ENGINEERING PHYSICS BT - 201

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

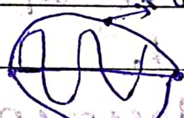
Date: / / Page no: 2

★ Properties of Matter waves :-

① $\boxed{\lambda = \frac{h}{mv}}$. h = constant

① If $m = 0$, $\lambda = \infty$
For the existance of wave , $m \neq 0$
(It should be material particle)

② For the existance of λ, $v \neq 0$
(particle should be moving particle)



③ Not EM wave (does not depend on charge)

④ Velocity of matter wave is greater then speed of light 'c'.

Relation in particle velocity, phase velocity, wave velocity (Phase velocity)

- Particle velocity :- Let we consider a particle of mass 'm' and velocity 'v', then its kinetic energy 'E' will be equal to

$E = \frac{1}{2} m v^2$

$v = \sqrt{\frac{2E}{m}}$ —— ①

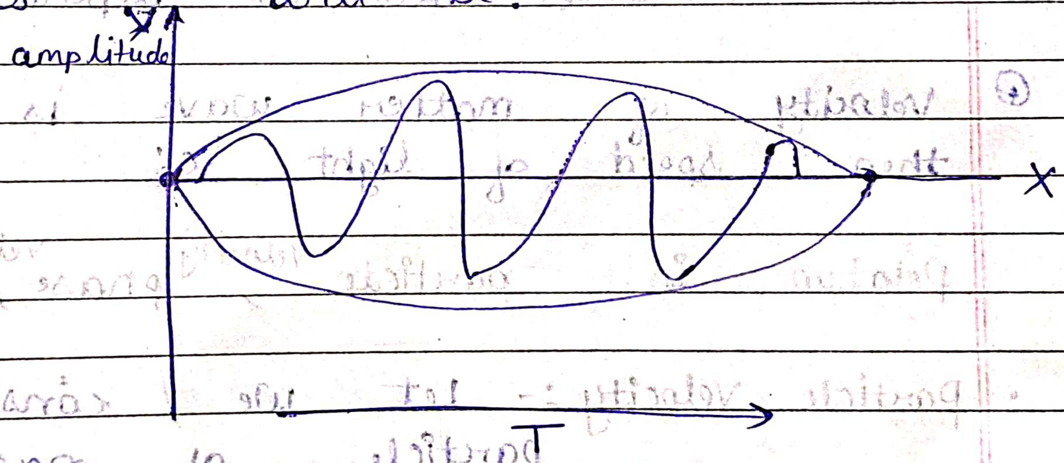
and

$E = h\nu$ planck's ~~constant~~ law of radiation.

$$v = \sqrt{\frac{2h\nu}{m}} \quad \text{--- (2)}$$

★ Group, wave (phase) velocity

Let we consider a wave packet in which two waves of same amplitude 'A' and slitly difference in angular frequencies (ω_1, ω_2) and propagation constant (k_1, k_2) propagat in x direction then displacement equations for the waves will be.



resulting of displacement 'y'

$$Y_1 = A \sin(\omega_1 t - k_1 x) \quad \text{--- (1)}$$

$$Y_2 = A \sin(\omega_2 t - k_2 x) \quad \text{--- (2)}$$

$$Y = Y_1 + Y_2$$

Date: / / Page no:

(6) $y = A [\sin(\omega_1 t - k_1 x) + \sin(\omega_2 t - k_2 x)]$

$\sin C + \sin D = 2 \sin \frac{C+D}{2} \cos \frac{C-D}{2}$

$y = A \left[2 \sin \left(\frac{\omega_1 + \omega_2}{2} t - \frac{(k_1 + k_2)}{2} x \right) \cos \left(\frac{(\omega_1 - \omega_2)}{2} t - \frac{(k_1 - k_2)}{2} x \right) \right]$

Consider, $\frac{\omega_1 + \omega_2}{2} = \omega$, $\frac{k_1 + k_2}{2} = k$

$\frac{\omega_1 - \omega_2}{2} = \frac{d\omega}{2}$, $\frac{k_1 - k_2}{2} = \frac{dk}{2}$

$$y = A \left[2 \sin(\omega t - kx) \cos \left(\frac{d\omega}{2} t - \frac{dk}{2} x \right) \right] \quad (3)$$

Standard equation for displacement is

$$y = A \sin(\omega t - kx) \quad (4)$$

Compare eq. (3) & (4)

$$y = 2A \cos \left(\frac{d\omega t}{2} - \frac{dkx}{2} \right) \sin(\omega t - kx) \quad (5)$$

eq^n (5) $2A \cos \left(\frac{d\omega}{2} t - \frac{dk}{2} x \right)$ is cosine term or amplitude.

Date: / / Page no:

from sine term of equation (5)

$\sin(\omega t - kx)$,

wave (phase) velocity $= \frac{\omega}{k}$

$$\boxed{v_p = \frac{\omega}{k}} \quad \text{—— (6)}$$

$\omega t = kx$

$\frac{x}{t} = \frac{\omega}{k}$

velocity $= \frac{\omega}{k}$

from cosine term,

$$\cos\left(\frac{d\omega}{2} t - \frac{dk}{2} x\right)$$

$$\frac{\frac{d\omega}{\cancel{2}}}{\frac{dk}{\cancel{2}}} = \text{velocity}$$

group velocity $= \frac{d\omega}{dk}$

$$\boxed{v_g = \frac{d\omega}{dk}} \quad \text{—— (7)}$$

Date: / / Page no:

- Relation between particle and group velocity. (non-relativistic)

From the definition of group velocity

$$V_g = \frac{d\omega}{dk} \quad \text{--- (1)}$$

A wave (Packet) move with its own velocity known as group velocity.

from, $d\omega = 2\pi \nu$, $k = \frac{2\pi}{\lambda}$

$$v_g = \frac{d(2\pi\nu)}{d\left(\frac{2\pi}{\lambda}\right)}$$

$$v_g = \frac{\cancel{2\pi}\,(d\nu)}{\cancel{2\pi}\, d\left(\frac{1}{\lambda}\right)}$$

$$\frac{1}{v_g} = \frac{d\left(\frac{1}{\lambda}\right)}{d\nu} \quad \text{--- (2)}$$

from de-Broglie hypothesis

$$\lambda = \frac{h}{p} \quad \text{--- (3)} \qquad \boxed{\lambda = \frac{h}{mv}}$$

$$\lambda = \frac{h}{\sqrt{2mE}}$$

$E = h\nu$ --- Plank's Law

$$\lambda = \frac{h}{\sqrt{2mh\nu}}$$

$$\frac{1}{\lambda} = \frac{(2mh\nu)^{1/2}}{h} \quad — (4)$$

From eq. (2) and (4) we get

$$\frac{1}{V_g} = \frac{d}{d\nu} \frac{(2mh\nu)^{1/2}}{h}$$

$$= \frac{1}{h}\left[\frac{1}{2}(2m.h\nu)^{-1/2} \times 2mh\right]$$

$$\frac{1}{V_g} = \frac{1}{h} \times \frac{1}{2} \times \frac{1}{\sqrt{2mh\nu}} 2mh$$

$$\frac{1}{V_g} = \sqrt{\frac{m^2}{2mh\nu}}$$

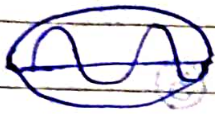
$$\frac{1}{V_g} = \sqrt{\frac{m}{2h\nu}} \quad — (5)$$

From partical velocity

$$v = \sqrt{\frac{2h\nu}{m}} \quad (6)$$

$$\frac{1}{V_{group}} = \frac{1}{v}$$

$$\boxed{V_g = v} \quad — (7)$$

 =

group velocity is equal to particle velocity

- Relation b/w particle and group velocities (relativistic)

put $\boxed{m = \frac{m_0}{\sqrt{1 - v^2/c^2}}}$ $\left\{ \begin{array}{l} E_0 = m_0 c^2 \\ E = mc^2 \end{array} \right.$

Same derivation of non relativistic only change in "m"

* Relation in v_p and v_g

from, phase → $v_p = \frac{\omega}{k}$ — ① $\left\{ V_g = \frac{d\omega}{dk} \right.$ → group

or $\omega = v_p \cdot k$ — ②

② diff. w.r. to. k

$$\frac{d\omega}{dk} = v_p \frac{dk}{dk} + k \frac{dv_p}{dk} \quad — ③$$

or $$\boxed{v_g = v_p + k \frac{dv_p}{dk}} \quad ④$$

where $v_g = \frac{d\omega}{dk}$

$\boxed{k = \frac{2\pi}{\lambda}}$, $k = 2\pi\lambda^{-1}$ diff. w.r. to k.

$$dk = 2\pi\left[-1\lambda^{-2}\right] d\lambda$$

from eqn ④ $$v_g = v_p + \frac{2\pi}{\lambda} \frac{dv_p}{(-2\pi) d\lambda} \lambda^2$$

Date: / / Page no:

$$\boxed{v_g = v_p - \lambda \frac{dv_p}{d\lambda}} \quad \text{—— (5)}$$

if $\frac{dv_p}{d\lambda} = 0$; $\boxed{v_g = v_p}$ —— (6)

v_p independent of λ' non dispersive midium.

For dispersive medium

$$\frac{dv_p}{d\lambda} \neq 0$$

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

$$\boxed{v_p > v_g}$$

* Relation in wave (Phase) velocity v_p and particle velocity v

from wave velocity $v_p = \frac{\omega}{k}$ —— (1)

$$\omega = 2\pi\nu \quad , \quad k = \frac{2\pi}{\lambda}$$

$$v_p = \frac{\omega}{k} = \frac{2\pi\nu}{\frac{2\pi}{\lambda}}$$

$$v_p = \nu\lambda \quad \text{—— (2)}$$

from

$E = h\nu$ Planck's law

$$\nu = \frac{E}{h} = \left(\frac{\frac{1}{2}mv^2}{h}\right)$$

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

$$\lambda = \frac{h}{mv}$$ — de Broglie hypothesis.

$$v_p = \left(\frac{\frac{1}{2}mv^2}{h}\right)\left(\frac{h}{mv}\right)$$

$$\boxed{v_p = \frac{1}{2}v} \leftarrow (3).$$

Phase velocity v_p is half of particle velocity v

Q. Show that wave velocity & velocity of matter wave is greater then speed of light.

Wave velocity $V_p = \frac{\omega}{k}$ — (1)

$\omega = 2\pi\nu$, $k = \frac{2\pi}{\lambda}$

$$v_p = \frac{\omega}{k}$$

$$v_p = \frac{2\pi\nu}{\frac{2\pi}{\lambda}}$$

$$v_p = \frac{2\pi\nu}{1} \times \frac{\lambda}{2\pi}$$

$$\boxed{v_p = \nu\lambda} \leftarrow (2)$$

$$E = h\nu$$

$$\nu = \frac{E}{h} \text{ — (3)}$$

$$\lambda = \frac{h}{mv} \text{ — (4)}$$

$$v_p = \frac{E}{h} \times \frac{h}{mv}$$ $\frac{h}{mv} = \lambda$

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

$$\boxed{v_p = \frac{c^2}{v}} \quad (5)$$

or

$$\boxed{v_p \cdot v = c^2} \quad (6)$$

Always $v << c$, then
$v_p >> c$

ये लिखना नहीं है ये सिर्फ समझने के लिए है

It is impossible, $v \approx c$ {then $v_p \approx c$}
mass, $m \rightarrow 0$ (micro particle)

Particle should be microparticle.

Heisenberg's Uncertaintly particle:-

It is impossible to determine exact position and momentum of microparticle simultaneously.

Let we consider a wave packet, at the boundary of wave packet position are x_1 and x_2 (assume) then change in position is

$\Delta x (= x_1 \sim x_2)$ and if change

$\hbar$ (h not)

in velocity be Δv or momentum ΔP ($= m \Delta v$) then mathematically

$$\Delta x \cdot \Delta P \geq \frac{h}{4\pi}$$

where, h is planck's constant,

$h = 6.6 \times 10^{-34}$ Joule sec.

$$\left\{ \frac{h}{2\pi} = \hbar \text{ (h not)} \right\}$$

or

$$\Delta x \cdot \Delta P \geq \frac{\hbar}{2}$$

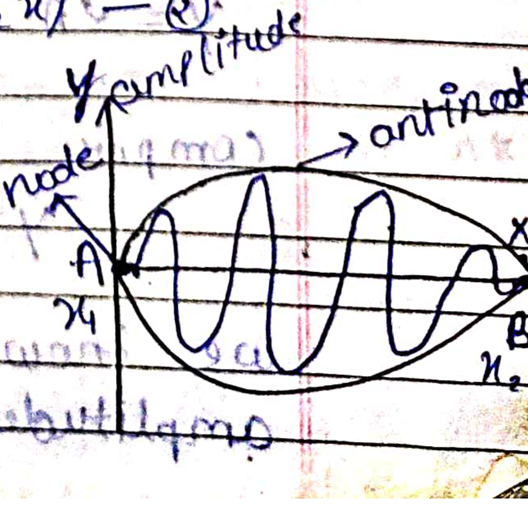
Proof:-

Let we consider two waves in a wave packet of amplitude 'A' and ω_1, k_1 and ω_2, k_2 are angular frequencies and propagation constants respectively. Displacement eqn of the wave are

$$y_1 = A \sin(\omega_1 t - k_1 x) \quad \text{--- (1)}$$

$$y_2 = A \sin(\omega_2 t - k_2 x) \quad \text{--- (2)}$$

$$y = y_1 + y_2$$



$$y = A[\sin(\omega_1 t - k_1 x) + \sin(\omega_2 t - k_2 x)]$$

$$\sin C + \sin D = 2 \sin \frac{C+D}{2} \cdot \cos \frac{C-D}{2}$$

$$y = A\left[2 \sin \left(\frac{\omega_1 t - k_1 x + \omega_2 t - k_2 x}{2}\right) \cdot \cos\left(\frac{\omega_1 t - k_1 x - \omega_2 t + k_2 x}{2}\right)\right]$$

$$y = A\left[2 \sin \left(\left(\frac{\omega_1 + \omega_2}{2}\right)t - \left(\frac{k_1 + k_2}{2}\right)x\right) \cdot \cos\left(\left(\frac{\omega_1 - \omega_2}{2}\right) - \left(\frac{k_1 - k_2}{2}\right)x\right)\right]$$

Assume $\frac{\omega_1 + \omega_2}{2} \approx \omega$ $\quad \frac{k_1 + k_2}{2} \approx k$

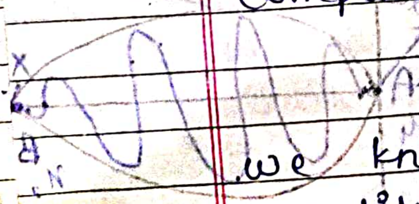
$\frac{\omega_1 - \omega_2}{2} \approx \frac{d\omega}{2}$, $\frac{k_1 - k_2}{2} \approx \frac{dk}{2}$

$$y = 2A \sin(\omega t - kx) \cos\left(\frac{d\omega}{2} t - \frac{dk}{2} x\right)$$

In above eq^n $2A \cos\left(\frac{d\omega}{2} t - \frac{dk}{2} x\right)$ is amplitude

$$y = 2A \cos\left(\frac{d\omega}{2} t - \frac{dk}{2} x\right) \sin(\omega t - kx)$$

compare with
$$y = A \sin(\omega t - kx)$$



we know that at node (point A and B amplitude is zero or

Date: / / Page no:

or $2A \cos\left(\frac{d\omega}{2}t - \frac{dk}{2}x\right) = 0$ ——— ①

or $\cos\left(\frac{d\omega}{2}t - \frac{dk}{2}x\right) = \cos \pi/2$

$$\frac{d\omega}{2}t - \frac{dk}{2}x = \pi/2 \quad \text{——— ②}$$

or At point 'A'

$$\frac{d\omega}{2}t - \frac{dk}{2}x_1 = \pi/2$$

At point 'B'

$$\frac{d\omega}{2}t - \frac{dk}{2}x_2 = 3\pi/2$$

by elinimation method.

$$\cancel{\frac{d\omega}{2}t} - \frac{dk}{2}x_1 = \pi/2$$

$$\cancel{\frac{d\omega}{2}t} - \frac{dk}{2}x_2 = 3\pi/2$$

$$- \quad + \qquad -$$

$$\Rightarrow \frac{dk}{2}(x_2 - x_1) = -\pi \Rightarrow \cancel{-}\frac{dk}{2}(x_1 - x_2) = \cancel{-}\pi$$

$$\Rightarrow \frac{dk}{2}\Delta x = \pi \Rightarrow \frac{\Delta k}{2}\Delta x = \pi \qquad \left\{ \begin{array}{l} x_1 - x_2 = \Delta x \\ dk = \Delta k \end{array} \right.$$

$$\Rightarrow \boxed{k = 2\pi/\lambda}, \quad \boxed{k = \frac{2\pi p}{h}} \quad \text{or}$$

$$\boxed{\lambda = \frac{h}{p}} \text{ de Broglie hypothesis} \qquad \Delta k = \Delta \frac{2\pi}{h}\Delta p$$

$$\frac{\frac{2\pi}{h}\Delta p}{2}\,\Delta x = \pi$$

or $$\Delta x \cdot \Delta p = \frac{\pi \times 2 \times h}{2\pi}$$

$$\Delta x \cdot \Delta p = h \quad \text{---} \; (3)$$

hence proved.

Product of change in position and change in momentum is in order of planck's constant 'h'.

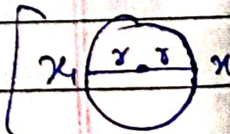
* Verifications :-

1. Electron can not exist in the nucleus
we know that, radius of nucleus = 10^{-14} r
max^m K.E. = 4 MeV.

Using Heisenberg's uncertainty principle,

$$\Delta x \cdot \Delta p = \frac{h}{4\pi}$$

$$\Delta x = 2 \times r = 2\times 10^{-14}\,m$$



$$\boxed{\Delta p = \frac{h}{4\pi \times \Delta x}}$$

$$\Delta p = \frac{6.6\times10^{-34}\,J\cdot sec}{4\times3.14\times2\times10^{-14}\,m} = 0.2627\times10^{-20}$$

$E = \sqrt{(m_0c^2)^2 + (PC)^2} \Rightarrow$ 60.= MeV

ये भी हो सकती है

Date: / / Page no.

$\Delta P = 2.627 \times 10^{-21}$ kg m/sec.

$E = \Delta P\, C$

$= 2.62 \times 10^{-21} \dfrac{J\,sec}{m} \times 3 \times 10^{8} \dfrac{m}{sec}$

$= \dfrac{7.86 \times 10^{-13}\, J}{1.6 \times 10^{-19}\, C}$

$E = 4.91 \times 10^{6}\ eV$

$\boxed{E = 4.91\ MeV}$ ----- $10^{6}\ eV = 1\ MeV$

It is clear that [4.9 MeV > 4 MeV], electron does not exist in the nucleus.

$E = \sqrt{(m_0c^2)^2 + (PC)^2}$

$\Leftarrow$ size of slit in order of $\boxed{e=\lambda}$

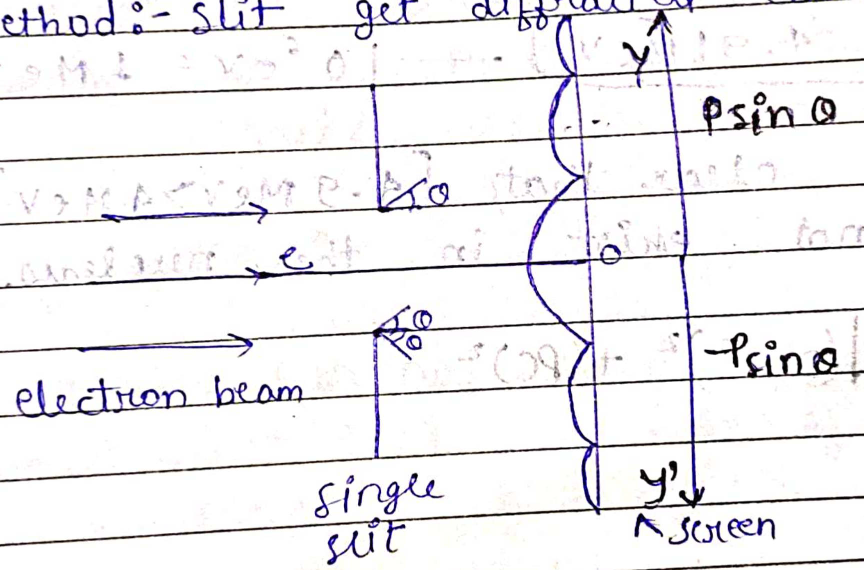
Date: / / Page no:

* Verification :-

2. Diffraction at single slit :-

Parts :- It based on diffraction phenomena in this experiment an electron beam, a single slit (of size 'e') and a screen used.

Method :- Electron beam passes through the single slit get diffracted (bend) to the corner with diffraction angle θ. We can observe diffraction pattern on screen.



Using Heisenberg's uncertainty principle.

$$\boxed{\Delta x \cdot \Delta P \geq \frac{h}{4\pi}}$$

$\Delta x = e$, and from diffraction at single slit : $e\sin\theta = n\lambda$

or $\Delta x = e = \dfrac{\lambda}{\sin\theta}$ [n = 1 for max^m intensity

$\Delta P = p\sin\theta - (-p\sin\theta) = 2p\sin\theta$

Date: / / Page no:

we can find $\Delta x . \Delta p$

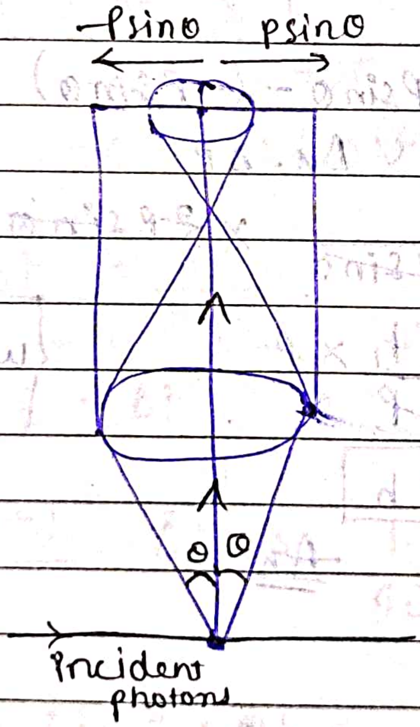
$$= \frac{\lambda}{\sin\theta} \times 2 p \sin\theta$$

$$\Delta x . \Delta p = 2 p \lambda = 2p \times \frac{h}{p} = 2h \quad \left\{ \lambda = \frac{h}{p} \right.$$

$$\boxed{\Delta x . \Delta p = 2h}$$

* Verification :-

3. Electron Microscope :-



$\boxed{4000-7800 \mathring{A}}$
VIBGYOR

$1.7 \mathring{A}$

Date: / / Page no:

Using uncertainty principle

$$\Delta x \cdot \Delta P \geq \frac{h}{4\pi}$$

$\Delta x = e$ and from electron microscope

$\because$ $2d \sin\theta = \lambda$

or

$$\Delta x = d = \frac{\lambda}{2\sin\theta}$$

We can find

$$\Delta P = P\sin\theta - (-P\sin\theta) = 2P\sin\theta$$

we can find $\Delta x \cdot \Delta P$

$$= \frac{\lambda}{\cancel{2\sin\theta}} \times \cancel{2P\sin\theta}$$

$$\Delta x \cdot \Delta P = \frac{h}{\cancel{p}} \times \cancel{P}$$ {where, $\lambda = \frac{h}{P}$

$$\boxed{\Delta x \cdot \Delta P = h}$$

Ans

7/04/2023

Date: / / Page no:

* Prove that $\Delta E \, \Delta t \sim h$ using Heisenberg's uncertainity principle.

I

$$\Delta x \cdot \Delta P \geq \frac{h}{4\pi} \quad \text{--- (1)}$$

$\Delta P = M \cdot \Delta v$

$$\Delta v = \frac{\Delta x}{\Delta t},$$

$$\Delta v \cdot \Delta t \cdot M \Delta v \geq \frac{h}{4\pi}$$

$$M(\Delta v)^2 \cdot \Delta t \geq \frac{h}{4\pi} \quad \text{--- (2)}$$

assume $\Delta E = M(\Delta v)^2$

$$\Delta E \cdot \Delta t \geq \frac{h}{4\pi}$$

or $\Delta E \cdot \Delta t \sim h$

II

$$\frac{2m(\Delta v^2)}{2} \, \Delta t \geq \frac{h}{4\pi}$$

$$\Delta E \cdot \Delta t \geq \frac{1}{2} \cdot \frac{h}{4\pi}$$

or $\Delta E \cdot \Delta t \sim h$

Date: / / Page no:

Que. Calculate Uncertainity in position for an electron if its velocity is 300 m/s with accuracy 0.001%

$\Delta x = ?$

$\Delta v = 300 m/s$

accuracy = 0.001%

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

$$\Delta x \cdot \Delta P \geq \frac{h}{4\pi}$$

$$\Delta x \geq \frac{h}{4\pi \cdot \Delta P}$$

$$\Delta x \geq \frac{h}{\Delta P \cdot 4\pi}$$

$\Delta P = M.\Delta v$

$\Delta v = v \times$ limit of accuracy

$= 300 m/s \times \frac{0.001}{100}$

$\Delta v = 0.003 m/s$

$$\Delta x = \frac{6.6 \times 10^{-34} J/sec}{4 \times 3.14 \times 9.1 \times 10^{-31} kg \times 0.003 m/s}$$

$$= \frac{6.6 \times 10^{-34} Jsec}{0.342 \times 10^{-31} kg\ m/s}$$

$= 19.29 \times 10^{-34+31}$ m

$= 19.29 \times 10^{-3}$ m

$= 1.929 \times 10^{-2}$ m

* Operators

* E and P operators

Wave function ψ can be written as

$$\psi = A e^{-i(\omega t - kx)} \quad \text{—— (1)}$$

where,

ω and k are angular frequency and propogation constant

'ψ' has real, imaginary, root, negative, and positive valued.

Therefore, ψ is not observable and not acceptable

$$\psi = A + iB \quad \text{—— (2)}$$

$\omega = 2\pi\nu$, $k = \frac{2\pi}{\lambda}$

eq^n (1) becomes,

$$\psi = A e^{-i(2\pi\nu t - \frac{2\pi}{\lambda} x)}$$

$E = h\nu$ —— Planck's law

$$\boxed{\nu = \frac{E}{h}}$$

$\lambda = \frac{h}{P}$ —— de Broglie hypothesis

$$\boxed{\frac{1}{\lambda} = \frac{p}{h}}$$

$$\psi = A\, e^{-i\left(\frac{2\pi}{h}Et - \frac{2\pi}{h}px\right)}$$

$$\psi = A e^{-\frac{i}{\hbar}(Et - px)} \quad \text{———} \ (3) \qquad \left[\hbar = \frac{h}{2\pi}\right]$$

eq^n (3) diff. w.r.to 't'

$$\frac{d\psi}{dt} = A e^{-\frac{i}{\hbar}(Et - px)}\left[\frac{-i}{\hbar}(E-0)\right]$$

$$\frac{d\psi}{dt} = \frac{-i}{\hbar} E\psi$$

$$E\psi = \frac{\hbar i}{(-i^2)} \cdot \frac{d\psi}{dt}$$

$$\boxed{E\psi = \frac{\hbar}{-i} \cdot \frac{d\psi}{dt}} \quad \text{———} \ (4)$$

multiply and devide b (i) in eq (4)

$$E\psi = i\hbar \frac{d\psi}{dt} \qquad \{i^2 = -1\}$$

$$\boxed{E - \text{operator} = i\hbar \frac{d}{dt}} \quad \text{———} \ (5)$$

Again diff. eq. (3) w.r.to 'x'

$$\frac{d\psi}{dx} = A e^{-\frac{i}{\hbar}(Et - px)}\left[\frac{-i}{\hbar}(0-p)\right]$$

$$\frac{d\psi}{dx} = \frac{i}{\hbar} p \psi$$

$$p\psi = \frac{\hbar}{i} \frac{d\psi}{dx}$$

Date: / / Page no:

$$\boxed{\text{P- operator} = \frac{\hbar}{i}\frac{d}{dx}} \quad \text{—⑥}$$

IMP * Wave function (ψ) :-

→ To stablise diff. eqⁿ for de-Broglie we need a function known as wave function and denoted by 'ψ'. where, ψ is

$$\psi = A e^{-i(\omega t - kx)} \quad \text{—①}$$

And 'ψ' is a complex quantity.

$$\psi = A + iB \quad \text{—②}$$

'ψ' has real, imaginary, root, (+) ve & negative valued, which is not observable and acceptable.

$$\psi^* = A - iB \quad \text{—③}$$

Where 'ψ^*' is complex conjugate of 'ψ'

$$\psi\psi^* = A^2 + B^2 \quad \text{—④}$$

and $\psi\psi^* = (\psi)^2$

or

$$|\psi|^2 = A^2 + B^2 \quad \text{—⑤}$$

for 4th Property in 3D

$$\iiint_{-\infty}^{\infty} |\psi|^2 \, dx\,dy\,dz = 1$$

Date: / / Page no:

$|\psi|^2$ has real, (+)ve and single valued. It is observable and acceptable.

⇒ $|\psi|^2$ is Probability density of finding electron anywhere, any time.

Properties:-

1. It must be finite.
2. — " — continuous.
3. — " — (+)ve and single valued
4. — " — Normalized.

According to Max Born interpretation Normalization is

$$\int_{-\infty}^{+\infty} |\psi|^2 \, dx = 1$$

Q. What is Orthogonal Property?

$$\int_{-\infty}^{+\infty} |\psi|^2 \, dx = 0$$

Date: / / Page no:

Schrodinger wave equation :-

→ It is differential form of de-broglie wave.

→ Schrodinger wave eqⁿ is eqⁿ for discribing or discribe motion of particle (or wave) in quantum mechanics.

→ which is similar to newtons law of motion in classical mechanics.

→ wave function $\psi = A e^{-i(\omega t - kx)}$ and $\psi = A e^{-i(Et - px)}$

→ and we have E-operator $= i\hbar \frac{d}{dt}$ and p-operator $= \frac{\hbar}{i} \frac{d}{dx}$

→ Total energy of particle is equal to K.E. $(= \frac{1}{2} mv^2)$ and potential energy (v)

$$E = \frac{1}{2} mv^2 + v \quad \text{--- (1)}$$

Ist term of R.H.S. eqn. (1)

$$\frac{1}{2} \frac{mv^2 m}{m} = \frac{p^2}{2m} \qquad \{p = mv\}$$

$$E = \frac{p^2}{2m} + v \quad \text{--- (2)}$$

Apply 'ψ' in eq (2)
wave function

$$E\psi = \frac{p^2 \psi}{2m} + v\psi \quad \text{--- (3)}$$

Date: / / Page no:

P-operator $= \frac{\hbar}{i} \, d/dx$

$$P^2 = \left(\frac{\hbar}{i} \, d/dx\right)\left(\frac{\hbar}{i} \, d/dx\right)$$

$$E\psi = \frac{1}{2m} \frac{\hbar^2}{i^2} \frac{d^2\psi}{dx^2} + V\psi \qquad \{ i^2 = -1$$

$$E\psi = \frac{-\hbar^2}{2m} \frac{d^2\psi}{dx^2} + V\psi$$

$$\frac{\hbar^2}{2m} \frac{d^2\psi}{dx^2} + E\psi - V\psi = 0$$

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

devide (÷) by $\left(\frac{\hbar}{2m}\right)$ in eq. above eqn both sid

$$\frac{d^2\psi}{dx^2} + \frac{2m}{\hbar} (E - V)\psi = 0 \quad \text{--- (4)}$$

eqn (4) known as 1-D Time Indepen
SWE. (schrodinger wave equation)
In above eqn 'ψ' is not a functi
of time $[\psi \longrightarrow \psi_x]$

For a free particle

$V = 0$

$$\frac{d^2\psi}{dx^2} + \frac{2m}{\hbar^2} E\psi = 0 \quad \text{—— (5)}$$

$$\frac{d^2\psi}{dx^2} + \frac{d^2\psi}{dy^2} + \frac{d^2\psi}{dz^2} + \frac{2m}{\hbar^2}(E-V)\psi = 0 \quad \text{—— (6)}$$

eqn (6) is 3-D time independent SWE (schrodinger wave equation)

⇨ from $E\psi = \frac{-\hbar^2}{2m}\frac{d^2\psi}{dx^2} + V\psi$

Put E-operator $= i\hbar \frac{d}{dt}$ in above eqn

$$i\hbar \frac{d\psi}{dt} = \frac{-\hbar^2}{2m}\frac{d^2\psi}{dx^2} + V\psi \quad \text{—— (7)}$$

eqn (7) is 1-Dimentional Time Dependent Schrodinger wave equnT (SWE)

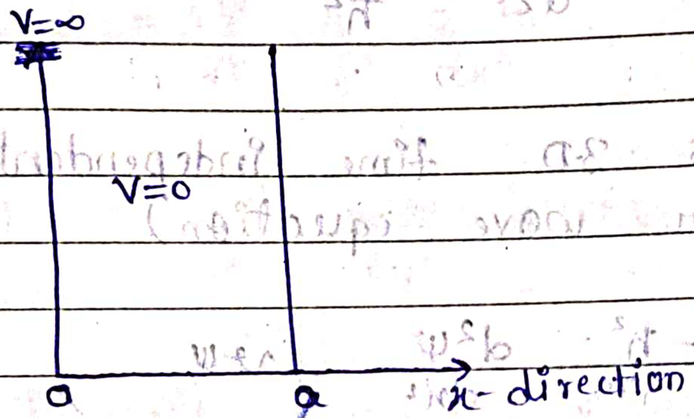
In above eqn 'ψ' is function of position 'x' & time 't'

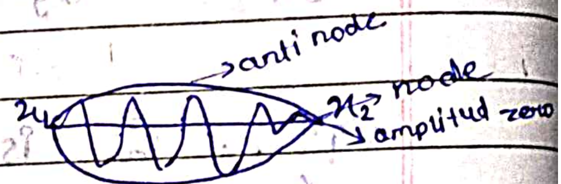
$[\psi \to \psi_{(x,t)}]$

Particle in a box

or Application of Time Independent schrodenger wave equation (TISWE)

Let we consider a 1-D box of size 'a'





An electron move in x-direction

Inside the box, K.E → ∞ (max) V → 0 (min)
At boundary, K.E → 0 (min) V → ∞ (max)

From Time independent schrodenger wave equation.

$$\frac{d^2\psi}{dx^2} + \frac{2m}{\hbar^2}(E-V)\psi = 0 \quad \text{--- (1)}$$

For free particle (inside a box)

$V=0$

$$\frac{d^2\psi}{dx^2} + \frac{2m}{\hbar^2}E\psi = 0 \quad \text{--- (2)}$$

Date: / / Page no:

$$\frac{d^2\psi}{dx^2} + k^2\psi = 0 \quad \text{——} (3)$$

Where $k^2 = \frac{2mE}{\hbar^2}$ —— (4)

General solution of equation (3)

$$\psi = A \sin kx + B \cos kx \quad \text{——} (5)$$

Boundary conditions are

$x = 0$; $\psi = 0$ —— (6)

$x = a$; $\psi = 0$ —— (7)

from (5) and (6)

$$0 = A \sin k \times 0 + B \cos k \times 0$$

$$0 = 0 + B$$

$$\boxed{B = 0} \text{——} (8)$$

Put $B = 0$ in eq. (5)

$$\boxed{\psi = A \sin kx} \text{——} (9)$$

Apply Boundary condition using eq^n (7) and (9)

$$0 = A \sin ka$$

$\{\sin 0^\circ = \sin n\pi\}$

$$\sin ka = \sin n\pi$$

$$ka = n\pi$$

Date: / / Page no:

$$k = \frac{n\pi}{a} \quad \text{——— (10)}$$

from eq^n (9) and (10)

$$\boxed{\psi = A \sin \frac{n\pi}{a} x} \quad \text{——— (11)}$$

from eq^n (4) and (10)

$$k^2 = \frac{2mE}{\hbar^2}$$

$$\left(\frac{n\pi}{a}\right)^2 = \frac{2mE}{\hbar^2} \qquad \left\{ \hbar = \frac{h}{2\pi} \right.$$

$$E = \frac{n^2\pi^2}{a^2} \times \frac{h^2}{2^2\pi^2} \times \frac{1}{2m}$$

$$\boxed{E = \frac{n^2 h^2}{8a^2 m}} \quad \text{——— (12)}$$

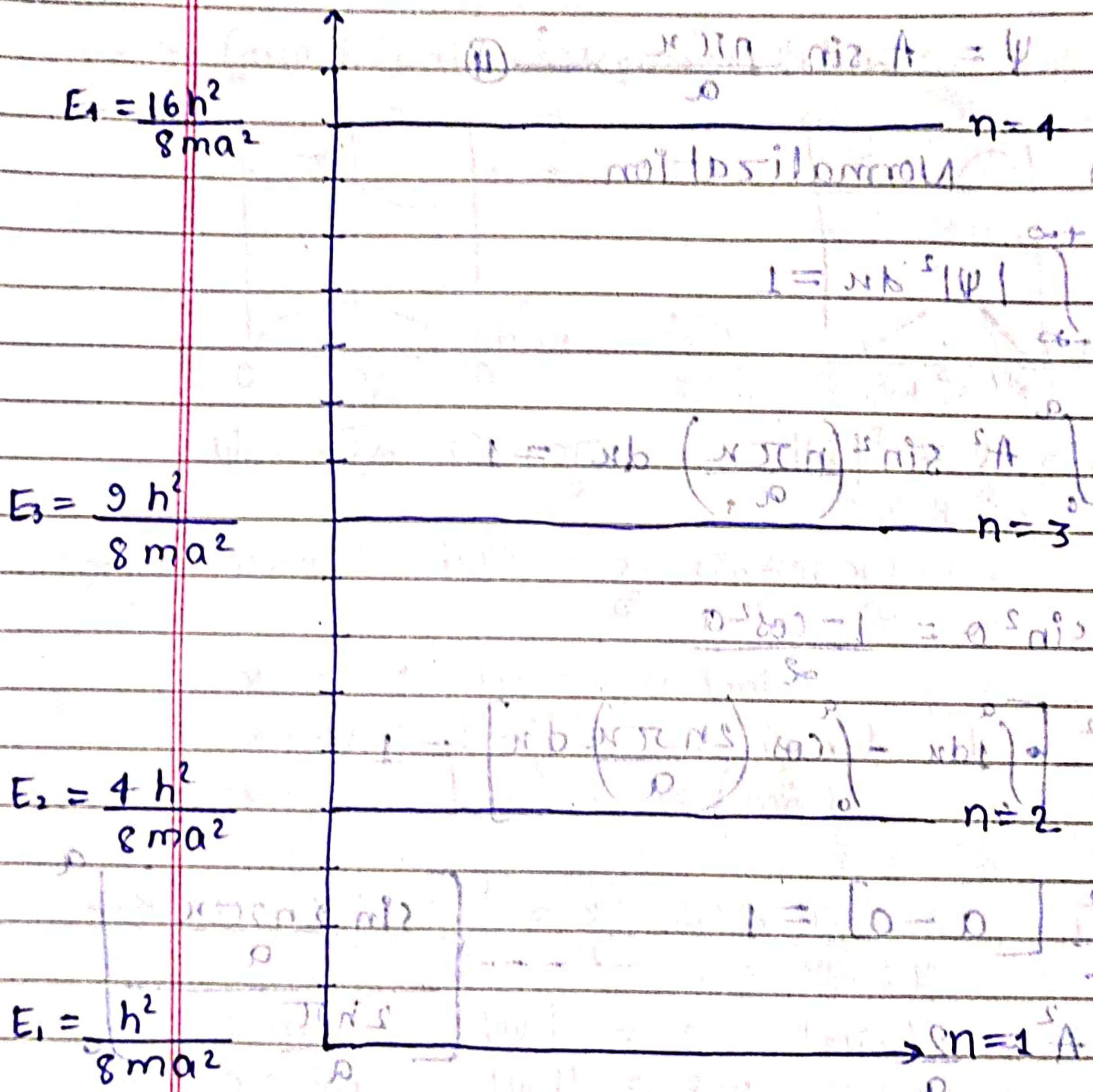
$$E \propto n^2$$

$$E \longrightarrow E_n$$

$$E_n = \frac{n^2 h^2}{8ma^2} \quad \text{——— (13)}$$

(13) is eq^n for eigen value for a particle in 1-D box

plot a graph in (ii) E (y-axis) vs n (x-axis)



from graph,

$E_2 - E_1 \neq E_3 - E_2 \neq E_4 - E_3$

It is clear that, energy spectrum of particle in a box is descreate

Date: / / Page no:

from eqn (11)

for $\psi = A \sin \frac{n\pi x}{a}$ — (11)

from Normalization

$$\int_{-\infty}^{+\infty} |\psi|^2 \, dx = 1$$

$$\int_0^a A^2 \sin^2\left(\frac{n\pi x}{a}\right) dx = 1$$

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

$$\frac{A^2}{a}\left[\int_0^a 1\,dx - \int_0^a \cos\left(\frac{2n\pi x}{a}\right) dx\right] = 1$$

$$\frac{A^2}{2}\left[a - 0\right] = 1 \quad \cdots\cdots \left[\frac{\sin \frac{2n\pi x}{a}}{\frac{2n\pi}{a}}\right]_0^a$$

$$A^2 = \frac{2}{a}$$

$$A = \sqrt{\frac{2}{a}}$$

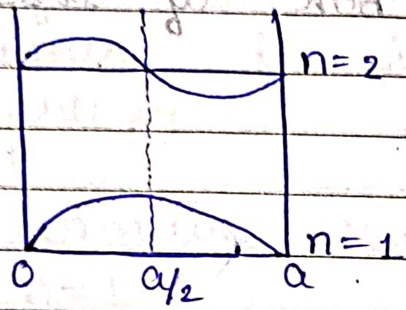
Eqn (11) becomes

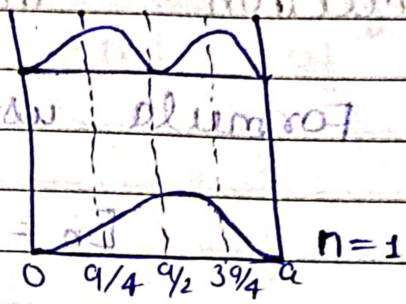
$$\psi = \sqrt{2/a}\,\sin \frac{n\pi x}{a} \quad (14)$$

$$\psi \longrightarrow \psi_n$$

and $|\psi|^2 = \frac{2}{a}\sin^2\frac{n\pi x}{a}$ (13)

→ Graphical representation :





$\psi_n = \sqrt{2/a}\,\sin\frac{n\pi x}{a}$ $\quad |\psi_n|^2 = \frac{2}{a}\sin^2\frac{n\pi x}{a}$

→ $n=1$, $|\psi_1|^2 = \frac{2}{a}\sin^2\frac{\pi x}{a}$

$x=0$; $|\psi_1|^2 = 0$ (min)
$x=a/2$; $|\psi_1|^2 = 2/a$ (max)
$x=a$; $|\psi_1|^2 = 0$ (min).

→ $n=2$, $|\psi_2|^2 = \frac{2}{a}\sin^2\frac{2\pi x}{a}$

$x=0$; $|\psi_2|^2 = 0$ (min.)
$x=a/4$; $|\psi_2|^2 = 2/a$ (max)
$x=a/2$; $|\psi_2|^2 = 0$ (min)
$x=3a/4$; $|\psi_2|^2 = 2/a$ (max)
$x=a$; $|\psi_2|^2 = 0$ (min)

$|\psi_n|^2$ has real, single valued and positive.

Date: / / Page no:

Numerical :-

Q.1 Calculate zero energy state for an electron in a box of size 1Å

Solve ⇒

Formula used :-

$$E_n = \frac{n^2 h^2}{8 m a^2}$$

$n = 1$

$h = 6.6 \times 10^{-34}$ J sec.

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

$a = 1\,Å = 10^{-10}$ m

$$E_1 = \frac{1^2 \times (6.6)^2 \times (10^{-34})^2}{8 \times 9.1 \times 10^{-31} \times (10^{-10})^2}$$

$$E_1 = \frac{43.56 \times 10^{-68}}{72.8 \times 10^{-31} \times 10^{-20}}$$

$$E_1 = 0.598 \times 10^{-17}\ J$$

$$E_1 = \frac{5.98 \times 10^{-18}\ J}{1.6 \times 10^{-19}\ C}$$ { for unit conversion divide by charge of electron

$E_1 = 37.37$ ev.

Ans

Date: / / Page no:

Q3. What is minimum uncertainity in the frequency of a photon whose life time is about 10^{-8} sec ?

Solve =

Formula used :-

By Heisenberg uncertainity principle

$$\Delta E \cdot \Delta t = \frac{h}{4\pi} \quad \text{--- (1)}$$

put $\Delta E = h \Delta \nu$

$$\Delta \nu \cdot \Delta t = \frac{1}{4\pi}$$

$$\Delta \nu = \frac{1}{4\pi} \times \frac{1}{\Delta t}$$

$$\Delta \nu = \frac{1}{4\pi} \times \frac{1}{10^{-8}}$$

$$\Delta \nu = \frac{1}{12.56} \times \frac{1}{10^{-8}}$$

$$\Delta \nu = 0.0796 \times 10^{8}$$

$$\Delta \nu = 7.96 \times 10^{6} \text{ hz.}$$

Ans

Q.4 An electron is bound by a potential which closely approaches in infinite square well of width $a = 2.5 \times 10^{-10}$ m calculate the three energies the electron can have.

$$\boxed{eV = \frac{J}{C}}$$
electron volt

Date: / / Page no:

Solve ⇒ $E_n = \frac{n^2 h^2}{8ma^2}$ $n = 1, 2, 3$

$a = 2.5 \times 10^{-10}$ m

$h = 6.6 \times 10^{-34}$ J sec

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

n = 1

$$E_1 = \frac{1 \times (6.6 \times 10^{-34})^2}{8 \times 9.1 \times 10^{-31} \times (2.5 \times 10^{-10})^2}$$

$$E_1 = \frac{43.56 \times 10^{-68}}{455 \times 10^{-51}}$$

$$E_1 = 0.0957 \times 10^{-17}$$

$$E_1 = \frac{9.57 \times 10^{-19}\ J}{1.6 \times 10^{-19}\ C}$$

{ for convert the u
devide by 1 elect
charg

$$E_1 = 5.983\ eV$$

Ans

n = 2

$$E_2 = (2)^2 \times E_1$$

$$= 4 \times 5.983\ eV$$

$$\therefore E_2 = 23.932\ eV$$

Ans

n = 3

$$E_3 = (3)^2 \times E_1$$

$$= 9 \times 5.983\ eV$$

$$E_3 = 53.847\ eV$$

Ans

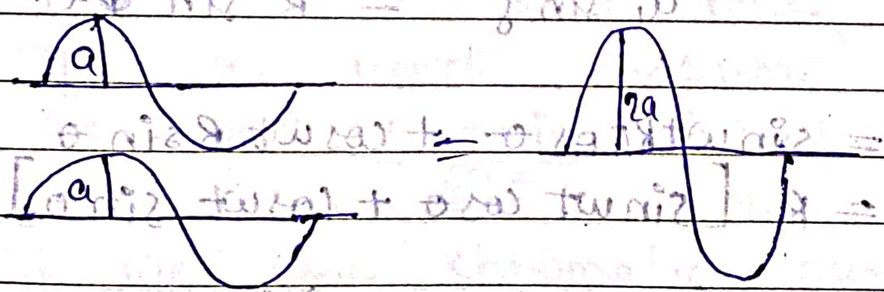
WAVE OPTICS

★. Interference of light:-

→ When two or more then two waves of same amplitude, coherent and monochromatic sorce, Suprimpose then resultant amplitude of the new wave is different from the original waves. This redistribution is known as interference of light.

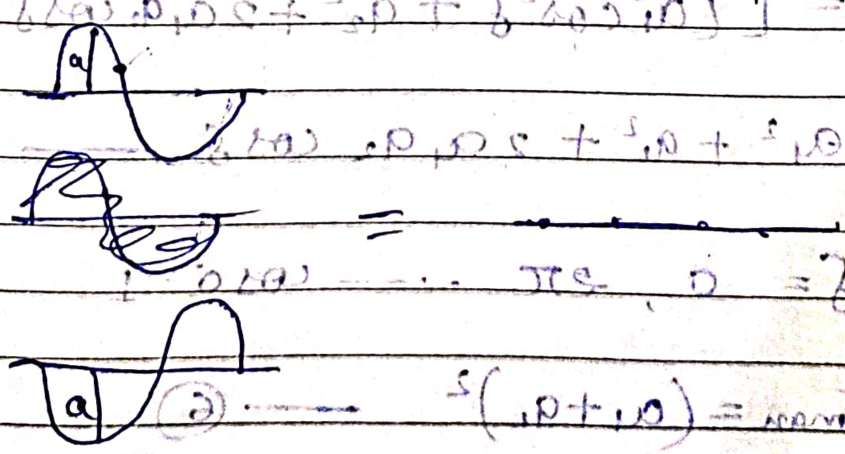
(1) Constructive interference :-

Phase difference two waves are same (0, 2π



maximum intensity

(2) Destructive interference:-



minimum intensity

Date: / / Page no:

★ Superposition of waves :-

$$y_1 = a_1 \sin(\omega t + \delta) \quad \text{--- (1)}$$

$$y_2 = a_2 \sin \omega t \quad \text{--- (2)}$$

$$y = y_1 + y_2$$

$$y = a_1 [\sin \omega t \cos \delta + \cos \omega t \sin \delta] + a_2 \sin \omega t$$

$$y = a_1 \sin \omega t \cos \delta + a_2 \sin \omega t + a_1 \cos \omega t \sin \delta$$

$$y = \sin \omega t [a_1 \cos \delta + a_2] + \cos \omega t (a_1 \sin \delta$$

Assume, $a_1 \cos \delta + a_2 = R \cos \theta$ --- (3)

$a_1 \sin \delta = R \sin \theta$ --- (4)

$$y = \sin \omega t R \cos \theta + \cos \omega t R \sin \theta$$

$$= R [\sin \omega t \cos \theta + \cos \omega t \sin \theta]$$

$$y = R [\sin(\omega t + \theta)]$$

$$R^2 = [(a_1^2 \cos^2 \delta + a_2^2 + 2 a_1 a_2 \cos \delta) + a_1^2 \sin^2$$

Interference, $I \Rightarrow R^2 = a_1^2 + a_2^2 + 2 a_1 a_2 \cos \delta$ --- (5)

$\delta = 0, 2\pi$ ---- $\cos 0 = 1$

$$I_{max} = (a_1 + a_2)^2 \quad \text{--- (6)}$$

$\delta = \pi, 3\pi$

$$I_{min} = (a_1 - a_2)^2 \quad \text{--- (7)}$$

Coherent source :- phase difference is constant with time.

Conditions of Interference of light.

1. Amplitude of wave should be same. max. Intensity

$a_1 = a_2 = a$, $I_{max} = (a+a)^2 = 4a^2$ Bright

$I_{min} = (a-a)^2 = 0$ Dark

2. Source should be coherent. Intensity mini

3. Source should be monochromatic.

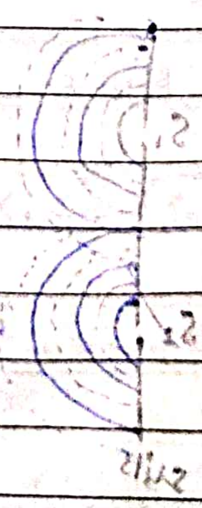
1 → For becoming perfect interference pattern amplitude should be same.

2 → Coherent source :- Phase difference is constant with time.

→ If we used coherent source then we get sustain interference pattern.

same

3 → If we use chromatic source in interference of light then colored pattern will form and it get overlapped.



Young's double slit experiment :-

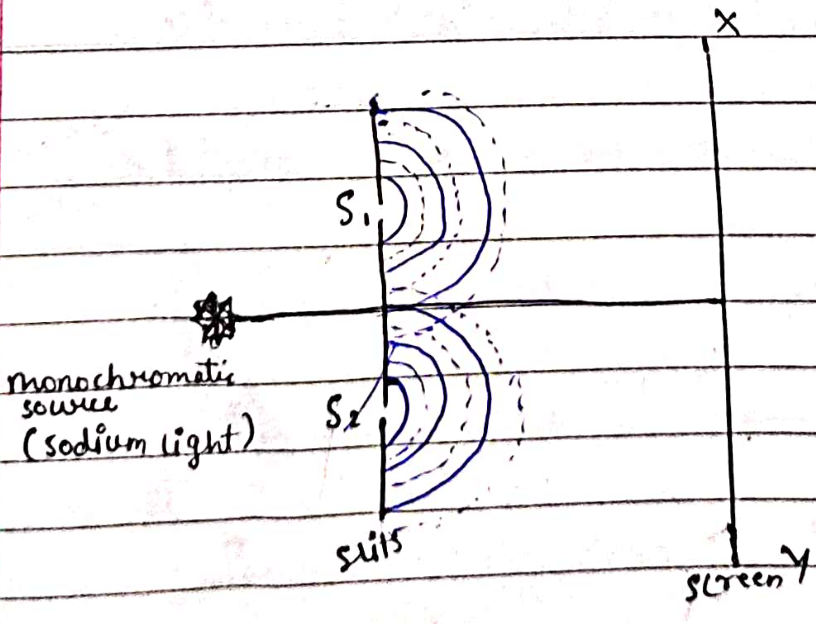
→ Young's double slit experiment. first demonstration of interference of light.

→ It consist monochromatic source Ex- sodium light ; ~~slits~~ and two slits S_1 and S_2 and screen.

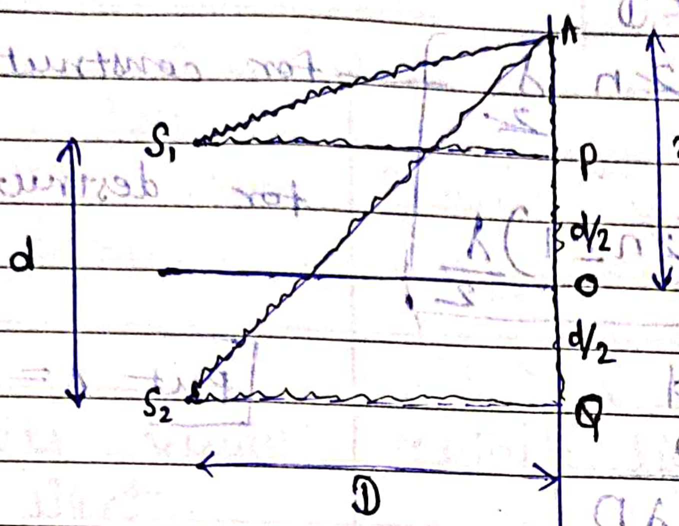
→ Sodium light when passes through slits S_1 and S_2 for alternate dark bright fringes.

→ We can observe interference pattern and can determine wavelength of light with the help of observation.

Fring width :-



Derivation for fringe width.



$\Delta = S_2A - S_1A$ In ΔS_1AP.

$S_1A^2 = S_1P^2 + AP^2$

$= D^2 + (x - d/2)^2$

$= D^2 + \left[x^2 + \frac{d^2}{4} - 2x\frac{d}{2}\right]$

$= D^2 + x^2 + d^2/4 - xd$

$S_2A^2 = S_2Q^2 + QA^2$ In ΔS_2QA

$= D^2 + (x + d/2)^2$

$= D^2 + \left[x^2 + \frac{d^2}{4} + 2x\frac{d}{2}\right]$.

$= D^2 + x^2 + d^2/4 + xd$

$S_2A^2 - S_1A^2 = (S_2A + S_1A)(S_2A - S_1A)$

$\left[(D^2 + x^2 + d^2/4 + xd) - (D^2 + x^2 + d^2/4 - xd)\right] = 2D\Delta$

$S_1A \approx S_2A \approx S_1P \approx S_2Q \approx D$

$$\Delta = \frac{2xd}{2D} \quad \text{(1)}$$

$$\boxed{\begin{aligned} &\rightarrow \Delta = 2n\frac{\lambda}{2} \text{ — for constructive} \\ &\underline{\text{or}} \\ &\rightarrow \Delta = (2n \pm 1)\frac{\lambda}{2} \text{ — for destructive} \end{aligned}}$$

$$\boxed{\text{put } \Delta = n\lambda}$$

$$n\lambda = \frac{xd}{D}$$

$$\boxed{x_n = \frac{n\lambda D}{d}}$$

$$x_{n+1} = \frac{(n+1)\lambda D}{d}$$

$$x_{n+1} - x_n = \frac{\lambda D}{d}$$

$x_{n+1} - x_n = \beta$ (fringe width)

$$\beta = \frac{\lambda D}{d} \quad \text{(2)}$$

$$\boxed{\lambda = \frac{\beta d}{D}} \quad \text{(3)}$$

Monochromatic source	Chromatic source	Highly monochromatic source
Sodium vapour lamp	Mercury vapour lamp	He-Ne laser
emits yellow light	White light (VIBGYOR)	Pink red color
D_1 Line 5890Å D_2 Line 5896Å	4000° to 7800Å	6328 Å exact wavelength
Average wavelength is 5893 Å		

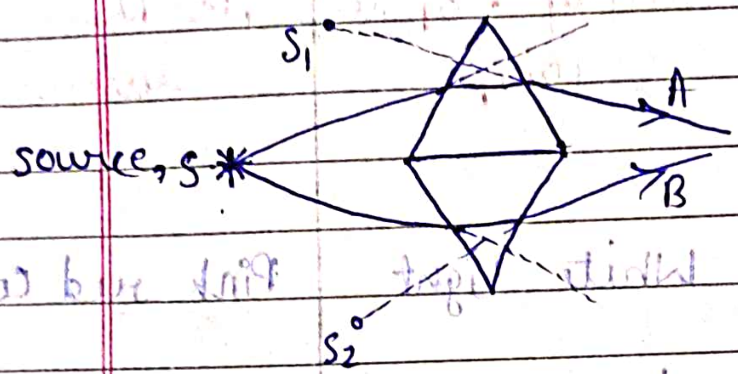
Date 13/04/23

(1) division of wave front.
(2) division of amplitude.

Date: / / Page no:

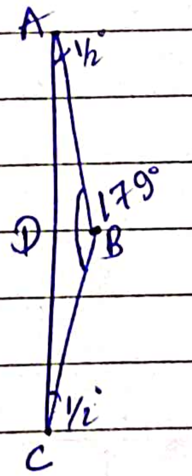
Types :

(1) Division of wave front :-



(Biprism)

A Biprism is a combination of two point join base to base, its obtuse an is about 179° and other two acute angle of $\frac{1}{2}$°.



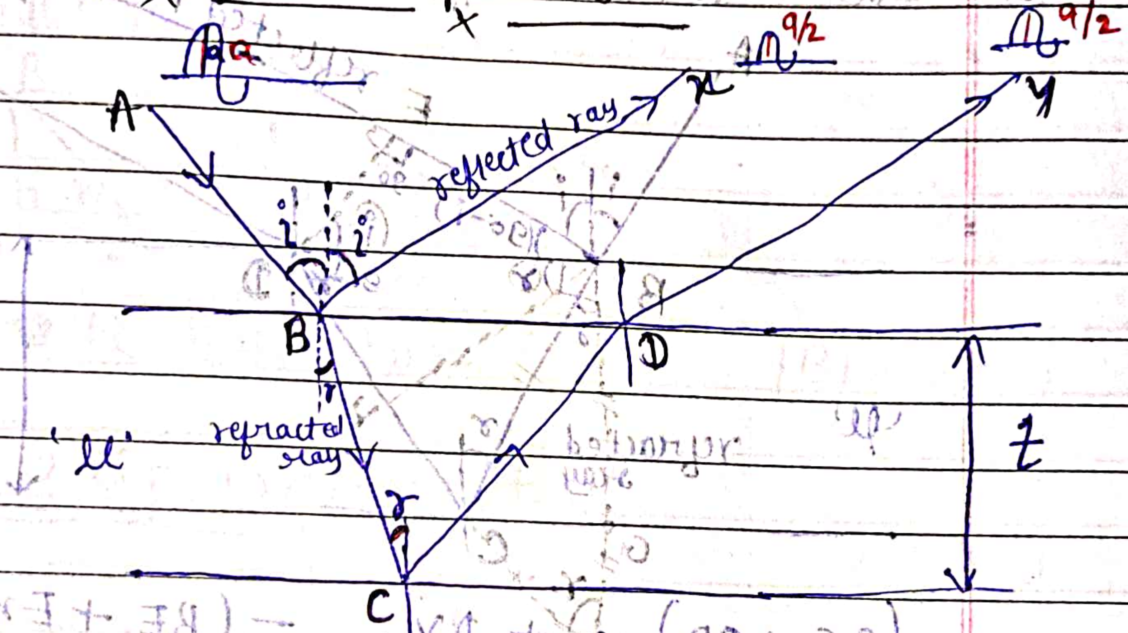
Biprism is used to divide source 'S' into 'S_1' & 'S_2', where 'S_1' and 'S_2' are coherent slits or images ~~of~~ or the 'S' (source)

→ Experiment based on division of ~~wave~~ wavefront is Fresel's Biprism exper

→ A source (wavefront) devides into 'S_1' and by means of an optical device.

Prism or biprism based on deviation of light.

(2) Division of amplitude :-

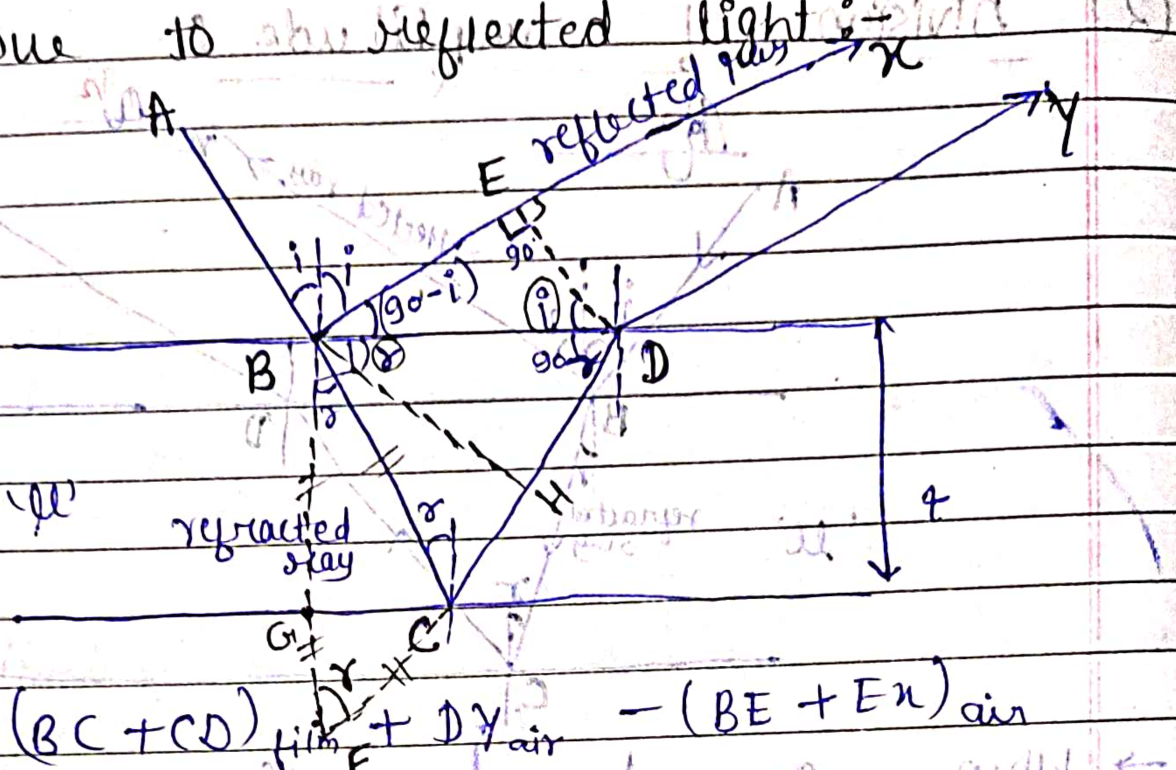


→ When a beam of light AB incident on a surface of thin film, it devides into two beams in different directions (BC & BX). After some time they travel in same direction, as BX and DY are of same amplitude and nearly parallel, divisions of amplitude takes place.

Date: / / Page no:

Interference of light in thin film:-

(1) Due to reflected light :-



$(BC+CD)_{film} + DY_{air} - (BE+EX)_{air}$

$\Delta = (BC+CD)_{film} - BE_{air}$ —— ①

$DE \perp BX$. and $EX = DY$ (construction)

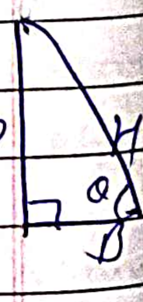
CD produce back side $BG = GF$, $BF = 2t$

$BC = CF$

$BH \perp CD$

$\Delta = \mu(BC+CD)_{air} - BE_{air}$ —— ②

$\mu = \frac{\sin i}{\sin r}$ $\frac{BE/BD}{DH/BD}$ $\underline{BE = \mu(DH)}$. P



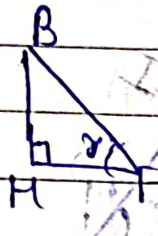
$\Delta = \mu(BC+CD) - \mu DH$ —— ③

$\Delta = \mu[BC + CD] - DH]$

$\Delta = \mu[CF + \cancel{DH} + HC - \cancel{DH}]$

$\Delta = \mu[FH]$

In $\triangle$



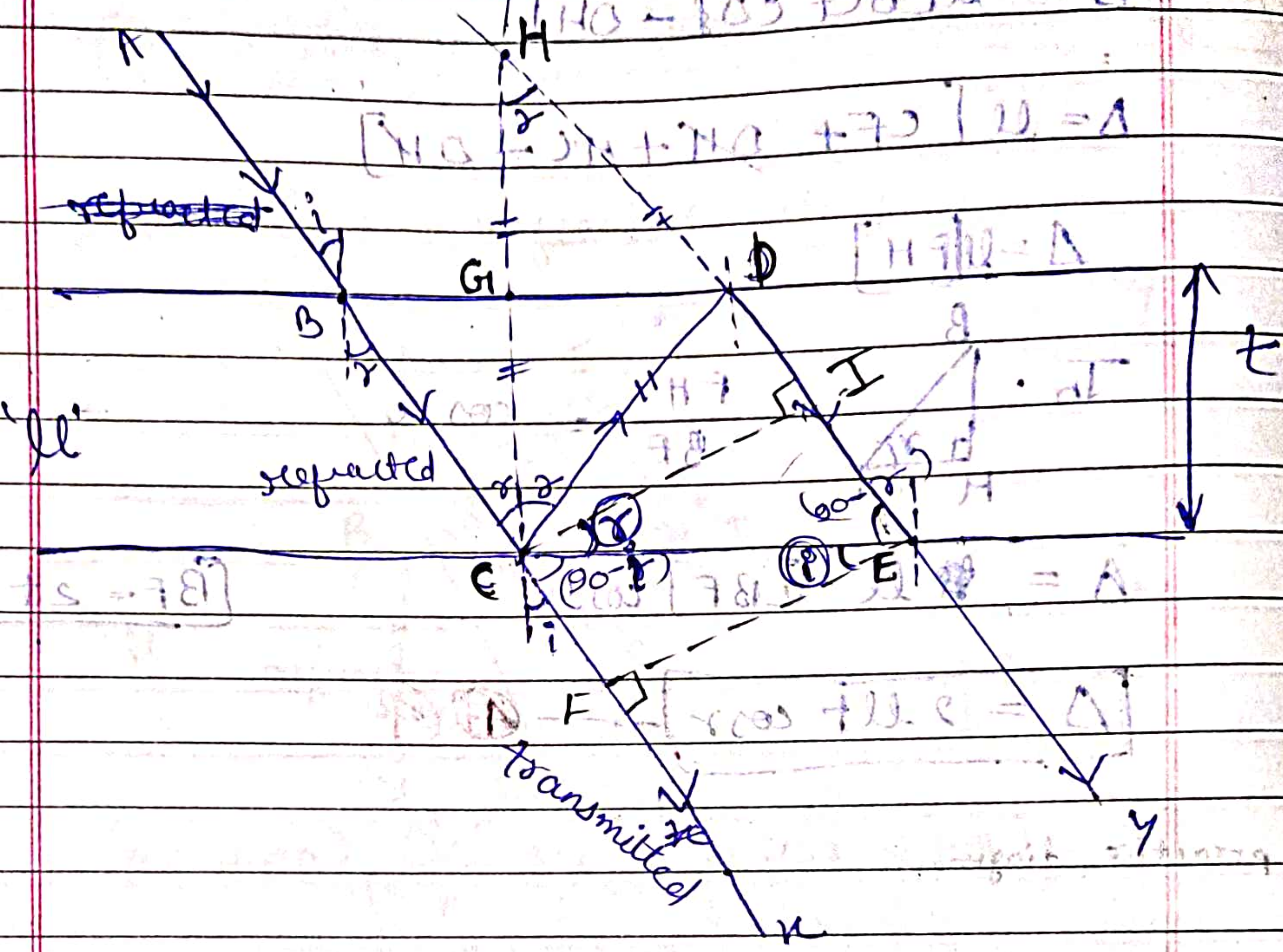
$\frac{FH}{BF} = \cos r$

$\Delta = \mu[BF]\cos r$ $\boxed{BF = 2t}$

$\boxed{\Delta = 2\mu t \cos r}$ —— (4)

practice diagram

② Due to transmitted light



EF ⊥ CX ; EY = FX

produce DE in back side as CD = DH,

HC = 2t

$$\Delta = (CD + DE)_{film} + CF_{air} \quad \text{—— (1)}$$

$$\Delta = \mu\,(CD + DE)_{air} + CF_{air} \quad \text{—— (2)}$$

$$\mu = \frac{\sin i}{\sin r} = \frac{CF/\cancel{CE}}{EI/\cancel{CE}} = \frac{CF}{EI}$$

$$CF = \mu(IE) \quad \text{—— (3)}$$

$$\Delta = \mu(CD + DE) + \mu(IE)$$

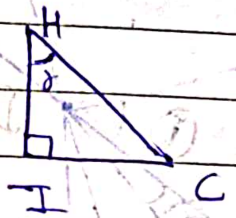
Date: / / Page no:

$\Delta = ll(CD + DE + IE)$

$\Delta = ll[DH + DI + \cancel{IE} - \cancel{IE})$

$\Delta = ll[DH + DI]$

$\Delta = ll(HI)$

In 

$\triangle CIH$, $\dfrac{HI}{HG} = \cos\gamma$

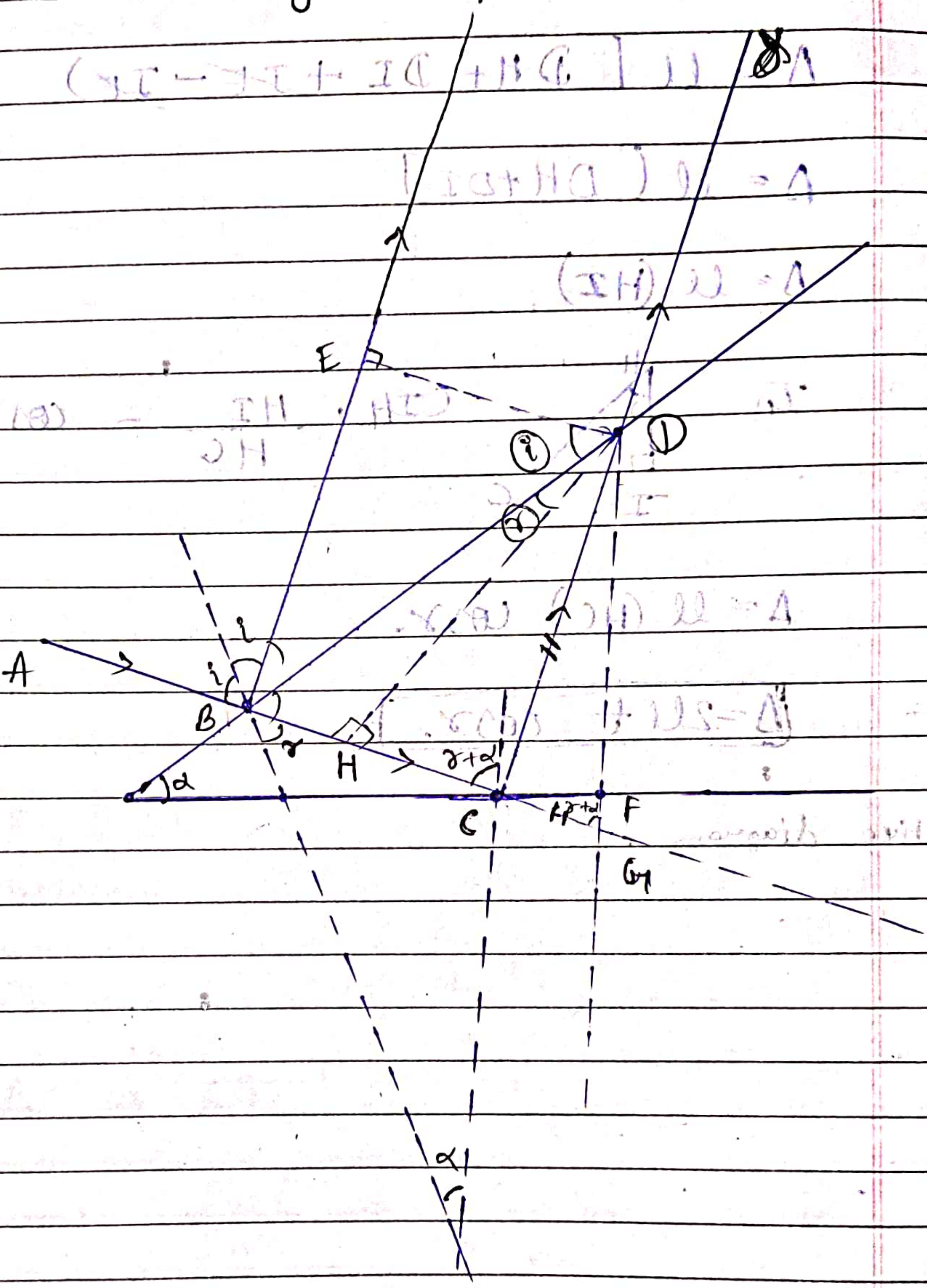
$HC = 2t$

$\Delta = ll(HC)\cos\gamma.$

$\boxed{\Delta = 2llt\cos\gamma.}$ (1)

Practice diagram

(C) Due to wadge shaped film (non-parallel)



Date: / / Page no:

$$\Delta = (BC + CD)_{film} - BE_{air} \quad \text{— (1)}$$

$$= \mu\,(BC + CD)_{air} - BE_{air} \quad \text{— (2)}$$

$$\mu = \frac{\sin i}{\sin r} = \frac{BE/BD}{BH/BD}$$

$$BE = \mu BH \quad \text{— (3)}$$

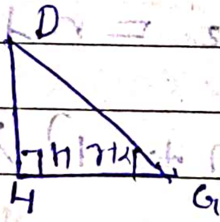
$$\Delta = \mu\,(BC + CD) - \mu BH$$

$$= \mu\,(BC + CD - BH)$$

$$= \mu\,(BH + HC + CG - BH)$$

$$\Delta = \mu HG$$

In



$$\frac{HG}{DG} = \cos(r + \alpha)$$

$$\Delta = \mu HG, \quad HG = DG\cos(r + \alpha)$$

$$\Delta = \mu\,[2t \cos(r + \alpha)]$$

$$\boxed{\Delta = 2\mu t \cos(r + \alpha)} \quad \text{— (5)}$$

* Show that results for Δ in reflected and transmitted light are complementa

Due to reflected light.

① Diagram

② Path diff. $\Delta = 2\mu t \cos r$

③ In case of reflected light, a phase change of π or $\lambda/2$ occurs.

or $\boxed{\Delta = 2\mu t \cos r \pm \lambda/2}$

④ for bright

$2\mu t \cos r \pm \lambda/2 = n\lambda$

$\boxed{2\mu t \cos r = (2n \pm 1)\lambda/2}$ —— ①

⑤ for dark

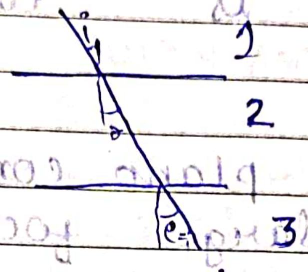
$2\mu t \cos r \pm \lambda/2 = (2n \pm 1)\lambda/2$

or $\boxed{2\mu t \cos r = n\lambda}$ —— ②

Due to transmitted light.

① Explain and diagram.

② $\Delta = 2\mu t \cdot \cos r$.



③ In case of transmitted light phase change of 2π (or in same phase) occurs means no change.

$$\boxed{2\mu t \cos r = \Delta}$$

④ for bright,

$$\boxed{2\mu t \cdot \cos r = n\lambda} \quad (3)$$

⑤ for dark

$$\boxed{2\mu t \cdot \cos r = (2n\pm1)\lambda/2} \quad (4)$$

Date: / / Page no:

* Newton's Ring Experiment:

→ It based on phenomena of interference of light.
→ Its type is division of amplitude.

→ When a plano convex lens is plac of large focal length is placed over the glass plate.

→ Convex surface of the plano convex lens is towards the glass plate.

→ then an air film is formed between convex surface and upper surface of glass plate.

→ At the point of contact thickness of air film is zero. And it gradually increases towards the outside. (wedge-shaped film)

→ From point of contact, circles can be drawn, and pattern in form of circular or ring, known as Newton's ring.

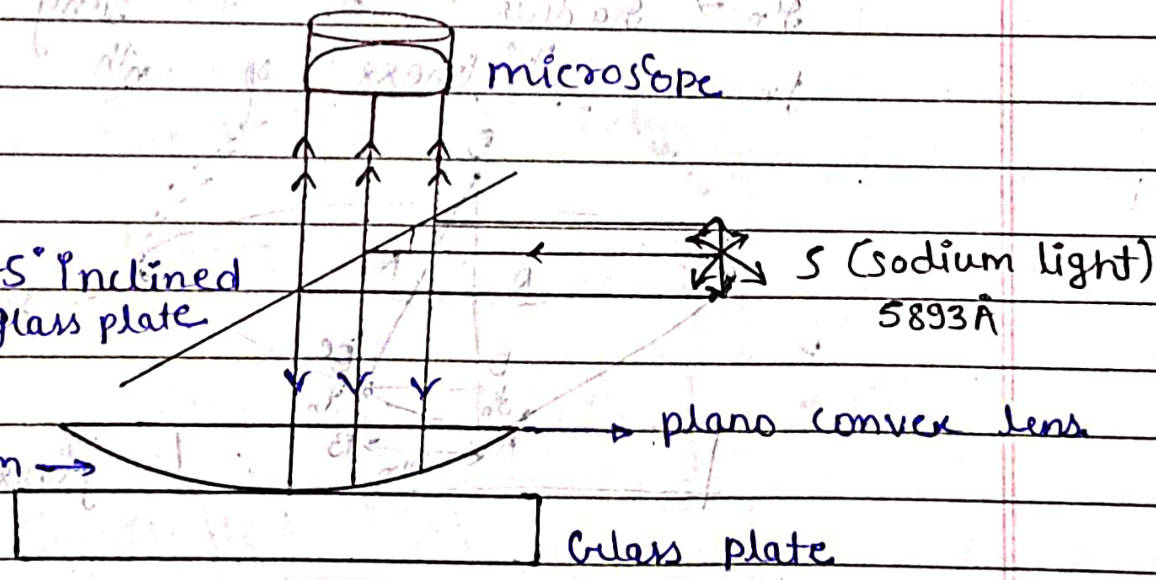
Date: / / Page no:

If we use chromatic source in place of sodium light (monochromatic source) then few coloured rings observed and then get overlap.

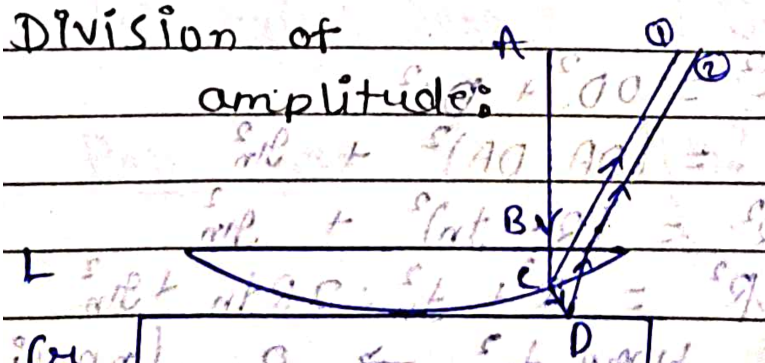
Experimental arrangement:

It consist of plano convex lens and glass plate, monochromatic source (sodium light) 5893 Å.

45° inclined glass plate on a microscope.



Division of amplitude:



$$\boxed{D_n^2 = 4Rn\lambda}$$

Date: / / Page no:

$$\boxed{\lambda = \frac{D_{n+p}^2 - D_n^2}{4PR}}$$

where, D_{n+p}^2 is square of diameter of $(n+p)^{th}$ ring.

D_n^2 is — " —

p is integer, and it is difference of $(n+p)^{th}$ and n^{th} ring.

$(n+p)-n = p$

R is radius of curvature of plano convex lens.

In Newton's ring experiment the diameter of 4^{th} and 12^{th} dark rings are 0.4 cm and 0.7 cm respectively. Deduce the direct diameter to 20^{th} ring.

Given,

$$D_4 = 0.4\,cm$$

$$D_{12} = 0.7\,cm$$

Formula used

$$\lambda = \frac{D_{n+p}^2 - D_n^2}{4PR}$$

$$\lambda = \frac{D_{12}^2 - D_4^2}{4 \times 8 \times R} \quad cm^2$$

$$\lambda R = \frac{(0.7)^2 - (0.4)^2}{4 \times 8}$$

Date: / / Page no:

$$R\lambda = \frac{0.49 - 0.16}{4 \times 8} \, cm^2$$

$$\boxed{R\lambda = 0.0103}$$

$$D_n^2 = 4 R n \lambda$$

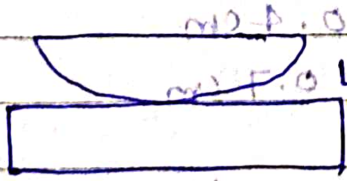
$$D_{20}^2 = 4 \times 0.0103 \times 20 \, cm^2$$

$$D_{20} = \sqrt{0.824 \, cm^2}$$

$$\boxed{D_{20} = 0.908 \, cm}$$

Ans

Q. Determination of RI (μ) of a liquid which is introduced in between convex surface and upper surface of glass plate.



For an air film $\mu = 1$, $\cos r = 1$

$$2\mu t \cos r = n\lambda$$

$$2t_n = n\lambda$$

$$\boxed{D_n^2}_{air} = 4Rn\lambda$$

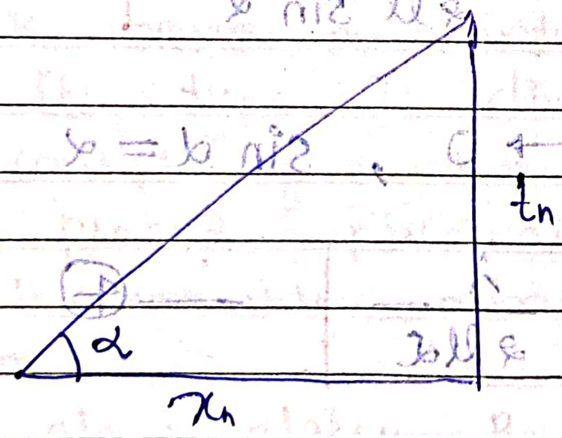
$$\mu_{air} = 1$$
$$\mu_w = 1.33 = 4/3$$
$$\mu_g = 1.5$$

$$[D_n^2]_{liquid} = \frac{4Rn\lambda}{\mu} \quad \text{— (e)}$$

$$[D_n^2]_{liquid} = \frac{[D_n^2]_{air}}{\mu}$$

$$\mu = \frac{[D_n^2]_{air}}{[D_n^2]_{liquid}}$$

→ Establish relation in β (fringe width) and α (angle of wedge)



$$\tan\alpha = \frac{t_n}{x_n}$$

$$2\mu t \cos(r+\alpha) = n\lambda$$

$$2\mu t_n \cos(r+\alpha) = n\lambda \quad \text{— (2)}$$

$$2\mu x_n \tan\alpha \cos\alpha = n\lambda$$

$r = 0°$ for normal incidence

$$2\mu x_n \frac{\sin\alpha}{\cos\alpha} \times \cancel{\cos\alpha} = n\lambda$$

$$2\mu x_n \sin\alpha = n\lambda$$

$$x_n = \frac{n\lambda}{2\mu \sin\alpha}$$

$$x_{n+1} = \frac{(n+1)\lambda}{2\mu \sin\alpha}$$

$$x_{n+1} - x_n = \frac{\lambda}{2\mu \sin\alpha}$$

$$\boxed{\beta = \frac{\lambda}{2\mu \sin\alpha}} \quad \text{—— (3)}$$

$$\alpha \rightarrow 0, \quad \sin\alpha = \alpha$$

$$\boxed{\beta = \frac{\lambda}{2\mu\alpha}} \quad \text{—— (4)}$$

Q. Find α if β is 3 mm and $\mu = 1$ and $\lambda = 5893$ Å

Solve⇒ Given,

$\beta = 3\text{ mm} = 3 \times 10^{-1}\text{ cm} = 0.3\text{ cm}$

$\mu = 1$

$\lambda = 5893$ Å $= 5893 \times 10^{-8}$ cm

Date: / / Page no:

$$\alpha = \frac{5893 \times 10^{-8}\ cm}{2 \times 1 \times 3 \times 10^{-1}\ cm}$$

$$\alpha = 9.8216 \times 10^{-5} \text{ radian}$$

$$\alpha = 9.8216 \times 10^{-5} \times \frac{180^\circ}{\pi}$$

$$\alpha = 562.98 \times 10^{-5}$$

$$\alpha = (0.056)^\circ$$

---

* Michelson's Interferometer (MI):-

- It is based on interference of light.
- And its type is division of amplitude.
- It consist of two mirrors M_1 and M_2 placed perpendicular to each other.
- M_1 is Moveable mirror, & M_2 is fixed mirror.
- Two glass plates P & Q of same type place parallel to each other and 45° to the mirrors.
- One surface of glass plate 'P' is semi-silvered which is toward glass plate 'Q'.

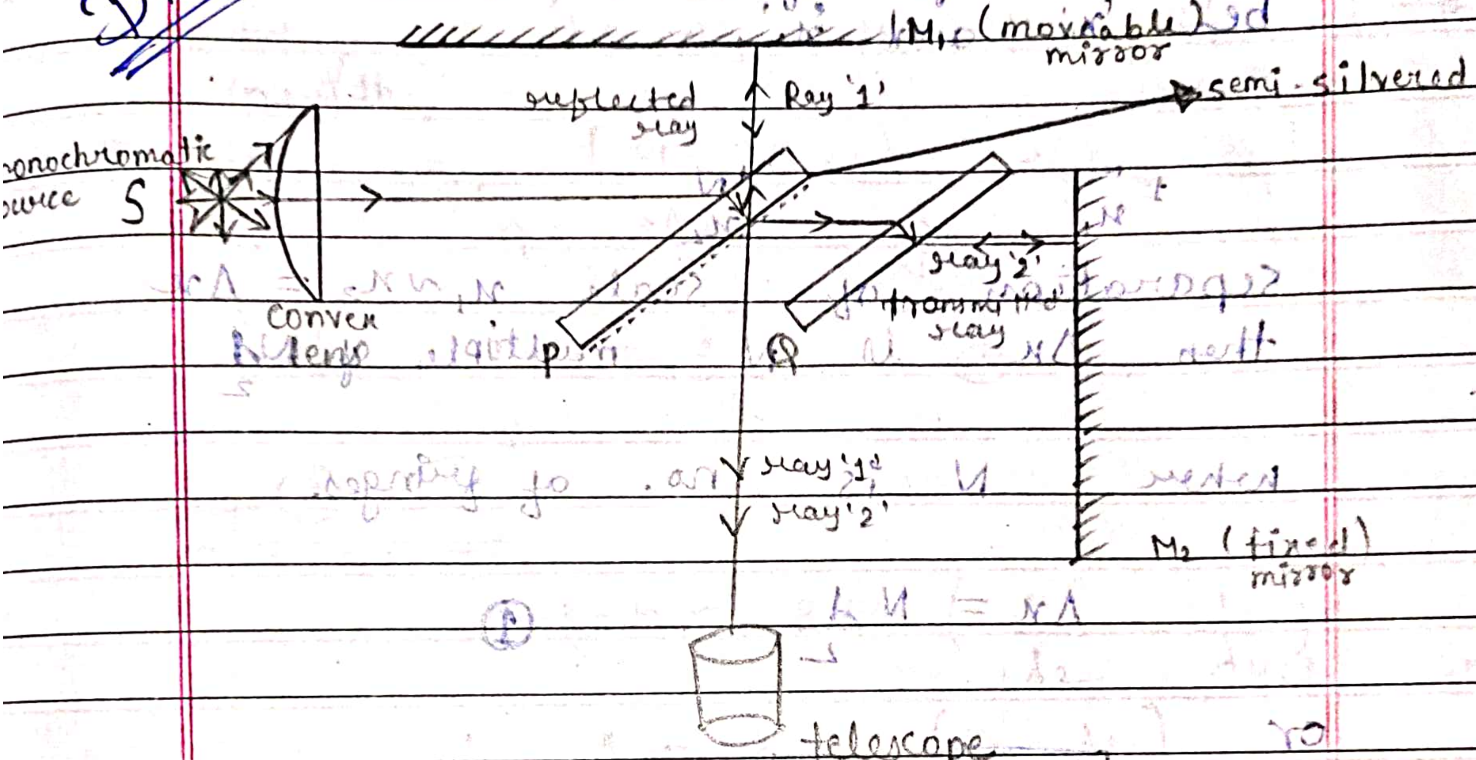
- If source of monochromatic light with convex lens is used, roll of convex lens is to make the beam parallel and a telescope.

→ <u>Working:-</u>

→ Light from source incident on semisilvered surface, division of amplitude takes place.

→ <u>Division of amplitude:-</u>

Diagram



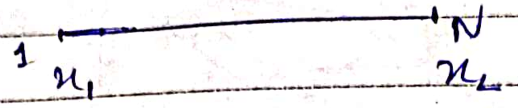
* Role of glass plate Q:- In absence of glass plate Q, ray '1' passes twice through glass whereas ray '2' does not even once. For compensating the path diff. in b/w two rays, a compensating glass plate of some type (same RI, dimension) introduced.

Applications:-

(A) Determination of wavelength 'λ' of light source.

$2\mu t \cos r = n\lambda$

Let reading of 1st and Nth fringe be 'x_1' and 'x_2'.



separation of scale $x_1 \sim x_2 = \Delta x$

then, Δx is N multiple of $\frac{\lambda}{2}$

where N is no. of fringes.

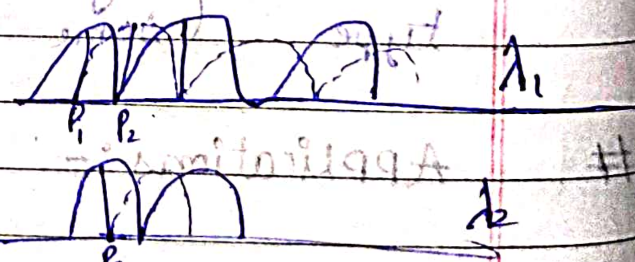
$$\Delta x = N\frac{\lambda}{2} \quad \text{——— (1)}$$

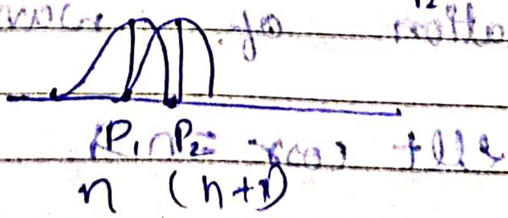
or

$$\boxed{\lambda = \frac{2\Delta x}{N}} \quad \text{——— (2)}$$

(B) Determination of change in wave length $\Delta\lambda$:-

If source has two closer wavelength 'λ_1' and 'λ_2' such as ~~solution~~ sodium light.





Date: / / Page no:

We can say if for λ_1 wavelength n^{th} fringe observed ~~there~~ then for $\lambda_2 \rightarrow$ $(n+1)^{th}$.

therefore, from eq^n $\lambda = \frac{2\Delta x}{N}$

$$n = \frac{2\Delta x}{\lambda_1} \quad \text{--- (1)}$$

and

$$n+1 = \frac{2\Delta x}{\lambda_2} \quad \text{--- (2)}$$

eq. (2) − (1)

$$n+1-n = 2\Delta x\left(\frac{1}{\lambda_2} - \frac{1}{\lambda_1}\right)$$

$$1 = 2\Delta x\,\frac{(\lambda_1 - \lambda_2)}{\lambda_1 \lambda_2}$$

$$\boxed{\lambda_1 - \lambda_2 = \frac{\lambda_1 \lambda_2}{2\Delta x}}$$

or

$$\boxed{\Delta\lambda = \frac{\lambda_1 \lambda_2}{2\Delta x}} \quad \text{--- (3)}$$

$\lambda_1 \approx \lambda_2$, then $\lambda_1\lambda_2 = \lambda_{av}^2$

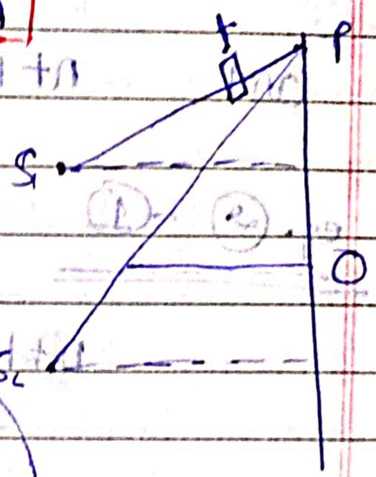
$$\boxed{\Delta\lambda = \frac{\lambda_{av}^2}{2\Delta x}} \quad \text{--- (4)}$$

$$\boxed{\Delta = (\mu - 1)t}$$

Date: / / Page no:

(c) Determination of 't' (thickness of glass plate) which is introduced in between one path of interference fringes.

$$\boxed{(\mu - 1)t = n\lambda}$$



In MI, ray passes twice

$$\boxed{(\mu - 1)t = 2x}$$

$$S_2P - S_1P = \Delta$$

$$S_1P = (S_1P - t)_{air} + t_{film}$$

$$= (S_1P - t) + \mu t$$

$$S_1P = S_1P + (\mu - 1)t$$

$$\Delta = S_2P - S_1P$$

$$= S_2P - [S_1P + (\mu - 1)t]$$

$$\Delta = S_2P - S_1P - (\mu - 1)t$$ in glass plate — ①

$$\Delta = S_2P - S_1P = \frac{xd}{D}$$ — ②

Types of fringes in MI

Date: / / Page no:

Numericals:-

Q. 1 In MI 200 fringes cross the field of ~~the~~ view when a moveable mirror displays through 0.0589 mm. Calculate wavelength of light. $\lambda = \frac{2\Delta x}{N}$

Q. 2 A glass plate of refractive index 1.5 is introduced normally in one of the path of ~~an~~ MI. which has eliminated by the wavelength of 5893Å. Determine 't' of glass plate 500 dark fringes cross the view

$$t = \frac{N\lambda}{2(\mu-1)}$$

Solve-1 Given,

$N = 200$

$\Delta x = 0.0589 \text{ mm} = 0.05 \times 10^{-3} \text{ m}$

$$\lambda = \frac{2\Delta x}{N} = \frac{\cancel{2} \times 0.0589 \times 10^{-3}}{\cancel{200}} \text{ m}$$

$$\lambda = \frac{0.0589 \times 10^{-3-2}}{100000} \text{ m}$$

$$\lambda = 5890 \times 10^{-10} \text{ m}$$

$$\boxed{\lambda = 5890 \text{ Å}} \qquad \{10^{-10} \text{ m} = 1 \text{ Å}\}$$

Date: / / Page no:

Solve-Q-2

$$2(\mu-1)t = N\lambda$$

$$t = \frac{N\lambda}{2(\mu-1)}$$

where

$\mu = 1.5$

$\lambda = 5893\ \text{Å} = 5893 \times 10^{-8}\ cm$

$N = 500$

$$t = \frac{500 \times 5893 \times 10^{-8}\ cm}{2(1.5-1)}$$

$$t = \frac{500 \times 5893 \times 10^{-8}\ cm}{2 \times 0.5}$$

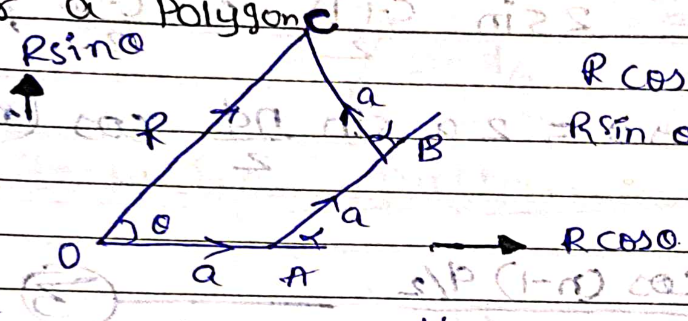
$$t = 2946500 \times 10^{-8}\ cm$$

$$t = 0.0294\ cm$$

{1 mm = 10 cm}

$$\boxed{t = 0.294\ mm}$$

Derivation for resultant amplitude for a Polygon



$R\cos\theta = a[1+\cos d + \cos 2d \ldots \cos(n-1)d]$ ①

$R\sin\theta = a[\sin d + \sin 2d + \ldots \sin(n-1)d]$ ②

In a polygon, 'a' is amplitude of each subslit (part) and 'd' is common phase difference and R is resultant amplitude

$R\cos\theta = a[1+\cos d + \cos 2d \ldots \cos(n-1)d]$ — ①

$R\sin\theta = a[\sin d + \sin 2d + \ldots \sin(n-1)d]$ — ②

Multiply by $2\sin d/2$ both the side in eq ①

$2\sin d/2 \, R\cos\theta = a[2\sin d/2 + 2\cos d \sin d/2 + 2\cos 2d \ldots$
$= \sin d/2 \ldots + 2\cos(n-1)d \sin d/2]$

Using $2\cos A \sin B = \sin(A+B) - \sin(A-B)$

$2\sin d/2 \, R\cos\theta = a[2\sin d/2 + 2\cos d \sin d/2 +$
$\ldots + 2\cos(n-1)\, d/2 \sin d/2]$

$= a[\cancel{2\sin d/2}^{\sin d/2} + (\cancel{\sin 3d/2} - \cancel{\sin d/2})$
$+ (\sin 5d/2 - \cancel{\sin 3d/2}) + \ldots$
$(\sin(n-\tfrac{1}{2})d/2 - \cancel{\sin(n-3/2)d/2}]$

$= a[\sin d/2 + \sin(n-1/2)\, d/2]$

$$\frac{C-D}{2} = \frac{\frac{d}{2} + (n-\frac{1}{2})d}{2} = \frac{d(2\ \ \ \ \frac{}{2})}{2}$$

Date: / / Page no:

$$\sin C + \sin D = 2\sin\frac{C+D}{2}\cos\frac{C-D}{2}$$

$$2\sin d/2\, R\cos\theta = 2a\sin\frac{nd}{2}\cos(n-1)\frac{d}{2}$$

$$R\cos\theta = \frac{a\sin\frac{nd}{2}\cos(n-1)d/2}{\sin d/2} \quad \text{—— (3)}$$

Similarly,

$$R\sin\theta = \frac{a\sin nd/2\,\sin(n-1)d/2}{\sin d/2} \quad \text{—— (4)}$$

Squaring eqn (3) & (4)
then sum eqn (3) & (4)

$$R^2(\sin^2\theta + \cos^2\theta) = \frac{a^2\sin^2\frac{nd}{2}\cos^2(n-1)\frac{d}{2}}{\sin^2 d/2} + \frac{a^2\sin^2 nd/2\cdot\sin(n-1)\frac{d}{2}}{\sin^2\frac{d}{2}}$$

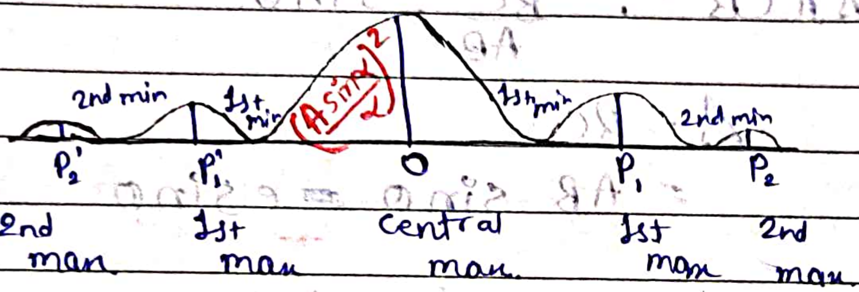
$$R^2 = \frac{a^2\sin^2\frac{nd}{2}\cos^2(n-1)\frac{d}{2} + a^2\sin^2\frac{nd}{2}\cdot\sin^2(n-1)\frac{d}{2}}{\sin^2\frac{d}{2}}$$

$$R^2 = \frac{a^2\sin^2\frac{nd}{2}}{\sin^2\frac{d}{2}}\left[\cos^2(n-1)\frac{d}{2} + \sin^2(n-1)\frac{d}{2}\right]$$

$$R^2 = \frac{a^2\sin^2\frac{nd}{2}}{\sin^2\frac{d}{2}} \quad \text{— Intensity —— (5)}$$

$R = \dfrac{a \sin\left(\frac{n d}{2}\right)}{\sin d/2}$ ⑥

Diffraction pattern :-

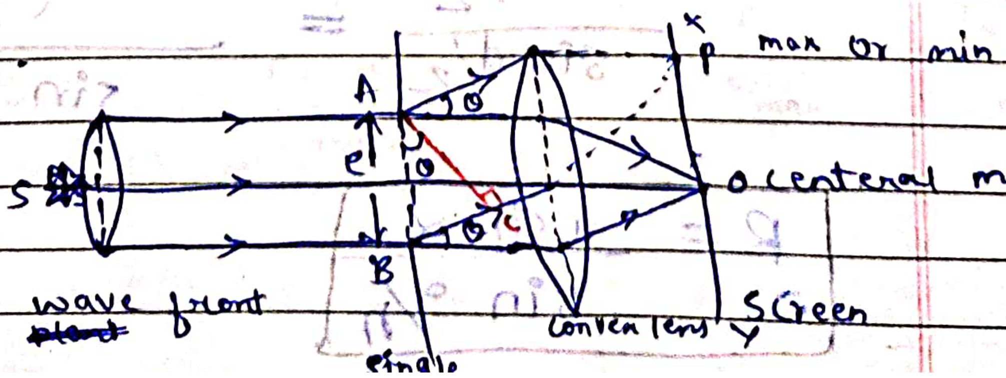


Home work
Distinguish b/w interference and diffraction of light.
Definition
Diagram
Interference
Diffraction

(1) Central or principle max.
(2) secondary ~~max.~~ minima
(3) —"— maxima

Diffraction at single slit :-

It based on frounchofer diffraction and it consist of plan wave front and a single slit AB of size 'e' and a convex lens and a screen.



Date: / / Page no:

When $\theta \uparrow$ then Intensity $\downarrow$

$AC \perp BP$ as $AP = CP$, AB slit divides into n- equal parts

$\Delta = BC$

In ΔACB, $\frac{BC}{AB} = \sin\theta$

$\Delta = BC$

$= AB \sin\theta = e\sin\theta$

Phase diffrance $= \frac{2\pi}{\lambda} \Delta$ (1)

Phase diff (AB) $_{slit}$ $= \frac{2\pi \times e\sin\theta}{\lambda}$ (2)

phase diff for 1 part $= \frac{2\pi}{\lambda} \times \frac{e}{n} \sin\theta$

$$d = \frac{2\pi}{\lambda} \cdot \frac{e\sin\theta}{n}$$

$$\frac{nd}{2} = \frac{\pi e \sin\theta}{\lambda} = \alpha \text{ (assume)}$$

$$\boxed{\frac{d}{2} = \alpha/n}$$

Using eqn for resultant amplitude

$$R = \frac{a\sin nd/2}{\sin d/2} = \frac{a\sin\left(\frac{\pi e\sin\theta}{\lambda}\right)}{\sin d/2}$$

$$\boxed{R = \frac{a\sin\alpha}{\sin \alpha/n}}$$

$\sqrt{I} = R$ $(R^2 = I)$

Where, R is an resultant amplitude of single slit
I is intensity.

$$\boxed{R = \frac{a \sin\alpha}{\alpha/n}}, \quad \frac{\alpha}{n} \to 0 \qquad \lim_{\frac{\alpha}{n} \to 0} \sin\frac{\alpha}{n} = \frac{\alpha}{n}$$

$\cancel{R}$ $\alpha \longrightarrow 0$.

$$\alpha = \frac{\pi e \sin\theta}{\lambda}$$

$$R = \frac{na \sin\alpha}{\alpha}$$

$na \Rightarrow$ no of parts of amplitude

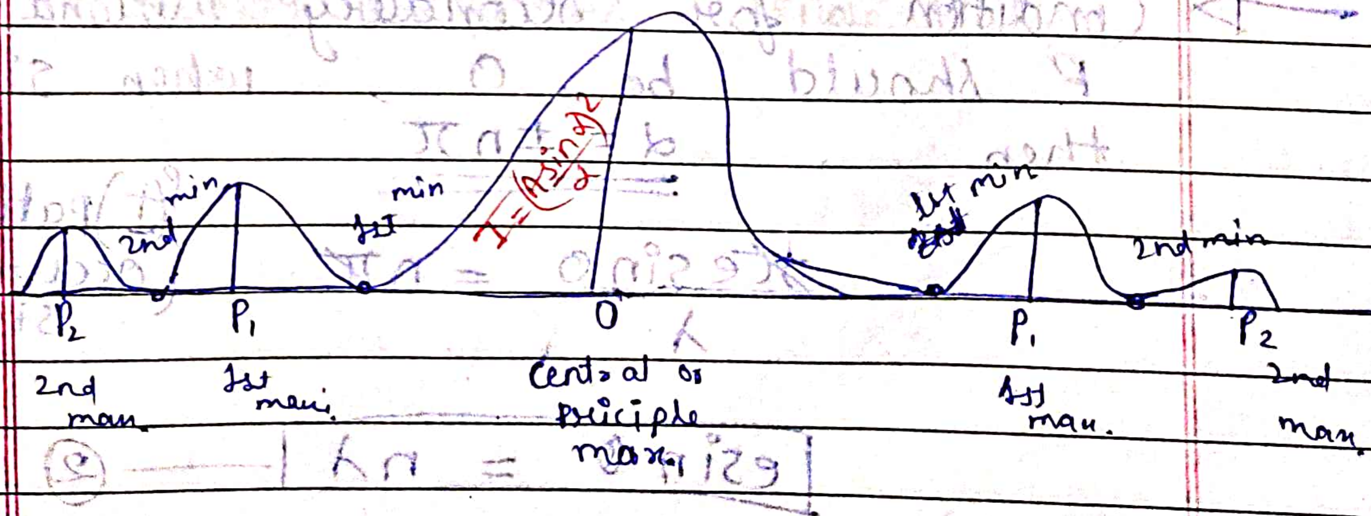
$$\boxed{R = \frac{A \sin\alpha}{\alpha}} \quad \text{--- (1)}$$

Where $A(=na)$ in amplitude of slit AB.

a = amplitude of 1 part
R = resultant amplitude of single slit

$$I = \left(\frac{A \sin\alpha}{\alpha}\right)^2$$

Diffraction pattern:-



Date: / / Page no:

→ Condition for central maxima for central maxima, R should be maximum.

$R = A^2$, $A \neq \alpha = 0$

$$I = \left(\frac{A \sin\alpha}{\alpha}\right)^2$$

or

$$R = \frac{A \sin\alpha}{\alpha}$$

at $\alpha = 0$

$$R = A \lim_{\alpha \to 0} \frac{\sin\alpha}{\alpha} \qquad \boxed{\lim_{\alpha \to 0} \frac{\sin\alpha}{\alpha} = 1}$$

$$\boxed{R = A}$$

$$\boxed{I = A^2}$$

→ Condition for secondary minima
R should be 0, when $\sin\alpha = 0$
then, $\alpha = \pm n\pi$

$$\frac{\pi e \sin\theta}{\lambda} = n\pi$$

{($\pm$) pattern occur both sides

$$\boxed{e \sin\theta = n\lambda} \quad \text{——— (2)}$$

or $$\lambda = \frac{e \sin\theta}{n} \quad \text{——— (3)}$$

Date: / / Page no:

Condition for secondary maxima

$$\frac{dI}{d\alpha} = 0$$

$$\frac{d}{d\alpha}\left(\frac{A\sin\alpha}{\alpha}\right)^2 = 0$$

$$\Rightarrow A^2\left[\frac{d}{dx}\left(\frac{\sin\alpha}{\alpha}\right)^2\right] = 0$$

$$\Rightarrow A^2\, 2\frac{\sin\alpha}{\alpha}\left[\frac{d}{dt}\left(\frac{\sin\alpha}{\alpha}\right)\right] = 0$$

$$\Rightarrow 2A^2\frac{\sin\alpha}{\alpha}\left[\frac{\alpha\cos\alpha - \sin\alpha \cdot 1}{\alpha^2}\right] = 0$$

$\sin\alpha \neq 0$, or $\alpha\cos\alpha - \sin\alpha = 0$

[because it is the condition of secondary minima $\sin\alpha = 0$.]

$$\boxed{\alpha = \tan\alpha} \quad (4)$$

Intensity decreases tangentially

Q. Show that in single slit the relative intensity of successive maxima are nearly $1 : \frac{1}{22} : \frac{1}{61} : \frac{1}{121}$ --------

Sdve ⇒ $I = \left(\frac{A\sin\alpha}{\alpha}\right)^2$

$$\alpha = \frac{\pi e \sin\theta}{\lambda}$$

$$e\sin\theta = n\lambda$$

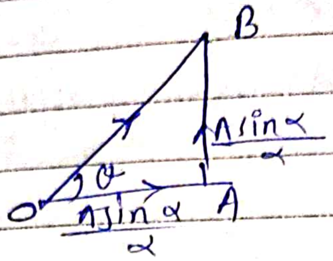
$$\alpha = \frac{\pi n\lambda}{\lambda} \quad ; \quad \alpha = \left(n + \tfrac{1}{2}\right)\frac{\lambda}{2}$$

$$\alpha = 3\pi/2, \quad 5\pi/2, \quad 7\pi/2, \ldots\ldots$$

$$I_1 = A^2\left(\frac{\sin 3\pi/2}{3\pi/2}\right)^2 = A^2 \frac{4}{9\pi^2} = \frac{1}{9\pi^2/4}$$

$$I_2 = A^2\left(\frac{\sin 5\pi/2}{5\pi/2}\right)^2 = A^2\frac{4}{25\pi^2} = \frac{1}{61.68}$$

Double slit:-



$$R^2 = a_1^2 + a_2^2 + 2a_1a_2\cos\delta$$

$$= \left(\frac{A\sin\alpha}{\alpha}\right)^2 + \left(\frac{A\sin\alpha}{\alpha}\right)^2 + 2\left(\frac{A\sin\alpha}{\alpha}\right)\left(\frac{A\sin\alpha}{\alpha}\right.$$

$$= 2\left(\frac{A\sin\alpha}{\alpha}\right)^2 + 2\left(\frac{A\sin\alpha}{\alpha}\right)^2\cos\delta$$

$$R^2 = (1+\cos\delta)\,2\left(\frac{A\sin\alpha}{\alpha}\right)^2$$

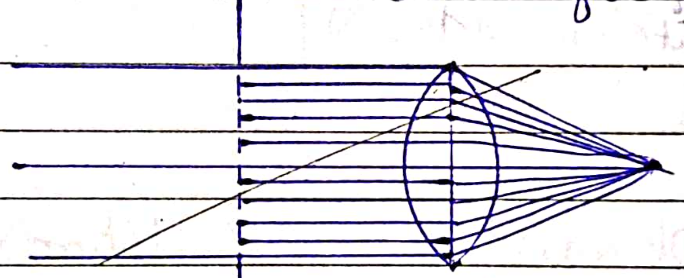
$$R = \sqrt{1+\cos\delta} \times \sqrt{2} \times \left(\frac{A\sin\alpha}{\alpha}\right)$$

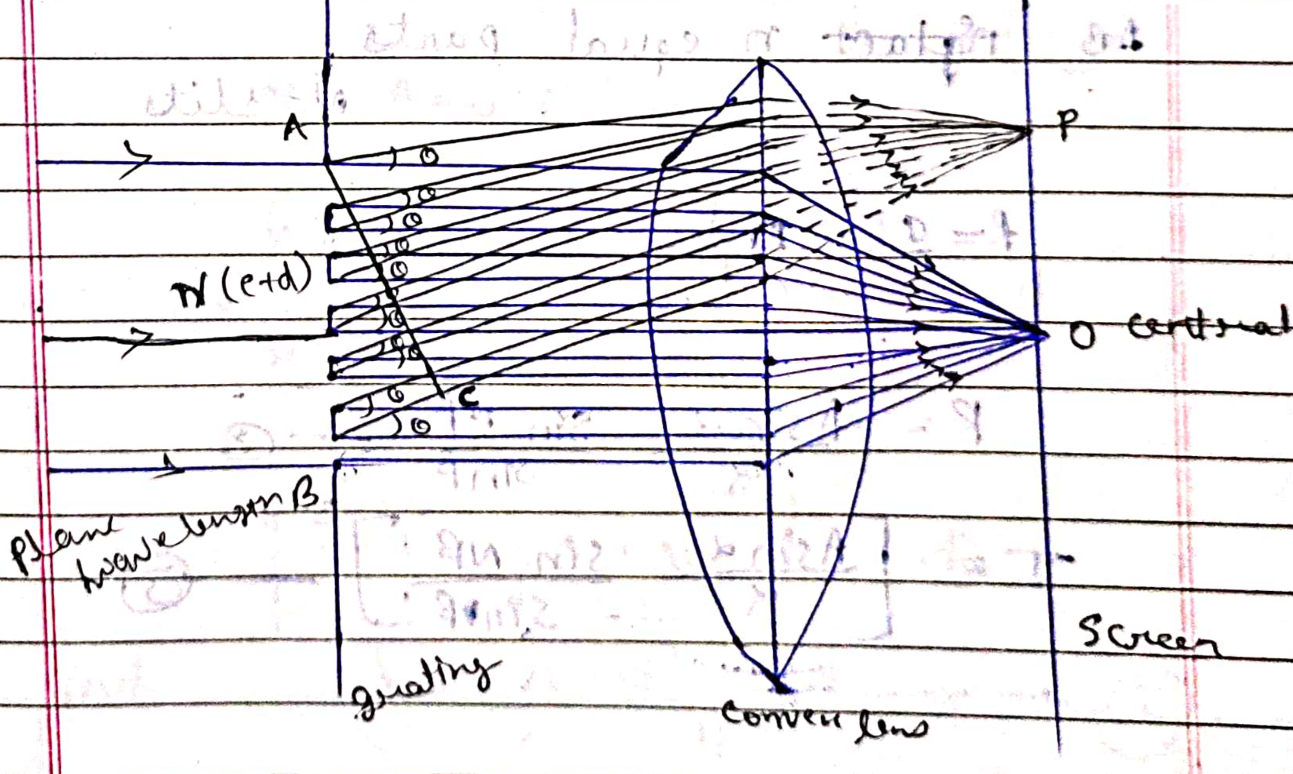
→ Fraunhofer diffraction at N-slits (grating)

Grating is large no. of parallel slit.

It consist of plan wave front and granting of grating element e+2 (AB n times of e+2) and a conven lens and screen.

A/c to Hyguenge Principle plan wave fronts travel normally and focus at 'O' and secondary wave fronts deviates its angle θ to the normal and focus at P.





Date: / / Page no:

Theory:-

Path differnce b/w AP and BP.

$AC \perp BP$ as $AP = CP$.

$\Delta = BC$, $\frac{BC}{AB} = \sin\theta$

$\Delta = AB \sin\theta$.

$\Delta = N(e+d)\sin\theta$ ——— (1).

Phase diff. $= \frac{2\pi}{\lambda}\Delta$

phase diff. for AB $= \frac{2\pi}{\lambda} N(e+d)\sin\theta$

d (Phase diff for 1 slit) $= \frac{2\pi}{\lambda}(e+d)\sin\theta$

$d/2 = \beta$

$n \to N$

AB - ~~refract~~ n equal parts

N - slits

$R = \frac{a \sin n d/2}{\sin d/2}$

$R = \frac{A\sin\alpha}{\alpha} \frac{\sin N\beta}{\sin\beta}$ ——— (2)

$I = \left[\frac{A\sin\alpha}{\alpha} \frac{\sin N\beta}{\sin\beta}\right]^2$ ——— (3)

Date: / / Page no:

→ condition for central maxima

$$\boxed{\beta = \frac{\pi (e+d) \sin\theta}{\lambda}}$$

$R = N \frac{A \sin\alpha}{\alpha}$ (at $\beta = 0$)

$$R = \frac{A \sin\alpha}{\alpha} \cdot \frac{\sin N\beta}{\sin\beta}$$

$$R = \frac{A \sin\alpha}{\alpha} \times \frac{\lim_{\beta \to 0} \frac{\sin N\beta}{N\beta} \times N\beta}{\lim_{\beta \to 0} \frac{\sin\beta}{\beta} \times \beta}$$

$$R = \frac{N A \sin\alpha}{\alpha} \times \frac{1}{1}$$

$$\boxed{R = N A \frac{\sin\alpha}{\alpha}}$$

or

→ condition of secondary minima

$\sin N\beta = 0$, $R = 0$

$\beta = \pm n\pi$

or

$$\frac{\pi (e+d) \sin\theta}{\lambda} = n\pi$$

$$\boxed{(e+d) \sin\theta = \lambda n} \quad \text{——— (4)}$$

and, $$\lambda = \frac{(e+d) \sin\theta}{n} \quad \text{——— (5)}$$

Date: / / Page no:

Eqn no ⑤ is required relation for ~~called~~ for wavelength of light at grating differection

where, $(e+d) \longrightarrow$ grating element
and $e =$ thickness of transparent part
$d \rightarrow$ — " — opaque — " —
$\theta =$ angle of diffraction
$n =$ order of spectrum

(c) condition for secondary maxima

$$\frac{dI}{d\beta} = 0$$

$$I = \left[\frac{A\sin\alpha}{\alpha} \frac{\sin N\beta}{\sin\beta}\right]^2$$

$$\frac{dI}{d\beta} = \left(\frac{A\sin\alpha}{\alpha}\right)^2 \frac{d}{d\beta}\left[\frac{\sin N\beta}{\sin\beta}\right]^2$$

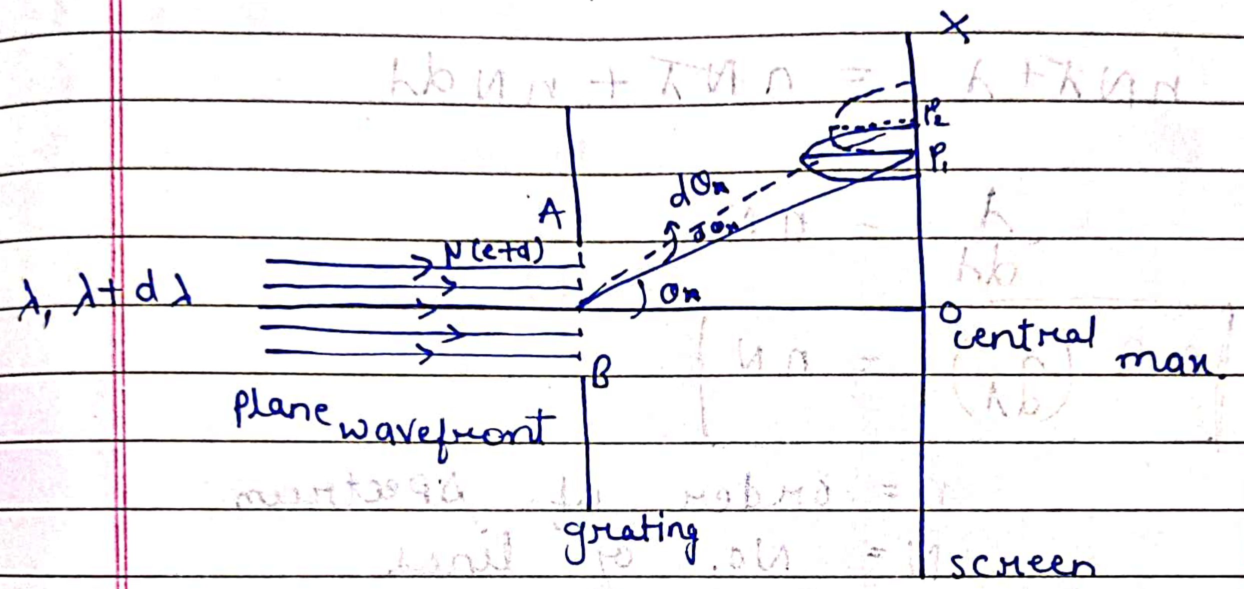
$$\frac{dI}{d\beta} = \left(\frac{A\sin\alpha}{\alpha}\right)^2 2\frac{\sin N\beta}{\sin\beta} \times \cos N\beta$$

Imp

Date: / / Page no:

Resolving power of grating

An ability of diffraction grating to separate or reduce to two diffrent closer or very closer wavelength 'λ' and 'λ + dλ'.



~~It consist of~~

Equation for grating are

$$N(e+d)\sin\theta = nN\lambda \quad - \text{minima}$$

$$N(e+d)\sin\theta = (nN+1)\lambda \quad - \text{maxima}$$

According to Rayleigh criteria.

P_2 max. for 'λ' in direction $\theta_n + d\theta_n$

Similarly, P_1 min. for λ+dλ -- -- -- " --

$$N(e+d)\sin\theta = (nN+1)\lambda \quad \text{——— (1)}$$

$$N(e+d)\sin\theta = nN(\lambda + d\lambda) \quad -② $$

from eqn ① & ②

$$(nN+1)\lambda = nN(\lambda + d\lambda)$$

$$\cancel{nN\lambda} + \lambda = \cancel{nN\lambda} + nN\,d\lambda$$

$$\frac{\lambda}{d\lambda} = nN$$

$$\boxed{R.P.\left(\frac{\lambda}{d\lambda}\right) = nN}$$

n = order of spectrum
N = No. of lines.

Q.1) A grating having 18000 LPI, find maximum order of spectrum if $\lambda = 6000$ Å

Solve =

$$(e+d)\sin\theta = n\lambda \quad , \quad n_{max} \quad , \quad \theta = 90°$$

$$\frac{2.54\,cm}{18000}\sin 90° = n \times 6000 \times 10^{-8}\,cm$$

$$n = \frac{2.54\,cm}{18000} \times \frac{1}{6 \times 10^{-5}\,cm}$$

$$\boxed{n = 2.35}$$

$n = 2$

2nd order of spectrum

CO - 3

Semiconductor

Semiconductor

Material - Ge, Si

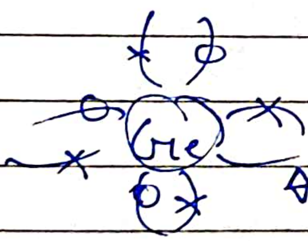
Types:- ① Intrinsic semiconductor

- Purer material
- $n = p$
- as insulator at 0 K

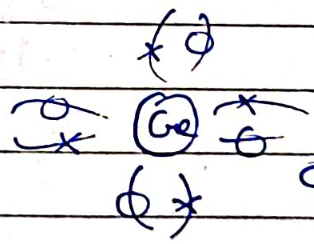
② Extrinsic (doping)

P-type | N-type

- Trivalent :- Al, B process
- Pentavalent :- N, Ph



hole



electron

- $p \gg n$
- $n \gg p$

- holes are majority charge carrier
- electrons are majority charge carrier

- P → excess
- N → access

type P = holes
type n = electrons

→ ~~Fermilevel's in intrinsic / Extrinsic semiconductor~~

→ Fermilevel's in intrinsic semiconductor.

Intrinsic semiconductor : It is pure material

$$n = p$$

$$N_c\, e^{-(E_c - E_F)/KT} = N_v\, e^{-(E_F - E_v)/KT}$$

taking Log both the sides

$$\frac{-(E_c - E_F)}{KT} = \log \frac{N_v}{N_c} - \frac{(E_F - E_v)}{KT}$$

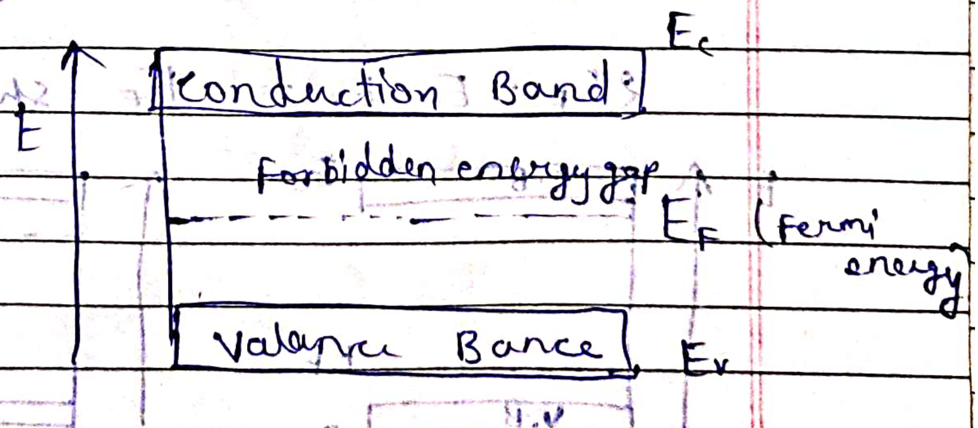
or

$$-E_c + E_F = KT \log \frac{N_v}{N_c} - E_F + E_v$$

$$-E_c + E_F + E_F - E_v = KT \log\left(\frac{N_v}{N_c}\right)$$

$$2E_F - E_c - E_v = 0$$

$$\boxed{E_F = \frac{E_c + E_v}{2}}$$



Fermilevel lies in middle CB & VB

Date: / / Page no:

★ Fermi levels in Extrinsic Semiconductor

Extrinsic semiconductor

P-type: $p >> n$

N-type: $n >> p$

p type semiconductor

$n << p$

$$N_c e^{-(E_c - E_F)/KT} << N_v e^{-(E_F - E_v)/KT}$$

taking log

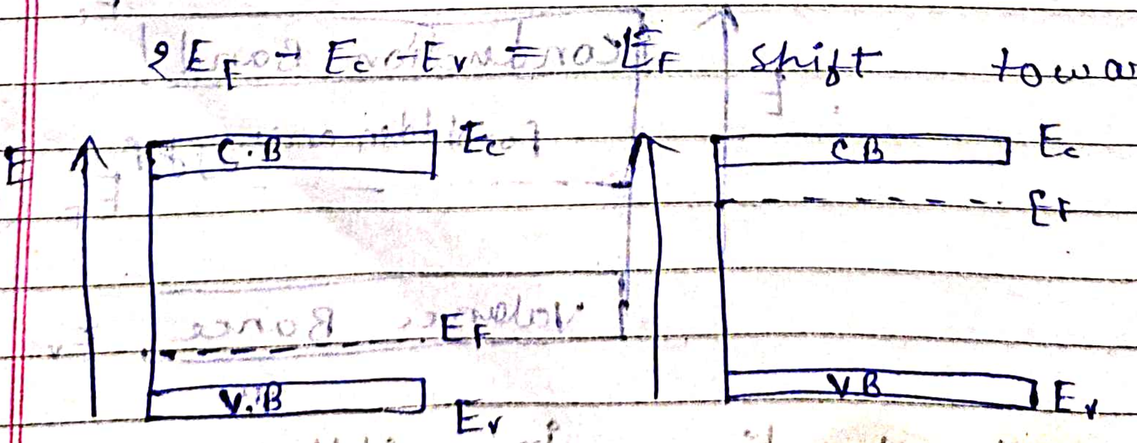
$$\frac{-(E_c - E_F)}{KT} << \log \frac{N_v}{N_c} - \frac{E_F - E_v}{KT}$$

or

$$-E_c + E_F << KT \left[\log \frac{N_v}{N_c}\right] - E_F + E_v$$

$$-E_c + E_F + E_F - E_v << KT \left[\log \frac{N_v}{N_c}\right], \quad p >> n$$

$2E_F - E_c - E_v$ ... E_F shift toward VB



P-type. N-type

Fermi Dirac Distribution function.

$$F_{(E)} = \frac{1}{e^{(E-E_F)/KT}+1}$$

$T > 0K$, $E = E_F$

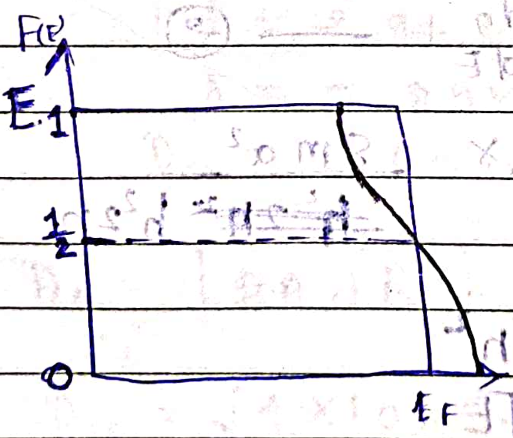
$$F_{(E)} = \frac{1}{e^{0}+1} = \frac{1}{2}$$

$T = 0.K$, $E > E_F$

$$F_{(E)} = \frac{1}{e^{+\infty}+1} = \frac{1}{\infty+1} = 0.$$

$E < E_F$

$$F_{(E)} = \frac{1}{e^{-\infty}+1} = \frac{1}{0+1} = 1$$



Date: / / Page no:

* Density of state:-
It is defined as
$$\frac{dn}{dE}$$

no. of atoms / Energy

from $E_n = \frac{n^2 h^2}{8ma^2}$ —— ① $E_n \to E$

$$dE = \frac{h^2}{8ma^2} 2n\,dn$$

$$\frac{dn}{dE} = \frac{8ma^2}{h^2 2n}$$

A/c to Polies prin
Electron has 2 spins $(\frac{1}{2}, -\frac{1}{2})$

$$DOS = 2\frac{dn}{dE} \quad —— ②$$

$$DOS = 2 \times \frac{8ma^2}{\cancel{h^2 2n^2}\ h^2 2n} \quad —— ③$$

$$E \propto n^2$$

or $n \propto \sqrt{E}$

$$DOS \propto \frac{1}{\sqrt{E}}$$

Problem's

Q1 Newton's ring are obserbed normally in reflected light of wavelength 5.89×10^{-5} cm The diameter of 10th dark ring is 0.50 cm. Find the Radius of curvature of lens & thickness of film.

solve:-

Q2 The moveable mirror of milhelron's Interferometer is moved through a distance of 0.02603 mm. Find the number of frings shifted across the cross-wire of eye piece of telescope, if a wavelength of 52060 Å is used.

solve:- 1) Given,

$$\boxed{\begin{array}{l} R = 10,6.11 \text{ cm} \\ t = 2.94 \times 10^{-4} \text{ cm} \end{array}}$$ Ans

$\lambda = 5.89 \times 10^{-5}$ cm

$D_{10} = 0.50$ cm

$D_n = \sqrt{4 n \lambda R}$

$D_{10} = \sqrt{4 \times 10 \times 5.89 \times 10^{-5} \times R}$

$(0.50)^2 = 4 \times 5.89 \times 10^{-4} \times R$

0.25

$\cancel{0.25 \times 10} = 2.356 \times 10^{-3} \times R$

$\cancel{\boxed{1.0611 = R}}$ $\boxed{R = 106.11}$ cm

Date: / / Page no:

$$2t = \frac{D_n^2}{4R}$$

$$2t = \frac{D_{10}^2}{4R}$$

$$2t = \frac{0.5 \times 0.5}{4 \times 106.11}$$

$$\boxed{t = 2.94 \times 10^{-4}\ cm}$$

Solve-2- Given,

$$x = 0.02603 \times 10^{-3}\ m$$

$$\lambda = 52060 \times 10^{-8}\ m$$

$$\lambda = \frac{2x}{N}$$

$$52060 \times 10^{-8}\ m = \frac{2 \times 0.02603 \times 10^{-3}\ m}{N}$$

$$N = \frac{52060 \times 10^{-8}}{2 \times 0.02603 \times 10^{-3}}$$

$$\boxed{N = 1.00}$$