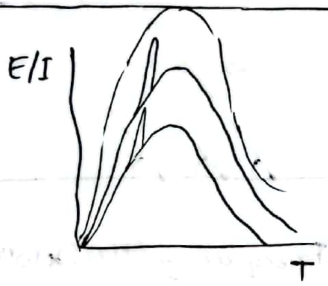
physics 1107

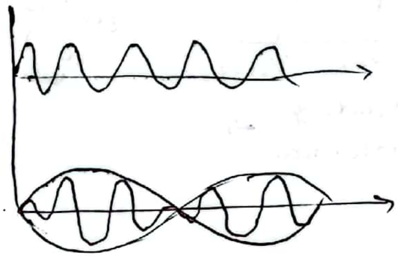
Lecture-1

Dr MD. Asaduzzaman → Assistant Prof
Mr Md. Idris Ali → Assistant Prof

Concept of Modern Physics
- A Beiser

Inadequance of classical concept





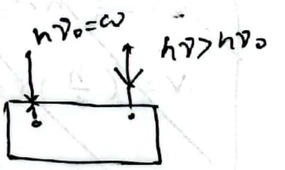
Photon, $E = h\nu$

Quantum Theory of Light

Lecture-2

Date: 08.01.2023
Sunday

Threshold energy → amount of energy needed to remove a e^- from it's orbit



$h\nu = \omega + KE_{max}$

Stopping potential → potential enegy = K.E.
↓ নিবৃত্তি বিভব
Retarding Potential

$\boxed{W = h\nu_0}$
↓ threshold energy
→ threshold frequency

| 1 m² area 1 atm thick | → Na

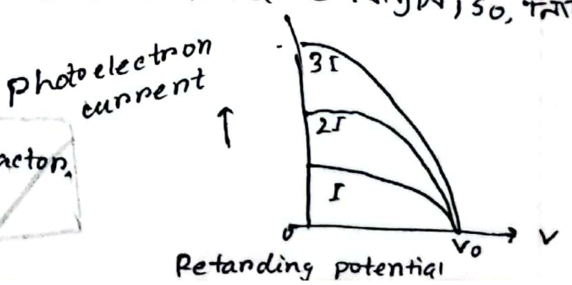
↓

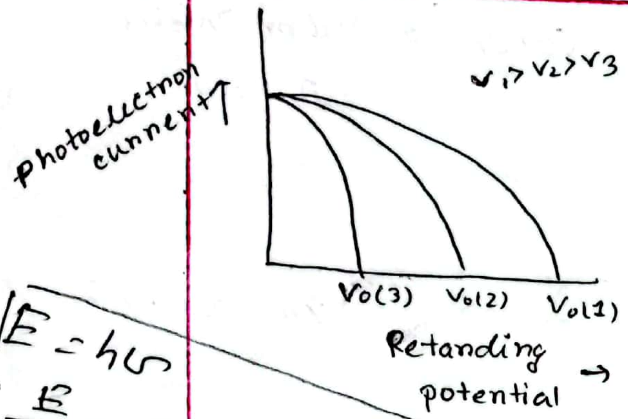
10^{19} atoms (roughly)

① Why individual metal has individual threshold energy?

→ Becoz individual metal has individual e^- বিন্যাস, so, নির্দিষ্ট e^- বের হবে,

frequency is the main factor,
energy বাড়ালে না num বাড়বে।

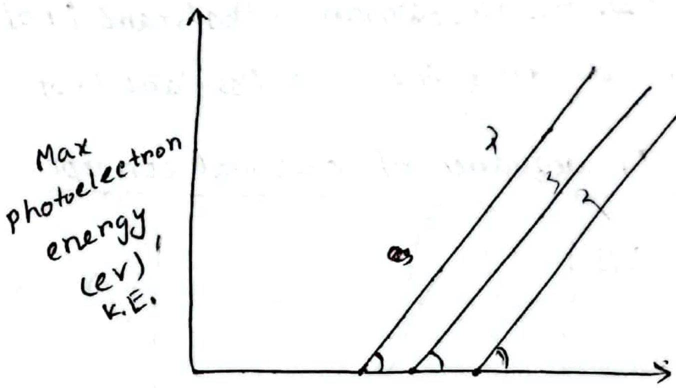




$E = h\nu$

$\frac{E}{h} = \nu = m = \tan\theta$

$y = mx$



Frequency (Hz) ($\times 10^{14}$ Hz)
Range

Individual metal needs individual threshold energy

$$\boxed{h\nu = K.E_{max} + \varphi / W_0 / W}$$

$$= KE_{max} + h\nu_0$$

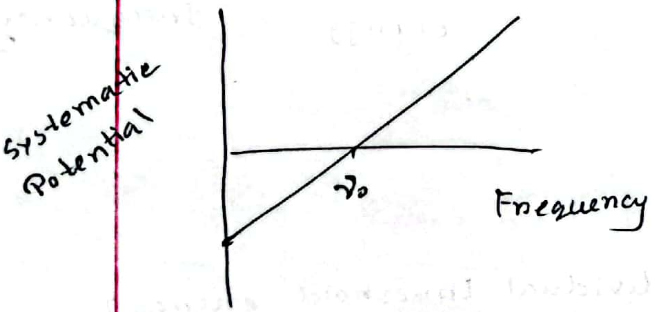
$$h\nu = KE_{max} + \frac{hc}{\lambda_0}$$

$$\boxed{\Rightarrow KE_{max} = h(\nu - \nu_0)}$$

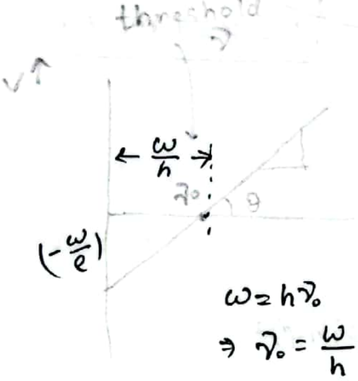
Millikan's equation

Na – 5890 Å, 5896 Å } monochromatic ধরে নেওয়া হয়

$$\boxed{\begin{aligned} eV &= \frac{1}{2}mv^2 = h\nu - \omega_0 \\ \Rightarrow V &= \left(\frac{h}{e}\right)\nu - \left(\frac{\omega_0}{e}\right) \end{aligned}}$$



Date: 15.01.2023
Sunday



threshold energy

$$\frac{1}{2}mV_{max}^2 = eV = h\nu - h\nu_0$$

$$V = \left(\frac{h}{e}\right)\nu - \frac{\omega}{e}$$

$$\boxed{\therefore V = \left(\frac{h}{e}\right)\nu + \left(\frac{\omega}{e}\right)}$$

$$y = mx + c$$

$\omega = h\nu_0$

$\Rightarrow \nu_0 = \frac{\omega}{h}$

- $\tan\theta = \frac{\omega/e}{\omega/h}$
- slope $= \frac{h}{e}$

slope $= \frac{dy}{dx} = \frac{h}{e}$ $\rightarrow 6.55 \times 10^{-34}$ Js

photon $\rightarrow$ massless particle

Compton effect :

$$E = mc^2 = \frac{m_0 c^2}{\sqrt{1-\frac{v^2}{c^2}}}$$

$$p = mv = \frac{m_0 v}{\sqrt{1-\frac{v^2}{c^2}}}$$

$$E^2 = m_0{}^2c^4 + p^2c^2$$

$$\Rightarrow p^2c^2 = \frac{m_0{}^2 v^2 c^2}{1-\frac{v^2}{c^2}} \quad \text{— (ii)}$$

- $E^2 = \dfrac{m_0^2 c^4}{1-\frac{v^2}{c^2}}$ — (i)

$$\boxed{\Rightarrow \cancel{\frac{m_0{}^2c^4}{E^2}} = \cancel{\frac{m_0{}^2 v^2 c^2}{p^2c^2}} \quad \Rightarrow}$$

(i) $-$ (ii) $\Rightarrow$

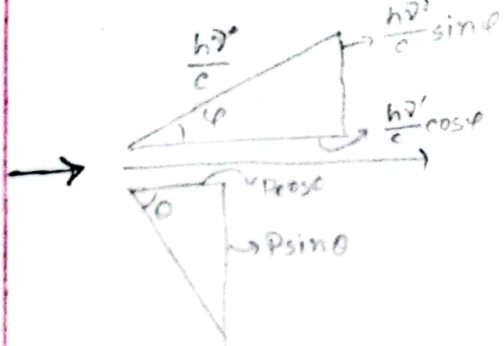
$$E^2 - p^2c^2 = \frac{m_0{}^2c^4\left(1-\frac{v^2}{c^2}\right)}{\left(1-\frac{v^2}{c^2}\right)}$$

$$\Rightarrow E^2 = m_0^2c^4 + p^2c^2$$

$$\Rightarrow E = \sqrt{m_0{}^2c^4 + p^2c^2}$$

$m_0 = 0$, $E = pc$

$$\Rightarrow p = \frac{h\nu}{c}$$



- In the incident photon direction before collision momentum = After collision momentum

$$\frac{h\nu}{c}+0 = \frac{h\nu'}{c}\cos\varphi + p\cos\theta$$

$$\Rightarrow pc\cos\theta = h\nu - h\nu'\cos\varphi \quad \text{--- (i)}$$

$$\boxed{E = KE + m_0c^2}$$

- Perpendicular to the direction,

$$0+0 = \frac{h\nu'}{c}\sin\varphi - p\sin\theta$$

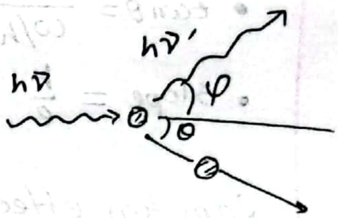
$$\Rightarrow pc\sin\theta = h\nu'\sin\varphi \quad \text{--- (ii)}$$

$$(i)^2 + (ii)^2 \Rightarrow \quad p^2c^2 = (h\nu - h\nu'\cos\varphi)^2 + (h\nu'\sin\varphi)^2$$

$$= (h\nu)^2 - 2h\nu h\nu'\cos\varphi + (h\nu')^2$$

$$\boxed{KE = h\nu - h\nu'}$$

electron



- $$\frac{2m_0c^2(h\nu - h\nu')}{2h^2c^2} = \frac{2(h\nu)(1-\cos\varphi)(h\nu')}{2h^2c^2}$$

$$\Rightarrow \frac{m_0c}{h}\left(\frac{\nu}{c} - \frac{\nu'}{c}\right) = \frac{\nu}{c}\frac{\nu'}{c}(1-\cos\varphi)$$

$$\Rightarrow \frac{m_0c}{h}\left(\frac{1}{\lambda} - \frac{1}{\lambda'}\right) = \frac{1}{\lambda}\frac{1}{\lambda'}(1-\cos\varphi)$$

$$\Rightarrow \lambda' - \lambda = \left(\frac{h}{m_0c}\right)(1-\cos\varphi)$$

λ' → scattered photon wavelength

$\frac{h}{m_0c}$ → compton wavelength

Date: 18.01.2023
Wednesday

(*) $\frac{d^2y}{dt^2} + 2\lambda \frac{dy}{dt} + \omega^2 y = f_0 \sin pt$ —(i)

$\Rightarrow \quad y = A\sin(pt-\theta)$ —(ii)

$\frac{dy}{dt} = Ap\cos(pt-\theta)$

$\frac{d^2y}{dt^2} = -Ap^2\sin(pt-\theta)$

Putting the values in eq^n(i),

$-Ap^2\sin(pt-\theta) + 2\lambda Ap\cos(pt-\theta) + \omega^2 A\sin(pt-\theta)$
$= f_0 \sin\{(pt-\theta)+\theta\}$
$= f_0\sin(pt-\theta)\cos\theta + f_0\cos(pt-\theta)\sin\theta$ —(iii)

• If this solution is to be hold good for all values of it, the respective co-efficient of $\sin(pt-\theta)$ and $\cos(pt-\theta)$ on either side of eq^n(iii) must be equal.

$A(\omega^2-p^2) = f_0\cos\theta$ —(iv)

$\Rightarrow 2\lambda Ap = f_0\sin\theta$ —(v)

Squaring and adding eq^n(iv) and (v) $\rightarrow$

$A^2(\omega^2-p^2)^2 + 4\lambda^2A^2p^2 = f_0^2$

$\Rightarrow A^2[(\omega^2-p^2) + 4\lambda^2p^2] = f_0^2$

$\Rightarrow A^2 = \frac{f_0^2}{(\omega^2-p^2)^2 + 4\lambda^2p^2}$

$\Rightarrow \boxed{A = \frac{f_0}{\sqrt{(\omega^2-p^2)^2+4\lambda^2p^2}}}$

Dividing eq^n(v) to (iv) $\Rightarrow$

$\frac{f_0\sin\theta}{f_0\cos\theta} = \frac{2\lambda Ap}{A(\omega^2-p^2)}$

$\Rightarrow \tan\theta = \frac{2\lambda p}{1(\omega^2-p^2)}$

$\Rightarrow \boxed{\theta = \tan^{-1}\left(\frac{2\lambda p}{\omega^2-p^2}\right)}$

(*) Solution of forced vibration,

$\boxed{y = \frac{f_0}{\sqrt{(\omega^2-p^2)^2+4\lambda^2p^2}}\sin\left(pt - \tan^{-1}\frac{2\lambda p}{(\omega^2-p^2)}\right)}$

$\boxed{\text{Resonance}}$

Maximum displacement of a driven oscillator,

$$A^2 = \frac{f_0^2}{(\omega^2-p^2)^2+4\lambda^2p^2}$$

The amplitude is maximum when the denominator is minimum,

$$\frac{d}{dp}\left[(\omega^2-p^2)^2+4\lambda^2p^2\right]=0$$

$$\Rightarrow 2(-2p)(\omega^2-p^2)+4\lambda^2 2p=0$$

$$\Rightarrow -4p(\omega^2-p^2)+8\lambda^2p=0$$

$$\Rightarrow p(p^2-\omega^2)+2\lambda^2p=0$$

$$\Rightarrow p(p^2-\omega^2+2\lambda^2)=0 \qquad \because p\neq 0$$

$$\therefore p^2-\omega^2-2\lambda^2=0$$

$$\Rightarrow p^2=\omega^2-2\lambda^2 \qquad \therefore \boxed{p=\sqrt{\omega^2-2\lambda^2}}$$

• Then the amplitude will be maximum when the driven frequency $\boxed{\frac{p_r}{2\pi}=\frac{\sqrt{\omega^2-2\lambda^2}}{2\pi}}$ resonant frequency

The state of vibration when the amplitude of the driven oscillator is maximum is called resonance.

In the absence of damping, ~~resp~~ resonance take place when natural frequency of oscillator, is equal to the frequency of driving force,

The maximum Amplitude,

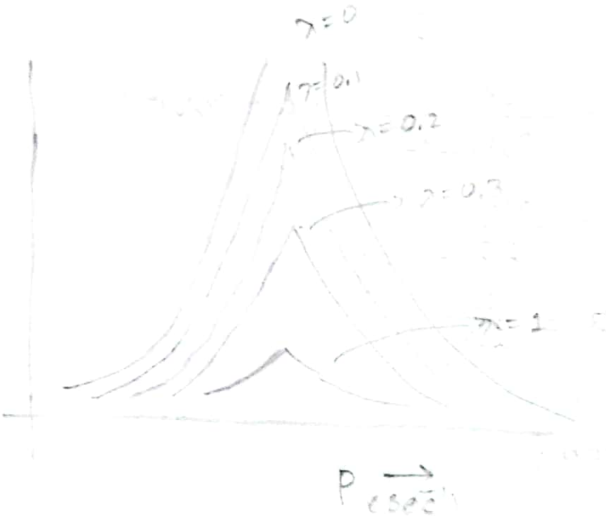
$$A_{max}=\frac{f_0}{\sqrt{(\omega^2-p^2)^2+4\lambda^2p^2}}$$

$$= \frac{f_0}{\sqrt{(\omega^2-\omega^2+2\lambda^2)^2+\lambda^2\times 4(\omega^2-2\lambda^2)}}$$

$$= \frac{f_0}{\sqrt{4\lambda^4+4\lambda^2\omega^2-8\lambda^4}}$$

$$= \frac{f_0}{\sqrt{4\lambda^2\omega^2-4\lambda^4}}$$

$$\therefore A_{max} = \frac{f_0}{2\lambda\sqrt{\omega^2-\lambda^2}}$$



Sharpness of Resonance :

It is a measure of the rate of fall amplitude from it's maximum value at resonant frequency on either side of it. The sharper the fall in amplitude sharper the resonance.

• Forced vibration of quality ~~[illegible]~~ factor.

Quality factor of forced vibration :

The ratio of the response of the oscillation when the driven frequency is equal to the resonant frequency to the response when the driven frequency is zero is called the quality factor of the forced vibration.

$$A = \frac{f_0}{\sqrt{(\omega^2-p^2)+4\lambda^2p^2}} \quad \text{when} \quad p = 0$$

p → driving frequency

$$A_{p=0} = \frac{f_0}{\omega^2}$$

when, $p = p_r$ $\qquad A_{max} = \frac{f_0}{2\lambda\sqrt{\omega^2-\lambda^2}}$

Quality factor $= \frac{A_{max}}{A_{p=0}} = \frac{f_0/2\lambda\sqrt{\omega^2-\lambda^2}}{\frac{f_0}{\omega^2}}$

$$= \frac{\omega^2}{2\lambda\sqrt{\omega^2-\lambda^2}} \quad [\omega^2 >> \lambda^2]$$

$$= \frac{\omega^2}{2\lambda\omega}$$

$$Q = \frac{\omega}{2\lambda}$$

Phase of the driven Oscillator:

$y = A\sin(pt-\theta)$ $\qquad \theta = \tan^{-1}\frac{2\lambda p}{\omega^2-p^2}$

The phase angle θ depends upon damping and relative values of ω and p, following cases are,

(i) when $p<\omega$; i.e

$\tan\theta$ will positive and values of θ lies between 0 to $\frac{\pi}{2}$ for all values of λ.

(ii) when $p>\omega$; i.e, the $\tan\theta$ will be a negative quantity and the values of θ lies between $\frac{\pi}{2}$ to π for all values of λ.

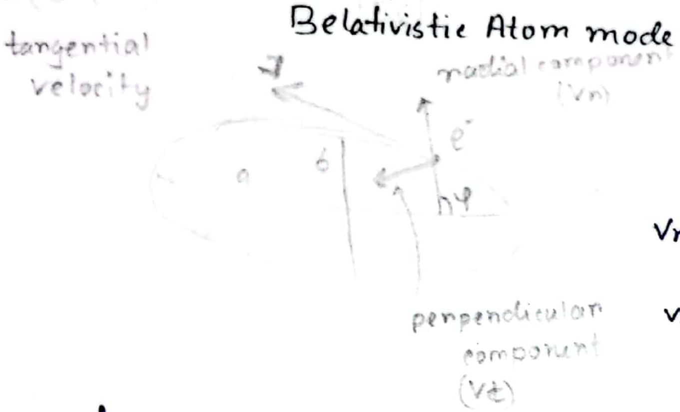
(iii) when, $p=\omega$

$\tan\theta = \infty$, $\quad \theta = \frac{\pi}{2}$

Date: 22.01.2023
Sunday

$\boxed{\text{Atomic Physics}}$ → J.B. Rajan

Relativistic Atom model



$$v_r = \frac{dr}{dt}$$

$$v_t = r\frac{d\varphi}{dt}$$

$\boxed{\text{Elliptical Orbits}}$

$$\oint p_r \, dr = n_r h$$

$$P_r = m\left(\frac{dr}{dt}\right) \qquad P_r = m v_r$$

$$\oint p_\varphi \, dr = n_\varphi h$$

$$P_\varphi = m r^2 \left(\frac{d\varphi}{dt}\right)$$

$$= m v r \cdot \left(\frac{d\varphi}{dt}\right)$$

Total energy (W) = P.E + radial K.E. + angular KE.

$$= -\frac{Ee}{r} + \frac{1}{2}m\left(\frac{dr}{dt}\right)^2 + \frac{1}{2}mr^2\left(\frac{d\varphi}{dt}\right)^2$$

$$W = -\frac{2\pi^2 m E^2 e^2}{h^2} \left(\frac{1}{n_\varphi + n_r}\right)^2$$

$$\boxed{\begin{aligned} 1-\epsilon^2 &= \frac{b^2}{a^2} \\ \Rightarrow \epsilon^2 &= 1-\frac{b^2}{a^2} \qquad a>b \end{aligned}}$$

Now,

$$\sqrt{1-\epsilon^2} = \frac{b}{a} = \frac{n_\varphi}{n_\varphi + n_r} = \frac{n_\varphi}{n}$$

$\boxed{\text{A special case } a=b, \ \frac{n_\varphi}{n}=1}$

$$W = -\frac{2\pi^2 m E^2 e^2}{n^2 h^2}$$

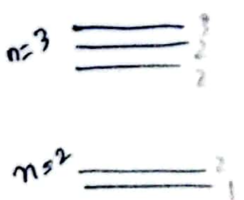
Relativistic variation of mass

$$W = -\frac{2\pi^2 m E^2 e^2}{n^2 h^2}\left[\frac{1}{n^2} + \frac{4\pi^2 E^2 e^2}{c^2 h^2}\left(\frac{n}{n_\varphi} - \frac{3}{4}\right)\frac{1}{n^4} + \dots\right]$$

n: 3
3 kinds of ellipse

$$\therefore \ -\frac{2\pi^2 m e^4}{h^2} \times \frac{Z^4 \alpha^2}{n^4}\left(\frac{n}{n_\varphi} - \frac{3}{4}\right)$$

where, $E = Ze$ $\qquad \alpha = \frac{2\pi e^2}{ch}$



6 transition possible

$3_3 \to 2_2$, $3_3 \to 2_1$,

$3_2 \to 2_2$, $3_2 \to 2_1$,

$3_1 \to 2_2$, $3_1 \to 2_1$

De Broglee Waves :

Wave-panticle duality

Date: 29.01.2023
Sunday

particle

A moving body behaves in certain ways as though it has a wave nature.

$E = h\nu \therefore p = \frac{h}{\lambda}$

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

↓
De brog lee wave-length

$\boxed{\Psi}$
wave function

- Waves of what?

matter wave

- light wave → electric & magnetic
- spherical wave → sinusoidal
- Sound wave → Pressure

Quantum mechanics basic equation

$\boxed{\text{Shrodinger's equation}}$

$$\frac{\partial^2\psi}{\partial x^2} + \frac{\partial^2\psi}{\partial y^2} + \frac{\partial^2\psi}{\partial z^2} + \frac{8\pi^2 m}{h^2}(E-u)\psi = 0$$

$\boxed{\text{Probability } |\psi|^2}$ → probability density

$\Psi = A + iB$

$\Psi^* = A - iB$

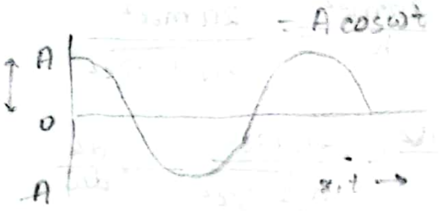
$|\Psi\Psi^2| = A^2 + B^2$

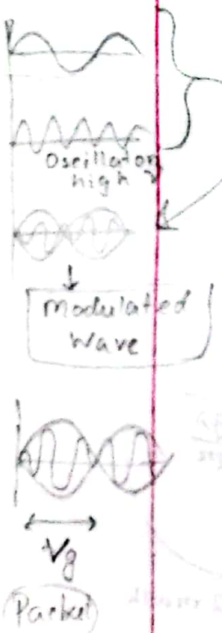
electrical signal → mechanical

Modulated wave

group velocity:

$y = A\cos 2\pi\nu t$
$= A\cos\omega t$





Describing a wave

$v_p = \nu\lambda$
↓
phase velocity
wave velocity

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

$= \left(\frac{mc^2}{h}\right) \times \left(\frac{h}{mv}\right)$

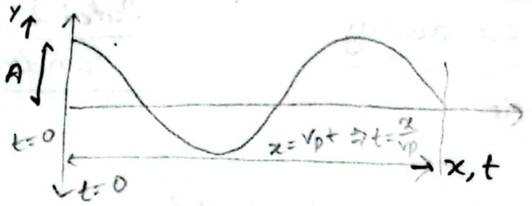
$$\boxed{v_p = \frac{c^2}{v}} \ **$$

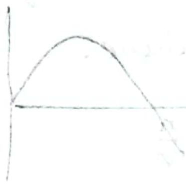
$$\boxed{\lambda = \frac{h}{\gamma m v}}$$

→ Relativistic calculation
→ p → momentum

The greater the particle's momentum, the shorter its wavelength decay

Date : 05.02.2023
Sunday





$$y = A\cos 2\pi\nu t = A$$

$$= A\cos\omega t$$

$$y = A\cos 2\pi\nu\left(t - \frac{x}{V_p}\right)$$

$$= A\cos\left(2\pi\nu t - \frac{2\pi\nu x}{V_p}\right)$$

$$= A\cos\left(\omega t - \frac{2\pi}{\lambda}x\right)$$

$$V_p = \nu\lambda$$

$$\Rightarrow \frac{1}{\lambda} = \frac{\nu}{V_p}$$

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

$$\boxed{y = A\cos(\omega t - Kx)}$$ Wave formula

wave group

$$y_1 = A\cos(\omega t - kx)$$

$$y_2 = A\cos\{(\omega t + \Delta\omega)t - (K + \Delta K)x\}$$

$$y = y_1 + y_2 = A2\left\{\cos\frac{\alpha+\beta}{2} \cdot \cos\frac{\alpha-\beta}{2}\right\}$$

$$\boxed{\text{phase velocity, } V_p = \frac{\omega}{K}}$$

$$\boxed{V_K = \frac{d\omega}{dK}}$$

$$E = h\nu$$

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

$$E = mc^2$$

$$\Rightarrow h\nu = mc^2$$

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

- $\omega = 2\pi\nu = \dfrac{2\pi mc^2}{h} = \dfrac{2\pi m_0 c^2}{h\sqrt{1 - v^2/c^2}}$

- $K = \dfrac{2\pi}{\lambda} = \dfrac{2\pi m v}{h} = \dfrac{2\pi m_0 v}{h\sqrt{1 - v^2/c^2}} \longrightarrow \dfrac{dk}{d\omega}$

- $V_g = \dfrac{d\omega}{dk} = \dfrac{d\omega/dv}{dk/dv}$

group velocity

$$\boxed{V_g = V_p - \lambda\frac{dV_p}{d\lambda}}$$

$$V_p = \frac{\omega}{K}$$

$$\Rightarrow \omega = V_p K$$

$$\Rightarrow \frac{d\omega}{dK} = V_p + K\frac{dV_p}{dK}$$

$$\Rightarrow V_g = V_p + K\frac{dV_p}{dK}$$

$$\boxed{\Rightarrow V_g = V_p - \lambda\frac{dV_p}{d\lambda}}$$

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

$$\Rightarrow dK = -\frac{2\pi}{\lambda^2}d\lambda$$

$$\Rightarrow \frac{K}{dK} = \frac{2\pi/\lambda}{-\frac{2\pi}{\lambda^2} \times d\lambda} = -\frac{\lambda}{d\lambda}$$

$$\sqrt{\frac{2\pi S}{\rho\lambda}}$$

$$V_p = \sqrt{\frac{g\lambda}{2\pi}}$$

Last 2 math from .... book.

Uncertainty Principle

$$\Psi(x) = \int_0^\infty g(k) \cos kx \, dk$$

Date: 12.02.2023

Sunday

Electron Orbits:

Thompson, Ruthenford
~~Wa~~ Light experiment
~~✓~~ Bohn Model $\longrightarrow$ (1, 2, 3, 4) point
• electron radiate energy why?

Angular momentum = $n\hbar$

• $\Delta E = E_2 - E_1$ ↗ ground state
E_2: excited state

Electrostatic force
F_c = Centrifugal force

• $F_c = F_e$

$$\Rightarrow \frac{mv^2}{r} = \frac{1}{4\pi\epsilon_0} \times \frac{e^2}{r^2}$$

$$\boxed{\therefore v = \frac{e}{\sqrt{4\pi\epsilon_0 mr}}} **$$

electron velocity

• $KE = \frac{1}{2}mv^2$

• $PE = -\frac{e^2}{4\pi\epsilon_0 r}$ → doesn't need extra force comes automatically

$= + \frac{e^2}{4\pi\epsilon_0 r}$

↑ needed extra force to move 1C charge inside a electrial field

Total energy of Hydrogen Atom, $E = KE + PE$

$$= \frac{mv^2}{2} - \frac{e^2}{4\pi\epsilon_0 r}$$

$$= -\frac{e^2}{8\pi\epsilon_0 r}$$

• The wavelength is exactly the same as the circumference of the electron orbit.

4.4 The Bohr Atom:

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

$$v = \frac{e}{\sqrt{4\pi\epsilon_0 mr}}$$

$$\Rightarrow \lambda = \frac{h}{m \times \frac{e}{\sqrt{4\pi\epsilon_0 mr}}}$$

$=$

Circumference $= n\lambda$

$\Rightarrow 2\pi r_n = n\lambda$

$$\frac{nh}{e}\sqrt{\frac{4\pi\epsilon_0 r_n}{m}} = 2\pi r_n$$

$$\Rightarrow r_n = \frac{n^2h^2\epsilon_0}{\pi me^2}, \; n = 1, 2, 3, \ldots$$

↑ Orbital radii in Bohr model

$$\boxed{r_n = n^2 a_0} **$$

* Energy levels and spectra:

$$E_n = -\frac{e^2}{8\pi\epsilon_0 r_n}$$

↑ when saying say only just magnitude, no operator ill.soul

Origin of Line Spectra:

Inital enegy − Final enerng = photon energy

$$E_i - E_f = h\nu$$

$$= E_1\left(\frac{1}{n_i^2} - \frac{1}{n_f^2}\right)$$

$$= -E_1\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right) = h\nu$$

$$\Rightarrow \boxed{\nu = \frac{E_i - E_f}{h}} \;**$$

$$\boxed{= \frac{E_1}{h}\left(\frac{1}{n_i^2} - \frac{1}{n_f^2}\right)}$$

$$-\frac{E_1}{ch} = -\frac{me^4}{8\epsilon_0^2 ch^3}$$

$$R_H = 1.097\times10^7\,m^{-1}$$

↓

রিডবার্গ ধ্রুবক

$$\frac{E_1}{h}\left(\frac{1}{(n-p)^2} - \frac{1}{n^2}\right)$$

Correspondences Principle:

The greater the quantum number, the closer quantum physics approaches classical physics.

$$\text{frequency of revolution, } f = \frac{\text{electron spein}}{\text{orbit circumference}} = \frac{v}{2\pi r}$$

$$= \frac{e}{2\pi\sqrt{4\pi\epsilon_0 m r^2}}$$

$$\text{frequency of photon} = -\frac{E_1}{h}\left(\frac{2p}{n^3}\right)$$

$$2np - p^2 = 2np$$

$$(n-p)^2 = n^2$$

$$= -\frac{E_1}{h}\left(\frac{2}{n^3}\right)$$

The vector Atom Model

Date: 26.02.2023
Sunday

① Spatial quantization
② Spinning electron

H → magnetic field direction

Orbital Q.N. Spin Q.N.

$J = L \pm S$

$1 \pm \frac{1}{2}$

$3/2, \frac{1}{2}$

Shell Model

1. $n \rightarrow$ Principal Q.N./Total Q.N.

2. $l \rightarrow$ Orbital Q.N. ~~(0 to n)~~ (0 to $n-1$)
subshell

Orbital angular momentum,

$$P_l = l \cdot \frac{h}{2\pi}$$

$$= l \cdot \hbar$$

↓
average

$$P_l = \sqrt{l(l+1)} \cdot \frac{h}{2\pi}$$

$$= \sqrt{l(l+1)} \cdot \hbar$$

3. $s \rightarrow$ Spin Q.N.

Spin angular momentum

$$P_s = s \cdot \frac{h}{2\pi}, \text{ where } s = \frac{1}{2}$$

but according to wave mechanics,

$$P_s = \sqrt{s(s+1)} \cdot \frac{h}{2\pi}$$

$$= \sqrt{s(s+1)}\ \hbar$$

P_l, P_s
↓ ↓
small letter used for single e^-

vector multiplication

$\vec{2} + \vec{1}$

$|2+1|$ to $|2-1|$

$|2+1|-1, |2+1|-2,$

$|2+1|-1,$

$|2+1|-$

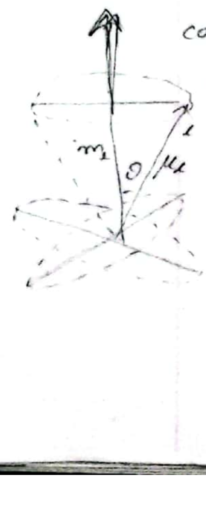
4. A total angular Q.N. (j)

J value always $\frac{1}{2}$ ~~integral~~ int value for single e^-

Total angular momentum $P_j = \sqrt{J(J+1)} \times \frac{h}{2\pi}$

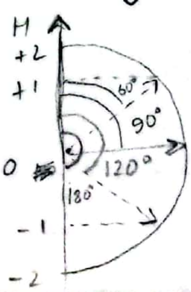
$\cos\theta = \frac{m_l}{l}$

$\Rightarrow m_l = l\cos\theta$



5. A magnetic orbital Q.N. (m_l) ($-l$ to $+l$)

$\boxed{m_l = l\cos\theta}$



$m_l = 2 \times \cos 180° = -2$

magnetic field direction
orbital

6. Magnetic spin Q.N. $(2s+1) = m_s$

$\downarrow$

value always two $(+\frac{1}{2}, -\frac{1}{2})$

$\downarrow$

(−s to +s)
excluding zero

7. Magnetic Total Q.N. (m_j) → can only have $(2j+1)$ values

$j = l \pm \frac{1}{2}$

$\downarrow$

$\frac{1}{2}$ integral value
m_j always

from j to −j
excluding zero

Coupling Schemes

L.S. coupling

$L = l_1 + l_2$

$S = s_1 + s_2$

$J = L + S$

j-j coupling

$j_1 = l_1 + s_1$

$j_2 = l_2 + s_2$

$J = j_1 + j_2$

Date: 01.03.2023
Wednesday

J-J coupling

$J = j_1 + j_2$ $\qquad J_1 = l_1 + s_1, \quad J_2 = l_2 + s_2$ $\qquad \left(\frac{1}{2}, \frac{3}{2}, \frac{5}{2} \dots\right)$

$\frac{1}{2}$ Integral value

L-S coupling much effective

$J = L + S, \quad L = l_1 + l_2$

$S = s_1 + s_2$

Two electron

$^5D_{\frac{3}{2}}$ → $(2S+1) = 5$ → $S = 2$
→ $L = 2$ So, it is not possible

3 electron

$S = \frac{3}{2}$

$S = \frac{1}{2}$

$^Y X_J$ $\qquad Y = (2S+1)$
$= (2L+1)$

$^1S_0$ → J, L, S → value?

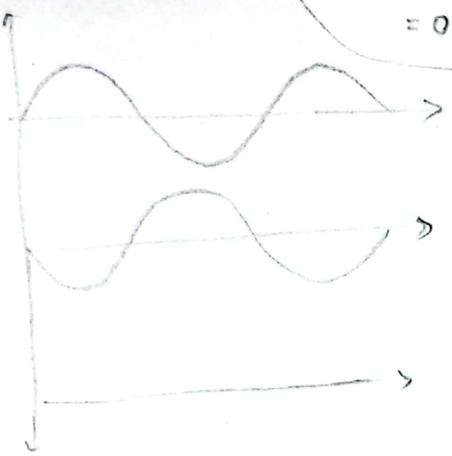
$n = 1$

$L = 0, 1, 2, 3$
s p d f

$2S+1 = 1$
$\boxed{\Rightarrow S = 0}$

L = 0 because S

Total J → $J = L + S$
$= 0 + 0$
$= 0$

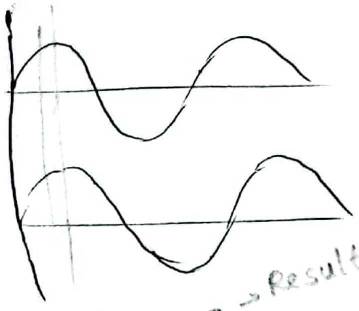


Interference

Light + light = more light
Light + light = no light

Coherent source

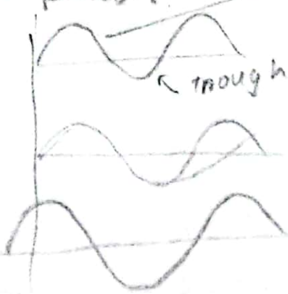
1. Amplitude nearly same
2. Freq/wavelength nearly same
3. Same phase/constant phase diff

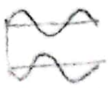


→ Resultant much

Wave, A disturbance produced by a periodic vibration

wavefront
→ A locus of all points vibrating in phase.



- Only one source there
  2 टा virtual source possible
  amplitude, frequency same
- 2 टा indepent source यखन dark place देखाय कखनो पारत ना?
  
  Amplitude not same

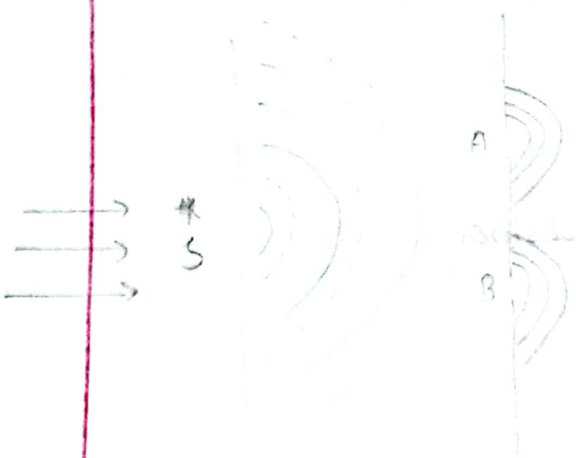
$(a,b) \in R$
$(b,a) \in R$
$\Rightarrow (a=b)$

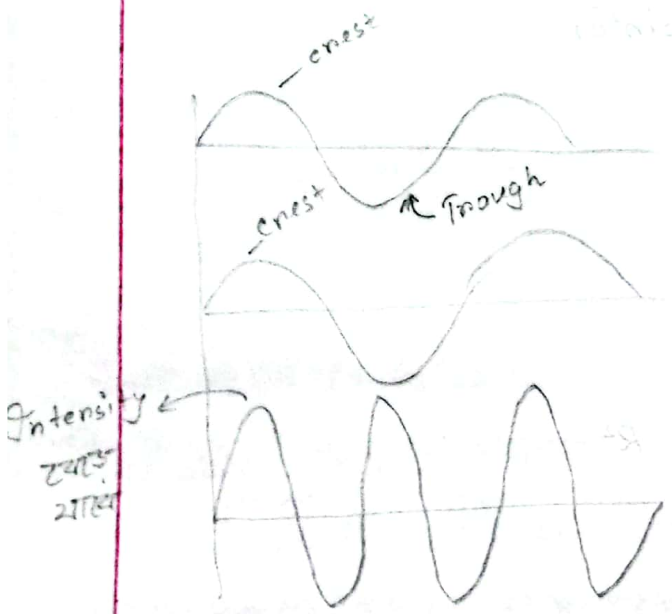
$(a,b) \in A$
$(b,a) \notin A$

Date: 05.03.2023
Sunday

● Draw spherical waves how dark & bright are made?

Interference:





Crest + crest = Bright
Trought Trough = Bright
Crest + Trough = Dark

• Show the Interference using spehenical wave

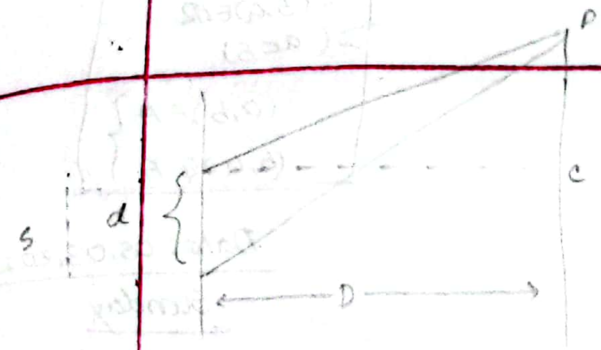
Phase Difference and Path Difference:

~~at~~

Dark position e Intensity 0 কেন?

● If the path difference between 2 waves λ, the phase difference $= 2\pi$

$$\boxed{\delta = \frac{2\pi}{\lambda} \times x}$$



$y_1 = a\sin\omega t$

$y_2 = a\sin(\omega t+\delta)$

$y = y_1 + y_2$

$= a\sin\omega t + a\sin(\omega t+\delta)$

$= a\sin\omega t + a\sin\omega t\cos\delta + a\cos\omega t\sin\delta$

$= a\sin\omega t\,(1+\cos\delta) + a\cos\omega t\,.\sin\delta$

Taking, $a(1+\cos\delta) = R\cos\theta$ — ①

$a\sin\delta = R\sin\theta$ — ②

$y = \cancel{R\sin\omega t\cos} \; R\sin\omega t\cos\theta + R\cos\omega t\sin\theta$

$= R\sin(\omega t+\theta)$ — ③

$(1)^2 + (2)^2 \Rightarrow$

$R^2 = a^2(1+\cos\delta)^2 + a^2\sin^2\delta$

$= a^2 + 2a^2\cos\delta + a^2(\cos^2\delta + \sin^2\delta)$

$= 2a^2 + 2a^2\cos\delta$

$= 2a^2(1+\cos 2.\frac{\delta}{2})$

$= 2a^2\left(2\cos^2\frac{\delta}{2}\right)$

$= 4a^2\cos^2\frac{\delta}{2}$

Intensity, $I = ($বিস্তার$/$amplitude$)^2$

$\Rightarrow I = R^2$

$\Rightarrow I = 4a^2$

$R^2 \rightarrow$ why R is regarded as amplitude
Shouldn't it be a?

Normally, $I = a+a = 2a$ হওয়ার কথা

But, $I = 4a^2$ হচ্ছে

Reason:

Dark এর energy গুলো bright এ energy transfer করে। এর কারণে $2a \times 2a = 4a^2$ = Intensity.

i) $I = R^2$

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

Maximum

when $\delta = 0, 2\pi, 2(2\pi), \ldots\ldots, n(2\pi)$

or path difference, $x = 0, \lambda, 2\lambda, \ldots\ldots, n\lambda$

$\boxed{I = 4a^2}$

Intensity is maximum when the phase difference is a whole num multiple of 2π / path difference is a whole num ~~of~~ multiple of λ.

ii) $\delta = \pi, 3\pi, \ldots\ldots (2n+1)\pi$

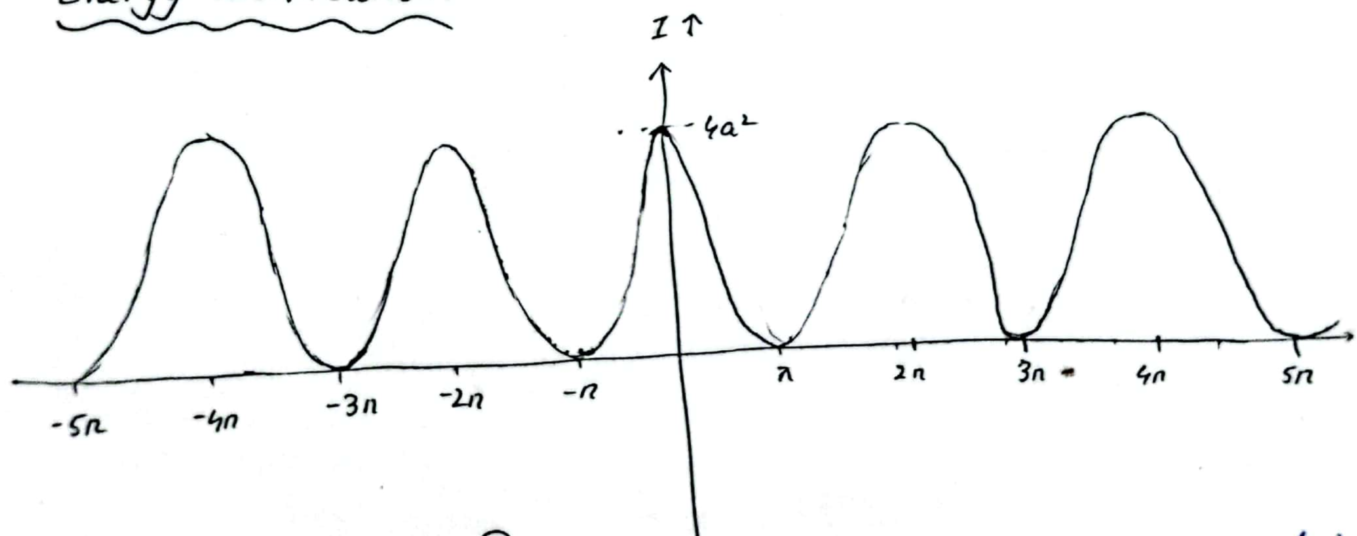
Path diff, $x = \frac{\lambda}{2}, \frac{3\lambda}{2}, \frac{5\lambda}{2}, \ldots\ldots, (2n+1)\frac{\lambda}{2}$

$\boxed{I = 0}$

Minimum

Intensity is minimum when the path difference is an odd num multiple of half λ.

Energy distribution:

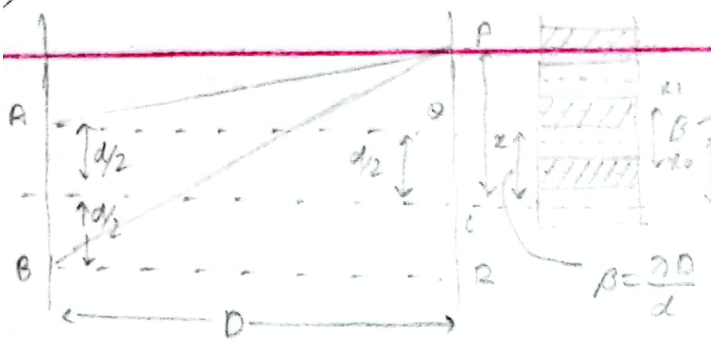


from eq (iv) $I = 4a^2 \cos^2 \frac{\delta}{2}$, we can say intensity at bright points $4a^2$ and at dark points it is zero.

In the fig it is shown that the intensity varie from 0 to $4a^2$. and the average is still $2a^2$. ~~In~~ It is equa to the uniform intensity $2a^2$ which will be present in the absence of the interference phenomemon due to the two waves, Therefore the formation of interference fringes is in accordance with the law of conservation of energy.

Fringe: Bright Position + Dark position

Date: .03.2023



$BP \approx AP \approx D$

- $PQ = x - \frac{d}{2}$
- $PR = x + \frac{d}{2}$
- $BP^2 - AP^2 = (BR^2 + PR^2) - (AQ^2 + PQ^2)$

$$= D^2 + (x+\tfrac{d}{2})^2 - D^2 - (x-\tfrac{d}{2})^2$$

$$= 4x.\frac{d}{2}$$

$$= 2xd$$

$$\boxed{\therefore BP - AP = \frac{2x.d}{BP+AP}}$$

$$= \frac{2xd}{2D}$$

$$\boxed{\therefore \text{Path Difference} = \frac{xd}{D}}$$

Bright fringe (उज्ज्वल):

$0, \lambda, 2\lambda, \ldots \ldots n\lambda$

$0, 2\pi, 2(2\pi)$

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

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

$$x_1 = \frac{\lambda D}{d}, \quad x_2 = \frac{2\lambda D}{d}$$

Here, $x_2 - x_1 = \frac{\lambda D}{d} = \beta$

$x_3 - x_2 = \frac{\lambda D}{d} = \beta$

Dark fringe:

$$\frac{x_n d}{D} = (2n+1)\frac{\lambda}{2} \quad \Rightarrow x_n = \frac{(2n+1)\lambda D}{2d}$$

$$\Rightarrow x_0 = \frac{\lambda D}{2d}$$

$$x_1 = \frac{3\lambda D}{2d}$$

$$x_1 - x_0 = \frac{\lambda D}{d} = \beta \quad . \quad \beta$$

Fringe Width, β

Dark + Bright

$= \frac{\lambda D}{d} + \frac{\lambda D}{d}$

$= \frac{2\lambda D}{d}$

~~Fresnel's~~ Fringe width $\boxed{\frac{\lambda D}{d}}$ is independent of the order of fringes, equal for both bright & dark.

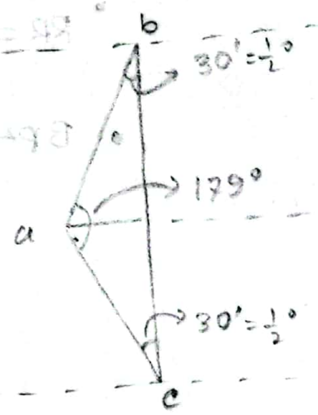
① $\boxed{\beta \propto \lambda}$ $\quad \beta \propto \frac{1}{d}$

① $\beta \propto D$

two acute angle prism joint

$\underbrace{\text{acute}}_{\text{সূক্ষ্মকোণ}}$

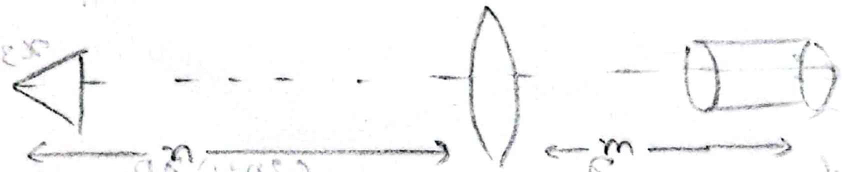
Prism:



$\frac{d_1}{d} = \frac{v}{u} = \frac{n}{m}$ (1) $\quad \frac{d_2}{d} = \frac{v}{u} = \frac{m}{n}$ (2)

case-1

case-2



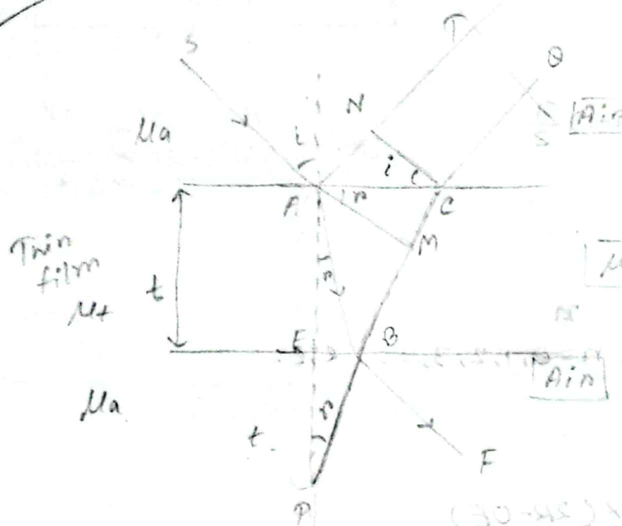
$\frac{d_1 d_2}{d} = 1$

$\boxed{d = \sqrt{d_1 d_2}}$

Date: 22.03.2023
Wednesday

[1] Interference in thin films

- Interference due to reflected light (Thin films)



Δ^s ACN and ACM

$$\mu = \frac{\sin i}{\sin r} = \frac{AN/AC}{CM/AC} = \frac{AN}{CM}$$

$$\Rightarrow \boxed{AN = \mu CM} \quad \text{—(ii)}$$

eq(i) ⇒

Path diff $= \mu(AB+BC) - AN$

$= \mu(AB+BC) - \mu CM$ [(ii)]

$= \mu(PB+BC - CM)$

$= \mu(PC - CM)$

$= \mu PM$ [(iii)]

Δ APM

$$\cos r = \frac{PM}{AP} = \frac{PM}{AE+EP} = \frac{PM}{2t}$$

$$\Rightarrow PM = 2t \cdot \cos r \quad \text{—(iii)}$$

$\boxed{\text{Path diff } (x)_\sigma = 2\mu t \cos r}$

$\boxed{\text{Corrected Path diff } (x) = 2\mu t \cos r \pm \frac{\lambda}{2}}$

For bright position:

- $2\mu t \cos r - \frac{\lambda}{2} = n\lambda$

$\Rightarrow \boxed{2\mu t \cos r = (2n+1)\frac{\lambda}{2}}$ → bright position

For dark position:

- $2\mu t \cos r - \frac{\lambda}{2} = (2n+1)\frac{\lambda}{2}$

$\Rightarrow 2\mu t \cos r = (n+1)\lambda$

$\Rightarrow \boxed{2\mu t \cos r = n\lambda}$ → dark position

↳ We can write $(n+1)$ as n

Newtons Rings

For light ring

$2\mu t\cos\theta = (2n-1)\frac{\lambda}{2}$ $\quad n = 1, 2, 3 \ldots$ etc.

Here, θ is small, $\cos\theta = 1$

$\mu = 1.$

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

For the dark ring.

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

$\Rightarrow 2t = n\lambda$, $n = 0, 1, 2, 3, \ldots$ etc.

In the fig,

$EP \times HE = OE \times (2R - OE)$

, $EP = HE = r$, $OE = PQ = t$

$2R - t = 2R$

$\boxed{r^2 = 2Rt}$ $\Rightarrow \boxed{t = \frac{r^2}{2R}}$ (A)

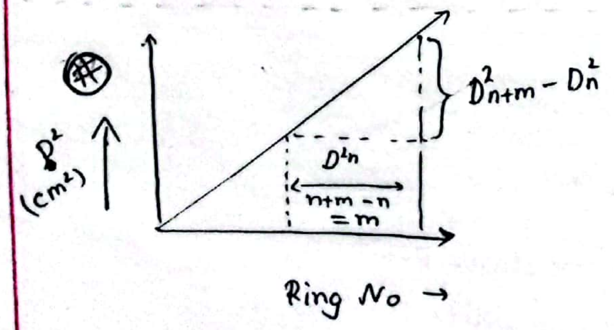
For bright rings, $r^2 = \frac{(2n-1)\lambda R}{2}$

$r = \sqrt{\frac{(2n-1)\lambda R}{2}}$

For dark rings, $r^2 = n\lambda R$ → Radius of curvature

$\Rightarrow r = \sqrt{n\lambda R}$

- $\sqrt{\frac{2n-1}{2}}$
- $\sqrt{\lambda}$
- $\sqrt{R}$



$r_n^2 = n\lambda R$

$D_n^2 = 4n\lambda R$

Determination of the wavelength of sodium light using newton's ring

$D^2_{n+m} = 4(n+m)\lambda R$

$D^2_{n+m} - D^2_n = 4m\lambda R$

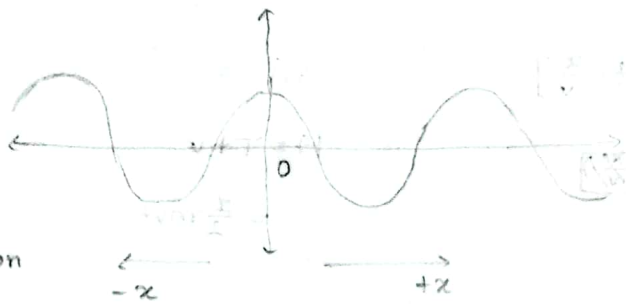
$$\Rightarrow \boxed{\lambda = \frac{D^2_{n+m} - D^2_n}{4mR}}$$

Date: 29.03.2023

Wednesday

Quantum Mechanics:

Ψ



$\Psi = A + iB$

$\downarrow$

wave function

$\Psi^* = A - iB$

$$\boxed{|\Psi|^2 = \Psi \times \Psi^* = A^2 + B^2}$$

$\downarrow$

Probability

Classical mechanics is an approximation of quantum mechanics

$$\int_{-\infty}^{\infty} |\Psi|^2 dV = 0.$$

Probability:

$$P_{x_1, x_2} = \int_{x_1}^{x_2} |\Psi|^2 dx$$

Wave equation,

$$\frac{\partial^2 y}{\partial x^2} = \frac{1}{v^2} \cdot \frac{\partial^2 y}{\partial t^2}$$

$$\underbrace{y = F\left(t + \frac{x}{v}\right)}_{-x \text{ direction}}$$

$$\therefore \boxed{y = F\left(t \pm \frac{x}{v}\right)} \text{ for both direction}$$

To summarise:

1. Ψ must be continuous and single valued everywhere

2. $\frac{\partial \Psi}{\partial x}, \frac{\partial \Psi}{\partial y}, \frac{\partial \Psi}{\partial z}$ must be continuous and single valued everywhere.

3. Ψ must be normalizable, which means that Ψ must go to 0 as $x \to \pm\infty$, $y \to \pm\infty$, $z \to \pm\infty$ in order that $\int |\Psi|^2 dV$ over all space be a finite constant

$y = A\cos(\omega t - kx)$

$$= \underbrace{A\cos 2\pi v \left(t - \frac{x}{v}\right)}_{+x \text{ direction}}$$

$\downarrow$

F

$= F\left(t - \frac{x}{v}\right)$

$\boxed{\cancel{= F(t+x)}}$

$$\boxed{y = A e^{-i\omega(t - \frac{x}{v})}} \rightarrow \text{Solution}$$

$$\boxed{y = A\cos\omega\left(t - \frac{x}{v}\right) - iA\sin\omega\left(t - \frac{x}{v}\right)}$$

Schrodinger equation (Time dependent form):

Schrodinger eq^n is a special kind of eigen value eq^n:

→ Hamiltonian operator

$$\boxed{H\Psi = a\Psi} \qquad \hat{A}\Psi = a\Psi$$

$$\left(\frac{d}{dx}\right)\Psi = A e^{-i\omega(t - \frac{x}{v})}$$

$$= A e^{-i\omega(t - \frac{x}{v})}\left[-i\omega\left(t - \frac{x}{v}\right]\right.$$

$$= \frac{i\omega}{v}\Psi \quad \boxed{\cancel{[-i\omega(t - \frac{x}{v})]}}$$

$$H = T + V$$

$$= \frac{1}{2}mv^2$$

wave function → matter wave

Date: 02.04.2023

Sunday

$$H\Psi = E\Psi \qquad \hat{A}\Psi = a\Psi$$

↓ Eigen function

$$P = -i\hbar\vec{\nabla} \qquad \vec{\nabla} = \hat{i}\frac{\partial}{\partial x} + \hat{j}\frac{\partial}{\partial y} + \hat{k}\frac{\partial}{\partial z}$$

$$\Psi H = \left(\frac{p^2}{2m} + V\right)\Psi \qquad \boxed{\cancel{\nabla/1}}/2 \qquad \nabla^2 = \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2}$$

$$= \left(\frac{i^2\hbar^2\nabla^2}{2m} + V\right)\Psi$$

$$H = \left(-\frac{\hbar^2}{2m}\cdot\frac{d^2}{dx^2} + V\right)\Psi$$

$$\therefore \boxed{H\Psi = -\frac{\hbar^2}{2m}\cdot\frac{d^2}{dx^2}\cdot\Psi + V\Psi = E\Psi}$$

Schrodinger's equation:

(Time dependent ~~to~~ Form)

A basic physical principle that can not be derived from anything else.

$$\psi = Ae^{-i\omega(t - \frac{x}{v})} \quad \text{—①}$$

$$\hbar = \frac{h}{2\pi}$$

Putting $\omega = 2\pi\nu$, $v = \lambda\nu$ gives eq(1)

$$\boxed{\lambda = \frac{h}{mv} = \frac{h}{p} = \frac{\cancel{h}2\pi\hbar}{p}}$$

$$\boxed{h = 2\pi\hbar}$$

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

$$= Ae^{-i(2\pi\nu t - \frac{x2\pi}{\lambda})}$$

$$= Ae^{-i(\frac{E}{\hbar}t - \frac{2\pi p x}{2\pi\hbar})}$$

$$= Ae^{-(\frac{i}{\hbar})(Et - px)}$$

And,

$$E = h\nu$$

$$= 2\pi\hbar$$

$$\lambda = \frac{2\pi\hbar}{p}$$

And, $$\frac{\delta^2\psi}{\delta x^2} = -\frac{p^2}{\hbar^2}\psi$$

$$\Rightarrow p^2\psi = -\hbar^2 \frac{\partial^2\psi}{\partial x^2}$$

Differenciating once with respect to t

$$\frac{\partial\psi}{\partial t} = -\frac{iE}{\hbar}\psi$$

$$\frac{p^2}{2m}$$

$$\Rightarrow E\psi = -\frac{\hbar}{i} \cdot \frac{\partial\psi}{\partial t}$$

$$\boxed{E\psi = \frac{p^2\psi}{2m} + U\psi}$$

Date: 03.05.2023
Wednesday

$$\psi = Ae^{-(i/h)(Et-px)} \quad —(1)$$

Differenciating,

$$\frac{\partial^2 \psi}{\partial x^2} = -\frac{p^2}{\hbar^2}\psi$$

$$\Rightarrow p^2\psi = -\hbar^2 \frac{\partial^2 \psi}{\partial x^2}$$

Differenciating equation (1) with respect to t,

$$\frac{\partial \psi}{\partial t} = -\frac{iE}{\hbar}\psi$$

$$-\frac{\hbar}{i}\frac{\partial \psi}{\partial t}$$
$$= i^2 \frac{\hbar}{i} \times \frac{\partial \psi}{\partial t}$$
$$= i\hbar \frac{\partial \psi}{\partial t}$$

(*) $$\boxed{i\hbar \frac{\partial \psi}{\partial t} = -\frac{\hbar^2}{2m} \cdot \frac{\partial^2 \psi}{\partial x^2} + U\psi}$$

Time dependent scrodinger equation in one dimension.

Q. Derive time dependent scrodinger eq. in one dimension/ three dimension

Q. Derive time independent scrodinger eq one/three dimension.

$$\psi = Ae^{-(i/h)(Et-px)}$$
$$= Ae^{-(iE/h)t} e^{+(ip/\hbar)x}$$
$$= \psi e^{-(iE}$$

(*) $$E\psi = -\frac{\hbar^2}{2m} \cdot \frac{\partial^2 \psi}{\partial x^2} + U\psi$$

$$\Rightarrow \frac{\hbar^2}{2m} \cdot \frac{\partial^2 \psi}{\partial x^2} + E\psi - U\psi = 0$$

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

Steady state Scrodinger eq. —(2)

$\boxed{\text{3dimension}}$ $$\frac{\partial^2 \psi}{\partial x^2} + \frac{\partial^2 \psi}{\partial y^2} + \frac{\partial^2 \psi}{\partial z^2} + \frac{2m}{\hbar^2}(E-U)\psi = 0$$

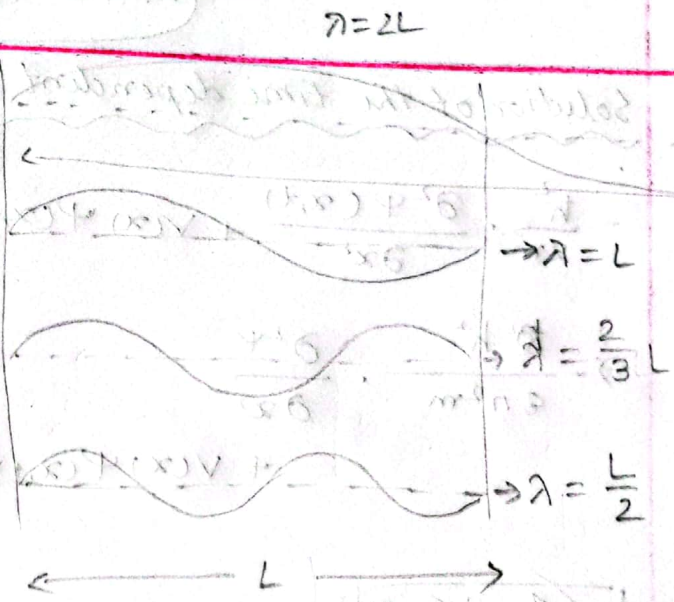
$$\psi = e^{mx}$$
$$\Rightarrow \frac{\partial \psi}{\partial x} = me^{mx}$$
$$\Rightarrow \frac{\partial^2 \psi}{\partial x^2} = m^2 e^{mx} \quad (3)$$

(2) $\Rightarrow$
$$\Rightarrow m^2 e^{mx} + \underbrace{\left(\frac{2mE}{\hbar^2}\right)}_{k^2} e^{mx} = 0$$
$$\Rightarrow (m^2 + k^2)e^{mx} = 0$$

$m^2+k^2=0$

$\Rightarrow m^2 = -k^2 = i^2k^2$

$\Rightarrow m = +ik$



Eigenvalue & Eigenfunctions

Proper

$\hat{A}\Psi = a\Psi$

$$\boxed{\lambda = \frac{2L}{n+1}}$$

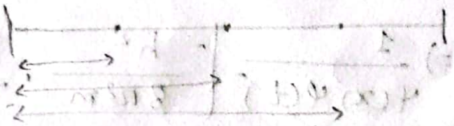
Expectation value ($\bar{x}$)

How to extract information from a wave function

Most Probable value

~~1st Part~~

N_1 Particle in x_1 position



$$\bar{x} = \frac{N_1x_1+N_2x_2+\ldots}{N_1+N_2+\ldots} = \frac{\Sigma N_i x_i}{\Sigma N_i}$$

Normalized form

$\int \psi^2 dv = (1) \rightarrow$ Particle exists (Probability)

$\int \psi^2 dv = 0 \rightarrow$ Particle doesn't exist

$P_i = |\psi_i|^2 dx$

$$(x) = \frac{\int_{-\infty}^{\infty} x|\psi|^2 dx}{\int_{-\infty}^{\infty} |\psi|^2 dx}$$

$\rightarrow$ Normalized condition (maximum probability)

$$\boxed{(x) = \int_{-\infty}^{\infty} x|\psi|^2 dx}$$

~~Expectation value for position~~

↳ ~~Some Prob~~ ~~indicat~~ive