^{-28}}{1.6 \times 10^{-19}}$ $\boxed{E_g = 3.75 \times 10^{-9} eV}$

$\boxed{E_{es} = \frac{n^2}{l^2} \times 0.60 \times 10^{-37} J}$ $E_g = \frac{(2)^2}{0.1 \times 10^{-9}} \times 0.60 \times 10^{-37}$

$E_g = \frac{4}{0.1} \times 0.60 \times 10^{-28} \Rightarrow E_g = \frac{24 \times 10^{-28}}{1.6 \times 10^{-19}}$

$\boxed{E_{se} = 15 \times 10^{-9} eV}$ $\boxed{E_{es} - E_{gs} = (15 \times 10^{-9}) - (3.75 \times 10^{-9})}$

$\boxed{E_{eg} = 11.25 \times 10^{-9} eV}$

Teacher's Signature :

(PYQ) An electron is confined to a one dimensional potential box of length 2Å Calculate the energies corresponding to the second and fourth quantum state in eV

Ans ⇒ $l = 2Å$ $\boxed{l = 2\times10^{-10}\,m}$

Calculate energies at second and third excited state

$$E_{sec.state} = \frac{n^2h^2}{l^2 8m}$$

$$E_{SS} = \frac{n^2}{l^2}\times 0.60\times10^{-37}J \Rightarrow \frac{(3)^2}{(2\times10^{-10})^2}\times 0.60\times10^{-37}$$

$$E_{S.S} = \frac{9}{4\times10^{-20}}\times 0.60\times10^{-37} \Rightarrow E_{S.S} = \frac{5.4}{4}\times10^{-17}J$$

$$\boxed{E_{S.S} = \frac{1.35\times10^{-17}}{1.6\times10^{-19}}}\quad \boxed{E_{SS} = 0.84\times10^{2}\,eV}$$

$$E_{4th\,state} = \frac{n^2}{l^2}\times 0.60\times10^{-37}J$$

$$= \frac{(5)^2}{(2\times10^{-10})^2}\times 0.60\times10^{-37} = \frac{25\times0.60}{4\times10^{-20}}\times10^{-37}$$

$$E_{4thS} = \frac{15}{4}\times10^{-37}\times10^{20} \Rightarrow 3.75\times10^{-17}J$$

$$E_{4th.S} = \frac{3.75\times10^{-17}}{1.6\times10^{-19}}\quad \boxed{E_{4thS} = 2.34\times10^{2}\,eV}$$

Energy corresponding to second quantum state $= \boxed{0.84\times10^{2}\,eV}$

Energy corresponding to fourth quantum state $= \boxed{2.34\times10^{2}\,eV}$

Date ____________

Expt. No. ____________ Page No. ____________

pr 18) Find the probability of finding a particle trapped in a 1-dimensional box of length L between 0.45L & 0.55L. Assume the particle to be in ground state and first excited state

ans ⇒ $\text{probability} = \int_{x_1}^{x_2} \psi^* \psi \cdot dx$ $x_1 = 0.45L$, $x_2 = 0.55L$, $n = 1$

$\psi = \sqrt{\frac{2}{L}} \sin\left(\frac{n\pi x}{L}\right) \Rightarrow \psi = \sqrt{\frac{2}{L}} \sin\left(\frac{n\pi x}{L}\right)$

$\psi^* = \sqrt{\frac{2}{L}} \sin\left(\frac{n\pi x}{L}\right)$

$P = \int_{0.45L}^{0.55L} \sqrt{\frac{2}{L}} \sin\left(\frac{n\pi x}{L}\right) \times \sqrt{\frac{2}{L}} \sin\left(\frac{n\pi x}{L}\right) dx$

$P = \int_{0.45L}^{0.55L} \left(\frac{2}{L}\right) \cdot \sin^2\left(\frac{n\pi x}{L}\right) \cdot dx$

$\cos 2x = 1 - 2\sin^2 x$

$\sin^2 x = \frac{1 - \cos 2x}{2}$

$P = \frac{2}{L} \int_{0.45L}^{0.55L} \frac{1}{2}\left[1 - \cos\left(\frac{2n\pi x}{L}\right)\right] \cdot dx$

$P = \frac{2}{L} \times \frac{1}{2} \left[x - \frac{\sin\left(\frac{2n\pi x}{L}\right)}{\left(\frac{2n\pi}{L}\right)} \right]_{0.45L}^{0.55L}$

Teacher's Signature : ____________

Put $n = 1$

$$p = \frac{1}{L}\left[\left[x - \frac{\sin\left(\frac{2n\pi x}{L}\right)}{\left(\frac{2\pi}{L}\right)} \right]_{0.45L}^{0.55L} \right.$$

$$p = \frac{1}{L}\left[\left[0.55L - \frac{\sin\left(\frac{2(0.55\cancel{L})\pi}{\cancel{L}}\right)}{\left(\frac{2\pi}{L}\right)} \right]_{0.45L}^{0.55L} \right.$$

$$- \left[0.45L - \left(\frac{L}{2\pi}\right)\sin\left(\frac{2(0.45\cancel{L})\pi}{\cancel{L}}\right) \right]_{0.45L}^{0.55L}$$

$$p = \frac{1}{L}\left[\left(0.55L - \left(\frac{L}{2\pi}\right)\sin(1.1\pi)\right) - \left(0.45L - \frac{\sin(0.9\pi)}{\left(\frac{2\pi}{L}\right)}\right) \right]$$

$$p = \frac{1}{L}\left(\left[0.55L + \frac{0.30}{\left(\frac{2\pi}{L}\right)} - 0.45L + \frac{0.30}{\left(\frac{2\pi}{L}\right)} \right] \right.$$

$$p = \frac{1}{L}\left[0.55L + \frac{L}{2\pi} \times 0.30 - 0.45L + \frac{L}{2\pi} \times 0.30 \right]$$

$$p = \frac{1}{L}\left[0.10L + \frac{L}{2\pi} \times 0.60 \right]$$

$$p = \frac{1}{\cancel{L}}\cancel{L}\left[0.10 + \frac{0.60}{2\pi} \right]$$

$$p = \left[0.10 + \frac{0.60}{2 \times 3.14} \right]$$

$$p = [0.10 + 0.095]$$

$$\boxed{p = 0.1954}$$

in % $p = 0.1954 \times 100$ $\boxed{p = 19.5\%}$

Expt. No. ______ Date ______

Page No. ______

$$P = \frac{1}{L}\left[x - \frac{L}{(2n\pi)}\sin\left(\frac{2n\pi x}{L}\right)\right]_{0.45L}^{0.55L}$$

for excited state put $\boxed{n=2}$

$$P = \frac{1}{L}\left[x - \frac{L}{4\pi}\sin\left(\frac{4\pi x}{L}\right)\right]_{0.45L}^{0.55L}$$

$$P = \frac{1}{L}\left[0.55L - \frac{L}{4\pi}\sin\left(\frac{4\pi(0.55L)}{L}\right) - \left(0.45L - \frac{L}{4\pi}\sin\left(\frac{4\pi\times 0.45L}{L}\right)\right)\right]$$

$$P = \frac{1}{L}\left[0.55L - \frac{L}{4\pi}\sin(6.911) - 0.45L + \frac{L}{4\pi}\sin(5.65)\right]$$

$$P = \frac{1}{L}\left[0.55L - \frac{L}{4\pi}\times \underset{1.177300}{\overset{0.5873}{\cancel{0.1208227}}} - 0.45L + \frac{L}{4\pi}\,(-0.59)\right]$$

$$P = \frac{1}{L}\left[0.10L - \frac{L}{4\pi}\times \cancel{0.0021877}\right] \qquad P = \frac{1}{L}\left[0.10L - \frac{1.1773L}{4\pi}\right]$$

$$P = \frac{1}{L}\times L\left[0.10 - \cancel{0.09313}\right] \quad 0.0968340764$$

$$P = 0.0062$$

in %. $P = 0.0062\times 100$ $\quad \boxed{P = 0.62\ \%}$

Teacher's Signature :

(Pro) Consider a 1 D box of length L/4 in which a particle is trapped. find the particle wave function and the corresponding energy for its 2^{nd} excited state.

Sol^{n} :- $L = L/4$ $\boxed{\psi = ?}$ $\boxed{E = ?}$ for excited State

wave function $\psi = \sqrt{\frac{2}{L}} \sin\left(\frac{n\pi x}{L}\right)$

$$\psi = \sqrt{\frac{2}{L/4}} \sin\left(\frac{n\pi x}{\frac{L}{4}}\right)$$

$$\psi = \sqrt{\frac{8}{L}} \sin\left(\frac{4n\pi x}{L}\right)$$

$$\boxed{\psi = 2\sqrt{\frac{2}{L}} \sin\left(\frac{4n\pi x}{L}\right)}$$

$E = \frac{n^2h^2}{8mL^2}$ $E = \frac{n^2}{l^2}\left(0.60 \times 10^{-37} J\right)$ excited state $\boxed{n=3}$

$$E = \frac{(2)^2}{\left(\frac{L}{4}\right)^2} \times 0.60 \times 10^{-37} J$$

$$E = \frac{64}{L^2} \times 0.60 \times 10^{-37} J$$

$$E = \frac{38.4 \times 10^{-37}}{L^2} J$$

in terms of eV

$$\boxed{E = \frac{24 \times 10^{-18}}{L^2} eV}$$

Date

Expt. No. Page No.

Prq The wave function of a certain particle is $\psi = A\cos^2 x$ for $-\pi/2 < x < \pi/2$. find the value of A. Also find the probability that a particle be found between $x=0$ and $x=\pi/4$.

Sol^n: probability

$$p = \int_0^{\pi/4} \psi \cdot \psi^* \cdot dx \Rightarrow \int_0^{\pi/4} \psi \cdot \psi^* \cdot dx \quad \text{where } \psi = \sqrt{\frac{2}{L}} \sin\left(\frac{n\pi x}{L}\right)$$

$$p = \int_0^{\pi/4} \sqrt{\frac{2}{L}} \times \sqrt{\frac{2}{L}} \sin^2\left(\frac{n\pi x}{L}\right) \cdot dx$$

$$p = \frac{2}{L} \int_0^{\pi/4} \frac{1 - \cos\left(\frac{2n\pi x}{L}\right)}{2} \cdot dx$$

$$p = \frac{2}{L} \times \frac{1}{2} \left[x - \frac{\sin\left(\frac{n\pi x}{L}\right)}{\left(\frac{n\pi}{L}\right)} \right]_0^{\pi/4}$$

~~put n =~~

$$p = \frac{1}{L} \left[\frac{\pi}{4} - \frac{L}{n\pi} \sin\left(\frac{n \cdot \pi \cdot \frac{\pi}{4}}{L}\right) - 0 \right]$$

$$\boxed{p = \frac{1}{L} \left[\frac{\pi}{4} - \frac{L}{4\pi} \sin\left(\frac{n\pi^2}{4L}\right) \right]}$$

Teacher's Signature :

(PYQ) Give a detailed description of spontaneous and stimulated emission and hence derive the relation for the einstein coefficients for the same

Soln → page $\boxed{1, 2 \& 3}$

(PYQ) obtain the relation between transition probabilities of spontaneous and stimulated emission.
Mention characteristic properties of a laser beam
→ (i) monochromatic (single frequency, sing wavelength)
(ii) intense (beam focoused on a very small area)
(iii) coherence (highly coherent).

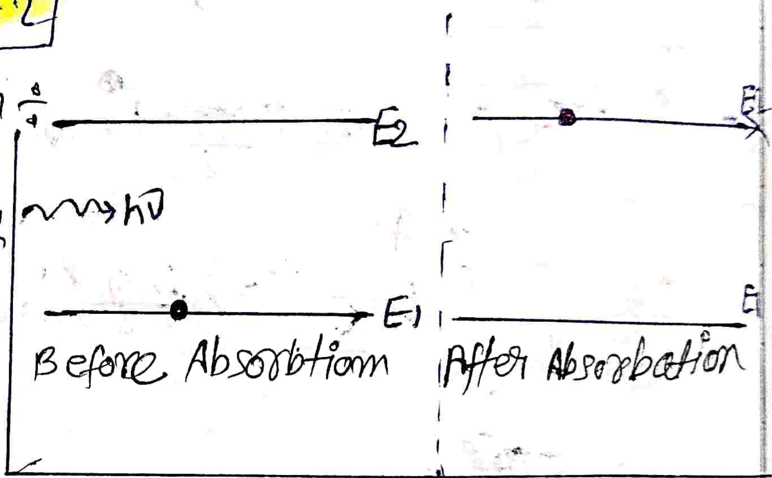
$\boxed{\text{page} \to 10.01, 1 \& 2}$

(*) Stimulated Absorption:-

Consider that initially an atom is in lower energy state having energy E1, if a photon of energy $h\nu$ is incident on an atom in lower state, then atom absorb this energy & jumps to upper state whose energy E2.

$$h\nu = E2 - E1$$

this process is known as stimulated Absorption.



$A + h\nu \to A^*$ (Exited state)

(PYQ) Describe how Laser radiation is different from ordinary light? and laser light is better than ordinary lite why

ans ⇒ ordinary lite is divergent and incoherent whereas laser radiation is highly intense, highly coherent, highly directional this the how laser radiation is different from ordinary light?
laser light is better than ordinary lite becaus of laserlight is highly intense, highly directional and highly coherent that's why better that ordinary light.

On which factor stimulated absorption depends

(i) The no of atoms in the ground state.

(ii) The energy of the incoming photon.

(iii) The intensity of the incoming photon.

(iv) nature of atom (v) energy difference.

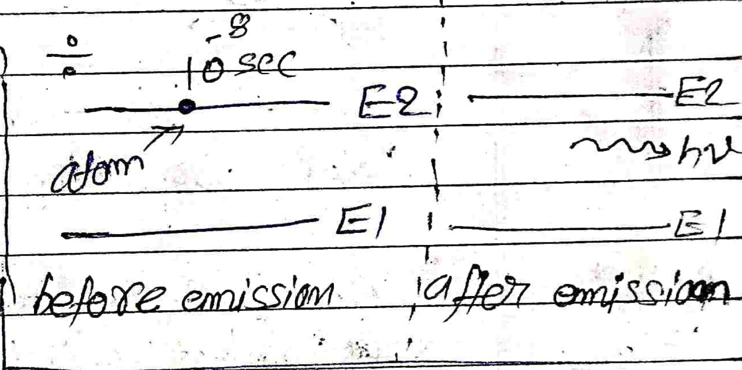
Laser

* what is laser and it's full form.

ans ⇒ Laser is a device that emits a monochromatic, coherent, highly intense, unidirectional beam of light. The full form of laser is

L → Light
A → Amplification by
S → Stimulated
E → Emission of
R → Radiations

* Spontaneous Emission :



Consider that initially an atom is in higher energy state E2, atom in exicited state lives for 10^{-8} sec, so atom will make a trasistion to come to lower energy state E1, During this transistion atom will release a photon of energy hν where $\boxed{h\nu = E2 - E1}$, this process is called spontaneous emission.

Thus we can say that the process of emission of a photon by an Atom without any external energy is called spontaneous emission

$$\boxed{A^* \longrightarrow A + h\nu}$$

on which factor S.E depends

(i) Energy difference (ii) Nature of atom
(iii) Excited state Liftime ~~(iv) Temperature~~.
(v) no of atom in exited state.

Stimulated emission :- At high energy state when energy $h\nu$ is given to the atom, it falls back to the ground energy state by emitting two photons ~~is called~~ and these two photons have same frequency, same direction same phase is called stimulate emissition.

On which factor stimulated emission depends.

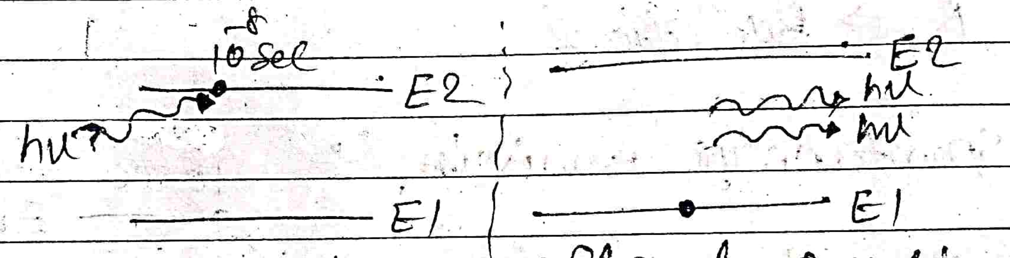
(i) no of atom present in the excited state.

(ii) nature of atom.

(iii) energy of given photon.

यहाँ हम hν emit कर रहे हैं। atom को निचले स्तर पर लाने के लिए

$$A + h\nu \longrightarrow A + 2h\nu$$



Before transistion | after transistion

RXQ Differenciate spontaneous emission and stimulate emission

	stimulated emission	spontaneous emission
(i)	emitted photons move in the same direction.	emitted photons move in all direction.
	Need of external energy.	No need of external energy
(ii)	the rate of transition is $R_{StE} = B_{21}N_2E(\nu)$.	the rate of transition is $SpE = A_{21}N_2$.
	It emits two photon.	It emits only one photon.
(iii)	light emitted through this process is coherent.	light emitted through this process is incoherent.
(iv)	High directional.	less directional.
(v)	High intense	less intense.
(vi)	Coherent radiation	incoherent.

Some basic background for
(*) Einstein's Coefficients :-
Three process of (E.C) (Three einstein's coefficients)
(i) Stimulated ~~emission~~ Absorption
(ii) Spontaneous emission
(iii) Stimulated emission

(i) B_{12} → Einstein coefficient for stimulated Absorption

(ii) B_{21} → " " " " emission

(iii) A_{21} → " " " Spontaneous emission

Note → Rate of Stimulated Absorption → (R_{stA})
Rate of Stimulated emission → (R_{stE})
Rate of spontaneous emission → (R_{spE})

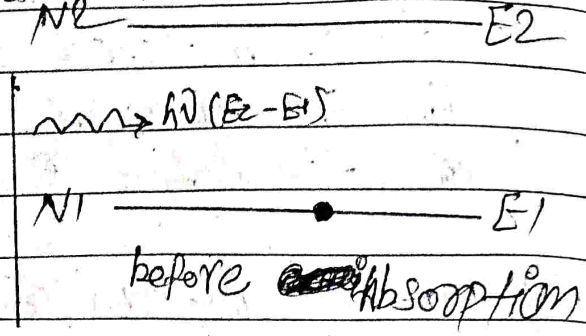
PYQ) Find the units of Einstein Coefficients.
(A) $\boxed{\text{Jule}^{-1}\ \text{sec}^{-2}\ m^3}$

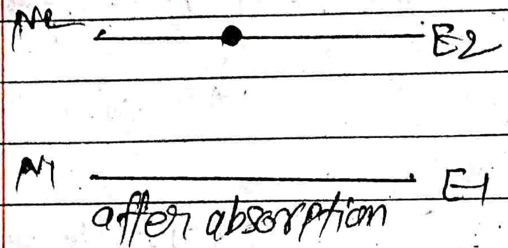
Q) Explain principle of working of laser.

ans → The principle of working of laser is based on the process of stimulated emission of radiation.

PYQ Einstein's coefficients and right condition necessary for lasing action to take place.

① Stimulated Absorption





P.1 (i) Rate of Stimulated absorption is directly proportional to (N1) How much atoms present in ground state.

$$R_{StA} \propto N1$$

P.2 (ii) Rate of Stimulate absorption is directly proportional to incident radiation of energy density.

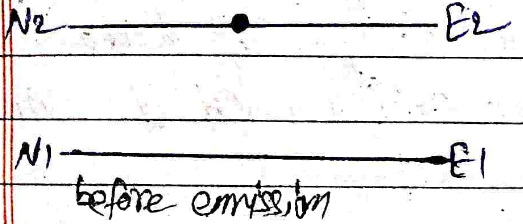
$$R_{StA} \propto E(\nu)$$

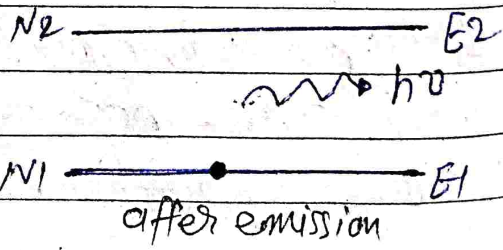
$$R_{StA} \propto N1 E(\nu)$$

$$\boxed{R_{StA} = B12 N_1 E(\nu)} \rightarrow (A)$$

where B12 → is proportionality coefficient

② Spontaneous emission





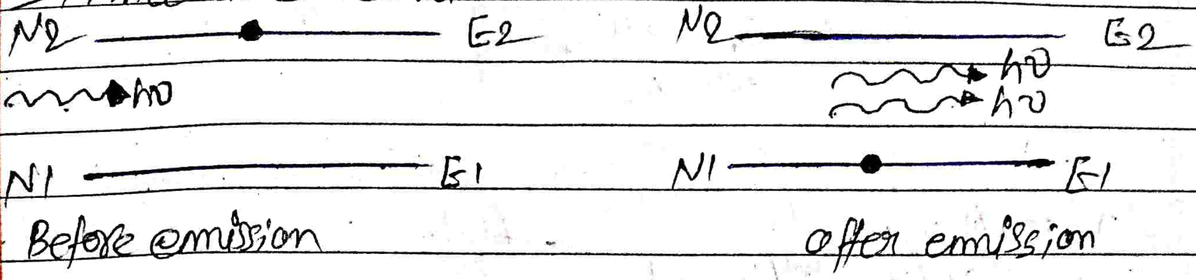
(i) Rate of Spontaneous emission is directly proportional to (N2) how much atoms present in excited state

$$R_{SPE} \propto N2$$

$$\boxed{R_{SPE} = A21 N2} \rightarrow (B)$$

where A21 is proportionality constant

③ Stimulated emmission



D p.3

ⓘ Rate of stimulated emmission is directly proportional to (N_2) how much atoms present in excited state.

$$R_{StE} \propto N_2$$

ⓘⓘ Rate of stimulated emmission is directly proportional to $E(\nu)$ incident radiation of energy density.

$$R_{StE} \propto E(\nu)$$

{ B_{21} → is proportionality constant }

$$R_{StE} \propto N_2 E(\nu)$$

$$\boxed{R_{StE} = B_{21} N_2 E(\nu)} \text{ — (C)}$$

$$\boxed{R_{StA} = B_{12} N_1 E(\nu)} \text{ — (A)}$$

$$\boxed{R_{SpE} = A_{21} N_2} \text{ — (B)}$$

In thermodynamic equilibrium

$$\boxed{R_{StA} = R_{SpE} + R_{StE}}$$ by using eqⁿ A, B, C

$$B_{12} N_1 E(\nu) = A_{21} N_2 + B_{21} N_2 E(\nu)$$

$$B_{12} N_1 E(\nu) - B_{21} N_2 E(\nu) = A_{21} N_2$$

$$E(\nu)(B_{12} N_1 - B_{21} N_2) = A_{21} N_2$$

$$E(\nu) = \frac{A_{21} N_2}{B_{12} N_1 - B_{21} N_2}$$

$$E(\nu) = \frac{A_{21} \cancel{N_2}}{B_{21} \cancel{N_2} \left(\frac{B_{12} N_1}{B_{21} N_2} - 1 \right)}$$

$$\boxed{E(\nu) = \frac{A_{21}}{B_{21} \left(\frac{B_{12} N_1}{B_{21} N_2} - 1 \right)}} \text{ — (D)}$$

According to maxwell boltzmann law

$$\frac{N_1}{N_2} = e^{(E_2 - E_1)/k_B T}$$ ∵ $E_2 - E_1 = h\nu$

$$\boxed{\frac{N_1}{N_2} = e^{h\nu / k_B T}} \text{ — (E)}$$

using eq (D) & (E) put eq (E) in (D)

Page No.
Date / 20

$$E(\nu) = \frac{A21}{B21\left[\frac{B12}{B21}\frac{N1}{N2} - 1\right]}$$

$\because \frac{N1}{N2} = e^{h\nu/K_BT}$

$$\boxed{E(\nu) = \frac{A21}{B21} \times \frac{1}{\left[\frac{B12}{B21} e^{h\nu/K_BT} - 1\right]}} \quad (g)$$

according to plank's radiation law

$$\boxed{E(\nu) = \frac{8\pi h\nu^3}{c^3} \frac{1}{\left[e^{h\nu/K_BT} - 1\right]}} \quad (h)$$

by Compairing eq (g) & h

$$\boxed{\frac{A21}{B21} = \frac{8\pi h\nu^3}{c^3}} \quad \& \quad \frac{B12}{B21} = 1$$

$$\boxed{B12 = B21}$$

external pumping is required to supply energy to the system and achieve the necessary condition for lasing.

PYQ Disscuss on what factors the rate of stimulated absorption per unit volume (Ra) and rate of stimulated emission per unit volume (RstE) depend. write their mathematical expression. Hence find Condition when rate of stimulated emission per volume will be more than rate of stimulated absorption per unit volume.

Calling (P.1, P.2, P.3) here $\boxed{Ra \leftrightarrow RstA}$

$RstE > RstA$

$$\boxed{RstE = B21\, N2\, E(\nu)} \text{ — A} \qquad \boxed{\frac{RstE}{RstA} >> 1}$$

$$\boxed{RstA = B12\, N1\, E(\nu)} \text{ — (B)}$$

Q. Compare the properties of He-Ne and ruby laser.

ans ⇒

property	Ruby laser	He-Ne laser
1. Active medium	Ruby - crystal	He-Ne - gass 10:1
2. Pumping mechanism	optical pumping	Electric discharge
3. output power	up to 100 watts	up to 50 miliwatt
4. Beam quality	poor	good
5. Applications	laser surgery, spectroscopy, Rangefinding, Holography, research and develop	display technology, Barcode scanning, interferometry.

Q. Compare the properties of He-Ne and CO_2 laser.

Property	CO_2 laser	He-Ne laser.
Active medium	N_2 & He	He-Ne - gass. 10:1
Pumping mechanism	Electric. discharge	Electric discharge
output power	upto 100 KW	up to 50 miliwatt
Beam quality	good	excellent
Applications	cutting, welding, drilling, marking.	display, technology Barcode scanning interferometer

Q. application of optical fiber

ans ⇒ Telecommunication, medical, Defense, industry High speed Net service.

Q metastable state

ans ⇒ An excited state of an atom that remains stable for a relatively long time before emitting a photon & returning to its ground state.

Q what do you mean by total internal reflection give two example of TIR in daily life.

ans ⇒ The angle at which the incident ray travelling from denser to rare medium is equal to or greater than critical angle then ray will graze & reflected back into the same medium. This phenomenon is called TIR.

Q write three transition in He-Ne laser

(i) E6 - E5 - Infrared - 3.39 μm

(ii) E6 - E3 - visible (Red) - λ = 6328 Å

(iii) E4 - E3 - Infrared - 1.15 μm

→ (1) Fiber optic communication.

(2) Diamond sparkling.

(*)

Metastable state ⇒ A metastable state refers to an excited state of an atom that has a relatively long lifetime compared to other excited states.

dividing eq (A) ÷ (B)

$$\frac{B21\ N2\ \cancel{E(\nu)}}{B12\ N1\ \cancel{E(\nu)}} >> 1 \quad \text{Einstein Coefficient} \quad \boxed{B12 = B21}$$

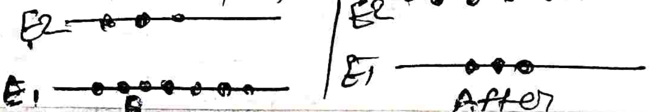
$$\frac{\cancel{B21}\ N2}{\cancel{B21}\ N1}$$

$$\frac{N2}{N1} >> 1 \qquad \boxed{N2 >>> N1} \quad \text{Population inversion}$$

~~inversion~~

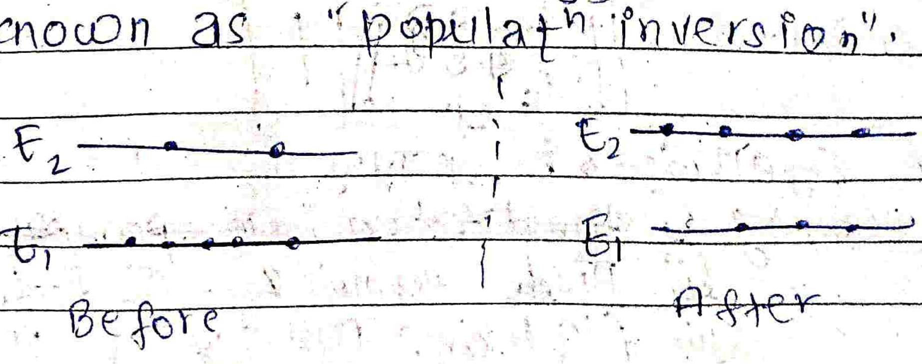
PYQ What is population inversion and what is need to achieve population inversion?

ans population inversion: Population inversion in a laser refers to the condition where no of atoms in excited state is greater than ground state, which is necessary for laser amplification and emission of coherent light



To achieve population inversion, it is necessary to excite the atoms or molecules into the higher energy states by supplying energy from an external source such as optical pumping. this is need.

The situat^n in which the no. of atoms in the higher energy state exceeds that in the lower energy state ($N_2 > N_1$) is known as "populat^n inversion".



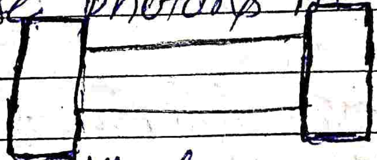
Page No.
Date / 20

PYQ How does a laser work? Explain active medium, optical pumping and optical resonators.

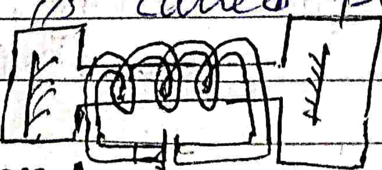
ans ⇒ lasers produce a narrow beam of light in which all of the light wave have similar wavelength.

laser / its type
(i) Solid state
(ii) liquid
(iii) Gas
(iv) semi-conductor

active medium :- Active medium is a material in which laser action takes place. the active medium may be solid, liquid or gases. it contains atoms or molecules that can be exited into a higher energy state to when these excited atoms or molecules returns to their lower energy state they release photons in the form of laser light



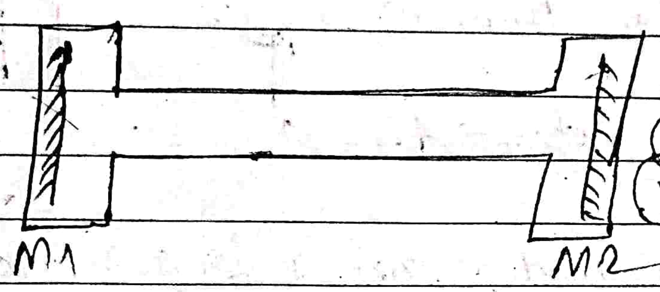
optical pumping :- optical pumping is the process used to excite the atoms or molecules in the active medium. This is done by using light source which can be form of lamp. the light source provides energy to the atoms or molecules exciting them into a higher energy state this process is called population inversion.



optical resonators :- # Types of O.P
(i) Discharge lamp pumping (i) ~~stimulated emission pumping~~
(ii) Diode pumping. (iv) electrical pumping
(iii) flashlamp pumping.

Page No.
Date / 20

optical resonator :- An optical resonator is a device used to reflect the light to convert light into a laser radiation, resonator consists two mirrors placed at end of active medium. one mirror is totally reflective another is partially reflective, laser light passes through partially reflective mirror.



Types of resonator
(i) Confocal resonator
(ii) Ring resonator
(iii) Spherical resonator

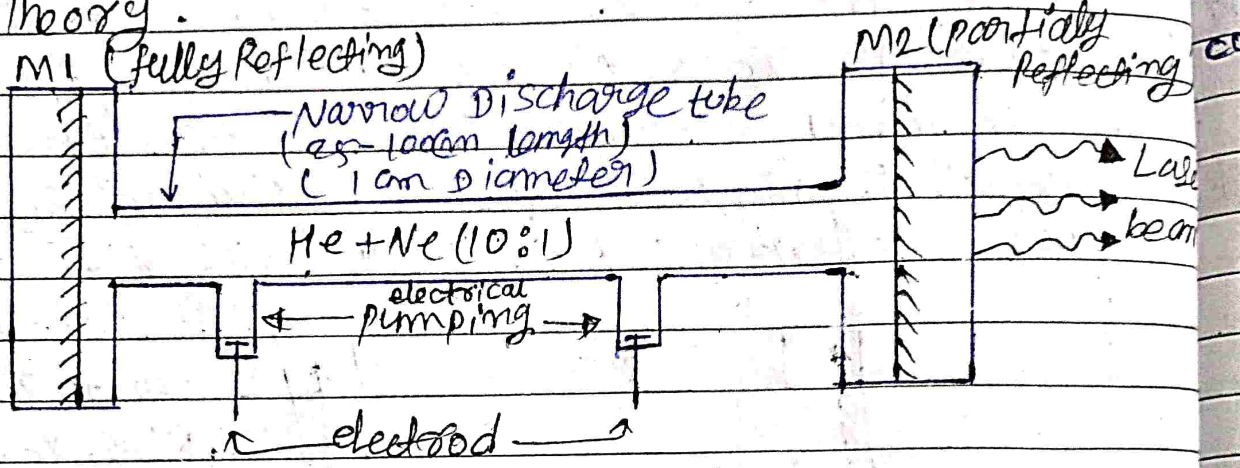
(PYQ) In LASER, in place of 'A', it should be 'O' why?

ans ⇒ 'A' refers to Amplifiers it is always either no feed back or negative feed back this is employed, on the other hand Stimulated emission is basically oscillation process so 'O' refers to oscillation. Hence in place of (A) there must be 'O' in the word LASER.

(PYQ) what is the role of helium in He-Ne laser

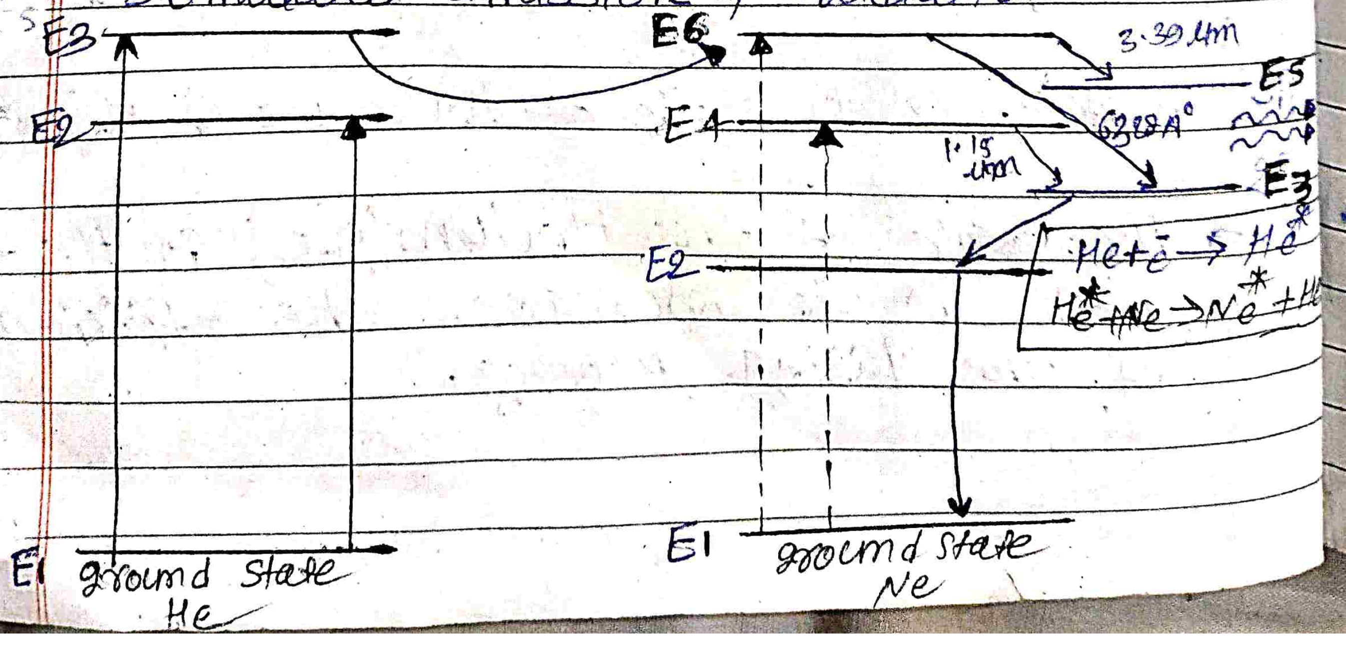
ans ⇒ The role of the Helium (gas) in He-Ne laser is to increase the efficiency of the lasing process.

PYQ (He-Ne laser) or (4 level laser) or (gaseous laser) it's construction, working, diagram, principle, Theory.



Construction ⇒ Shown in above diagram a long narrow discharge tube length 25 - 100 cm & diameter 1 cm. We filled Helium (He) & Neon (Ne) gasses of amount (10:1) at 1mm of Hg and 0.1 mm of Hg pressure. There are two mirror (M1 & M2) at the corner of the tube makes resonater cavity, M1 mirror is fully reflective and M2 mirror is partially reflective. There are two electrical pumping attached with tube having two different electrod.

principle :- He-Ne laser works on the principle of stimulated emission of radiation.



Page No.
Date / 20

Working :- As we apply dc voltage intube than there
electron will be produce in tube, Now there are two atoms
collision He & Ne in tube so Helium atom will be excited by
electron because mass of Helium is 4 and mass
of neon is 20 so firstly Helium will be excited and
again neon. So Helium will be gone from ground
state to excited state, so excited Helium atom will
transfer energy to the neon (Ne) present in ground
state so neon will be gone to excited state from
ground state after this neon atom will show
transition and come to lower level than when
a electron is coming from E6 level to E5 level than
it emits a photon of 3.39 μm when electron will
jump from E6 to E3 level than again it will
be emits a photon of 6328 Å and this photon
will bring the new atoms of the second excited of
neon atom from uper level to the ground state,
then another photon will be emitted so this
photon has 6328 Å and when a electron jumped
from E6 level to E3 level that those electron
was emits a photon of 6328 Å so both photon
will be same wavelength and these two photon
will be recombined these two photon will be reflected
between two mirror M1 & M2 again and again
than we will get laser light of red colour

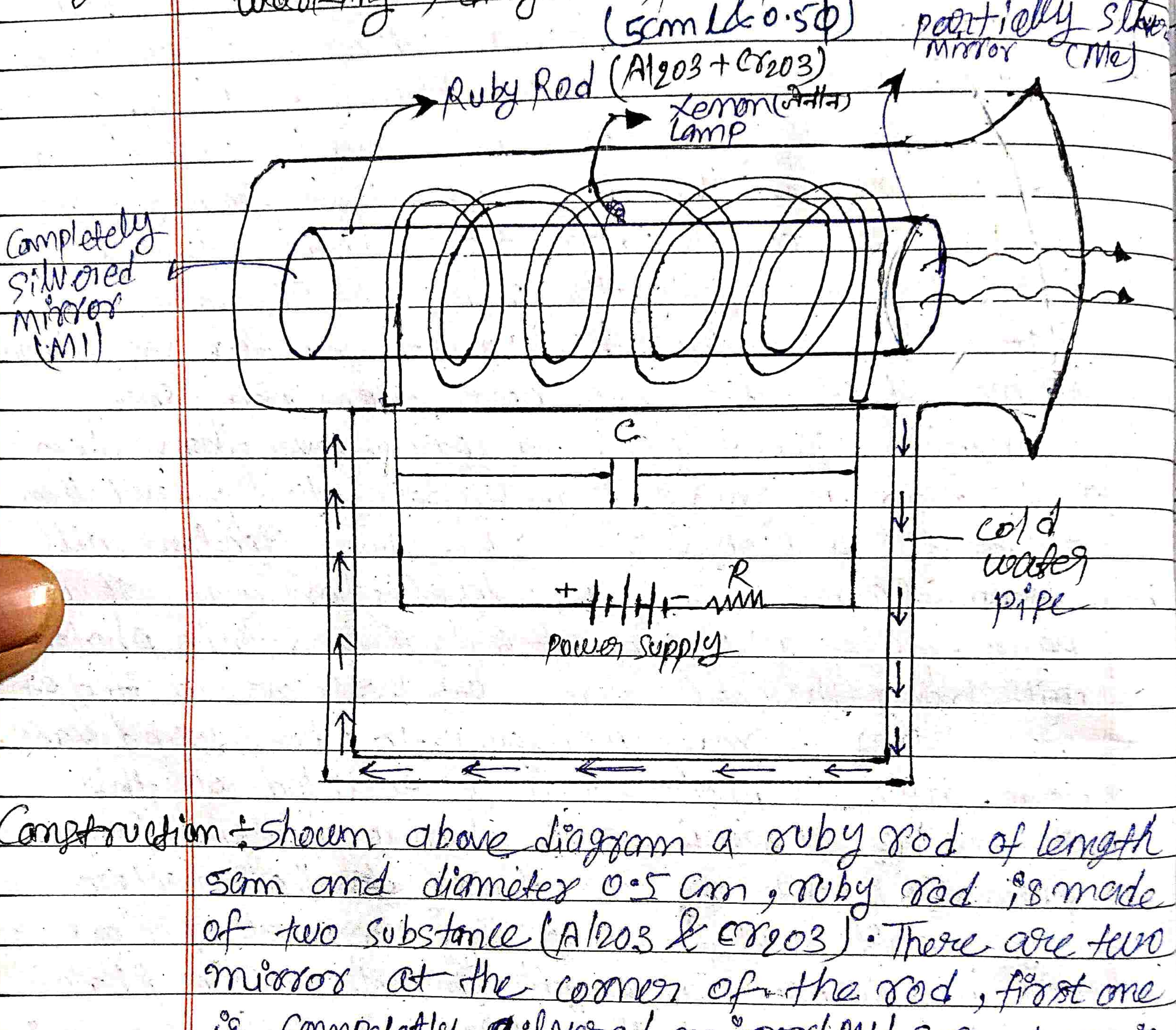
E6 → E5 → 3.39 μm (useless) ← infrared
E6 → E3 → 6328 Å (usefull) visible
E4 → E3 → 1.15 μm (useless) (infrared)

$He + \bar{e} \rightarrow He^*$
$He^* + Ne \rightarrow Ne^* + He$

Application :- ① 3D images of objects | to read bar codes.
(ii) in laboratory
(iii) in library to scan bar code.

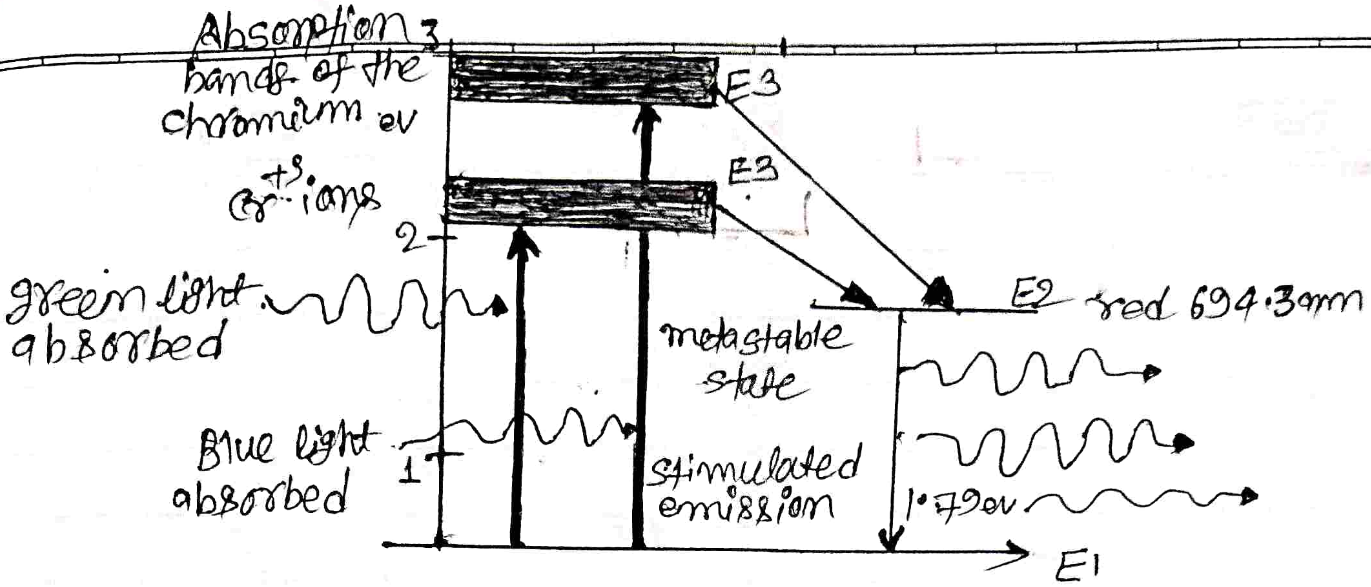
(Solid laser)

(PYQ) (Ruby laser) or three level laser Construction, working, diagram, principle.

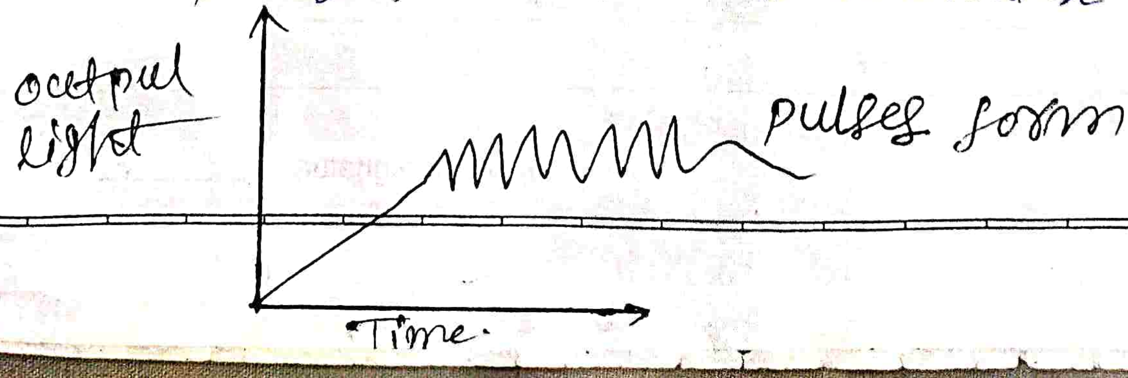


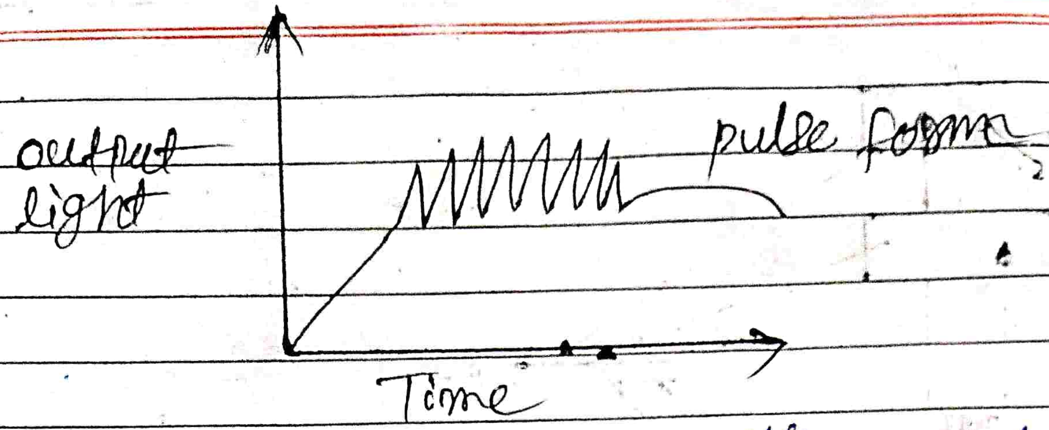
Construction:- shown above diagram a ruby rod of length 5cm and diameter 0.5 cm, ruby rod is made of two substance (Al_2O_3 & Cr_2O_3). There are two mirror at the corner of the rod, first one is compeletly silvered mirror (M1) second one is partially silvered mirror (M2) both mirror M1 & M2 will make resonater cavity and there is a optical pumping attached with xenon lamp which is connected by a power supply & capacitor. we kept ruby rod and optical lamp in a chamber in which cold water pipe is present to cool ruby laser.

principle:- Ruby laser works on the principle of stimulated emission of radiation.



When power supply is turned on capacitor start geting discharge due to which xenon lamp emits thousent of Joules of energy in miliseconds. this energy is absorbed by Cr^{+3} ions in ruby laser and they go from ground state to exited state. the ions which absorb 0.55um compenent from light go to green band and ions which absorb 0.42 um component goto blue band. the life time of excited state is 10^{-8}s therefor these ions jump ~~[illegible]~~ to metastable. the ions of both ~~level~~ blue & green level go to metastable level therefor population invorsion is achieved when these ions travel from metastable state to ground state than it shows transition from metastable state to ground state and emits two photons which are coherent and same wavelength which is called spontoneous emission & these two photons travels in resonater cavity again ~~&~~ ~~[illegible]~~ again than we get laser light of red colour. found laser light is not ~~[illegible]~~ in the form of continious light rather in the form of pulses form this is the disadvantage of Ruby laser.





Applications → cutting, drilling, welding, decoration

(PYQ) Explain why He-Ne laser is superior to a ruby laser?

ans ⇒ Ruby laser requires high power pumping source whereas Helium-neon laser requires low power pumping source. Efficiency of He-Ne laser is more than ruby laser so He-Ne laser is superior to a ruby laser.

(PYQ) Explain spiking in Ruby laser.

ans ⇒

~~The laser ... is made up of spikes of high intensity emissions. This phenomena is called spiking of~~

The term 'spiking' in ruby laser refers to a phenomenon that can occur when the laser is operated normally. The output power is stable and constant.

Page No.
Date / 20

Basics for numericles

(1) $\boxed{h\nu = E_2 - E_1}$ (2) population inversion $\boxed{N = N_0 e^{-\frac{E}{KT}}}$

(3) population invesion ratio $\Rightarrow$ $\boxed{\frac{N_2}{N_1} = e^{-h\nu/KT}}$

(4) Intensity $\Rightarrow$ $\boxed{I = \frac{P}{A}}$ $\frac{W}{m^2}$, (5) $\boxed{P = \frac{I}{A} \frac{J}{s}}$ (6) $\boxed{E = h\nu}$ energy

(7) Total energy $\Rightarrow$ E = no of atom x energy of one photon

$\boxed{E = nh\nu}$ $\boxed{\nu = \frac{c}{\lambda}}$ $\boxed{\text{area} = \pi r^2}$

(8) no of ions $\Rightarrow$ $\boxed{n = \frac{E\lambda}{hc}}$ $\boxed{K = 1.38 \times 10^{-23} \frac{m^2 kg}{s^2 \cdot K}}$

$\boxed{K = 8.6 \times 10^{-5} \frac{eV}{K}}$

(9) rate of SPE = $A_{21} N_2$

(10) rate of STE = $B_{21} N_2 E(\nu)$

(11) To find P(power) $\Rightarrow$ $\boxed{P = R = N \times E}$

where R → Rate of emission of energy

N → No of total lasring particle

E → Energy

Pr(Q) Compute the ratio of population of the two states in a He-Ne laser that produces light of wavelength 6.328×10^{-5} cm at 27°C.

ans ⇒ ratio of population =

$\frac{N_2}{N_1} = e^{-h\nu/KT} \Rightarrow \frac{N_2}{N_1} = e^{-\frac{hc}{\lambda}/KT}$

given : $\lambda = 6.328 \times 10^{-5}$ cm

$\lambda = \frac{6.328 \times 10^{-5}}{10^{2}}$ m

$\boxed{\lambda = 6.328 \times 10^{-7} \text{ m}}$

$h = 6.62 \times 10^{-34}$, $c = 3 \times 10^{8}$

$T = 27°C$ $T = 27 + 273$ K

$\boxed{T = 300 K}$

$\boxed{K = 1.38 \times 10^{-23}}$

$\Rightarrow hc = 6.62 \times 3 \times 10^{-26}$

$\boxed{hc = 19.86 \times 10^{-26}}$

$\Rightarrow -\frac{hc}{\lambda} = \frac{-19.86 \times 10^{-26}}{6.328 \times 10^{-7}} = 3.138 \times 10^{-19}$

$KT = 1.38 \times 10^{-23} \times 300$

$KT = 1.38 \times 3 \times 10^{-21}$

$KT = 4.14 \times 10^{-21}$

$\frac{N_2}{N_1} = e^{-(3.138 \times 10^{-19})/(4.14 \times 10^{-21})}$

$\frac{N_2}{N_1} = e^{-(0.7579 \times 10^{2})} \Rightarrow \boxed{\frac{N_2}{N_1} = e^{-75.79}}$

pxq) In a given laser, total number of lasing particle is 2.8×10^{19}. If laser emits a wavelength of 6328 Å, then calculate the energy of one photon being emitted by the laser. If the laser beam is focused on an area equal to the square of its wavelength for 1s, find intensity of the focused beam. Assume the efficiency of laser to be 100%.

ans → Given: $n = 2.8 \times 10^{19}$ find $E = ?$

$\lambda = 6328$ Å $I = ?$

Area $= \lambda^2$

$E = h\nu$ $E = \frac{hc}{\lambda}$ $E = \frac{19.86 \times 10^{-26}}{6328 \times 10^{-10} m}$

$E = 0.003138 \times 10^{-16} m$

$\boxed{E = 3.13 \times 10^{-19} J}$ ∴ $\boxed{I = \frac{P}{A}}$

$A = \lambda^2$ $A = 6.328 \times 6328 \times 10^{-20} m^2$

$A = 40043584 \times 10^{-20}$

$\boxed{A = 4 \times 10^{-13} m^2}$

$P = R = N \times E$

$P = 2.8 \times 10^{19} \times 3.13 \times 10^{-19}$

$\boxed{P = 8.764 \, W}$

$I = \frac{P}{A}$ $I = \frac{8.764}{4 \times 10^{-13}}$ $\boxed{I = 2.19 \times 10^{13}}$ $\frac{W}{m^2}$

(pyq) find the ratio of rate of spontaneous emission to rate of stimulated emission at 300K corrosponding to emission of gr light photon with $\lambda = 550$ nm -

given $T = 300K$

ans → $\lambda = 550$, $\lambda = 550 \times 10^{-9}$ m

$$\frac{A_{21}}{B_{21}} = \frac{8\pi h \nu^3}{c^3} \quad \text{where } \nu = \frac{c}{\lambda}$$

solution page no-4 in this series

$$= \frac{\frac{8\pi h c^3}{\lambda^3}}{c^3} \Rightarrow \frac{8\pi h \cancel{c^3}}{\lambda^3} \times \frac{1}{\cancel{c^3}}$$

$$= \frac{8\pi h}{\lambda^3} \Rightarrow \frac{8 \times 3.14 \times 6.62 \times 10^{-34}}{(550 \times 10^{-9})^3}$$

$$= \frac{166.37 \times 10^{-34}}{166375 \times 10^{-24}}$$

$= 1 \times 10^{-13}$ answer

(pyq) find the intensity of a laser beam of 10mW power having laser beam diameter of 1cm.

ans ⇒ $I = \frac{P}{A}$ $P = 10mW$ $\boxed{P = 10^{-2} W}$

$P = 10 \times 10^{-3} W$

$d = 1cm$ ~~P = 10000 W~~

$d = 1 \times 10^{-2}$

$r = \frac{10^{-2}}{2}$ $r = \frac{1}{200}$, $\boxed{r = 0.005 \text{ m}}$ $A = \pi r^2$

$A = 3.14 \times (0.005)^2$

$A = 7.85 \times 10^{-5}$ m^2

$I = \frac{10^{-2}}{7.85 \times 10^{-5}}$ $\boxed{I = 127.38 \frac{W}{m^2}}$

(PYQ) Calculate the ratio of stimulated absorption to stimulated emission for a material at 300K if the population density of an excited state is 1000 times that of a ground state.

Given

$N_2 = 1000 N_1$

$\frac{N_1}{N_2} = \frac{1}{1000}$ (given)

As $\frac{\text{rate of } R_{stA}}{\text{Rate of } R_{stE}} = \frac{N_1 B_{12} E(\nu)}{N_2 B_{21} E(\nu)}$

$= \frac{N_1}{N_2}$

$= \frac{1}{1000}$ Ans

(PYQ) A laser beam having intensity 2m W/m² is passed through a circular cross-sectional area of 1mm². find energy of the photons emitted by laser in 1s.

Ans given → $\boxed{I = 2\times10^{-3}\ W/m^2}$ $a = 10^{-3}\times10^{-3}$ $\boxed{a = 10^{-6} m^2}$

$\because I = \frac{E}{A \cdot t}$

$2\times10^{-3} = \frac{E}{10^{-6}\times 1}$ $E = 2\times10^{-9}$

$\boxed{E = 2\times10^{-9}\ J}$

$\boxed{I = \frac{P}{A}}$ ~~Power~~ P = the rate of doing work

rate mean per unit time

so $\boxed{t = 1}$

Sol^n: $T = 300K$, $\lambda = 550 \times 10^{-9} m$

$$\frac{R_{sp}}{R_{st}} = \left(e^{h\nu/KT} - 1\right)$$

$$\Rightarrow \left(e^{(hc/KT\lambda)} - 1\right)$$

$$\because \boxed{hc = 19.86 \times 10^{-26}}$$

$$KT\lambda = 1.38 \times 10^{-23} \times 300 \times 550 \times 10^{-9}$$

$$KT\lambda = 1.38 \times 3 \times 55 \times 10^{-23} \times 10^{-9} \times 10^{3}$$

$$\boxed{KT\lambda = 227.7 \times 10^{-29}}$$

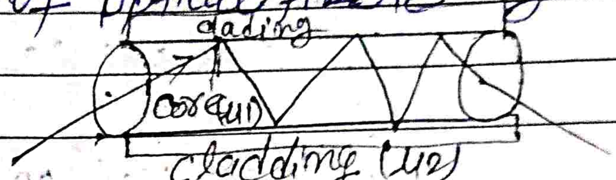
$$\frac{R_{sp}}{R_{st}} = \left(e^{(19.86 \times 10^{-26} / 227.7 \times 10^{-29})} - 1\right)$$

$$= \left(e^{87.22} - 1\right) \text{ ans}$$

Optics fiber

PYQ Define acceptance angle and numerical aperture write the it's significance hence find expression for numerical aperture and acceptance angle. physical significance and Merit of acceptance angle & numerical aperture.

Acceptance angle ÷ Acceptance angle is the maximum angle of incident light at which incident light propagates inside the core of optical fibere by total internal Reflection.



(figure)

$$\boxed{i_0 = \sin^{-1}\sqrt{\mu_1^2 - \mu_2^2}}$$

Merit ÷ (i) Increased light collection ÷ A large acceptance angle means optical fiber can collect light from a wider range of angles.

(ii) Improved flexibility ÷ By increasing the acceptance angle, optical fiber becomes more flexible and easier to use.

Physical significance of acceptance angle ÷ To [redacted] transmit as much as light from the source [redacted] as posible.

Numerical aperture ÷ It is measurement of sin of acceptance angle and this value is always based on refrective index values of core [redacted] clad denoted by NA.

$$\boxed{NA = \sin i_0} \quad \boxed{NA = \sqrt{\mu_1^2 - \mu_2^2}}$$

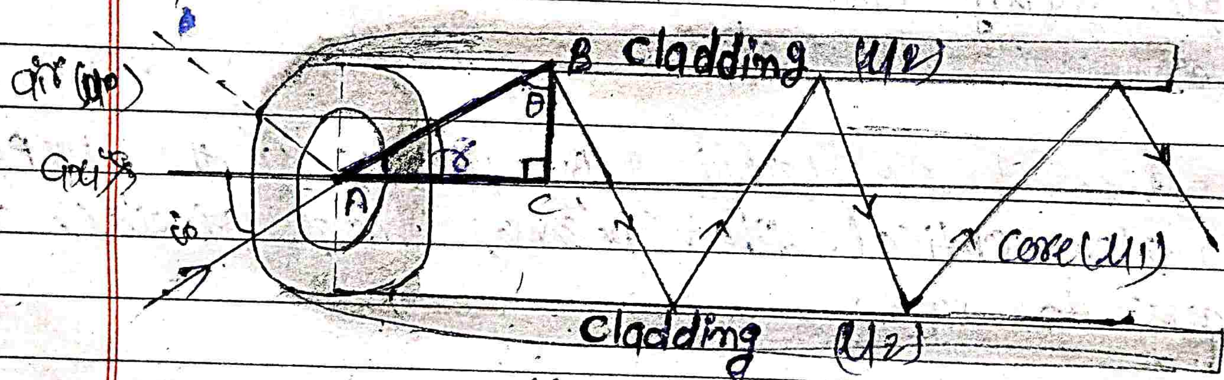
* Merit of numerical aperature :
  (i) Improved resolution
  (ii) increased brightness

* physical significance of numerical aperture :

(i) numerical aperture is a measure of the acceptance angle of the fiber.

(ii) Numerical aperture is used in microscopy.

* Mathematical expression of acceptance angle & numerical aperture :



from snell's law at incident side

$$\frac{\sin i}{\sin r} = \frac{\mu_1}{\mu_0} \Rightarrow \boxed{\sin i = \left(\frac{\mu_1}{\mu_0}\right)\sin r} \quad \text{--- A}$$

from $\triangle$ ACB

$\angle r = (90 - \theta)$

$\sin r = \sin(90 - \theta)$

$\sin r = \cos\theta$ --- (B) put in (A)

$$\boxed{\sin i = \left(\frac{\mu_1}{\mu_0}\right)\cos\theta} \quad \text{--- (C)}$$

for maximum acceptance angle

$\theta = \theta_c$

express numerical aperture in terms of Δ, that is fractional change in a refractive index of fiber.

$$NA \rightarrow \Delta$$

$$\because N \cdot A = \sqrt{\mu_1^2 - \mu_2^2}$$

$$NA = \sqrt{\frac{(\mu_1 + \mu_2)(\mu_1 - \mu_2) 2\mu_1}{2\mu_1}}$$

$$NA = \sqrt{\left(\frac{\mu_1 + \mu_2}{2}\right)\left(\frac{\mu_1 - \mu_2}{\mu_1}\right) 2\mu_1} \qquad \left\{ \because \boxed{\Delta = \frac{\mu_1 - \mu_2}{\mu_1}} \right.$$

$$NA = \sqrt{\mu_1 \Delta 2\mu_1} \qquad \left\{ \frac{\mu_1 + \mu_2}{2} = \text{Average of } \mu_1 \right.$$

$$NA = \sqrt{2\Delta\mu_1^2}$$

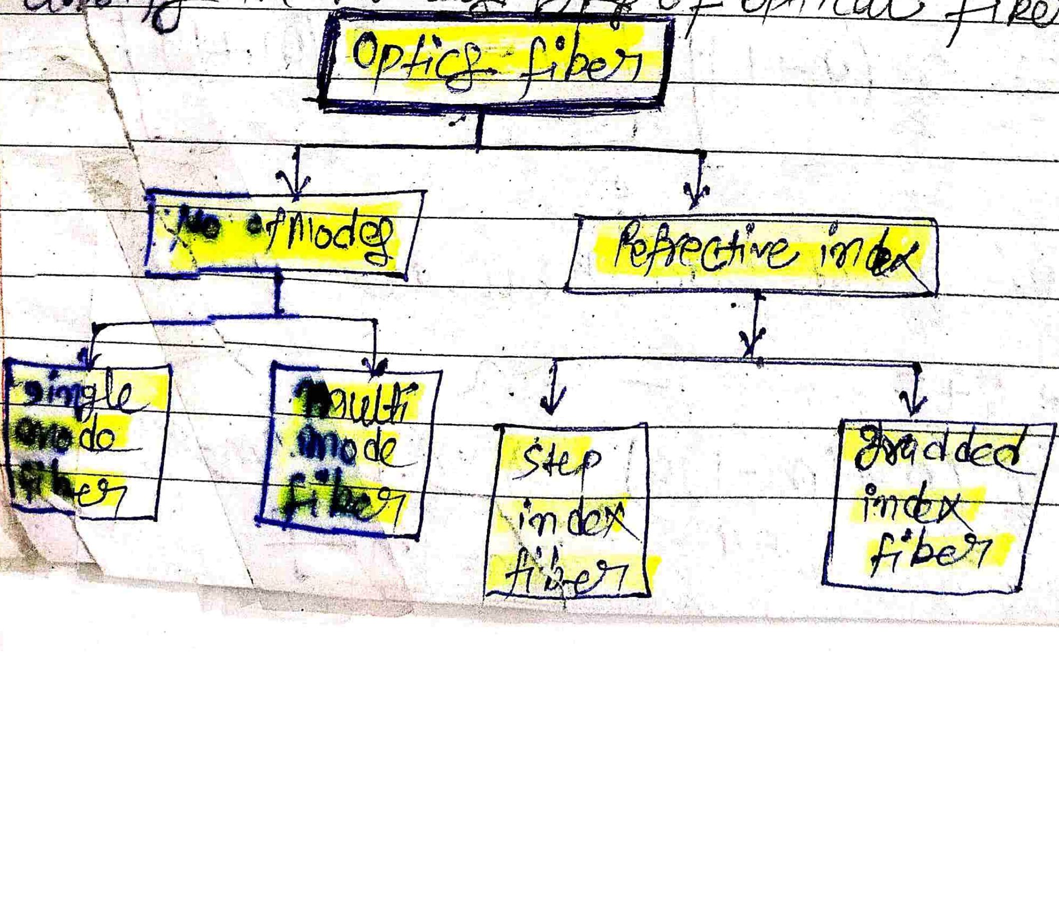
$$\boxed{NA = \mu_1 \sqrt{2\Delta}}$$

(4)

SMF	MMF
(i) It core diameter is very small.	It core diameter is very large.
(ii) It has only one path	It has more than one path.
(iii) It has only one direction	It has more than one direction.
(iv) It carry one wavelength.	It carry more than one do.
(v) It's V number is less than 2.405	It's V no is more than 2.405.

Teacher's Signature

9) classify the various types of optical fiber with diagram.



$\sin i = \left(\frac{\mu_1}{\mu_0}\right)\cos\theta_c \Rightarrow \sin i\left(\frac{\mu_1}{\mu_0}\right) = \sqrt{1-\sin^2\theta_c}$

$\because$ for critical angle $\sin\theta_c = \frac{\mu_2}{\mu_1}$ $\left\{\because \theta_c = \sin^{-1}\left(\frac{\mu_2}{\mu_1}\right)\right\}$

$\sin i = \left(\frac{\mu_1}{\mu_0}\right)\sqrt{1-\left(\frac{\mu_2}{\mu_1}\right)^2}$

$\sin i = \frac{\mu_1}{\mu_0}\sqrt{\frac{\mu_1^2-\mu_2^2}{\mu_1^2}}$

$\sin i = \frac{\mu_1}{\mu_0}\times\frac{1}{\mu_1}\sqrt{\mu_1^2-\mu_2^2} \Rightarrow \sin i = \frac{1}{\mu_0}\sqrt{\mu_1^2-\mu_2^2}$

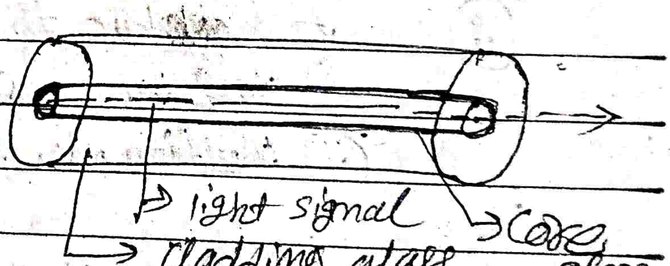
$\boxed{\sin i = \sqrt{\mu_1^2-\mu_2^2}} \rightarrow NA$ $\quad \because \left\{\mu_0 \cong 1 \text{ due to air}\right\}$

$\boxed{i = \sin^{-1}\sqrt{\mu_1^2-\mu_2^2}} \rightarrow i_0$

$\{i = i_0 = i_{max}\}$

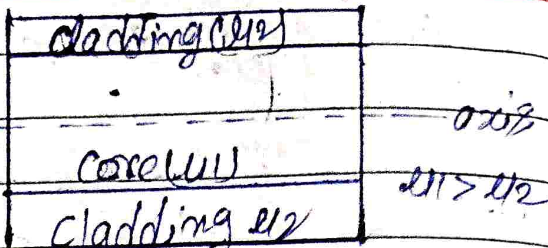
Q10) What do you understand about single mode fiber, and Multimode fiber.

(i) Single mode fiber (SMF):-



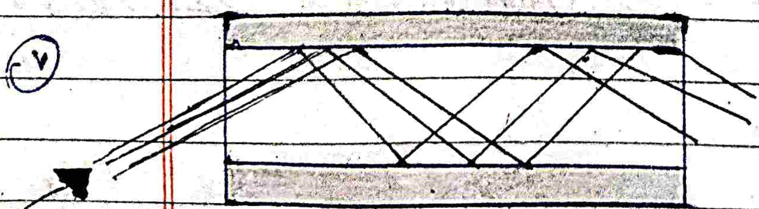
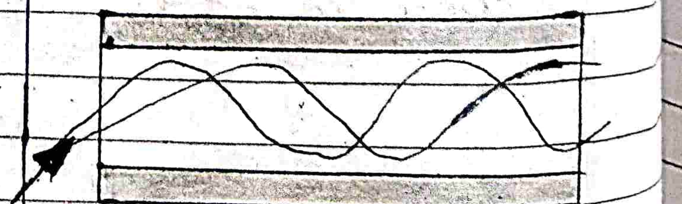
Singlemode fiber has a very small core diameter ϕ and it has only one path and only one direction through light propagates, it can carry only one wavelength of light. They donot show dispersion effect. it's V number is less than 2.405

(ii) Multimode fiber :-



Multimode fiber has very large diameter ϕ and it have many path and directions through many lights propagate, it can carry more than one wavelength of light.

PYQ difference between step index fibre and graded index fibre? use suitable diagrams.

	Step index fiber	Graded index
(i)	It's refractive index of core is greater than cladding by some step so it is called as step index	It's refractive index of core will change gradually as we go away from axis so it is called graded index
(ii)	It have two types (i) single mode fiber (ii) Multimode fiber	It has one type (i) Multimode fiber
(iii)	It's refractive index of core is uniform.	It's refractive index of core is non-uniform.
(iv)	It's path is zig-zag	It's path is Helical
(v)	 Step index	 gradded index fiber

* V - number (Normalis. frequency) or cutoff parameter

$$\boxed{V = \frac{2\pi r}{\lambda}\sqrt{\mu_1^2 - \mu_2^2}} \quad \text{or} \quad \boxed{V = \frac{D\pi}{\lambda}\sqrt{\mu_1^2 - \mu_2^2}}$$

$$\boxed{N \cdot A = \mu_1 \sqrt{2\Delta}} \quad \text{where} \quad \boxed{\Delta = \frac{\mu_1 - \mu_2}{\mu_1}}$$

$$\boxed{V = \frac{2\pi r \mu_1 \sqrt{2\Delta}}{\lambda}}$$

r - radius of core
λ - wavelength of incident light
$\mu_1 \rightarrow$ refractive index of core
$\mu_2 \rightarrow$ ref index of cladding

if $\boxed{V \leq 2.405}$ (only one, single mode)

if $\boxed{V > 2.405}$ (multimodes are possible)

$N \approx \frac{V^2}{2}$ (for ~~S~~tep index multi mode fiber

& $N \approx \frac{V^2}{4}$ (for Gradded index multi mode)

* No of Modes in multi mode fiber:

$\boxed{N \simeq \frac{V^2}{2}}$ { for step index multimode f

$\boxed{N \simeq \frac{V^2}{4}}$ { for gradded index MMf

$\simeq 70.89 \Rightarrow 70$
$\simeq 70.09 \Rightarrow 70$

Note → light gathering ablity = NA

PYQ Enlist various types of losses in optical fiber

(i) scattering of light
(ii) Absorption of light by materials
(iii) waveguide & Micro bend losses.
(iv) Splicing losses

PYQ Enlist various types of losses in optical fiber.

(i) Scattering loss
(ii) Absorption loss
(iii) Bend loss
(iv) ~~Dispersion loss~~ polarization loss

(i) Scattering loss :- This loss occurs when light is scattered by impurities of the fiber, causing a loss of signal strength.

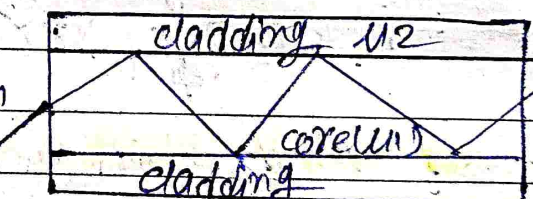
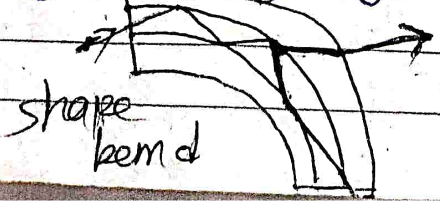


fig → 17.6 (Define)

(ii) Absorption loss :- Calling fig 17.6 ;
Absorption loss occurs when light is absorbed by impurities in the fiber, causing a loss of signal strength, intensity of signal.

(iii) Bend loss :- Calling fig 17.6 ;
:- Bend loss occurs when the fiber is bent too sharply, causing light to leak out of the fiber



(iv) Polarization loss :- polarization loss occurs when the polarization of the light wave changes as it travels through the fiber, causing a loss of signal strength.

Calling fig 17.6 illover here.

(PYQ) Give four advantage of optical fibers over copper wires :-

(i) Greater bandwith
(ii) Immunity to interference
(iii) Security
(iv) Durability

Q Explain pulse dispersion & its three types.

ans ⇒ Pluse dispersion is the spreading of a pulse of light as it travels through an optical fiber. This is caused by the different wavelengths of light traveling at different speeds within the fiber.

Inter Types

(i) Modal dispersion (ii) intera modal dispersion (iii) waveguide dispersion

(1) inter modal dispersion :- It is caused by light rays travelling in different modes of a multimode fiber have different propagation delays

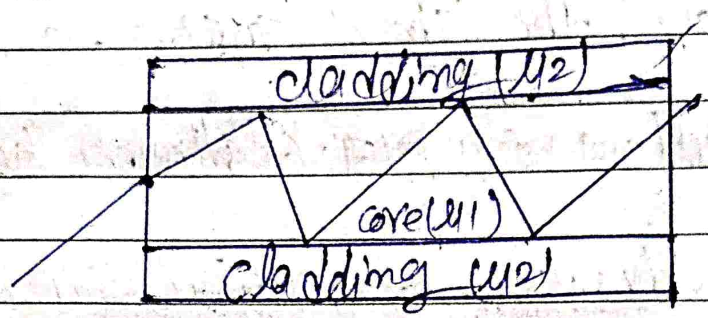
(2) intera modal dispersion :- It caused by the refractive index of the fiber material varies with wavelength

(3) Waveguide dispersion :- It is caused by the waveguid structure of the fiber. It is a small effect in single-mode fibers, but it can be significant in multimode fibers.

Page No.
Date / 20

PYQ Disscuss the propagation machanism of light waves in optical fiber.

Sol^n :



Machanism : The propagation of light waves in optical fiber is based on the principle of total internal reflection.

optical fiber consists of a core, which is made of transparent material such as si[lica] surrounded by a cladding layer which refract[ive] index is less than core refractive index

When a light wave enters the core of the fiber, it is refracted towards normal to the surface, if the angle of incidence light is greater than the critical angle than wave undergoes total internal reflection.

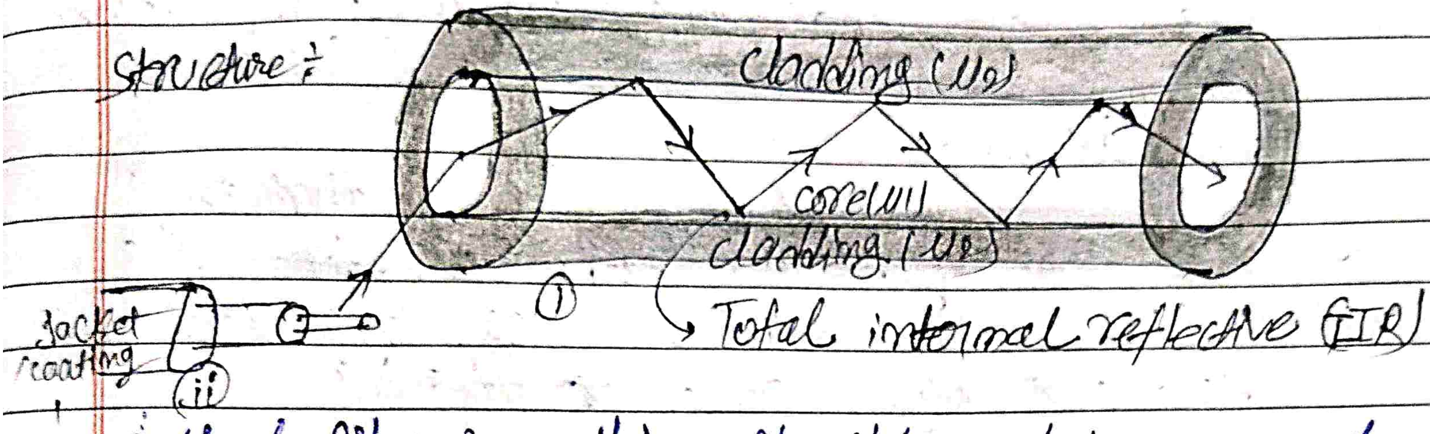
As the light wave propagates down the fiber, it experiances some loss due to absorption and scattering.

Allover, the propagation of light waves in an optical fiber is a complex process that work on total internal reflection, This process allow for efficient and high-speed transmission of light signals over long distance.

Page No.
Date / 20

PYQ write the principle of optical fiber. Explain its working and hence ~~[scribble]~~ structure of optical fiber? Explain structure of an optical fiber.

Structure ÷



Optical fiber is a thin, flexible and transparent ~~[scribble]~~ glass used to transmitting light signals over long distance, it consists of several layers of material, It works on the principle of TIR.

(i) core ÷ This is the central part of the fiber where light travels it made of glass and It has refractive index greater than cladding ($\mu_1 > \mu_2$)

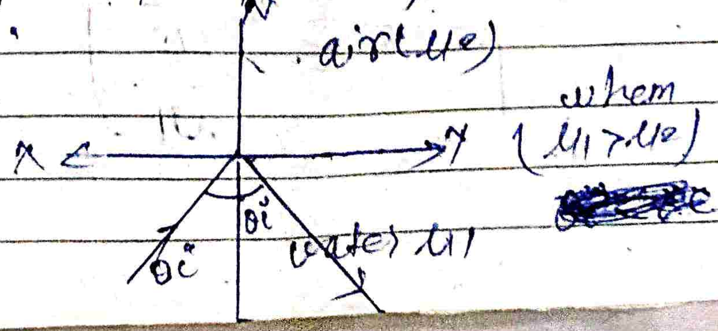
(ii) cladding ÷ This is a layer over the core and it is made of glass and It has refractive index less the core ($\mu_2 < \mu_1$)

or Jacket → protective sheath

(iii) Coating ÷ This layer protects the fiber and provides mechanical strength.

* principle ÷ The principle of optical fiber is Total internal reflection.

* working ÷



Working → When a light wave enters the core of the fiber, it is refracted towards normal in the surface, if the angle of incident is greater than the critical angle then wave ~~wave~~ undergoes total internal reflection.

As the light wave propagates ~~down~~ through the fiber it experiences some loss due to absorption and scattering

all over the propagation of light wave in an optical fiber is a complex process that working on total internal reflection. This process allows for efficient and high-speed transmission of light signals over long distance

Note → cut off wavelength की बात करे तो V का value होगा 2.405 जबकि V given हो given V no of modes निकालने के लिए use करेंगे।

(8). Relative refractive index :-

$$\boxed{\mu_r = \frac{\mu_2}{\mu_1}}$$

Basic concepts of Numeride on fiber

① acceptance angle $\boxed{i_0 = \sin^{-1}\sqrt{\mu_1^2 - \mu_2^2}}$

② Numeride aperature $\boxed{NA = \sqrt{\mu_1^2 - \mu_2^2}}$

③ critide angle $\boxed{\theta_c = \sin^{-1}\left(\frac{\mu_2}{\mu_1}\right)}$

④ V number (Normalise frequency) cutt off paramete

(i) $\boxed{V = \frac{2\pi r}{\lambda}\sqrt{\mu_1^2 - \mu_2^2}}$ for V number find

(ii) $\boxed{V = \frac{D\pi}{\lambda}\sqrt{\mu_1^2 - \mu_2^2}}$ for Diameter find

(iii) $\boxed{V = \frac{2\pi r \mu_1 \sqrt{2\Delta}}{\lambda}}$ where $\boxed{\Delta = \frac{\mu_1 - \mu_2}{\mu_1}}$

if $V \le 2.405$ (only one single mode)
$V > 2.405$ (multimode are posible)

$\mu_1 \Rightarrow$ core
$\mu_2 \Rightarrow$ clad $(\mu_1 > \mu_2)$

⑤

$\boxed{\Delta = \frac{(n_1 - n_2)}{n_1}}$ fractional change in refractive index

⑥ To calculate number of modes $= N = \frac{V^2}{2}$ {for step index MM}

$N = \frac{V^2}{4}$ {for gradded index MMf}

⑦ cladding is doped to give the index difference of

$\boxed{\Delta = \frac{n_1 - n_2}{n_1}}$

PYQ If the wavelength of carrier waves for step index fiber is 800nm and V number is 4.5, then calculate the diameter of the fiber, if the refractive index of core and clad is 1.50 and 1.49 respectively.

Sol^n: given: $\lambda = 800nm$

$\boxed{\lambda = 800 \times 10^{-9} m}$

$\boxed{V = 4.5}$ $\boxed{\mu_1 = 1.50}$

$\boxed{\mu_2 = 1.49}$

$\because V = \frac{D\pi}{\lambda}\sqrt{\mu_1^2 - \mu_2^2}$

$4.5 = \frac{D \times \pi}{8000 \times 10^{-9}}\sqrt{(1.50)^2 - (1.49)^2}$

$4.5 = \frac{D \times 3.14}{8 \times 10^{-7}}\sqrt{2.25 - 2.2201}$

$\frac{8 \times 10^{-7} \times 4.5}{3.14} = D\sqrt{0.0299}$

$\frac{8 \times 10^{-7} \times 4.5}{3.14} = D \times 0.1729$

$D = \frac{8 \times 10^{-7} \times 4.5}{3.14 \times 0.1729}$

$D = \frac{8 \times 4.5 \times 10^{-7}}{0.5429} \Rightarrow D = 36 \times 10^{-7}$

$\boxed{D = 66.31 \times 10^{-7} m}$

(PYQ) A step index fiber has normalized frequency $V = 26.6$ at 1300nm wavelength. If the core radius is $25 \mu m$, Calculate the numerical aperture and hence find the value of acceptance angle.

ans ⇒ given $V = 26.6$

$\lambda = 1300nm$

$\boxed{\lambda = 1300 \times 10^{-9} m}$

$r = 25 \mu m$

$\boxed{r = 25 \times 10^{-6} m}$

$NA = \sqrt{\mu_1^2 - \mu_2^2}$

$i_c = \sin^{-1}(\sqrt{\mu_1^2 - \mu_2^2})$

∵ we know that $V = \frac{2\pi r}{\lambda} \sqrt{\mu_1^2 - \mu_2^2}$

$$26.6 = \frac{2 \times \pi \times 25 \times 10^{-6}}{1300 \times 10^{-9}} \sqrt{\mu_1^2 - \mu_2^2}$$

$$\frac{1300 \times 26.6 \times 10^{-9}}{2 \times \pi \times 25 \times 10^{-6}} = \sqrt{\mu_1^2 - \mu_2^2}$$

$$\sqrt{\mu_1^2 - \mu_2^2} = \frac{3458 \times 10^{-9}}{157.07 \times 10^{-6}} \Rightarrow \frac{345.8 \times 10^{-7} \times 10^{6}}{157.07}$$

$NA = 2.20 \times 10^{-1}$ $\boxed{NA = 0.22}$

$i_c = \sin^{-1}(\sqrt{\mu_1^2 - \mu_2^2})$

$i_c = \sin^{-1}(0.22)$

$i_c = \sin^{-1}(0.22)$

$\boxed{i_c = 12.70^\circ}$

PYQ An optical fiber has numerical aperture of 0.2 and clading refractive index of 1.59 determine (i) acceptance angle for the fiber in liquid with refractive index 1.42 and (ii) critical angle between core - clad interface.

ans ⇒ $NA = 0.2$, $\mu_2 = 1.59$

~~acceptance angle $i_0 = \sin^{-1}(\sqrt{\mu_1^2 - \mu_2^2})$~~

$\sin i_0 = \sqrt{\mu_1^2 - \mu_2^2}$

$\sin i_0 = NA = \sqrt{\mu_1^2 - \mu_2^2}$

$0.2 = \sqrt{\mu_1^2 - \mu_2^2}$

$(0.2)^2 = \mu_1^2 - \mu_2^2$

$\mu_1^2 = (0.2)^2 + \mu_2^2$

$\mu_1^2 = 0.04 + (1.59)^2$

$\mu_1 = \sqrt{0.04 + 2.5281}$

$\mu_1 = \sqrt{2.5681}$ $\quad \mu_1 = \sqrt{2.5681}$

$\boxed{\mu_1 = 1.60}$

(i) acceptance angle

$i_0 = \sin^{-1} \dfrac{\sqrt{\mu_1^2 - \mu_2^2}}{\mu_0}$

$i_0 = \sin^{-1}\left(\dfrac{\sqrt{(1.60)^2 - (1.59)^2}}{1.42}\right)$

$i_0 = \sin^{-1}\left(\dfrac{\sqrt{2.56 - 2.5281}}{(1.42)}\right)$

$i_0 = \sin^{-1}\left(\dfrac{\sqrt{0.0319}}{1.42}\right)$ $\quad i_0 = \sin^{-1}\left(\dfrac{0.1786}{1.42}\right)$

$i_0 = \sin^{-1}(0.1257)$

$\boxed{i_0 = 7.22^\circ}$

(iii) critical angle $\theta_c = \sin^{-1}\left(\frac{\mu_2}{\mu_1}\right)$

$\theta_c = \sin^{-1}\left(\frac{1.59}{1.60}\right)$ $\theta_c = \sin^{-1}(0.99)$

$\boxed{\theta_c = 81.89^\circ}$

(Q9) Calculate the refractive index of the core and clading material of a fiber from the following data: NA = 0.22, relative refractive index is 0.012 where NA is numerical aperature.

Soln:- given: NA = 0.22, $\Delta = 0.012$

[illegible] $\Rightarrow 0.012 =$ [illegible]

[illegible]

$\because NA = \sqrt{\mu_1^2 - \mu_2^2} \Rightarrow 0.22 = \sqrt{\mu_1^2 - \mu_2^2}$

$(0.22)^2 = \mu_1^2 - \mu_2^2$

$(0.22)^2 = (1.012\mu_2)^2 - \mu_2^2$

$0.0484 = 1.024144\mu_2^2 - \mu_2^2$

$0.0484 = \mu_2^2(1.024 - 1)$

$\mu_2^2 = \frac{0.0484}{0.024}$ $\mu_2^2 = 2.016$

$\boxed{\mu_2 = 1.41}$

$\mu_1 = 1.012 \times 1.41$

$\boxed{\mu_1 = 1.43}$

Q) An optical fiber has a N.A. of 0.20 and a cladding refractive index of 1.59 determine the acceptance angle for the fiber in water which has a refractive index of 1.33.

ans → given → $\mu_2 = 1.59$
$\mu_0 = 1.33$
$NA = 0.20$

$i_0 = \sin^{-1}\sqrt{\mu_1^2 - \mu_2^2}$

$\sin i_0 = \sqrt{\mu_1^2 - \mu_2^2} = NA$

$NA = \sqrt{\mu_1^2 - \mu_2^2}$

$(0.20)^2 = \mu_1^2 - (1.59)^2$

$\mu_1^2 = (0.20)^2 + (1.59)^2$

$\mu_1^2 = 0.04 + 2.5281$

$\mu_1^2 = 2.5681$

$\mu_1 = \sqrt{2.5681}$

$\boxed{\mu_1 = 1.60}$

$i_0 = \sin^{-1}\left(\frac{\sqrt{\mu_1^2 - \mu_2^2}}{\mu_0}\right)$

$i_0 = \sin^{-1}\left(\frac{\sqrt{(1.60)^2 - (1.59)^2}}{1.33}\right)$

$i_0 = \sin^{-1}\left(\frac{\sqrt{2.56 - 2.5281}}{1.33}\right)$

$i_0 = \sin^{-1}\left(\frac{\sqrt{0.0319}}{1.33}\right) \Rightarrow \cancel{i_0 = \sin^{-1}(0.0239)}$

$i_0 = \sin^{-1}\left(\frac{0.17860}{1.33}\right)$ $i_0 = \sin^{-1}(0.1342)$

$\boxed{i_0 = 7.71^\circ}$

(PYQ) A step index fiber having length 2km is found to have $n_1 = 1.55$ and, $n_2 = 1.50$ find acceptance angle and numerical aperture of the fiber. If the radius of the core is 15 μm and the wavelength of the carrier is 850 nm, then check whether the fiber is SMF or MMF.

Ans ⇒ given
$l = 2km$
$\mu_1 = 1.55$
$\mu_2 = 1.50$
$\lambda = 850nm$ $\boxed{\lambda = 850 \times 10^{-9} m}$
$r = 15 \mu m$ $\boxed{r = 15 \times 10^{-6} m}$

find $i_0 = ?$ $NA = ?$ check SMF ? MMF ?

we know that $NA = \sqrt{\mu_1^2 - \mu_2^2}$

$NA = \sqrt{(1.55)^2 - (1.50)^2}$

$NA = \sqrt{2.4025 - 2.25} \Rightarrow NA = \sqrt{0.1525}$

$\boxed{NA = 0.39}$

$i_0 = \sin^{-1}\sqrt{\mu_1^2 - \mu_2^2}$

$i_0 = \sin^{-1}(0.39)$ $i_0 = 22.98°$

$\boxed{i_0 = 23°}$

$V = \frac{2\pi r}{\lambda}\sqrt{\mu_1^2 - \mu_2^2} \Rightarrow V = \frac{2 \times \pi \times 15 \times 10^{-6}}{85 \times 10^{-8}} \times 0.39$

$V = \frac{36.75 \times 10^{-6} \times 10^{8}}{85}$ $V = 0.4324 \times 10^{2}$

$\boxed{V = 43.24}$ ∵ $V > 2.405$

so it is MMF.

(pyq) A manufacturer wishes to make a silica core step index fiber with V = 75 and numerical aperature NA = 0.30 to be used at 820nm. If $n_1 = 1.458$, what should the core size and cladding index be? Also find the value of critical angle and acceptance angle of the given fiber.

ans ⇒ given :- $V = 75$ $\boxed{\lambda = 820\,nm}$

$NA = 0.30$

$\mu_1 = 1.458$

$\mu_2 = ?$ $\theta_c = ?$, $i_0 = ?$

∴ $NA = 0.30$ $NA = \sqrt{\mu_1^2 - \mu_2^2}$

$(0.30)^2 = \mu_1^2 - \mu_2^2$

$(\mu_2)^2 = (\mu_1^2) - (0.30)^2$

$(\mu_2)^2 = (1.458)^2 - (0.30)^2$

$(\mu_2) = \sqrt{(1.458)^2 - (0.30)^2}$

$\mu_2 = \sqrt{2.125764 - 0.09}$

$\mu_2 = \sqrt{2.035764}$

$\boxed{\mu_2 = 1.426}$

$\theta_c = \sin^{-1}\left(\frac{\mu_2}{\mu_1}\right)$ $\theta_c = \sin^{-1}\left(\frac{1.426}{1.458}\right)$

$\theta_c = \sin^{-1}(0.978052)$

$\theta_c = 77.97° \approx$ $\boxed{\theta_c = 78°}$

$i_0 = \sin^{-1}\sqrt{\mu_1^2 - \mu_2^2}$ $i_0 = \sin^{-1}\left(\sqrt{2.125764 - 2.033476}\right)$

$i_0 = \sin^{-1}\left(\sqrt{0.092288}\right)$ $i_0 = \sin^{-1}(0.303789)$

$\boxed{i_0 = 17.68°}$

Q10) find acceptance angle, numerical aperature, critical angle and v-number of the optical fiber from the data given below:
Refractive index of core = 1.48, fractional change in refractive index = 0.005, core radius 'a' = 50 μm, wavelength of radiation λ = 850 nm. Check whether the fiber is single mode ~~or~~ multimode.

$i_0 = ?$, $NA = ?$, $\theta_c = ?$ $V = ?$

ans ⇒ Check (SMF) or (MMF)

given data

$\therefore$ $\boxed{\mu_1 = 1.48}$, $\boxed{\Delta = 0.005}$

$r = 50 \mu m$ $\boxed{r = 50 \times 10^{-6} m}$

$\lambda = 850 nm$ $\boxed{\lambda = 850 \times 10^{-9} m}$

$\because$ $\Delta = \frac{\mu_1 - \mu_2}{\mu_1} \Rightarrow 0.005 = \frac{1.48 - \mu_2}{1.48}$

$0.0074 = 1.48 - \mu_2$

$\mu_2 = 1.48 - 0.0074$

$\boxed{\mu_2 = 1.47}$

$i_0 = \sin^{-1}(\sqrt{\mu_1^2 - \mu_2^2})$ $i_0 = \sin^{-1}(\sqrt{2.1904 - 2.1609})$

$i_0 = \sin^{-1}(\sqrt{0.0295}) \Rightarrow i_0 = \sin^{-1}(0.1717)$

$\boxed{i_0 = 9.88^\circ} \simeq \boxed{i_0 = 9^\circ}$

$\boxed{NA = 0.1717}$ $\theta_c = \sin^{-1}\left(\frac{\mu_2}{\mu_1}\right)$ $\theta_c = \sin^{-1}\left(\frac{1.47}{1.48}\right)$

$\theta_c = \sin^{-1}(0.993243)$

$\boxed{\theta_c = 83.33^\circ}$ $V = \frac{2\pi r}{\lambda} \sqrt{\mu_1^2 - \mu_2^2}$

$V = \frac{2 \times \pi \times 50 \times 10^{-6}}{850 \times 10^{-9}} \times 0.1717 = \frac{53.94 \times 10^{-6} \times 10^{9} \times 10^{-1}}{85}$

Page No.
Date / 20

10

$\Rightarrow 0.6345 \times 10^2$

$V = 63.45$

$\therefore V > 2.405$ so it is (MMF)

(P10) A glass clad fiber is made with core glass of refractive index 1.5 and cladding is doped to give the index difference of 0.05. Determine the refractive index of the cladding, numerical aperture of the fiber, critical angle of reflection and critical acceptance angle

Sol^n: given: $\boxed{\mu_1 = 1.5}$ $\Delta = 0.05$

$\mu_2 = ?$ $NA = ?$, $\theta_c = ?$, $i_0 = ?$

$\Delta = \frac{\mu_1 - \mu_2}{\mu_1} \Rightarrow 0.05 = \frac{1.5 - \mu_2}{1.5}$

$\Rightarrow 0.075 = 1.5 - \mu_2$

$\mu_2 = 1.5 - 0.075$

$\boxed{\mu_2 = 1.4}$ $NA = \sqrt{(\mu_1)^2 - (\mu_2)^2}$

$NA = \sqrt{(1.5)^2 - (1.4)^2}$ $NA = \sqrt{2.25 - 1.96}$

$NA = \sqrt{0.29}$ $\boxed{NA = 0.53}$

$\theta_c = \sin^{-1}\left(\frac{\mu_2}{\mu_1}\right) \Rightarrow \theta_c = \sin^{-1}\left(\frac{1.4}{1.5}\right)$

$\theta_c = \sin^{-1}(0.933333)$ $\boxed{\theta_c = 68.96}$

$i_0 = \sin^{-1}\sqrt{(\mu_1)^2 - (\mu_2)^2}$ $i_0 = \sin^{-1}(0.53)$

$\boxed{i_0 = 32^\circ}$

(10) An optical fiber of graded index type is made up of a core, where light travels, made of glass of refractive index $n_1 = 1.5$ surrounded by another layer of glass of lower refractive index n_2.

find

(i) n_2 of the cladding so that the critical angle at the core cladding interface is 80°.

(ii) Numerical Aperture of the fiber.

(iii) V-parameter for core radius 50 μm and operating wavelength of 0.850 μm.

(iv) Number of modes guided in the core.

Ans) given $\boxed{\mu_1 = 1.5}$ $\boxed{\theta_c = 80°}$ $r = 50 \mu m$

$\boxed{r = 5 \times 10^{-5} m}$ $\lambda = 0.850 \mu m$

$\boxed{\lambda = 0.850 \times 10^{-6} m}$

(i) $\mu_2 = ?$ $\theta_c = 80°$ $\because$ $\theta_c = \sin^{-1}\left(\frac{\mu_2}{\mu_1}\right)$

$80° = \sin^{-1}\left(\frac{\mu_2}{\mu_1}\right)$.

$\sin 80° = \frac{\mu_2}{1.5}$ $\mu_2 = 0.98 \times 1.5$

$\boxed{\mu_2 = 1.47}$

(ii) $NA = \sqrt{(\mu_1)^2 - (\mu_2)^2}$ $NA = \sqrt{(1.5)^2 - (1.47)^2}$

$NA = \sqrt{2.25 - 2.1609}$ $NA = \sqrt{0.0891}$

$\boxed{NA = 0.29}$

Date / 20

(iii) $V = \frac{2\pi r}{\lambda}\sqrt{(\mu_1)^2-(\mu_2)^2}$

$V = \frac{2\times\pi\times5\times10^{-5}}{0.850\times10^{-6}}\times 0.29$

$V = \frac{9.11\times10^{-5}\times10^{6}}{0.850}$

$V = 10.717\times10^{1}$ $\Rightarrow \boxed{V = 107.17}$ (MMf)

(iv) Number of modes → ∵ gradded index

$N = \frac{V^2}{4}$ $N = \frac{(107.17)^2}{4}$

$N = \frac{11485.40}{4}$ $\boxed{N = 2871.35}$

no of modes.

(Ex) A step index fiber with large core diameter compared with the wavelength of the transmitted index light has an acceptance angle in air of 30° and fractional refractive index difference of 0.03. Determine (i) numerical aperature of the fiber (ii) the critical angle at the core cladding interface (iii) necessary core radius for fiber to be multimode if the wavelength of transmitted light is 950 nm.

Sol^n:- given:- $i_0 = 30°$ $\Delta = 0.03$

we know that

$i_0 = \sin^{-1}\left(\sqrt{(\mu_1)^2 - (\mu_2)^2}\right) \Rightarrow 30^\circ = \sin^{-1} NA$

$\sin 30^\circ = \sqrt{(\mu_1)^2 - (\mu_2)^2}$

$\left(\frac{1}{2}\right)^2 = \mu_1^2 - \mu_2^2 \Rightarrow 0.25 = \mu_1^2 - \mu_2^2$

$\boxed{\mu_2^2 = \mu_1^2 - 0.25}$ — (1)

$\Delta = \frac{\mu_1 - \mu_2}{\mu_1} \Rightarrow 0.03 = \frac{\mu_1 - \mu_2}{\mu_1}$

$0.03\mu_1 = \mu_1 - \mu_2 \Rightarrow -\mu_2 = 0.03\mu_1 - \mu_1$

$+\mu_2 = +0.97\mu_1$ $\boxed{\mu_2 = 0.97\mu_1}$ (2)

put in (1)

$(0.97\mu_1)^2 = \mu_1^2 - 0.25$

$0.9409\mu_1^2 = \mu_1^2 - 0.25$

$0.9409\mu_1^2 - \mu_1^2 = -0.25$

$\mu_1^2(-0.0591) = -0.25$

$\mu_1^2 = \frac{0.25}{0.0591} \Rightarrow \mu_1^2 = 4.23$

$\mu_1 = \sqrt{4.23}$

$\boxed{\mu_1 = 2.05}$

$\mu_2 = 0.97 \times 2.05$

$\boxed{\mu_2 = 1.99}$

(i) $NA = \sqrt{(\mu_1)^2 - (\mu_2)^2}$

$NA = \sqrt{4.2025 - 3.9601}$

$NA = \sqrt{0.2424}$

$\boxed{NA = 0.49}$

(ii) $\theta_c = ?$ $\quad \theta = \sin^{-1}\left(\frac{\mu_2}{\mu_1}\right)$

$\theta_c = \sin^{-1}\left(\frac{1.99}{2.05}\right) \quad \theta_c = \sin^{-1}(0.970731)$

$\boxed{\theta_c = 76.10^\circ}$

(iii) $V = \frac{2\pi r}{d} NA$

$2.405 \geq \frac{2\pi r}{d} \times 0.49$

$2.405 \geq \frac{2\pi \times r \times 0.49}{350 \times 10^{-9}}$

$2\pi \times r \times 0.49 \leq 2.405 \times 350 \times 10^{-9}$

$r \leq \frac{2.405 \times 350 \times 10^{-9}}{2\pi \times 0.49}$

$\boxed{r \leq \_\_\_\_}$

PYQ $\mu_1 = 1.55$, $\mu_2 = 1.51$, $d = 50 \mu m$
$\lambda = 0.8 \mu m$
(a) NA (b) i_0 (c) V-number

Soln → $NA = \sqrt{(\mu_1)^2 - \mu_2^2}$ $NA = \sqrt{2.25 - 2.2801}$
$NA = \sqrt{0.0301}$
$\boxed{NA = 0.173}$

$i = \sin^{-1}(\sqrt{\mu_1^2 - \mu_2^2}) \Rightarrow i_0 = \sin^{-1}(0.17349)$
$i_0 = 9.99'' \cong \boxed{i_0 = 10°}$

$V = \frac{2\pi r}{\lambda} \sqrt{\mu_1^2 - \mu_2^2}$
$d = 50 \times 10^{-6} m$
[redacted] $r = \frac{50 \times 10^{-6} m}{2}$
$\boxed{r = 25 \times 10^{-6} m}$
$\boxed{\lambda = 0.8 \times 10^{-6} m}$

$V = \frac{2 \times \pi \times 25 \times \cancel{10^{-6}} \times 0.173}{0.8 \times \cancel{10^{-6}}}$

$\boxed{V = 33.96}$

PYQ An optical fiber has NA of 0.15 and cladding refractive index is equal to 1.50. find NA of the fiber in a liquid of refractive index 1.30.

ans → $NA = 0.15$, $\mu_2 = 1.50$
$\mu_0 = 1.30$ $NA = ?$

16

Page No.
Date / 20

$$NA = \sqrt{\mu_1^2 - \mu_2^2}$$

$$NA = \frac{\sqrt{\mu_1^2 - \mu_2^2}}{\mu_0}$$

$$(0.15)^2 = \mu_1^2 - \mu_2^2$$

$$NA =$$

$$\mu_1^2 = (0.15)^2 + (\mu_2)^2$$

$$\mu_1^2 = (0.15)^2 + (1.50)^2$$

$$\mu_1^2 = 0.0225 + 2.25$$

$$\mu_1^2 = 2.2725$$

$$\mu_1 = \sqrt{2.2725}$$

$$\boxed{\mu_1 = 1.507}$$

$$NA = \frac{\sqrt{(1.50748)^2 - (1.50)^2}}{1.30}$$

$$NA = \frac{\sqrt{2.27249 - 2.25}}{1.30}$$

$$NA = \frac{\sqrt{0.02249595}}{1.30}$$

$$NA = \frac{0.149986}{1.30}$$

$$\boxed{NA = 0.1153}$$

(PYQ) Calculate the refractive indices of the core and cladding material of a fiber if numerical aperture is 0.22 and fractional refractive index changes is 0.012.

Ans →

$$NA = 0.22$$

$$\Delta = 0.012$$

$NA = \sqrt{\mu_1^2 - \mu_2^2}$, $(0.22)^2 = \mu_1^2 - \mu_2^2$

$\Delta = \frac{\mu_1 - \mu_2}{\mu_1}$

$$\boxed{\mu_1^2 = 0.0484 + \mu_2^2} \text{ — (A)}$$

$0.012 = \frac{\mu_1 - \mu_2}{\mu_1}$

$0.012\mu_1 = \mu_1 - \mu_2$

$0.012\mu_1 - \mu_1 = -\mu_2$

$\mu_1(-0.988) = -\mu_2$

$$\boxed{\mu_1(0.988) = \mu_2} \text{ — (B)}$$

$$\boxed{\mu_2 = \mu_1(0.988)} \text{ — (B) put in A}$$

$\mu_1^2 = 0.0484 + (\mu_1(0.988))^2$

$\mu_1^2 = 0.0484 + \mu_1^2(0.976144)$

$\mu_1^2 - \mu_1^2(0.976144) = 0.0484$

$\mu_1^2(0.023856) = 0.0484$

$\mu_1^2 = \frac{0.0484}{0.023856}$ $\mu_1^2 = 2.0288$

$\mu_1 = \sqrt{2.0288}$

$$\boxed{\mu_1 = 1.42} \text{ put in (B)}$$

$\mu_2 = 1.42 \times (0.988)$

$$\boxed{\mu_2 = 1.40}$$

(Px9) · A step index fiber has numerical aperature of 0.26 a core refractive index 1.5 and diameter 100 µm. Calculate refractive index of planting angle of acceptance and critical angle at core clad interface, fractional change in a refractive index and cut off wavelength that can be passed through optical fibre with minimum loss.

ans → $NA = 0.26$, $\mu_1 = 1.5$ $d = 100 \mu m$

$\mu_2 = ?$, $i_0 = ?$ $\theta_c = ?$, $\Delta = ?$

$d = ?$ $loss = ?$

$0.26 = \sqrt{\mu_1^2 - \mu_2^2}$

$(0.26)^2 = (1.5)^2 - \mu_2^2$

$\mu_2^2 = (1.5)^2 - (0.26)^2$

$\mu_2^2 = 2.25 - 0.0676$

$\mu_2^2 = 2.1824$

$\mu_2 = \sqrt{2.1824}$

$\boxed{\mu_2 = 1.47}$

$i_0 = \sin^{-1} NA$

$i_0 = \sin^{-1}\sqrt{(1.5)^2 - (1.47)^2}$

$i_0 = \sin^{-1}(\sqrt{2.25 - 2.1609})$

$i_0 = \sin^{-1}(\sqrt{0.0891})$

$i_0 = \sin^{-1}(0.298496)$

$\boxed{i_0 = 17.36°}$

$\theta_c = \sin^{-1}\left(\frac{\mu_2}{\mu_1}\right)$

$\theta_c = \sin^{-1}\left(\frac{1.47}{1.5}\right)$ $\theta_c = \sin^{-1}(0.98)$

$\boxed{\theta_c = 78.52°}$

$\Delta = \frac{\mu_1 - \mu_2}{\mu_1}$

$\Delta = \frac{1.5 - 1.47}{1.5}$

$\Delta = \frac{0.03}{1.5}$

$\boxed{\Delta = 0.02}$

Minimum loss ⇒ Single mode

⇒ $V \leq 2.405$

Page No.
Date / 20

$$\frac{2\pi r \mu_1 \sqrt{2\Delta}}{\lambda} \leq 2.405$$

or $\frac{2\pi r}{\lambda}(N.A) \leq 2.405$

given
$r = 50\mu m$
$= 50 \times 10^{-6} m$

$$\frac{2 \times 3.14 \times 50 \times 10^{-6} \times 0.26}{2.405} \leq \lambda$$

$\lambda \geq$

Total internal reflection

→ when an incident light travells from denser to rare medium and if incident angle is greatter than critical angle than light reflect back in denser medium this pheonomena is knows as Total internal reflection.

Expt. No. .... Page No. .... Date ....

(Q28) The light gathering ablity of an optical fiber is 0.479. The fractional refractive index b/w core & cladding is 0.0005. Calculate the refractive index of the cladding.

Sol^n → Note light gathering ablity = NA

∴ $NA = \mu_1 \sqrt{2\Delta}$

$0.479 = \mu_1 \sqrt{2 \times 0.0005}$

$\mu_1 = \dfrac{0.479}{0.031622}$

$\boxed{\mu_1 = 15.15}$ $NA = \sqrt{\mu_1^2 - \mu_2^2}$

$NA^2 = \mu_1^2 - \mu_2^2$

$(0.479)^2 = (15.15)^2 - \mu_2^2$

$0.229441 = 229.5225 - \mu_2^2$

$\mu_2^2 = 229.29$ $\mu_2 = \sqrt{229.29}$

$\boxed{\mu_2 = 15.14}$

Page No.
Date / 20

(i) Doping :- Adding impurities to the semiconductor material to increase its conductivity.

(ii) Temperature increasing :- Increasing the temperature of a semiconductor can increase its conductivity by increasing the number of free electrons and holes.

Semiconductor

What are

PYQ Intrinsic semiconductor? Name the ways by which we can enhance the conductivity of intrinsic semiconductor. Discuss in detail the extrinsic semiconductors.

Intrinsic semiconductor:- An intrinsic semiconductor is a pure semiconductor material that has no any impurities or doping two important example (i) pure Silicon & pure Germanium, Intrinsic semiconductor has equal numbers of electrons and holes thus has no net electrical charge. The electrical conductivity of intrinsic semiconductor is generally low at room temperature.

P 2.3

→ At higher temperature we can enhance the conductivity of intrinsic semiconductor.

Extrinsic:- If in intrinsic semiconductor we add calculated amount of impurity in pure semiconductor two important example:- (i) boron and phosphorus is called extrinsic semiconductor and the process of adding impurity in pure semiconductor is called doping. Extrinsic semiconductor are two types (i) n-type and (ii) p type semiconductor.

PYQ What are Semiconductors? write two way to increase the conductivity of intrinsic semiconductors.

ans → Semiconductor are materials ~~that~~ that have electrical conductivity between a conductor and an insulator
Ex → silicon, germanium.

Page No.

Date / 20

PYQ What is difference between intrinsic and extrinsic semiconductors? Explain two types of extrinsic semiconductors.

	Intrinsic	Extrinsic
(i)	It is a pure semiconductor material.	It is impure semiconductor material.
(ii)	It has no any impurity and dopping.	It has impurity and dopping
(iii)	It has equal numbers of electron and holes.	It has not equal numbers of electrons and holes.
(iv)	It has low electrical conductivity at room temperature.	It has higher electrical conductivity at room temperature.
(v)	It's example is pure silicon, pure Germanium.	It's example is boron, phosphrous.
(vi)	It has no any type of semiconductor	It have two types of semiconductor n-type P-type semiconductor.

Extrinsic semiconductor — (i) n-type semiconductor
— (ii) p-type semiconductor

* N-type semiconductor :- N-type semiconductor is a type of semiconductor doped with a pentavalent impurity, the pentavalent impurity are added in the N-type semiconductor so it increases the numbers of electrons for conduction.
Ex ⇒ phosphorous, arsenic, antimony.

* P-type semiconductor :- p-type semiconductor is a type of semiconductor doped with a trivalent impurity in a small amount and result as a large number of holes are created in it. example → aluminium, boron, galium.

PYQ Differentiate n type and p type semiconductor?

	n-type	p-type
(i)	It is doped with a pentavalent impurity	It is doped with a trivalent impurity.
(ii)	in n-type electrons act as a majority charge carries	in p-type holes act as a majority charge carrier
(iii)	In n-type semiconductor conductivity is mainly due to electrons.	In P-type semiconductor conductivity is mainly due to holes.
(iv)	It is donor type	It is acceptor type
(v)	Impurity atoms is pentavalent.	Impurity atoms is trivalent
(vi)	Ex ⇒ phosphrous, arsenic	Ex ⇒ aluminium boron, galium.

PYQ Define fermi level and give its physical significance and How it varies with temperature in intrinsic semiconductors, Explain with diagram.

ans ⇒ Highest energy level occupied by electron in band at 0K is called fermi level.

→ significance of fermi level
(i) Determines the electrical conductivity of a material.
(ii) Affects the numbers of electrons available for conduction
(iii) Determines whether a material is a conductor, semiconductor, insulator.

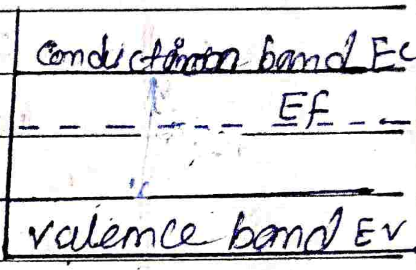
→ varies in fermi level with tem in intrinsic semiconductor
calling — 5.7

PYQ Discuss the effect of temperature on conductors and semiconductors in terms of conductivity.

ans ⇒ conductivity of semiconductors increases with increasing in temperature. Reason → with increase in temperature the number of electrons from the valence band can jump to the conduction band in semiconductor.

→ Conductivity of conductors decreases with increasing in temperature.

PYQ) Derive an expression for fermi energy in intrinsic semiconductor. what is the affect of temperature on fermi level in an intrinsic semiconductor.



Ans ⇒ no of $\bar{e}$ in conduction band

$$n = N_c e^{-(E_C-E_f)/KT}$$

no of $\bar{e}$ in valence band

$$p = N_V e^{-(E_f-E_V)/KT}$$

for intrinsic semiconductor $n = p$

$$N_C e^{-(E_C-E_f)/KT} = N_V e^{-(E_f-E_V)/KT}$$

$$\frac{N_C}{N_V} = \frac{e^{-(E_f-E_V)/KT}}{e^{-(E_C-E_f)/KT}} \Rightarrow \frac{N_C}{N_V} = e^{(-E_f+E_V+E_C-E_f)/KT}$$

$$\boxed{\frac{N_C}{N_V} = e^{(-2E_f+E_V+E_C)/KT}}$$

Taking log both sides

$$\log\left(\frac{N_C}{N_V}\right) = \log\left(e^{(-2E_f+E_V+E_C)/KT}\right)$$

$$\log\frac{N_C}{N_V} = \frac{-2E_f+E_V+E_C}{KT}$$

$$-2E_f = -(E_V+E_C) + KT\log\frac{N_C}{N_V}$$

$$2E_f = E_V+E_C - KT\log\frac{N_C}{N_V}$$

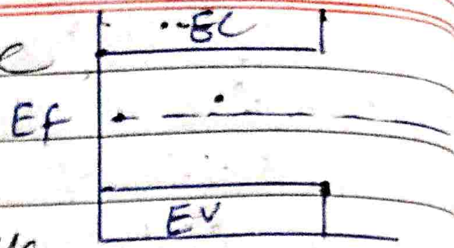
$$\boxed{E_F = \frac{E_C+E_V}{2} - \frac{KT}{2}\log\frac{N_C}{N_V}}$$

$$\boxed{E_f = \frac{E_C+E_V}{2} + \frac{KT}{2}\log\frac{N_V}{N_C}}$$

Define → 5·7

Page No.
Date / 20

→ Effect of temperature



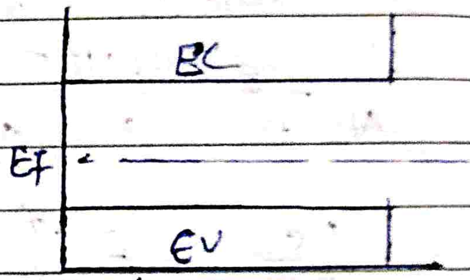
Case-1 → at $T = 0K$

$$E_f = \frac{EC+EV}{2} - \frac{KT}{2}\log\frac{NC}{NV}$$

$E_f = \frac{EC+EV}{2}$ It means fermi Energy level middle of energy Gap.

Case-2 → at $T = 300K$

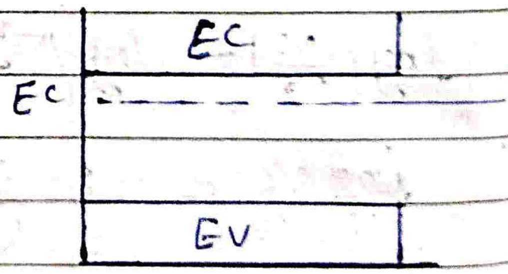
Fermi energy level below middle of energy Gap



diagram

Case-3 → at $T = -300K$

fermi energy level above middle of energy Gap



Q. How the resistivity of semiconductor & conductor vary with temperature.

ans →

Semi →	T↑	C↑	R↓
Condu →	T↑	C↓	R↑

(PYQ) Show the fermi level in case of intrinsic semiconductor lies in the middle of conduction and valence band. Also explain it's variation with temperature.

ans ⇒ no of $\bar{e}$ in conduction band

$$n = N_C\, e^{-(E_C - E_f)/KT}$$

no of $\bar{e}$ in valence band

$$p = N_V\, e^{-(E_f - E_V)/KT}$$

for intrinsic semiconductor

$$n = p$$

$$N_C\, e^{-(E_C - E_f)/KT} = N_V\, e^{-(E_f - E_V)/KT}$$

$$\frac{N_C}{N_V} = \frac{e^{(-E_F - E_V)/KT}}{e^{-(E_C - E_F)/KT}}$$

at equilibrium $N_C = N_V$

$$\cancel{\frac{N_V}{N_V}} = e^{(-2E_F + E_V + E_C)/KT} \Rightarrow e^{(-2E_f + E_V + E_C)/KT} = 1$$

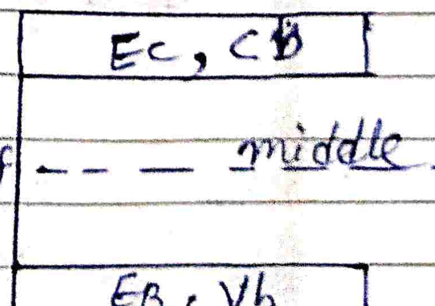
$$e^{(-2E_F + E_V + E_C)/KT} = e^0$$

$$\frac{-2E_f + E_V + E_C}{KT} = 0 \Rightarrow -2E_f + E_V + E_C = 0$$

$$2E_f = E_C + E_V$$

$$\boxed{E_f = \frac{E_C + E_V}{2}}$$

prooved that fermi level lies in the middle of conduction and valence band.



→ variation with temperature → calling (5·7)

PYQ position of fermi level in intrinsic semiconductors.

ans ⇒ The position of fermi level in intrinsic semiconductors depends on factors such that mass of electrons and holes, temperature.

Case-1 → $m_n = m_p$ (holes)
(e^-) then $N_C = N_V$

~~Ef = Ec~~ $E_f = \frac{E_C + E_V}{2} - \frac{KT}{2} \log \frac{N_C}{N_V}$

$E_f = \frac{E_C + E_V}{2} - \frac{KT}{2} \log \frac{\cancel{N_C}}{\cancel{N_C}}$

$E_f = \frac{E_C + E_V}{2} - \frac{KT}{2} \log(1)$ $\left(\because \log 1 = 0 \right.$

$E_f = \frac{E_C + E_V}{2} - 0$

$$\boxed{E_f = \frac{E_C + E_V}{2}}$$

Fermi energy lies in the middle conduction band and valence band.

Page No.
Date / 20

(PYQ) for a particular mass condition the position of the fermi energy level for intrinsic semiconductor is below the center of the intermediate energy gap justify.

ans ⇒ for a particular mass fermi energy level is below center of the intermediate energy gap. it implies that the density of states in the valence band is higher that that in the conduction band, this situation can occur in certain material where the effective mass of electrons is higher than that of holes.

(PYQ) Discuss the location of fermi levels under suitable limiting conditions with necessary theory.

ans → under suitable limiting conditions, the location of the fermi level can be determined by the following

① At absolute zero temperature :- fermi level lies in the center of the band gap b/w valence and conduction band.

② At higher temperature :- The fermi level shifts towards the conduction band due to the thermal excitation of electrons.

③ In a heavily doped semiconductor →, the fermi level lies close to the donor or accepter energy level.

(PYQ) Intrinsic semiconductor behave as insulator at 0K, comment ~~and add your opinion~~

ans ⇒ $E_f = \frac{E_C + E_V}{2} - \frac{KT}{2} \log \frac{N_C}{N_V}$

at [redacted] T = 0K

$E_f = \frac{E_C + E_V}{2}$

It is middle of energy gap.

E > Ef no ē found
E < Ef ē found

if energy state is less than fermi energy level so (ē) electron found if energy state is greater than fermi energy level so no ē found so at 0K any intrinsic semiconductor behave as insulator.

(ii) if we increase in the temperature then it behaves like conductor.

(PYQ) What is the physical meaning of fermi level?

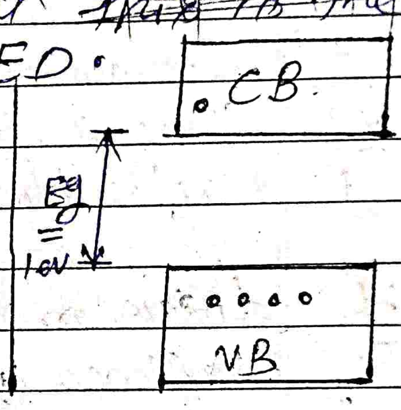
ans ⇒ The physical meaning of fermi level is that it represents the boundary between the occupied and unoccupied energy states of the electron in a material.

Date / 20

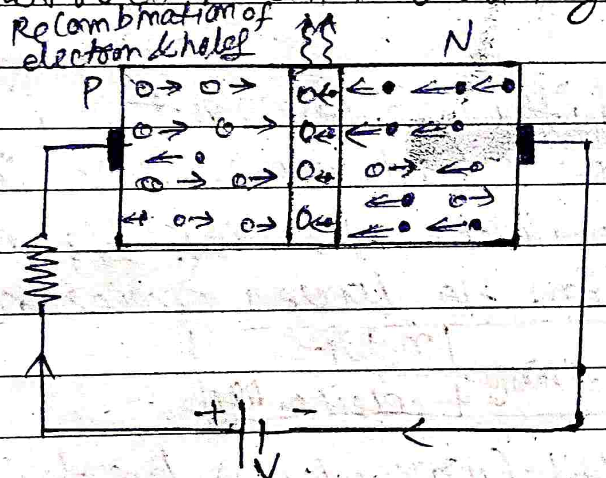
(PYQ) Discuss the working of a LED with proper energy band diagram.

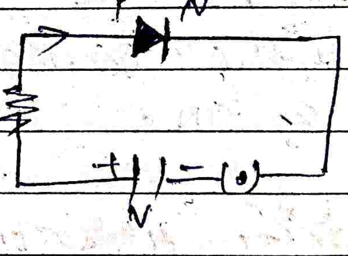
ans ⇒ LED is a semiconductor light source that emits light when current flows through it.

~~Principle: Energy is required to throw an e from valence band to conduction band to generate electron and hole pair. energy is emitted when an e & hole recombine in semiconductors. energy is emitted in the form of heat but some special semiconductors emit energy in the form of light this is the basic principle of~~ LED.



Construction and working





Led consists PN junction diode, a resistance R is connected in series to control the current through diode. In PN junction diode there is excess of holes in P-region and excess of es in N-region, when voltage is applied across the junction diode, the difussion of holes from P to N region and electrons from N to P region take place. while crossing the junction ēs and holes recombine with each-other's and energy released. The energy released due to recombination process is in the form of photon of energy $h\nu = E_g$ where E_g is bandgap.

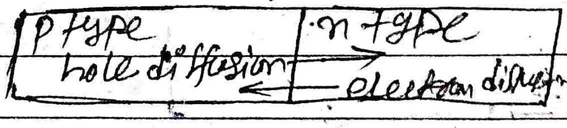
$$\therefore h\nu = E_g, \quad \boxed{E_g = \frac{hc}{\lambda}} \quad \left\{ \nu = \frac{c}{\lambda} \right.$$

$$\boxed{\lambda = \frac{hc}{E_g}}$$

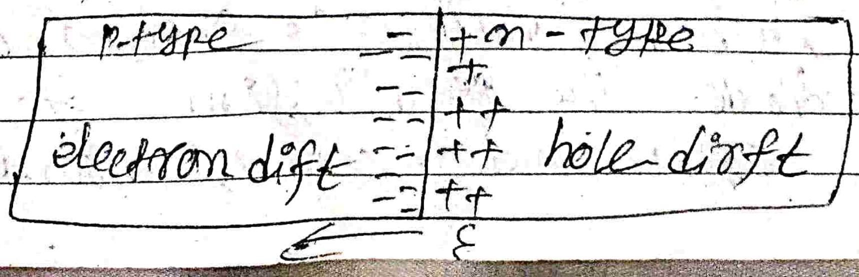
Some application of it

1. Aviation lightning
2. Automotive headlampes
3. Camera flashes
4. Mobile phone backlight

(*) diffusion current : diffusion current can be defined as the flow of charge carriers within a semiconductor travels from a higher concentration to lower concentration region.



(*) drift current : Drift current can be defined as the charge carrier's moves in a semiconductor because of the electric field. There are two kinds of charge carriers in a semiconductor like hole and electron.



Date / 20

Diffusion current	Drift current
(i) The diffusion current can be occurred because of the diffusion in charge carriers	The drift current can be occured because of movement of charge carriers.
(ii) It obeys Fick's law.	It obeys ohm's law.
(iii) It is independent of permittivity.	It depends on the permittivity.
(iv) Some amount of external energy is enough for the process of diffusion current.	It requires electrical energy for the process of drift current.

Date / 20

Q) Where does fermi level lie intrinsic semiconductor and in n type & p-type semiconductor.

ans ⇒ In intrinsic semiconductor, the fermi level lies in the middle of the band gap. this is because of no of electrons in the conduction band is equal to no of holes in the valence band.

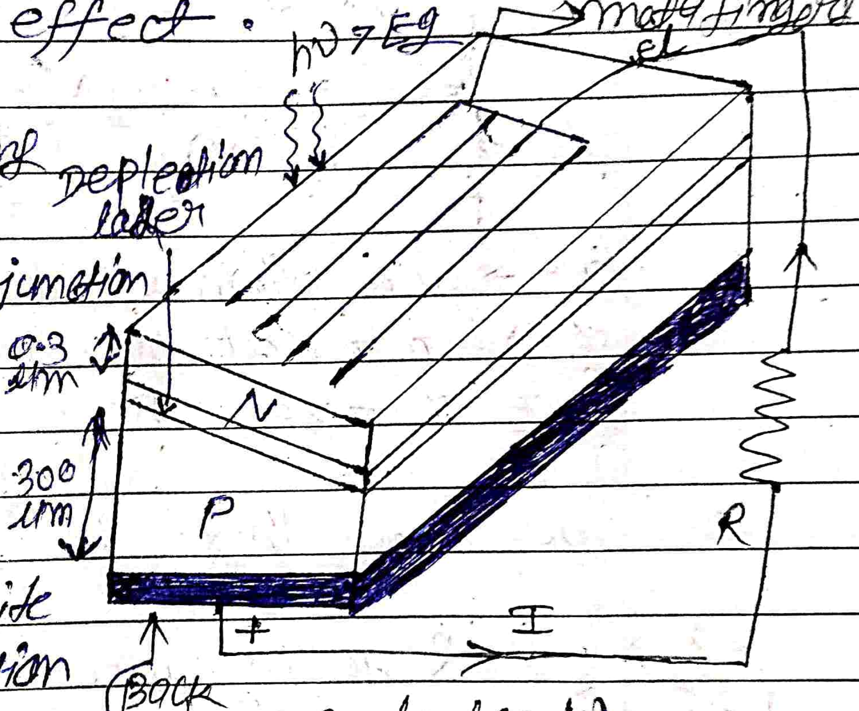
The fermi level in n-type semiconductor lies just below the conduction band.

The fermi level in a p-type semiconductor lies close to the top of the valence band.

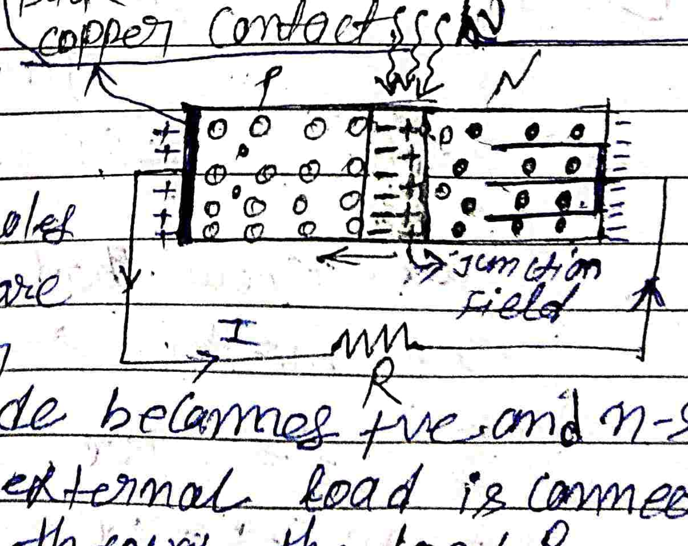
xi) Stating the principle of solar cell, briefly explain its working.

⇒ A solar cell or photovoltaic cell is a device that converts light energy from sun light

principle → Solar cell work on the principle of photovoltaic effect.



working → When photons of energy greater than Eg fall at the junction e-hole pairs are generated in the depletion layer, The e⁻s & hole produced removes in opposite direction due to junction field, The electrons move towards n-side of P-N junction are collected by the metal fingers & holes moves towards p-side are collected by back copper contact thus the p side becomes +ve and n-side becomes -ve, when external load is connected then current flows through the load R.



PYQ ~~Differem~~ Derive the differential equation for harmonic oscillator. Also show that total energy of the harmonic oscillator is constant at any instant of time.

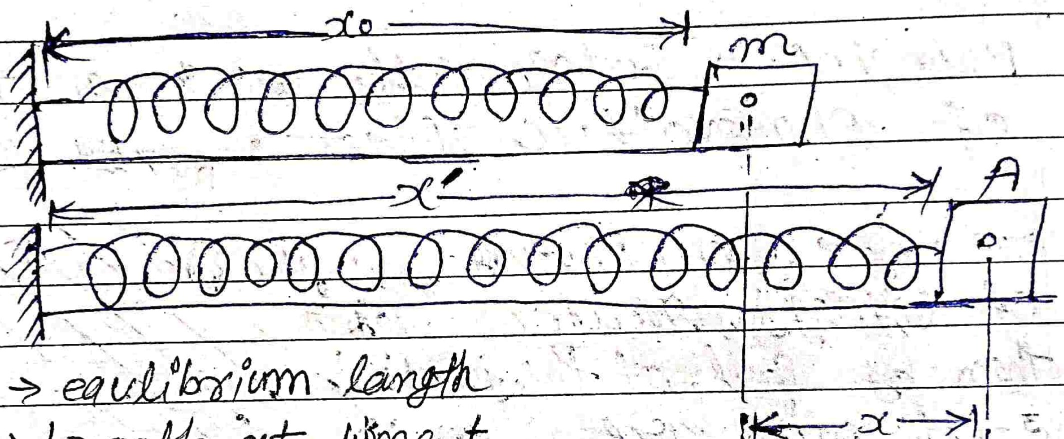
M

Page No.
Date / 20

Roshan paper last year

PYQ Establish the equation of simple harmonic oscillator using $x(t) = A \sin(\omega t + \phi)$ with symbols having their usual meaning. find kinetic energy and potential energy associated with SHM. Hence show that total energy of a simple harmonic oscillator is constant any instant of time.

ans ⇒



$x_0 \to$ equlibrium length
$x' \to$ Length at time t
$\boxed{x = x' - x_0}$ change in length (extension)

we know that in simple harmonic oscillation

Restoring force $\propto$ − displacement

$$f \propto -x \quad \therefore K - \text{force constant}$$

$$\boxed{f = -Kx} \text{ —— (i)}$$

we know that from newton's second law of motion $f = ma$ where m – mass
a = acceleration

$$f = -Kx$$

$$ma = -Kx \quad \left\{ \therefore a = \frac{d^2x}{dt^2} \right.$$

$$\frac{d^2x}{dt^2} = -\frac{Kx}{m}$$

$$\boxed{\frac{d^2x}{dt^2} + \frac{Kx}{m} = 0} \quad \text{equation of SHO.}$$

$$\frac{d^2x}{dt^2} + \frac{k}{m}x = 0 \quad \left\{ \because \boxed{\omega^2 = \frac{k}{m}} \right\} \Rightarrow \omega = \sqrt{\frac{k}{m}}$$ angular velocity

$$\frac{d^2x}{dt^2} + \omega^2 x = 0 \quad \text{— (2)}$$

Sol of SHM eqn

Multiplying by $2\frac{dx}{dt}$ in eqn (2) both side

$$2\frac{dx}{dt}\frac{d^2x}{dt^2} + \omega^2 2\frac{dx}{dt}x = 0$$

$$\frac{d}{dt}\left(\frac{dx}{dt}\right)^2 + \omega^2\frac{d(x^2)}{dt} = 0 \quad \text{— (3)}$$

$\because$ $\boxed{2\left(\frac{dx}{dt}\right)\frac{d^2x}{dt^2} = \frac{d}{dt}\left(\frac{dx}{dt}\right)^2}$

and $\boxed{\omega^2 2x\frac{dx}{dt} = \omega^2\frac{d(x^2)}{dt}}$

Integrating both sides in (3)

$$\int\frac{d}{dt}\left(\frac{dx}{dt}\right)^2 + \omega^2\int\frac{d(x^2)}{dt} = C$$

$$\left(\frac{dx}{dt}\right)^2 + \omega^2x^2 = C \quad \text{— (4)}$$

At $x = A$; $v = 0$; $\frac{dx}{dt} = 0$

$$(0)^2 + \omega^2 A^2 = C$$

$$\omega^2A^2 = C \quad \text{— (5)}$$ put 4 in (4)

$$\left(\frac{dx}{dt}\right)^2 + \omega^2x^2 = \omega^2A^2 \Rightarrow \left(\frac{dx}{dt}\right)^2 = \omega^2A^2 - \omega^2x^2$$

$$\left(\frac{dx}{dt}\right)^2 = \omega^2(A^2 - x^2)$$

$$\left(\frac{dx}{dt}\right)^2 = \omega^2 (A^2 - x^2)$$

$$\frac{dx}{dt} = \sqrt{\omega^2 (A^2 - x^2)}$$

$$\frac{dx}{dt} = \omega \sqrt{A^2 - x^2}$$

$$\frac{dx}{\sqrt{A^2 - x^2}} = \omega dt$$

Integrating both sides

$$\int \frac{dx}{\sqrt{A^2 - x^2}} = \omega \int dt + \phi$$

$$\sin^{-1} \frac{x}{A} = \omega t + \phi$$

$$\frac{x}{A} = \sin (\omega t + \phi)$$

$$\boxed{x = A \sin (\omega t + \phi)}$$ Solⁿ of diff eqⁿ of SHM.

Using the equation $x = A\sin(\omega t+\theta)$ for natural vibrations of a stretched spring in horizontal plane. Show that the total energy of a vibrator is a constant quantity.

The equation $x(t) = A\sin(\omega t+\phi)$ represents a simple harmonic motion, where $x(t)$ is the displacement of an object from its equilibrium position at time t, A is the amplitude of the motion, ω is the angular frequency of the motion, and ϕ is the phase angle.

→ we know that Kinetic energy is

$$K.E = \frac{1}{2} m v^2 \quad \text{— (A)}$$

value of v in SHM we know that

$$v = A\omega\cos\omega t$$

$$v = A\omega\sqrt{1-\sin^2\omega t}$$

put $\sin\omega t = \frac{y}{A}$

$$v = A\omega\sqrt{1-\frac{y^2}{A^2}} \qquad v = \frac{A\omega\sqrt{A^2-y^2}}{A}$$

$$\boxed{v = \omega\sqrt{A^2-y^2}} \text{ — (1) put in (A)}$$

$$K.E = \frac{1}{2} \times m \times \left[\omega\sqrt{A^2-y^2}\right]^2$$

$$K.E = \frac{1}{2} m.\omega^2(A^2-y^2)$$

$$\boxed{K.E = \frac{1}{2} m\omega^2A^2 - \frac{1}{2} m\omega^2y^2}$$

→ ∵ we know that potential energy ⇒ $PE = \frac{1}{2} Ky^2$

$PE = \frac{1}{2} Ky^2$ — (B) ∵ in SHM → $K = m\omega^2$

$$\boxed{PE = \frac{1}{2} \times m\omega^2y^2} \text{ — (C)}$$

∵ $y = A$ (max)

$$\boxed{PE = \frac{1}{2} m\omega^2A^2}$$

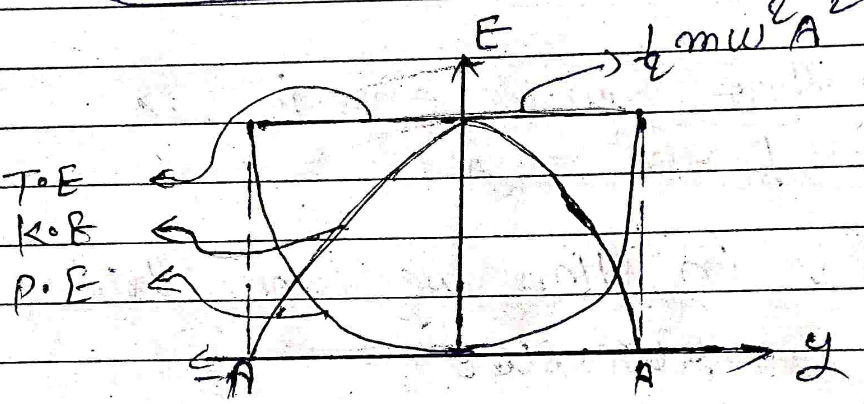
PYQ → Prove by mathematical analysis that the mechanical energy of free oscillations of a simple harmonic is conserved.

Page No.
Date / 20

Total energy = K.E + P.E

$= \frac{1}{2} m\omega^2 A^2 - \cancel{\frac{1}{2} m\omega^2 y^2} + \cancel{\frac{1}{2} m\omega^2 y^2}$

$$\boxed{T.E = \frac{1}{2} m\omega^2 A^2}$$



Here T.E (total energy) is constant at any instant of time.

PYQ Define simple Harmonic motion? give example.

ans ⇒ Simple harmonic motion is a type of periodic motion or oscillation motion where the restoring force is directly proportional to the displacement acts in opposite direction.

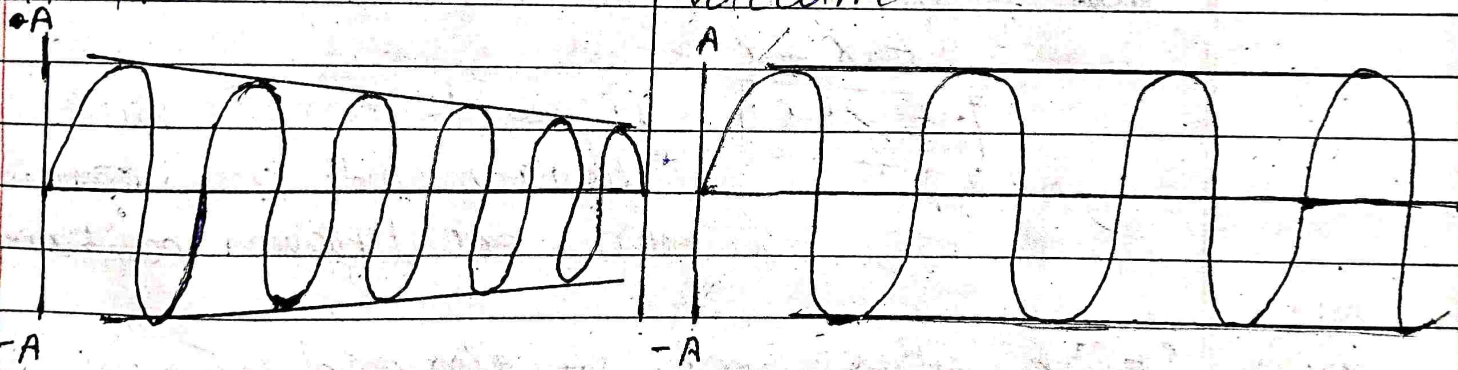
$f \propto -x$

$\boxed{f = -kx}$ k → force constant, x → displacement

Ex ⇒ Motion of a mass attached to a spring.

PYQ Differentiate damped and undamped oscillations.

	damped	undamped
(i)	The oscillations whose amplitude decreases with time called damped oscillation.	The oscillations whose amplitude remains constant with time called undamped oscillation.
(ii)	There is external force.	There is no external force.
(iii)	An example of damped oscillation is pendulum in Air.	An example of undamped oscillation is pendulum in vaccum.
(iv)		



What are oscillations?

PYQ What do you understand by fee oscillations and forced oscillations?

Oscillation is a periodic movement around an equilibrium point. There are two types of Oscillation (i) free oscillation (ii) forced oscillations.

free oscillations :- The oscillation of a body when it oscillates with its own frequency are called free oscillation.

Ex ⇒ a simple pendulum.

(ii) forced oscillation ÷ when a body is subjected to periodic force, it oscillates with the frequency of the periodic forces are called forced oscillation.

Ex ⇒ vibration of a guitar string.

PYQ Define Hooke's law

ans ⇒ The force needed to extend or compress a spring is directly proportional to the distance it is stretched or compressed from its equilibrium position.

$F \propto -x$

$\boxed{f = -kx}$ where K force constant
x displacement from its own equilibrium position.

MST
PYQ Define stress and strain and give their types.

ans ⇒ stress ÷ stress refers to the internal force per unit area that arises in a material.

Types of stress ÷ (i) Tensile stress
(ii) Compressive stress
(iii) Shear stress

strain ÷ strain is a measure of the change in shape that occurs in a material whe it is subjected to stress.

Types of stress ÷ (i) Tensile strain
(ii) Compressive strain
(iii) Shear strain

PYQ) Discuss briefly, the motion of a lightly damped oscillator

ans ⇒ The motion of a lightly damped oscillator is affected by its initial conditions and the characteristics of the damping force for example :- if the oscillator is initially displaced from its equilibrium position and released, it will oscillate with [redacted] decreasing amplitude until it comes to rest.

✓ eq^n of motion of damped oscillator

PYQ) Derive [redacted] differential equation of damped harmonic oscillations and discuss special cases of oscillatory motion. Discuss the case of critically damped and special cases of oscillatory motion.

ans ⇒ Restoring force $f_R \propto -x$

$$\boxed{f_R = -Cx} \quad (A) \qquad C \rightarrow \text{force constant}$$

frictional force $f_D \propto -\frac{dx}{dt}$

$$\boxed{f_D = -\gamma \frac{dx}{dt}} \quad (B) \qquad \gamma \text{ is damping coefficient}$$

$f = f_R + f_D$ (C)

$$\boxed{f = -Cx - \gamma \frac{dx}{dt}}$$ According to Newton's 2nd law

$f = ma \rightarrow \boxed{f = m\frac{d^2x}{dt^2}}$ (d)

equating eq^n (C) & (d)

$$m\frac{d^2x}{dt^2} = -Cx - \gamma\frac{dx}{dt}$$

$$\boxed{m\frac{d^2x}{dt^2} + Cx + \gamma\frac{dx}{dt} = 0}$$ divide by m both sides

$$\frac{d^2x}{dt^2} + \frac{\gamma}{m}\frac{dx}{dt} + \frac{c}{m}x = 0$$

put $\frac{\gamma}{m} = 2K$ / K is dampin constant

$$, \frac{c}{m} = \omega_0^2$$

$$\boxed{\frac{d^2x}{dt^2} + 2k\frac{dx}{dt} + \omega_0^2 x = 0}$$ diff eq^n

Critically damped ÷ critically damping is the point at which the system's motion returns to equilibrium as quickly as possible.

special damped ÷ in this type of motion the amplitude of the oscillation decreases with respect to time and oscillation frequency reduces untill the system ~~reaches~~ it equilibrium position.

Lightly damped ÷ Lightly damped motion refers to a system that has a small amount of resistance to motion.

(pxQ) lightly damped oscillations are simple harmonic or not.

any strictly ~~Yes they~~ lightly damped oscillation are not simple harmonic but they same in some cases.

Extra

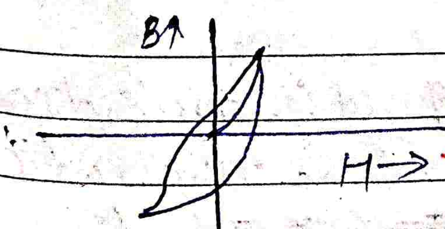
PYQ Application of superconductivity.

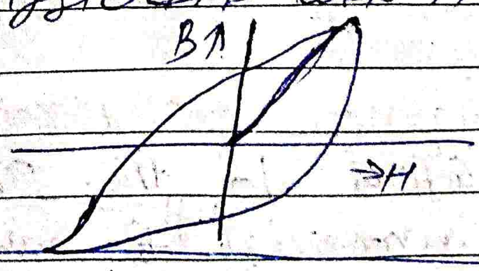
ans → (i) Magnetic levitation (Maglev)
(ii) power transmission
(iii) Super computer
(iv) MRI / NMR devices.
(v) motor / generators.

PYQ differentiate hard and soft magnetic materials.

ans →

Soft magnetic material	hard magnetic material
It can be easily magnetized or demagnetized.	I cannot be easily magnetized or demagnetized.
(ii) It's coercivity and Retentivity are small.	It's coercivity and retentivity are large.
(iii) It has high permeability	It has low permeability.
(iv) eddy current loss is ~~small~~ low.	eddy current loss is high.
(v) hysteresis loss is low.	hystersis loss is high.





PYQ what is hysteresis? based on Magnetic material

ans → when an external magnetic field is applied to a magnetic material, the material's magnetic domain align with the direction of the applied field. this is known as hysteresis.

Nanomaterial

PYQ write short note on Dielectric materials.

ans ⇒ Dielectric materials are often used as insulator because they can withstand high electric fields without conducting electricity, they can store electric charge. The capacitance of a capacitor depends on the dielectric constant of the material between plates.

Ex = capacitor, plastics, glass

* write short note on ferroelectric material

ans ⇒ Ferroelectric materials have a unique combination of electrical, mechanical, and optical properties, which make them useful in a wide range of application. They are used in electronic devices such as capacitors, transducers.

PYQ write short notes on (i) Magnetic Anisotropy (ii) Magnetostriction.

(i) Magnetic Anisotropy :- Magnetic anisotropy refers to the property of a magnetic material that have a ~~preffered~~ ~~di~~ particular direction of magnetization. This means that the material is easier to magnetize in one particular direction. Magnetic anisotropy is used in various applications such as magnetic data storage devices, magnetic sensors.

Page No.
Date / 20

(ii) Magnetostriction: when a magnetic field is given to a magnetic material it experiences change in all in shap or size or length or dimenshion with property of some magnetic materials is known as Magnetostriction. applications of magnetostriction is magnetic sensors, transformers

(PYQ) What are nanomaterials? How can we classify them? application of nanomaterials.

ans → Nanomaterial is a material made up of between 1 and 100 nanometers. It has at ~~least~~ least one dimension in the nanoscale. Nanomaterial used in electronics, medicine.

Classification of Nanomaterials:

(a) carbon based nanomaterials
(b) Metal based nanomaterials
(c) Dendrimers
(d) Nanocomposites

(PYQ) Write some ~~a~~ important applications and risks of nano materials.

Applications

ans → (i) Electronics: Nano materials are used in electronic devices to improve their performance
ex ⇒ transistor.

(ii) Biomedical: Nano materials are used in bio-madical - ex ⇒ drug delivery, imaging.

(3) Energy :- Nano materials are used in energy application such as solar cells, fuel cells and batterys.

(4) water treatment :- Nano materials are used in water treatment to remove pollutants ~~and~~ ex → titanium dioxide.

Risks:

(1) ~~Environmental~~ Environmental Impact
→ Nano materials can also have an environmental impact such as polluting water and soil.

(2) Toxicity :- Nano materials can be toxic to living organisms, including human.

Q(1) Explain factors responsible for change in properties when we change from bluk to nanomaterial or nanoscale.

ans ⇒ when we move from bulk materials to nanomaterials, there are several factors that can contribute to changes in their properties.

(i) Size :- ~~the~~ size of the nano material decreases, the surface area to volume ratio increases which can significantly affect the properties of the materials.

Page No.
Date / 20

(ii) Surface area: The high surface area of nanomaterials can lead to changes in their physical and chemical properties.

(iii) Quantum effects: At the nanoscale quantum effects can become dominant and can lead to unique electronic and optical properties.
Ex ⇒ band gap of a material can change as the size of the material decreases.

(iv) Crystal structure: As the size of a material decreases, its crystal structure can also change ex ⇒ change in crystal structure can result in changes in the material's hardness, strength and conductivity.

Q. Why these properties are different from bulk materials.

ans ⇒

Nano materials have different properties from bulk materials due to the increased surface area-to-volume ratio, quantum effects, and size dependent properties that arise at the nanoscale.

Page No.
Date / 20

(a) Ferrites : Ferrites are a type of ceramic material that have magnetic properties. They are composed of iron oxide (Fe_2O_3) combined with other metal oxides, such as nickel oxide (NiO); zinc oxide (ZnO). The specific combination of metal oxides determines the properties of the ferrite.

- Ferrites are known for their high electrical resistance and low eddy current losses which makes them useful in various application in electronics & telecommunication.

Page No.
Date / 20

SHM
Base of Nomeride

$\boxed{\omega = \frac{2\pi}{T} \quad T \to \text{Timeperiod}}$ $\boxed{t \to \text{given time}}$

$\to \phi = Kx$ $\boxed{K = \frac{2\pi}{\lambda}}$

Eq^n of SHM $\boxed{x = A\sin(\omega t + \phi)}$ mean position

$\boxed{x = A\cos(\omega t + \phi)}$ extreme position

$\boxed{v = \frac{dx}{dt}}$, $\boxed{a = \frac{d^2x}{dt^2}}$

at mean position $\boxed{\text{displacement } x = 0}$

at extreme position $\boxed{\text{displacement } x = \pm A}$

frequency $\boxed{\omega = 2\pi f}$ $\boxed{f = \frac{1}{T}}$ angular frequency

Time period = $\boxed{T = \frac{1}{f}}$ $\boxed{\text{unit} = Hz / s^{-1}}$

Amplitude = Mean position से extream position तक का distence (A) होता है।

time → small (t)
time period (T)

Note → mean position पर $\phi = 0$ होता है और
extream position पर भी $\phi = 0$ होता है

$\boxed{K.E = \frac{1}{2}mv^2}$ $\boxed{P.E = \frac{1}{2}Kx^2}$

Q5 - An electromagnetic beam of 100 photon having wavelength of 1 Å, passes throught 1 mm² area of crosssection. find the intensity of em waves that crosses the area in 5 sec.

ans ⇒ given → n of photon = 100

$\lambda = 1 Å$

1mm × 1mm $area = 1 mm^2 = (10^{-3})^2 = 10^{-6} m^2$

$t = 5$

$I = ?$

∴ formula of Intensity ⇒ $\boxed{I = \frac{E}{At}}$ W/m²

$$\boxed{\begin{array}{l} E = h\nu \\ E = \frac{hc}{\lambda} \end{array}} \quad E = \frac{hc}{\lambda}$$

$$E = \frac{nhc}{\lambda} \quad E = \frac{100 \times 6.63 \times 10^{-34} \times 3 \times 10^{8}}{10^{-10}}$$

$$E = 1989 \times 10^{-16} J$$

$$I = \frac{1989 \times 10^{-16}}{10^{-6} \times 5} \quad \boxed{I = 397.8 \times 10^{-10} \ W/m^2}$$

Q6 A car 2000 kg car is moving with speed 100 Km/h find de-broglie wavelength associated with moving car.

Sol ÷ $m = 2000 kg$, $V = 100 km/h$

$\lambda = ?$ $V = \frac{100 \times 1000}{60 \times 60}$ $V = \frac{1000}{36}$

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

$V =$

$V = \frac{500}{18}$ $V = \frac{250}{9}$ $V = 27.77\, m/s$

$v = 100\, km/h$

$= \frac{1000}{60 \times 60}$

$= \frac{10}{36} = \frac{5}{18}$

$\lambda = \frac{6.63 \times 10^{-34}}{2000 \times 27.27}$

$\lambda = \frac{6.63 \times 10^{-34} \times 10^{-3}}{27.27 \times 2}$

$\lambda = \frac{6.63 \times 10^{-34} \times 10^{-3}}{54.54}$

~~$\lambda = 0.1215 \times 10^{-36}\, m$~~

A $\lambda = 0.1215 \times 10^{-37}$

$\boxed{\lambda = 121.5 \times 10^{-40}\, m}$

Q8) de-broglie wavelength associated with a moving neutron and an electron is the same $\lambda = 1 Å$. Compare their energy.

ans $\because$ $\lambda = \frac{h}{\sqrt{2mE}}$ $\sqrt{2mE} = \frac{h}{\lambda}$

$\boxed{E = \frac{h^2}{2m\lambda^2}}$ $E_n = \frac{h^2}{2m\lambda^2}$

$E_n = \frac{h^2}{2m_n\lambda^2}$ $E_e = \frac{h^2}{2m_e\lambda^2}$

$\frac{E_n}{E_e} = \frac{\cancel{h^2}}{\cancel{2}m_n \cancel{\lambda^2}} \times \frac{\cancel{2}m_e \cancel{\lambda^2}}{\cancel{h^2}}$ $\frac{E_n}{E_e} = \frac{m_e}{m_n}$

Page No.
Date / 20

$em = 9.1 \times 10^{-31}\, kg$
$nm = 1.66 \times 10^{-27}\, kg$

$$\frac{E_n}{E_e} = \frac{9.1 \times 10^{-19}}{1.66 \times 10^{-27}} = \frac{1.66 \times 10^{-27}}{9.1 \times 10^{-31}}$$

$$\frac{E_n}{E_e} = \frac{1.66 \times 10^{-27}}{9.1 \times 10^{-31}}$$

$$\frac{E_n}{E_e} = 0.1824\overset{17582}{} \times 10^{-27} \times 10^{37}$$

$$\frac{E_n}{E_e} = 0.1824 \times 10^{10} \quad 17582$$

$$\frac{E_n}{E_e} = 0.182417582 \times 10^{10}$$

$$\frac{E_n}{E_e} = 1.82 \times 10^{9} J$$

$$\boxed{E_n = 1.82 \times 10^{9} J \times E_e}$$

Q(15) A swing in park executes SHM whose eqn of motion is expressed as $x(t) = 7 \sin(0.8t + 5\pi)$. find amplitude, angular frequency (ω), natural frequency (ν) initial phase of this SHM. Also find K.E & P.E of these oscillation at $t = 3s$

ans ⇒ $x(t) = 7 \sin(0.8t + 5\pi)$ $\left\{ \omega = \frac{2\pi}{T} \right.$
$x = A \sin(\omega t + \phi)$

$\boxed{A = 7}$, $\boxed{\omega = 0.8}$

$\therefore$ $\boxed{\omega = 2\pi f}$ $\omega = 2 \times \pi \times f$
$0.8 = 2 \times \pi \times f$

Page No.
Date / 20

$$f = \frac{0.8}{2 \times \pi} \qquad f =$$

$$\boxed{f = 1.25\ s^{-1}} \qquad \boxed{f = 1.25\ s^{-1}}$$

initial phase $\boxed{\phi = 5\pi}$

$K.E = ? \quad P.E = ? \quad \boxed{KE = \frac{1}{2} m v^2}$

$$\boxed{P.E = \frac{1}{2} K x^2}$$

$$P.E = \frac{1}{2} K [7 \sin(0.8t + 5\pi)]^2$$

$$PE = \frac{1}{2} K \times 49 \sin^2(0.8t + 5\pi)$$

$$PE = 24.5 K \sin^2(0.8 \times 3 + 5\pi)\ J$$

$$\boxed{PE = 24.5 K \sin^2(2.4 + 5\pi)\ J}$$

$$\boxed{K.E = \frac{1}{2} m v^2} \quad K.E = \frac{1}{2} m \left[\frac{d(7 \sin(0.8t + 5\pi))}{dt}\right]^2$$

$$K.E = \frac{1}{2} m [7 \cos(0.8t + 5\pi)\ 0.8]^2$$

$$K.E = \frac{1}{2} m [5.6 \cos(0.8t + 5\pi)]^2$$

$$K.E = \frac{1}{2} m [31.36 \cos^2(0.8t + 5\pi)]$$

$$\boxed{K.E = 15.68 m \cos^2(0.8t + 5\pi)\ J}$$

Q16 Give SHM with time period of 2 second find the frequency & wavelength of SHM, Also find angular frequency and velocity ~~[illegible]~~ 5m/s.

ans

$Sol^n \rightarrow$ given $T = 2\ sec$, $v = 5\ m/s$

frequency $= \frac{1}{T} = \frac{1}{2} = 0.5\ Hz / s^{-1}$

angular frequency

$\omega = 2\pi f$

$\omega = 2\pi \times 0.5$

$\omega = \cancel{2}\pi \times \frac{1}{\cancel{2}}$

$\boxed{\omega = \pi\ rad.}$

∴ wavelength $= \frac{\text{velocity}}{\text{frequency}}$

wavelength $= \frac{5}{0.5} = 10\ m$

$\boxed{\lambda = 10m}$

~~if →~~ $\cancel{\lambda = \frac{v}{f}}$

~~where v → speed of light~~

~~then~~ $\cancel{\lambda = \frac{3 \times 10^8}{0.5}}$

$\cancel{\boxed{\lambda = 6 \times 10^8\ m}}$

(17) A Spring has spring constant $K = 500 N/m$ find extension developed in the spring if ~~r~~estoring force of 10N is acting on it.

ans ⇒ $K = 500 N/m$ $f = 10N$

∴ $f = |-kx|$, magnitude.

$10 = 500 \times x$

$x = \frac{10}{500}$ $x = \frac{1}{50}$

$\boxed{x = 0.02m}$ magnitude.

(18) How much extension is spring will be produced if a mass of 10kg is attached to one end of ~~a~~ spring. Given $K = 500 N/m$

$g = 9.8 m/s^2$

ans ⇒ Given $m = 10kg$

$K = 500$

∵ $f = mg$

$f = kx$

$mg = kx$

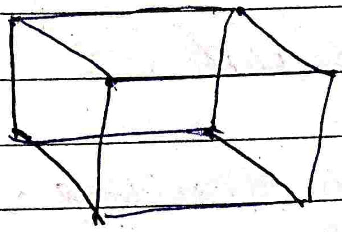
$x = \frac{mg}{k}$ $x = \frac{10 \times 9.8}{500}$

$x = \frac{98}{500}$

$\boxed{x = 0.196m}$

(28) given cube with side 1 cm is divided into 1000 small cubes find surface area to volume ration in both cases.

Sol:



$a = 1\,cm$

$a = 10^{-2}\,m$

$V = a^3 = V = (10^{-2})^3$

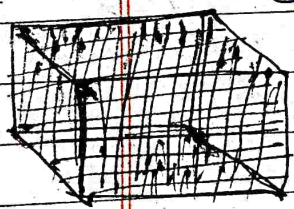
$\boxed{V = 10^{-6}\,m^3}$

$S.A = 6\times a^2 = 6\times 10^{-2}\times 10^{-2}$

$\boxed{S.A = 6\times 10^{-4}\,m^2}$

surface area to volume ratio $= \frac{6\times 10^{-4}}{10^{-6}} = 6\times 10^{2}\,m$

$\boxed{\frac{S.A}{Vol} = 600\,m}$



initial volum = final volum

$a^3 = 1000\,a_1^3$

$a_1^3 = \frac{a^3}{1000}$ $\quad a_1^3 = \left(\frac{a}{10}\right)^3$

$a_1 = \sqrt[3]{\left(\frac{a}{10}\right)^3}$ $\quad a_1 = \frac{10^{-2}}{10}$

$\boxed{a_1 = 10^{-3}\,m}$ $\quad vol = 1000\times 10^{-3}\times 10^{-3}\times 10^{-3}$ $\quad \boxed{V = 10^{-6}}$

$S.A = 1000\times 6\times 10^{-3}\times 10^{-3} = 1000\times 6\times 10^{-6}$

$\boxed{S.A = 6\times 10^{-3}\,m^2}$

$\frac{S.A}{Vol} = \frac{6\times 10^{-3}}{10^{-6}} = 6\times 10^{3} = 6000\,m$

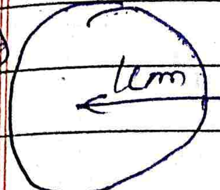
$\boxed{\frac{S.A}{V} = 6000}$

Page No.

Date / 20

(Q4) Given Sphere with radius 1 cm is divided into 1000 small spheres. find surface area to volume ratio in both cases. Does this new ratio same / more / less than the original ratio ?

ans ⇒



$r = 1\,cm$ $\boxed{r = 10^{-2} m}$

$V = \frac{4}{3}\pi r^3$

$S.A = 4\pi r^2$

$\frac{S.A}{V} = \frac{4\pi r^2}{\frac{4}{3}\pi r^3}$

$\frac{S.A}{V} = \frac{3 \times \cancel{4}\cancel{\pi}\cancel{r^2}}{\cancel{4} \times \cancel{\pi} r^{\cancel{3}}}$ $\frac{S.A}{V} = \frac{3}{r}$

$\boxed{\frac{S.A}{V} = \frac{3}{10^{-2}}}$ $\boxed{\frac{S.A}{V} = 300}$

initial volum = final volum

$\cancel{\frac{4}{3}}\cancel{\pi} r^3 = 1000 \times \cancel{\frac{4}{3}}\cancel{\pi} r_1^3$

$\frac{r^3}{1000} = r_1^3$ $r_1^3 = \left(\frac{r}{10}\right)^3$

$r_1 = \sqrt[3]{\left(\frac{r}{10}\right)^3}$ $r_1 = \frac{r}{10}$

$r_1 = \frac{10^{-2}}{10}$ $\boxed{r_1 = 10^{-3} m}$

$S.A = 4\pi r^2$ $S.A = 4\pi \times 10^{-3} \times 10^{-3}$ $\boxed{S.A = 4\pi\, 10^{-6}}$

$\boxed{V = \frac{4}{3}\pi \times 10^{-9}}$

$\frac{S.A}{Vol} = \frac{\cancel{4\pi} \times 10^{-6}}{\frac{\cancel{4\pi}}{3} \times 10^{-9}}$ $\boxed{\frac{SA}{Vol} = 3 \times 10^{3}}$

$\boxed{\frac{S.A}{Vol} = 3000}$ new ratio is more than original ratio.

Q Given a simple harmonic motion defined by $x(t) = 12\sin(0.7\pi t + 5\pi x)$ find the amplitude, natural frequency, time period, wavelength of the given SHM.

given : $x(t) = 12\sin(0.7\pi t + 5\pi x)$

ans ⇒

Comparing with $x(t) = A\sin(\omega t + kx)$

we find → Amplitude $A = 12$

$\omega = 0.7\pi$

$\because \omega = 2\pi f$

$0.7\cancel{\pi} = 2\cancel{\pi} f$

$f = \frac{0.7}{2}$ $\boxed{f = 0.35 \text{ hz/s}}$

$\because f = \frac{1}{T}$ $\boxed{T = \frac{1}{f}}$

$\boxed{T = 2.85\text{ s}}$ $\because k\cancel{x} = 5\pi\cancel{x}$

$k = 5\pi$

$\because k = \frac{2\pi}{\lambda}$ $\lambda = \frac{2\pi}{k}$

$\lambda = \frac{2\cancel{\pi}}{5\cancel{\pi}}$ $\boxed{\lambda = 0.4\text{ m}}$

Q. A particle of mass 9.1×10^{-31} kg has a kinetic energy of 80 eV. find the associated de-broglie wavelength, group velocity, phase velocity.

ans ⇒ ~~t~~ given.

$m = 9.1 \times 10^{-19}$ kg

$E = 80 \times 1.6 \times 10^{-19}$ J

find λ, v_g, v_p = ?

$\lambda = \frac{h}{\sqrt{2mK}}$ $\quad \lambda = \frac{6.62 \times 10^{-34}}{\sqrt{2 \times 9.1 \times 10^{-19} \text{ kg} \times 80 \times 1.6 \times 10^{-19}}}$

$\boxed{\lambda = x}$

now $\boxed{v_g = \frac{dE}{dP}}$

As ~~E~~ $p = \sqrt{2mK}$

$p^2 = 2mK \cdot E$

$E = \frac{p^2}{2m}$

diff w.r.to. p

$\frac{dE}{dP} = \frac{1}{2m} \times 2P$

$\frac{dE}{dP} = \frac{\cancel{2}P}{\cancel{2}m}$ $\quad \boxed{\frac{dE}{dP} = \frac{P}{m}}$

$v_g = \frac{P}{m}$

$v_g = \frac{h}{\lambda m}$

$v_g = \frac{6.62 \times 10^{-34}}{x \times 9.1 \times 10^{-31}}$

$\boxed{v_g = x_1 \text{ m/s}}$

$v_p = \frac{E}{p}$ $\quad v_p = \frac{80 \times 1.6 \times 10^{-19}}{\sqrt{2 \times 9.1 \times 10^{-31} \times 80 \times 1.6 \times 10^{-19}}}$

$\boxed{v_p = y}$ m/s

Page No.
Date : / 20

* What is superconductivity?

ans ⇒ A superconductivity is the ability of certain materials to conduct electric current with practically zero resistance.

Ex ⇒ Al, Hg.

* What are superconductor?

ans ⇒ A superconductor is defined as a substance that offers no resistance to the electric current when it becomes colder ~~than a~~ below critical temperature.

Ex ⇒ mercury, barium, calcium

* What is conductor?

ans ⇒ A. Conductor is a material that allows electricity to flow through it is called conductor. Ex ⇒ fe, Al, cu

* What is insulator?

ans ⇒ A Insulator is a material that do not allows electricity to flow through it is called insulator.

Ex ⇒ plastic, glass, wood

* Critical temperature ÷ Critical temperature is that temperature at which the resistance of a conductor becomes zero is called critical temperature. Ex ⇒ Hg it's T_c is 4.2K

Page No.
Date : / 20

* Application of Superconductor

(i) Magnetic Resonance imaging (MRI)

(2) Power transmission.

(3) Energy storage.

(4) Quantum Computing.

(5) Magnetic levitation.

(6) fusion energy.

* What is superconductivity?

ans ⇒ A superconductivity is the ability of certain materials to conduct electric current with practically zero resistance.

Ex ⇒ Al, Hg.

* What are superconductor?

ans ⇒ A superconductor is defined as a substance that offers no resistance to the electric current when it becomes colder ~~than~~ below critical temperature.
Ex ⇒ mercury, barium, calcium

* What is conductor?

ans ⇒ A. Conductor is a material that allows electricity to flow through it is called conductor. Ex ⇒ fe, Al, cu

* What is insulator?

ans ⇒ A Insulator is a material that do not allows electricity to flow through it is called insulator.
Ex ⇒ plastic, glass, wood

* Critical temperature ÷ Critical temperature is that temperature at which the resistence of a conductor becomes zero is called critical temperature. Ex ⇒ Hg it's T_c is 4.2K

Page No.
Date : / 20

* What is semiconductor

ans ⇒ A semiconductor is a substance which lies betweem the conductor and insulator.
Ex ⇒ Silicon, germanium.

* What is an ideal conductor?

ans ⇒ An ideal conductor is a hypothetical material whose resistance is ideally zero in ideal conductor A current will continiously flow through it even when the power source is removed.

* What is a perfect conductor?

ans ⇒ A perfect conductor is an idealized material that has zero electrical resistance and can conduct electricity infinitely well without any loss of energy.

* ~~What are~~

* Properties of superconductivity

(i) zero resistance
(ii) diamagnetic material
(iii) persistancent current

(Q) Name few properties which do not change when a conductor becomes superconductor?

Ans → (i) Electrical charge : ~~Super conductivity~~ Electrical charge is a property that arises due to the interactions between electrons in a material, However the charge of the material remains the same before and after the transition to superconductor

(ii) Atomic structure : The atomic structure of material remains unchanged when it transitions to a superconductor

(iii) Mass : The mass of the material also remains the same before and after transition to a superconductor

(iv) Volume : The volume of material does not change when it becomes a superconductor

(v) Elasticity : Elasticity property of a material does not change when a conductor becomes a superconductor.

* Name some property which change when a conductor becomes superconductor?

(i) Zero resistance :- The electrical resistance of a superconductor goes to zero, which means that an electrical current can flow through it without any loss of energy. but zero resistance can not posibile in conductor

(ii) Critical temperature :- At critical temperature, the ~~temperature~~ resistance of the superconductor is zero. but at critical temperature ~~not~~ the ~~resistance~~ temperature of conductor does not necessary to zero.

(iii) missner effect :- a normal conductor cannot repell magnaticline but when a becomes a superconductor than they repell the magnetic fields and behave like diamagnetic.

(iv) persistence current :- When we keep rings of superconductors in applied magnatic field and we connetc ring with power supply than there current induced in ring and steady current flows through superconductor for years even if power supply is off, but this things does not work in normal conductor.

9M

(*) What do you mean by Meissner effect? prove superconductors are perfect diamagnetic materials? It also called flux expulsion

(*) Application of missner effect (same) ~~~~

ans ⇒ When a superconducting material is placed in a magnetic field and cooled below the critical temperature, ~~it behaves~~ than superconducting material repells magnetic field lines and behaves like diamagnetic material is known as meissner effect

from magnetic property

$$B = \mu_0 (I + H) \quad \text{--- (1)}$$

$I \rightarrow$ intensity of magnetisation

$H \rightarrow$ applied magnetic field

when material becomes a superconductor

then, $B = 0$

$$0 = \mu_0 (I + H)$$

$$\boxed{I = -H} \quad \text{--- (2)}$$

Now, $\because \chi_m = \dfrac{I}{H}$

$$\chi_m = \frac{-H}{H} \qquad \boxed{\chi_m = -1} \quad \text{--- (3)}$$

magnetic susceptibility $\boxed{\chi_m = -1}$

so relative permeablity $\boxed{\mu_r = 1 + \chi_m}$

$$\mu_r = 1 - 1$$

$$\boxed{\mu_r = 0} \quad \text{--- (4)}$$

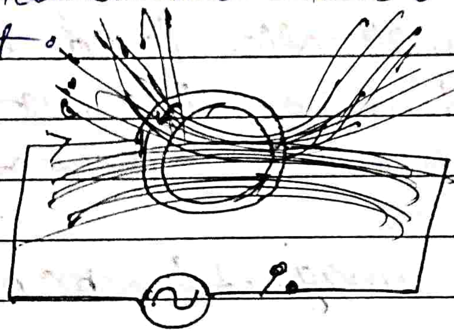
so from eq^n (3) and (4) it indicates that superconductors are perfect diamagnetic material.

→ Application of meissner effect.

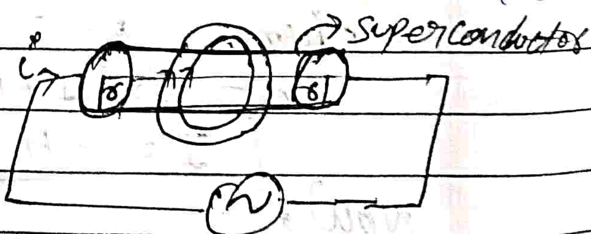
Magnetic levitation, Magnetic shielding, superconducting magnets.

Page No.
Date: / 20

Persistent current :- when a superconducting ring is placed in a magnetic field, a current is induced in the ring when ring connected through a power supply and if we remove that power supply, we find the magnitude of current is constant without power supply such steady current flowing in superconductor is called persistent current.



Critical current :- The maximum applied current in circuit which can be flow through a superconductor without destroying it's superconductivity is called critical current (Ic)



Conductor radius = r
from ampere's law

$$\oint \vec{B}\cdot d\vec{l} = \mu_0 i \quad \{B = \mu_0 H\}$$

$$\oint \vec{H}\cdot dl = i$$

$$H(2\pi r) = i$$

$$H = H_c,\ i = i_c$$

$$\boxed{I_c = 2\pi r H_c}$$

critical current refers to maximum current that a superconductor can carry without experiencing resistance. is called critical current.

$$\boxed{I_c = 2\pi r H_c}$$

* What are applications of the superconductor?

ans ⇒ use in
(i) Super Computer.
(ii) use in magnetic leviation. (train) [हवाई चलने वाली]
(iii) superconducting magnets
(iv) power transmission
(v) Medical diagnosis

* What is critical magnetic field (Hc)

ans ⇒ The strong magnetic field at which the superconducting material loses it's superconductivity is called critical magnetic field

* What is the effect of Magnetic field on super-conductor

ans ⇒ When a strong magnetic field is applied to a superconductor, superconductor loses it superconductivity.

PYQ * flux penetration / Define London penetration depth

ans ⇒ When the temperature of very thin film of superconductor decreased below critical temperature then field lines are not expelled out of material, that in there line continue to pass through the material this phenomena is called flux penetration.

* For sample & for a Material become a supercondu there are two Menditory Condition to be obed in respectly to each-other

ans ⇒ (i) Resistence of material should become 0 at a given value of temperature.

(ii) Material should be diamagnetic.

* Define critical value of Magnetic field.

ans ⇒ The critical value of magnetic field refers to the specific value of the magnetic field at which a material undergoes a phase transition from one magnetic state to another.

$$H(T) = H(0)\left[1 - \frac{T^2}{T_c^2}\right]$$

* Define critical value of current

ans ⇒ The critical value of current is the maximum current that a device can carry before it undergoes a significant change in its behavior, critical value of current varies widely depending on the type of device.

Q. Explain superconductors are non ohmic devices

ans ⇒ We know that from maxwell eq^n

$$\vec{\nabla} \times \vec{E} = -\frac{\partial \vec{B}}{\partial t} \quad \text{—} (1)$$

from ohm's law in vector form

$$\vec{J} = \sigma \vec{E} \quad \text{—} (2)$$

Let's consider super conductors obey ohm's law

but for superconductor

Resistivity $\boxed{\rho = 0}$ ∵ $\boxed{\sigma = \frac{1}{\rho}}$

σ put in (2)

$$\vec{J} = \frac{\vec{E}}{\rho} \Rightarrow \boxed{\vec{E} = \rho \vec{J}}$$

But $\rho = 0$

$\boxed{\vec{E} = 0}$ put in (1)

$$\vec{\nabla} \times 0 = -\frac{\partial \vec{B}}{\partial t} \Rightarrow -\frac{\partial \vec{B}}{\partial t} = 0$$

Integrate both side w.r.t. time

$\boxed{\vec{B} = C}$ constant

∴ when material becomes superconductor then magnetic flux density with in the superconductor should be remain constant

So when ρ becomes zero inside material or superconductor then B also become zero

Hence our assumption is wrong
Hence superconductor does not obey ohms law. So they are non ohmic devices.

* Define Cooper pair :- When a material goes below critical temperature then electrons which are present in material they make pair with together and that pair of electrons in superconductor electrons are called cooper pair

* Isotope effects :- The critical temperature of superconductor varies with isotope mass. on the other words
Mass of isotope is inversely related to critical temperature

$$\boxed{T_c \propto \frac{1}{M^{\alpha}}}$$

Q) significance of london equation.
ans ⇒ (i) They provide a simple description of the Meissner effect.
(ii) They explain why superconductors have zero resistance to electric current
(iii) They have been used in eg MRI machines, superconducting magnets.

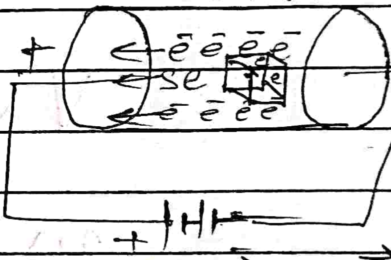
P(Q) Deduce London equations and define London penetration depth

(*) London equation and it's significance (पंचकर्म ईं)

→ In 1935, London brothers, F London & H London modified Maxwell's equation to explain the phenomena of superconductivity & gave london equation. According to london theory every super conductor contains two types of electron (i) Normal electron (ii) Super electron

When the temperature of superconductor is increased, no of normal electrons ($\bar{e}$) increased and when temperature of superconductor decreased, no of superelectron increased. at 0 kalvine all the $\bar{e}$ in superconductor are super $\bar{e}$

O-Kelvine



Let super electron $= n_s e$

$$\boxed{\vec{f} = -e\vec{E}}$$

according to Newton second law

$$\vec{f} = m\vec{a} \qquad \left(\vec{a} = \frac{d\vec{V_s}}{dt}\right)$$

$$\vec{E} = \frac{\vec{f}}{q} = \frac{\vec{f}}{\bar{e}}$$

$$\boxed{\vec{f} = -e\vec{E}}$$

(1) $\boxed{-e\vec{E} = m\left(\frac{d\vec{V_s}}{dt}\right)}$

$$\boxed{\frac{d\vec{V_s}}{dt} = \frac{-e\vec{E}}{m}} \quad (2)$$

$\because$ $\boxed{\vec{J} = \frac{i}{A}}$

$\because$ $i = -neAV \Rightarrow \frac{i}{A} = -nev \Rightarrow \boxed{\vec{J} = -nev}$

$$\vec{J} = -n_s e\vec{V_s} \quad (3)$$

diff eq (3) w.r.to. t

$$\boxed{\frac{d\vec{J_s}}{dt} = -n_s e \frac{d\vec{V_s}}{dt}} \quad (4)$$

put eq^n (2) in (4)

$$\frac{d\vec{J_s}}{dt} = -n_s e\left(\frac{-e\vec{E}}{m}\right)$$

$$\boxed{\frac{d\vec{J_s}}{dt} = \frac{e^2 n_s \vec{E}}{m}} \rightarrow \text{london 1st equation} \rightarrow (5)$$

from ~~e~~ eqⁿ (5) we find $\vec{E}$

$$\boxed{\vec{E} = \frac{m}{n_s e^2}\frac{d\vec{J_s}}{dt}} \text{ — } (6)$$

from maxwell ~~law~~ eqⁿ

$$\boxed{\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}} \text{ — } (7)$$

put eqⁿ (6) in (7)

$$\nabla \times \left(\frac{m}{n_s e^2}\frac{d\vec{J_s}}{dt}\right) = -\frac{\partial \vec{B}}{\partial t}$$

$$\frac{m}{n_s e^2}\left(\nabla \times \frac{d\vec{J_s}}{dt}\right) = -\frac{\partial \vec{B}}{\partial t}$$

Integrating both sides

$$\frac{m}{n_s e^2}\int\left(\nabla \times \frac{d\vec{J_s}}{dt}\right)dt = -\int_{\vec{B_0}}^{\vec{B}} \frac{\partial \vec{B}}{\partial t}\cdot dt$$

$$\frac{m}{n_s e^2}(\vec{\nabla} \times \vec{J_s}) = -\left[\vec{B}\right]_{\vec{B_0}}^{\vec{B}}$$

$$\frac{m}{n_s e^2}(\vec{\nabla} \times \vec{J_s}) = -(\vec{B} - \vec{B_0})$$

{ According to Missner effect $\vec{B_0} = 0$

$$\frac{m}{n_s e^2}(\vec{\nabla} \times \vec{J_s}) = -\vec{B}$$

$$\boxed{\vec{\nabla} \times \vec{J_s} = \frac{-\vec{B}\, n_s e^2}{m}} \text{ london second equation}$$

from maxwell eq^n $\vec{\nabla}\times\vec{B} = \mu_0\vec{J}$

Taking curl both side

$$\vec{\nabla}\times(\vec{\nabla}\times\vec{B}) = \mu_0(\vec{\nabla}\times\vec{J})$$

by a vector property $(\vec{A}\times(\vec{B}\times\vec{C})) = \vec{B}(\vec{A}\cdot\vec{C}) - \vec{C}(\vec{A}\cdot\vec{B})$

$$\vec{\nabla}(\vec{\nabla}\cdot\vec{B}) - \vec{B}(\vec{\nabla}\cdot\vec{\nabla}) = \mu_0\left(-\frac{\vec{B}n_s e^2}{m}\right)$$

from landon second eq^n.

$\because$ $\vec{\nabla}\cdot\vec{B} = 0$ so

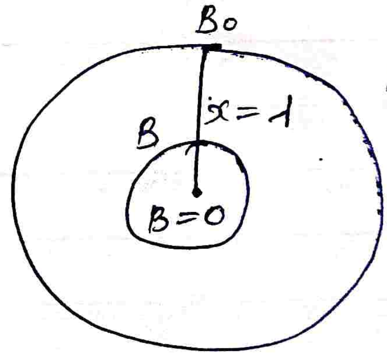
$$+\vec{\nabla}^2\vec{B} = +\frac{\mu_0 n_s e^2}{m}\vec{B}$$

Compair with $\boxed{\vec{\nabla}^2\vec{B} = \frac{1}{\lambda^2}\vec{B}}$

$$\boxed{\frac{1}{\lambda^2} = \frac{\mu_0 n_s e^2}{m}}$$ where λ is pentration depth

$$\boxed{\vec{\nabla}^2\vec{B} = \frac{1}{\lambda^2}\vec{B}}$$

sol^n. $\boxed{B(x) = B_0 e^{-\frac{x}{\lambda}}}$



$x = \lambda$

$B(x) = B_0 e^{-x/x}$

$B(x) = B_0 e^{-1}$

$\boxed{B(x) = \frac{B_0}{e}}$

so, B is decrasing by $\frac{1}{e}$

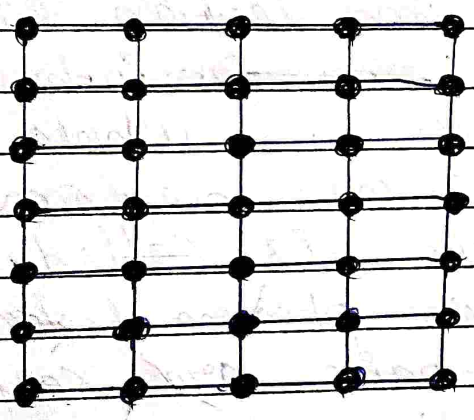
so, the depth at which B becomes zero is known as pentration depth ..

called electron phonon.

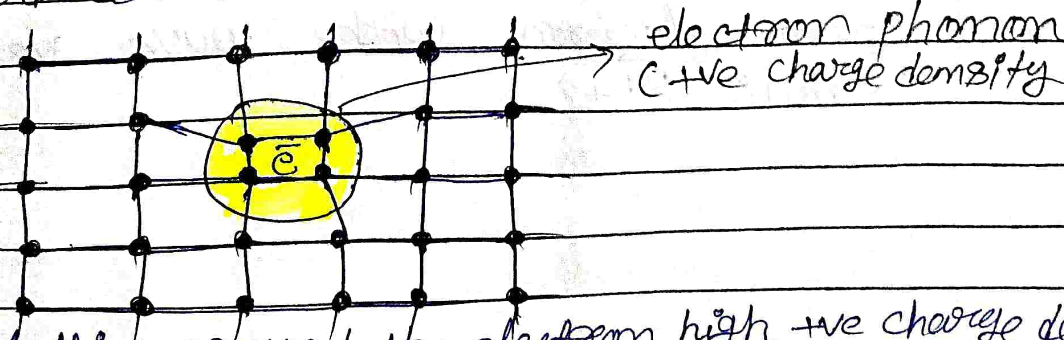
* BCS theory :- The quantum theory of superconductivity was given combinelly by three scientists Bardeen, Cooper and Schrieffer in 1957 this theory is called BCS theory

BCS theory explain superconductivity phenomena by 2 term
① electron ($\bar{e}$) phonon electron ($\bar{e}$) interaction
② Cooper pair

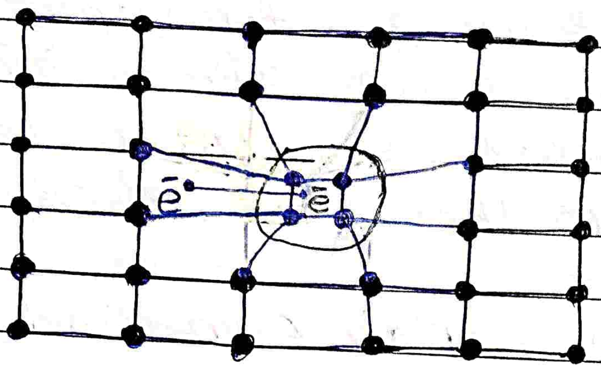
Let consider a normal lattice



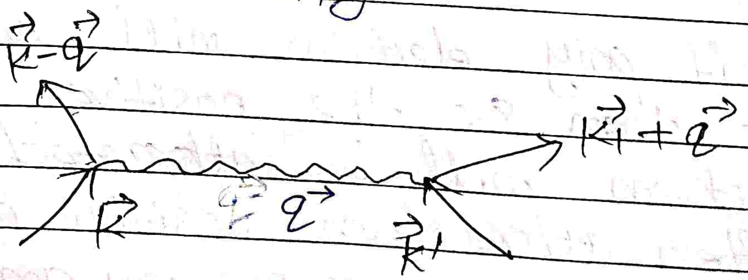
Now, if any electron will entered in lattice, than so the positive ions around the the electron will be attracted to the electron and after attraction positive ions will be displaced from own position and the bond of ions will be distorted so distoration will be produce in lattice.



In the lattice around the electron high +ve charge density will be produced called electron phonon.

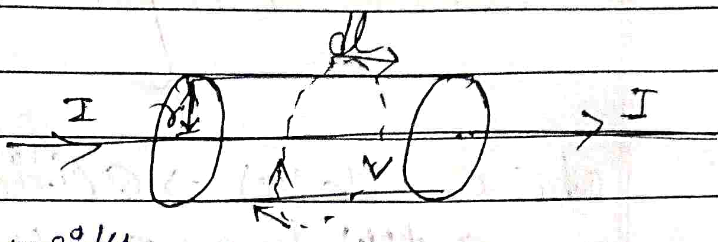


When another electron enters in the lattice so it will be attracted by the charge density and form a weak link between electron and phonon and this attraction between phonon and electron called electron phonon electron ~~attraction~~ interaction. Now 1st electron moves in whole lattice along with second electron in terms of pair this is called cooper pair so this electron phonon electron interaction and cooper pair are responsible for superconductivity.



Let the 1st electron have wave vector $\vec{k}$ & it emits a phonon $\vec{q}$ which is absorbed by second electron with wave vector $\vec{k'}$ and emits $k'+q$

* Silsbee's rule :



$r \rightarrow$ radius of wire
$I \rightarrow$ current of wire
$B \Rightarrow$ mag flux density

$\therefore$ By applying Ampere circuital law

$$\oint B \cdot dl = \mu_0 I$$

$$\oint B\,dl \cos 0^\circ = \mu_0 I \Rightarrow B(2\pi r) = \mu_0 I$$

$$\frac{B}{\mu_0}(2\pi r) = I \Rightarrow \boxed{H(2\pi r) = I} \text{ --- } (2)$$

let $H_c \rightarrow$ critical field
$H \leq H_c$ for material becom a superconductor

$$2\pi r H \leq 2\pi r H_c$$

$$I \leq 2\pi r H_c$$

I_C = max allowed current

$$\boxed{I_c = 2\pi r H_C} \rightarrow \text{absence of external magnetic field}$$

in the presence of external magnetic field I_c decreases

so $$\boxed{I_c = 2\pi r(H_c - 2H)}$$

This is called silsbee's rule.

* Numerical on critical temperature and critical magnetic field.

$$\boxed{H_C(T) = H_C(0)\left[1 - \frac{T^2}{T_C^2}\right]}$$

where $H_C(T)$ → critical magnetic field at any(K) temperature

$H_C(0)$ → critical magnetic field at 0K temperature
↳ or maximum magnetic field.

T → Temperature

T_C → critical temperature or Transition temperature

*PYQ The critical magnetic field for a superconductor at absolute zero is $9\times10^4\ Am^{-1}$ and at 6K is $5\times10^4\ Am^{-1}$. find the critical temperature and energy required to break cooper pair at absolute zero.

ans → given $H_C(0) = 9\times10^4\ Am^{-1}$
$H_C(6K) = 5\times10^4\ Am^{-1}$
find $T_C = ?$

$$H_C(T) = H_C(0)\left[1 - \frac{T^2}{T_C^2}\right]$$

$$5\times\cancel{10^4} = 9\times\cancel{10^4}\left[1 - \frac{36}{T_C^2}\right]$$

$$\frac{5}{9} = 1 - \frac{36}{T_C^2}$$

$$\frac{36}{T_C^2} = 1 - \frac{5}{9}$$

$$\frac{36}{T_C^2} = \frac{9-5}{9}$$

$$\frac{36}{T_C^2} = \frac{4}{9}$$

$$4T_C^2 = 36\times9$$

$$T_C^2 = \frac{\cancel{36}^{9}\times9}{\cancel{4}}$$

$$T_C^2 = 81$$

$$T_C = \sqrt{81} \qquad \boxed{T_C = 9K}$$

~~energy required to break cooper pair at absolute zero = 10^{-3} eV~~

Note → To find the energy required to break a cooper pair at absolute zero, we can use BCS theory

$$\boxed{\Delta = 1.76 \times K \times T_C}$$ $$\boxed{E = 3.54 \times 1.38 \times 10^{-23} \times T_C}$$

K = Boltzmann constant (1.38×10^{-23} J/K)

$\Delta = 1.76 \times$

$\Delta = 1.76 \times 1.38 \times 10^{-23} \times 9$

$\boxed{E = 2\Delta}$ $\Delta = 21.85 \times 10^{-23}$

energy require to break a cooper pair at absolute zero temp = 2Δ

$E = 2 \times 21.85 \times 10^{-23}$ $E = \frac{hc}{\lambda}$ | current density

$$\boxed{E = 43.71 \times 10^{-23}\ J}$$ $$\boxed{\lambda = \frac{hc}{E}}$$ $H_C = \frac{I_C}{2\pi r}$, $I_C = H_C 2\pi r$

you can get wavelength also

PYQ Given critical magnetic field of material at 0K is 15×10^{3} A/m calculate critical magnetic field at temp 5K for the same material. Given $T_C = 7K$.

ans →

$H_C(0) = 15 \times 10^{-3}$ A/m

$H_C(5K) = ?$ $H_C(T) = H_C(0)\left[1 - \frac{T^2}{T_C^2}\right]$

$T_C = 7K$

$H_C(5K) = 15 \times 10^{-3}\left[1 - \frac{25}{49}\right]$

$H_C(5K) = 15 \times 10^{-3}\left[1 - 0.51\right]$

$H_C(5K) = 15 \times 10^{3}[0.49] \Rightarrow \boxed{H_C(5K) = 7.35 \times 10^{-3}}$ A/m

Page No.
Date : / 20

PYQ Lead in superconducting state has critical temperature of 7K at zero magnetic field and critical field of 8.5 T at 0 K. Determine the critical field at 4K.

ans ⇒ $T_c = 7K$, $H_c(0) = 8.5\ T$ (Tesla)
$H_c(4K) = ?$, $T = 4K$.

Imp Note → To convert tesla to Ampere Per metre a formula here

$$\boxed{H = \frac{x\,T}{4\pi \times 10^{-7}}\ A/m}$$

$$\frac{8.5\,T}{4\pi \times 10^{-7}} = 6.76 \times 10^{-8}\ A/m$$

$$H_c(T) = H_c(0)\left[1 - \frac{T^2}{T_c^2}\right]$$

$$H_c(4K) = 6.76 \times 10^{-8}\left[1 - \frac{16}{49}\right]$$

$$= 6.76 \times 10^{-8}\left[1 - 0.32\right]$$

$$H_c(4K) = 6.76 \times 10^{-8}\left[0.68\right]$$

$$H_c(4K) = 4.60 \times 10^{-8}$$

$$\boxed{H_c(4K) = 4.60 \times 10^{-8}}\ A/m$$

PYQ For a given superconductor sample value of critical magnetic field corresponding to 14K and 13K respectively are 2.8×10^{5} A/m and 5.6×10^{5} A/m find critical temp T_c and critical magnetic field value at 0K.

ans→ $Hc(14) = 2.8 \times 10^5$ A/m
$Hc(13) = 5.6 \times 10^5$ A/m

$Tc = ?$, $Hc(0K) = ?$

for at tem 14K

$$Hc(14K) = Hc(0)\left[1 - \frac{T^2}{Tc^2}\right]$$

$$2.8 \times 10^5 = Hc(0)\left[1 - \frac{14^2}{Tc^2}\right]$$

$$2.8 \times 10^5 = Hc(0)\left[\frac{Tc^2 - 196}{Tc^2}\right] \quad \text{—— A}$$

for at tem 13K

$$Hc(13K) = Hc(0K)\left[1 - \frac{T^2}{Tc^2}\right]$$

$$5.6 \times 10^5 = Hc(0)\left[\frac{Tc^2 - 169}{Tc^2}\right] \quad \text{—— B}$$

divide eqn B ÷ A

$$\frac{\cancel{5.6 \times 10^5}\,2}{\cancel{2.8 \times 10^5}} = \frac{\cancel{Hc(0)}\left[\frac{Tc^2 - 169}{Tc^2}\right]}{\cancel{Hc(0)}\left[\frac{Tc^2 - 196}{Tc^2}\right]}$$

$$2 = \frac{Tc^2 - 169}{\cancel{Tc^2}} \times \frac{\cancel{Tc^2}}{Tc^2 - 196}$$

$$2 = \frac{Tc^2 - 169}{Tc^2 - 196} \Rightarrow 2Tc^2 - 392 = Tc^2 - 169$$

$$2Tc^2 - Tc^2 = -169 + 392$$

$$Tc^2 = 223 \qquad \boxed{Tc = 14.93\ K}$$

$$Hc(14K) = Hc(0K)\left[1 - \frac{196}{(14.93)^2}\right]$$

$$2.8\times10^5 = Hc(0K)\left[\frac{223-196}{223}\right]$$

$$\boxed{2.8\times10^5 = Hc(0)\left[\frac{27}{223}\right]}$$

$$27\,Hc(0) = 223\times2.8\times10^5$$

$$Hc(0K) = \frac{223\times2.8\times10^5}{27}$$

$$Hc(0K) = 8.25\times2.8\times10^5$$

$$\boxed{Hc(0K) = 23.1\times10^5\ A/m}$$

Shortcut

$$2.8\times10^5 = Hc(0)(0.1210)$$

$$Hc(0) = \frac{2.8\times10^5}{0.1210}$$

$$\boxed{Hc(0) = 23.1\times10^5\frac{A}{m}}$$

Q10) For a given superconducting sample the values of critical magnetic field corresponding to 0K and 5K respectively are 10×10^6 A/m and 5×10^6 A/m find wavelength of a photon required to break cooper pairs in the superconductor given Boltzmann's constant $K = 1.38\times10^{-23}$ J/K.

Ans

$$Hc(0) = 10\times10^6\ A/m$$

$$Hc(5K) = 5\times10^6\ A/m$$

$$\lambda = ? \quad K = 1.38\times10^{-23}\ J/K$$

$$E = 3.54\times1.38\times10^{-23}\times Tc$$

$$E = \frac{hc}{\lambda} \qquad \boxed{\lambda = \frac{hc}{E}}$$

$$Hc(T) = Hc(0)\left[1 - \frac{T^2}{T_c^2}\right]$$

$$5 \times 10^6 = 10 \times 10^6 \left[1 - \frac{25}{T_c^2}\right]$$

$$\frac{5 \times 10^6}{10 \times 10^6} = \left[1 - \frac{25}{T_c^2}\right] \Rightarrow \frac{1}{2} = 1 - \frac{25}{T_c^2}$$

2

$$\frac{25}{T_c^2} = 1 - 0.5$$

$$\frac{25}{T_c^2} = \frac{0.5}{1}, \quad T_c^2(0.5) = 25$$

$$T_c^2 = \frac{25}{0.5}, \quad T_c^2 = 50$$

$$\boxed{T_c = 7.07\,K} \quad \text{So} \quad \boxed{E = 3.54 \times k \times T_c}$$

$$E = 3.54 \times 1.38 \times 10^{-23} \times 7.07 \qquad E = \frac{hc}{\lambda}$$

$$\boxed{E = 34.53 \times 10^{-23}}\ J \qquad \boxed{\lambda = \frac{hc}{E}}$$

$$\lambda = \frac{6.62 \times 10^{-34} \times 3 \times 10^8}{34.53 \times 10^{-23}} \qquad \lambda = \frac{19.86 \times 10^{-34} \times 10^{23} \times 10^8}{34.53}$$

$$\cancel{\lambda = 0.57 \times 10^{-3}}$$

$$\boxed{\lambda = 0.57 \times 10^{-3}}$$

$$\cancel{\lambda = 5.7 \times 10^{-4}} \qquad \boxed{\lambda = 0.575152041 \times 10^{-3} m}$$

$$\cancel{\lambda = 5.75 \times 10^{-10}}$$

$$\cancel{\lambda = 5.75\,Å}$$

PYQ Calculate ~~to~~ the wavelength of the photon which will be required to break cooperpair in superconducting Zr with $T_c = 0.56K$

ans ⇒ $E = 3.54 \times 1.38 \times 10^{-23} \times 0.56K$ $\qquad \lambda = \frac{19.86 \times 10^{-34} \times 10^8}{2.73 \times 10^{-23}}$

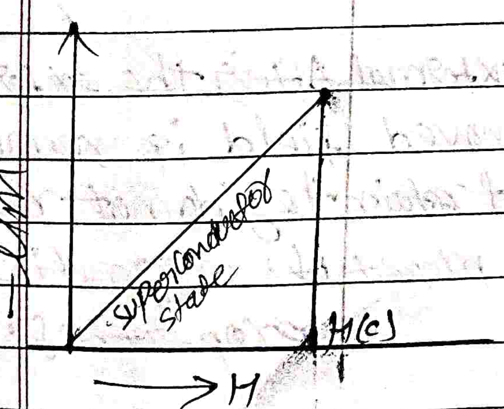
$$\boxed{E = 2.73 \times 10^{-23}}\ J$$

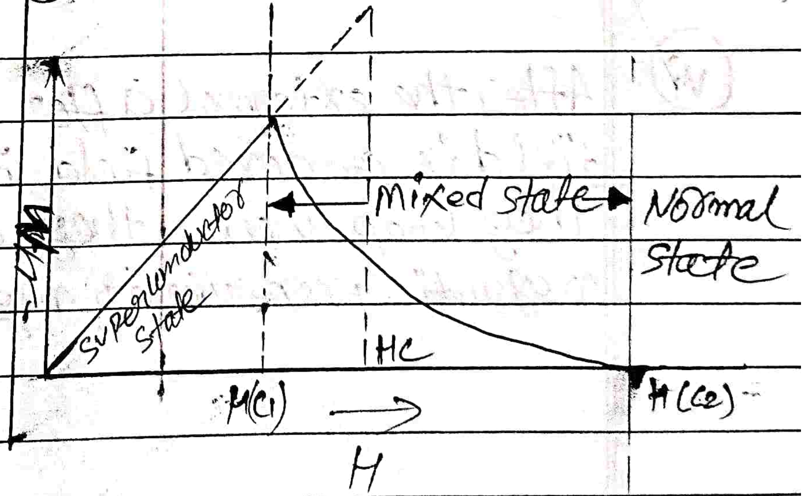
$$\boxed{\lambda = 7.27 \times 10^{-3}}\ m$$

P 78 ① Differenciate type-1 and type-2 superconductor

Type-1	Type-2
(i) It is also known as soft superconductor	(i) It is also known as hard superconductor
(ii) There is only one (Hc) critical magnetic field	(ii) There are two critical magnetic field. (HC1) & (HC2)
(iii) In this critical magnetic field is very low.	(iii) In this critical magnetic field is very high.
(iv) It shows perfect meissner effect.	(iv) It does not show perfect meissner effect.
(v) It is complete diamagnetic material.	(v) It does not complete diamagnetic material
(vi) Ex ⇒ Pb	(vi) Ex ⇒ Ba

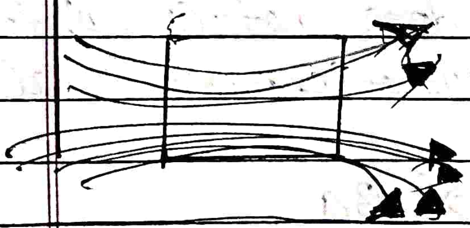
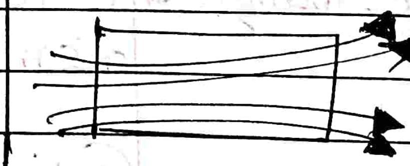
(vii)





Page No.
Date : / 20

PYQ Compare any four properties of diamagnetic, paramagnetic and ferromagnetic subtances.

	Ferromagnetic	Paramagnetic	diamagnetic
(i)	They are Solid	They can be solid, liquid or gas	They can be solid, liquid or gas.
(ii)	They strongly attracted by a magnet.	They weakly attracted by a magnet	They weakly repelled by a magnet.
(iii)	They tend to move from low to high field region.	They tend to move from low to high field region.	They tend to move from high to low field region.
(iv)	Ex ⇒ Iron	Ex ⇒ Lithium	Ex ⇒ Copper
(v)			
(vi)	After the external field is removed they keep their magnetic properties	after the external field is removed they do not retain its magnetic properties	After the external field is removed they do not retain its magnetic properties.

Page No.
Date : / 20

Q dielectric materials :- A dielectric material is a poor conductor of electricity but an efficient supporter of electrostatic fields. I can store electrical charges, have a high resistance and negative temperature coefficient of resistance.

Q B-H curve → from bee Notebook

Q Magnetostriction :- Coupling between the magnetization and the lattice does result in deformation, an effect called magnetostriction.

Q Magnetic anisotropy → Magnetic anisotropy refers to the property of a magnetic material that makes it exhibit different magnetic properties along different directions.

(दिखाना → exhibit)