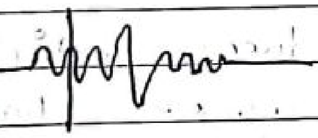
Ans (1). Define wave - particle duality nature of light.

→ The Concept of wave nature of Matter arose from the dual character of the radiation which sometimes behaves as a wave and sometimes as a particle.

In the phenomena where light interacts with itself, such as dispersion, interference, diffraction and polarization, the wave nature of light dominates. In the phenomena where the light interacts with matter, such as in photoelectric effect, Compton effect, Raman effect, the particle nature of light dominates.

Matter Waves travel as a wave packet with decreasing amplitude on either side of the present position.



Wave packet.

The evidence for the description of light as waves was well established at the turn of the Century when the "photoelectric effect" introduced firm evidences of a particle nature as well.

[illegible] the particle properties of

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It States that it is impossible to determine at any given instant, both the momentum and the position of subatomic particle electron, Simultaneously $\Delta x \cdot \Delta p \geq \frac{h}{4\pi}$

Where

Δx = Uncertainty in position

Δp = Uncertainty in momentum.

In 1927, Heisenberg proposed a very interesting principle, which is direct Consequence of the dual nature of Matter, known as "Uncertainty principle"

According to Heisenberg's Uncertainty principle "It is impossible to specify precisely and simultaneously the values of both members of particular pairs of physical Variables that describe the behaviour of atomic system".

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prove that $\Delta E \cdot \Delta t \geq h/2\pi$.

If Δx is the error in position

$\left(\frac{\Delta \omega t}{2} - \frac{\Delta k x}{2}\right) = (2n+1)\pi/2 \rightarrow$ for n^{th} node,

$\left(\frac{\Delta \omega t}{2} - \frac{\Delta k}{2} x_n\right) = (2n+1)\pi/2$ for $(n+1)^{th}$ node,

$\left(\frac{\Delta \omega t}{2} - \frac{\Delta k}{2} x_{n+1}\right) = [2(n+1)+1]\pi/2$

$-\frac{\Delta k}{2} x_{n+1} + \frac{\Delta k}{2} x_n = (2)\pi/2$, $\frac{\Delta k}{2}(x_n - x_{n+1}) = \pi$

$(x_n - x_{n+1}) = \frac{2\pi}{\Delta k}$ $\left\{ \because k = \frac{2\pi}{\lambda} = \frac{2\pi p}{h} \right.$ $\Delta k = \left(\frac{2\pi}{h} \Delta p\right)$

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

$[\Delta x \cdot \Delta p = h]$ $\because \left[\Delta x \cdot \Delta p \geq \frac{h}{2\pi}\right]$

in terms of energy (E) and time (t)

$c = x/t$, $x = ct$, $\Delta x = c\Delta t$ — (1)

& P = Momentum

$p = mc$ $\left\{ \because E = mc^2 \right.$

$p = \frac{E}{c}$ $\frac{E}{c} = mc$

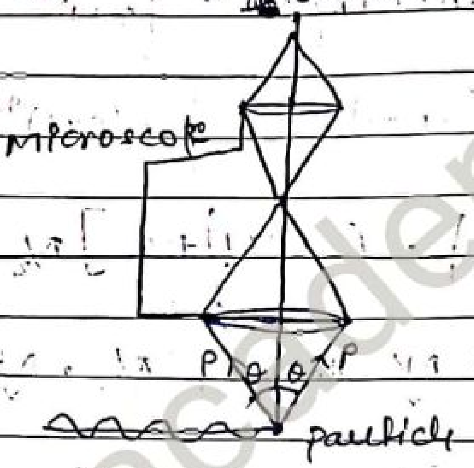
$\therefore \Delta P = \frac{\Delta E}{c}$ —

$\therefore c\Delta t \cdot \frac{\Delta E}{c} = h$

$\cancel{\Delta t}\ E = h$

(b). prove that $\Delta E . \Delta t \geq h/2\pi$.

$$\Delta x = \frac{d}{2\sin\theta} \quad \text{---(i)}$$



$$\Delta P_x = p\sin\theta - (-p\sin\theta)$$
$$= 2p\sin\theta$$
$$= \frac{2h}{d}\sin\theta \qquad [\because p = h/d]$$

from equations (i) and (ii), we have.

$$\Delta x \cdot \Delta p_x = \frac{d}{2\sin\theta} \times \frac{2h}{d}\sin\theta = h > h/2$$

This shows that the product of uncertainties in position and momentum is of the order of plank's Constant.

$$K = 2\pi - 2\pi P$$

Now, the product of Δx and Δk is given as

$$\Delta x \cdot \Delta k \geq 1/2 \quad \text{or} \quad \Delta k \geq \frac{1}{2\Delta x}$$

$$\Delta p_x \geq \frac{h}{2\pi} \cdot \frac{1}{2\Delta x}$$ (p_x = momentum in x-direction)

Heisenberg's Uncertainity principle.

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

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

Uncertainity in Kinetic energy

$$\Delta E = \frac{1}{2} m\, 2v\Delta v = mv\Delta v = (m\Delta v)v = \Delta p \cdot v$$

Uncertainity in time $\Delta t = \Delta x / v$

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Establish Time independent Schrödinger wave equation :-

→ Second order differential equation like the Schrödinger Equation, can be solved by "Separation of Variables". These Separated Solutions can then be used to solve the problem in general.

Assume that we can factorize the solution between time and space.

$$\psi(x,t) = u(x)\,T(t)$$

plug this into the Schrödinger Equation.

$$\left(\frac{-\hbar^2}{2m}\frac{\partial^2 u(x)}{\partial x^2} + V(x)\,u(x)\right)T(t) = i\hbar\, u(x)\ldots$$

put everything that depends on x on the left and everything that depends on t on the right

$$\frac{\left(\frac{-\hbar^2}{2m}\frac{\partial^2 u(x)}{\partial x^2} + V(x)\,u(x)\right)}{u(x)} = \frac{i\hbar\frac{\partial T}{\partial t}(t)}{T(t)} = \text{Const.} = E$$

$$i\hbar\frac{\partial T(t)}{\partial t} = E\,T(t)$$

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and an equation in x set equal to a Const,

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

which depends on the problem to be solved (through $V(x)$)

The x equation is often called the "time independent Schrödinger equation".

Explain Youngs...

When sunlight passes through pin hole p_0 spherical waves are spread out. According to Hygen's principle, each point on the wavefront is a centre of secondary wavelet. Thus spherical waves also spread out from pin holes p_1 & p_2. The value of radii of these wavefronts increases as they move away from pin holes p_1 & p_2 and hence they superimpose on each other.

At a point, where a crest due to one wave falls on the crest due to another wave. At points where a crest due to one wave falls on the crest due to another wave (or trough on a trough) the resultant amplitude is equal to the difference of the amplitude due to each wave separately. As the intensity is proportional to the square of the amplitude and hence decreased. This is called destructive interference. At point, where a crest due to one wave falls on the through of the other wave, the resultant amplitude is due to sum of the amplitude due to separate waves and hence the resultant intensity is increased. This is called constructive interference. Hence on the screen MN a number of alternate bright and dark areas of equal width, Known (b). Fringe width →

$$\Delta = (S_2P - S_1P)$$

$$[D^2 + (y+d)^2]^{1/2} - [D^2 + (y-d)^2]^{1/2}$$

$$\Rightarrow D\left[1 + \frac{(y+d)^2}{D^2}\right]^{1/2} - D\left[1 + \frac{(y-d)^2}{d^2}\right]^{1/2}$$

Binomial Expansion

$$(1+x)^n = (1+nx) + \frac{n(n-1)x^2}{2!} + \ldots$$

$$\because (y \pm d) << D$$

$$\therefore \Delta = D\left[1 + \frac{1}{2}\frac{(y+d)^2}{D^2}\right] - D\left[1 + \frac{1}{2}\frac{(y-d)^2}{D^2}\right]$$

$$\Delta = \left[D + \frac{(y+d)^2}{2D}\right] - \left[D + \frac{(y-d)^2}{2D}\right]$$

$$D = \frac{(y+d)^2 - (y-d)^2}{2D}$$

$$\Rightarrow \frac{y^2 + d^2 + 2yd - (y^2 + d^2 - 2yd)}{2D}$$

$$= \frac{4yd}{2D}$$

$$\Delta = \left(\frac{2yd}{D}\right)$$

Case 1 :- for maxima $\because \Delta = n\lambda$

$$\because \frac{2yd}{D} = n\lambda$$

$$\boxed{y_n = \frac{nD\lambda}{2d}} \quad \text{---} (2)$$

Case (ii) for minima,

$$\Delta = (2n+1)\frac{\lambda}{2}$$

$$\frac{2yd}{D} = (2n+1)\frac{\lambda}{2}$$

$$y = (2n+1)\frac{\lambda}{2}\cdot\frac{D}{2d}$$

$$y'_n = (2n+1)\frac{\lambda D}{4d}$$

let us consider n^{th} & $(n+1)^{th}$ bright fringe

$$y_n = n\left(\frac{\lambda D}{2d}\right); \quad y_{n+1} = (n+1)\frac{\lambda D}{2d}$$

$$\beta = (y_{n+1} - y_n) = \frac{\lambda D}{2d}(n+1-n)$$

$$\left\{ \beta = \frac{\lambda D}{2d} \right\}$$

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we have

$(\text{curl } A \cdot S_r) = \oint_{C_r} \vec{A} \cdot d\vec{l}$

$$\oint_C \vec{A} \cdot d\vec{l} = \sum_{r=1}^{n} \text{curl } \vec{A}\ S_r$$

$$= \text{curl } \vec{A} \sum_{r=1}^{n} S_r$$

$$= \text{curl } \vec{A}\ (S)$$

$$= \text{curl } \vec{A} \iint dS$$

$$\boxed{\oint_C \vec{A} \cdot d\vec{l} = \iint_S \text{curl } \vec{A} \cdot d\vec{S}}$$

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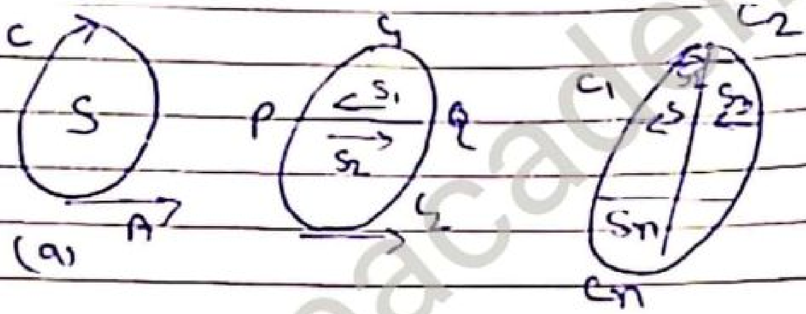

$$\oint \vec{A}\cdot\vec{dl} = \int_{C_1}\vec{A}\cdot\vec{dl} + \int_{C_2}\vec{A}\cdot\vec{dl} + \int_{PQ}\vec{A}\cdot\vec{dl} + \int_{QP}\vec{A}\cdot\vec{dl}$$

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*** Imp. [curl $\vec{A}$ - 5] — (2)

Sol. Stoke's theorem :-

statement :- The line integral of a vector field ($\vec{A}$) along the boundary of a closed curve is equal to the surface of curl of that vector field over the surface (s) where is surface S is ~~the~~ encloses by the curve C. That is

$$\oint_C \vec{A} \cdot d\vec{l} = \iint_S \text{curl}\, \vec{A} \cdot d\vec{s}$$

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$$\text{curl}\,\vec{A} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ A_x & A_y & A_z \end{vmatrix} \quad \text{—— (1)}$$

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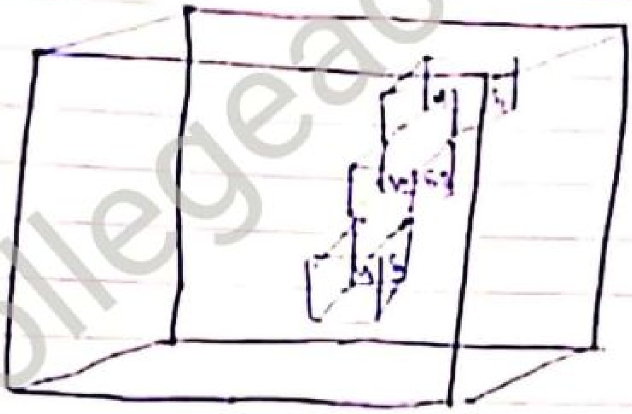
$$\text{div}\,\vec{A} \iiint_V dv = \iint_S \vec{A}\cdot d\vec{S}$$

$$\boxed{\iiint_V \text{div}\,\vec{A}\,dv = \iint_S \vec{A}\cdot d\vec{S}}$$ proof



Imp

5. curl of a vector field

$$\vec{A} = (\hat{i}A_x + \hat{j}A_y + \hat{k}A_z)$$

Also; $$\vec{\nabla} = \left(\hat{i}\frac{\partial}{\partial x} + \hat{j}\frac{\partial}{\partial y} + \hat{k}\frac{\partial}{\partial z}\right)$$

Mathematical definition

$$(\vec{\nabla}\times\vec{A}) = \text{curl}(\vec{A})$$

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r^{th} volume element

$$\text{div}\,\vec{A} = \frac{\iint_{S_r} \vec{A}\, d\vec{s}}{V_r}$$

Also we have by the definition of divergence

$$\text{div}\,\vec{A}\; V_r = \iint_{S_r} \vec{A}\, d\vec{s}$$

Considering all the volume elements

$$\sum_{r=1}^{n} \text{div}\,\vec{A}\cdot V_r = \sum_{r=1}^{n} \iint_{S_r} \vec{A}\cdot d\vec{s}$$

$$\text{div}\cdot\vec{A} \sum_{r=1}^{n} (V_r) = \sum_{r=1}^{n} \iint_{S_r} \vec{A}\cdot d\vec{s}$$

$$\text{div}\,\vec{A}\,(V) = \sum_{r=1}^{n} \left(\iint_{S_r} \vec{A}\cdot d\vec{s} \right)$$

$\because$ For inner surfaces $(\vec{A}\cdot d\vec{s})$ will be zero volume;

$$\boxed{\operatorname{div}\vec{A} = \frac{\iint_S \vec{A}\cdot d\vec{s}}{V}} \quad \text{---(2)}$$

$\operatorname{div}\vec{A}$ may be 0, postive and Negetive also.

(Soy) J-M Gauses's divergence theorem

Statement :- The surface intrigal of a vector feild $(\vec{A})$ over the Surface (s) = The volume intrigral of diverence of that vector feild (A) with in the volume (V) where is the volume (V) is enclosed by the Surface (S). that is

$$\iint_S \vec{A}\cdot d\vec{s} = \iiint_V \operatorname{div}\vec{A}\, dv$$

proof :- Let's consider a closed

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Application of Newton Rings experiment

1) Determination of wave length of a monocromatic source of light

2) Determination of radious of curvature of planocovex lens.

3) Determination of refractive index of a liquid

① → we know that the diameter of n^{th} & $(n+p)^{th}$ dark ring are mesure using it travelling microscope so the diameter is given by for n^{th}

$D_n^2 = 4nR\lambda$ —— ①

$D^2_{n+p} = 4(n+p)R\lambda$ —— ②

equ ② − equ ①

$D^2_{n+p} - D_n^2 = 4nR\lambda + 4pR\lambda - 4nR\lambda$

$\Rightarrow D^2_{n+p} - D_n^2 = 4pR\lambda$

$$\lambda = \frac{D^2_{n+p} - D_n^2}{4pR}$$

$\therefore \quad D_n = 2r_n$

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

$$D_n = \sqrt{4(2n-1)\frac{\lambda R}{2}}$$

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

Constant $= 2\lambda R$

$$D_n \propto \sqrt{(2n-1)}$$

There fore the diameter of bright ring are $\propto$ to the square root of odd natural no.

Ratio of few diameter $n=1$

$\sqrt{1} : \sqrt{3} : \sqrt{5} : \sqrt{7}$

$1 : 1.732 : 2.236 : 2.64$

0.732 0.504 0.410

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

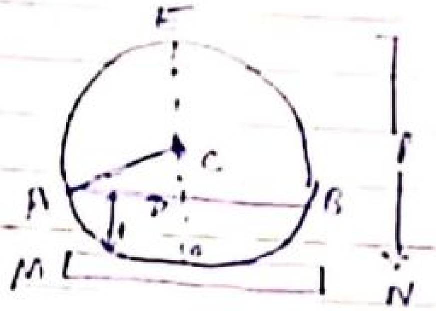
$$\boxed{2t = n\lambda}$$

This is the Condition of Darkness.

→ **Diameter of bright rings.**

To evaluate / find the diameter of bright and dark rings consider a plane convex lens placed on a glass plate. Let R to be the radius of curvature of plane convex lens and r radius of concentric ring.

Let us assume the plano convex lens is the part of its circle / sphere.



$$(AC)^2 = (CD)^2 + (AD)^2$$
$$R^2 = (R-t)^2 + (r)^2$$
$$R^2 = R^2 + t^2 + 2Rt + r^2$$
$$0 = t^2 + 2Rt + r^2$$
$$t << R$$
$$\Rightarrow 2Rt = r^2$$
$$\Rightarrow 2t = \frac{r^2}{R} \quad \text{—(1)}$$

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

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

$$\cancel{r^2 = (2n-1)\lambda} \qquad r^2 = R(2n-1)\frac{\lambda}{2}$$

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Where effective $\mu \Rightarrow$ R.I. of film.
$t \Rightarrow$ thickness of film.
$r \Rightarrow$ Angle of reflection.
$\lambda/2 \Rightarrow$ Extra path difference.

At point C.
$\mu = 1$, $\cos r = 1$
$r = 0$, $\boxed{\Delta = 2t + \frac{\lambda}{2}}$ — (3)

$t = 0$
$\boxed{\Delta = \frac{\lambda}{2}}$

This is a condition of minimum intensity.
Hence, the centre of newton's ring is dark.

→ Maxima Condition →
We know that
For maxima $\Delta = \lambda n$
$\Rightarrow 2t + \frac{\lambda}{2} = n\lambda$

$\Rightarrow 2t = (2n - 1)\frac{\lambda}{2}$ — (4)

→ Minima Condition → (Condition of darkness).
We know that
$\Delta = (2n+1)\frac{\lambda}{2}$ — (5)

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When a plano of convex lens. Placed on a plane glass plate. A thin film of air is produced between the upper and lower portion of lens and glass plate. The thickness of air film is 0 at the point of contact and gradually increases as right and left side from the upper portion and lower portion of the film. If monochromatic light is allow to fall normally on this film then after super position the alternate dark and bright concentric rings are seen with the help of travelling microscope. These rings are called Newton's ring.

Newton's ring are formed because the interference b/w the waves from top and bottom surface of an air film which are enclosed b/w plano convex lens and glass plate.

As the rings are observe in reflected light. So the effective path difference b/w interference of two waves is given by $\Delta = 2\mu t \cos r + \frac{\lambda}{2}$

Acc. to Stoke treatment:- (law).

When a ray of light is reflected of an optically denser medium it suffer a phase change of 180°.

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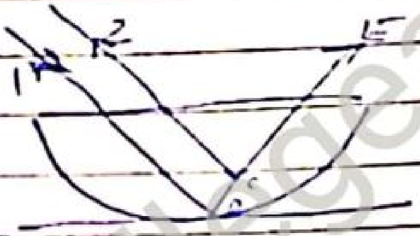
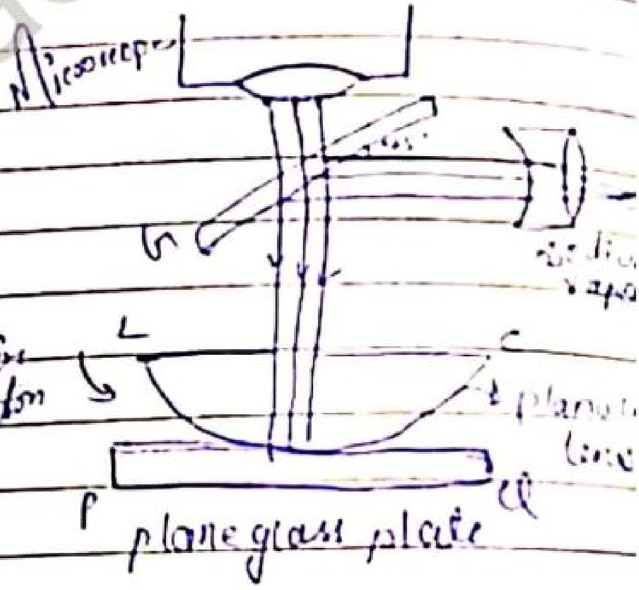
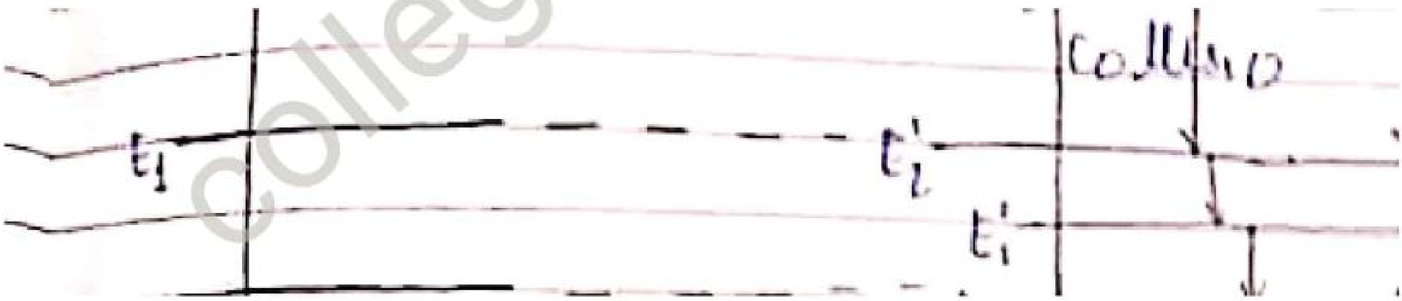
II Newton's ring Experiment



fig(b). Ray diagram of Newton's ring ex.



fig(a).
Experiment setup of Newton's ring.



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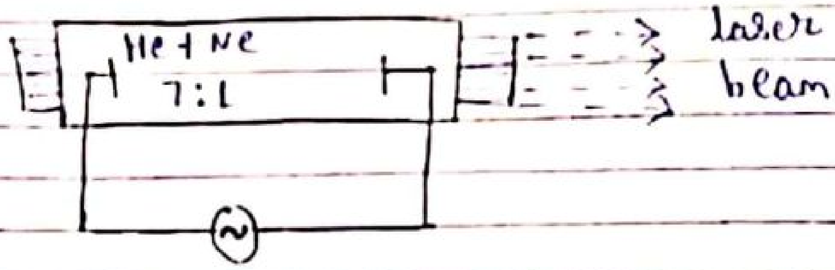
energy is supply in form of electric discharge.

3) optical Resonator :- both the silver polish ends of quartz tube works as the optical Resonator. It is used to increase the Intensity of laser light by laser oscillation.

Construction

SiO_2 (quartz tube).



4×10^7 Hz 4.6 (a)

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By max well - Baltzman distribution law;

$$N_n = N_o \cdot e^{-nh\nu/KT} \quad \text{——} \; ②$$

where; h = P. Cancks constant.
ν = free equation
K = Baltzman's constant
T = absolute temp.

$$N_1 = N_o e^{-h\nu/KT} \quad \text{——} \; ③$$

eqn ① Ⓐ becomes;

$$BUN_o = (A+BU) N_o e^{-h\nu/KT}$$

$$(BU - BUe^{-h\nu/KT}) = Ae^{-h\nu/KT}$$

$$BU(1-e^{-h\nu/KT}) = Ae^{-h\nu/KT}$$

$$\frac{U}{e^{-h\nu/KT}}(1-e^{-h\nu/KT}) = \frac{A}{B}$$

$$U\left(\frac{1}{e^{-h\nu/KT}} - 1\right) = \frac{A}{B}$$

$$U\left(\frac{1}{e^{-h\nu/KT)}} - 1\right) = \frac{A}{B}$$

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3) Stimulated Emission also depents on two factor that is where

N_1 = atoms in exited state
$U(\nu)$ = density of ensident radiation

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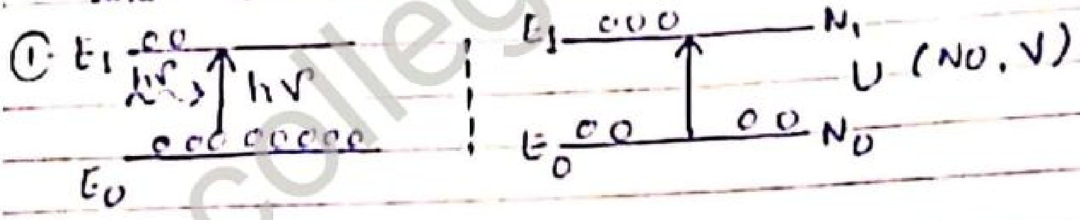
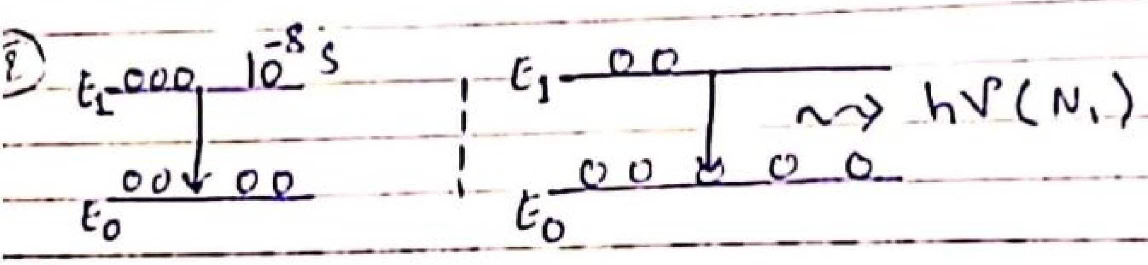
Que: Write Einstein's explanation of absorption & emission of radiation. Establish relation b/w coefficients A & B.

To explain Absorption emission of radion let's consider an atomic system having the two energy level E_0 and E_1 with energy difference ($h\nu$) is then we have

① 

(a) absorption

② 

(b) Self emission

∵ eq. 1 becomes

$$\boxed{E_H = \frac{B_z J}{n e w t}} \quad \text{—— (4)}$$

∵ This B Hall E.F

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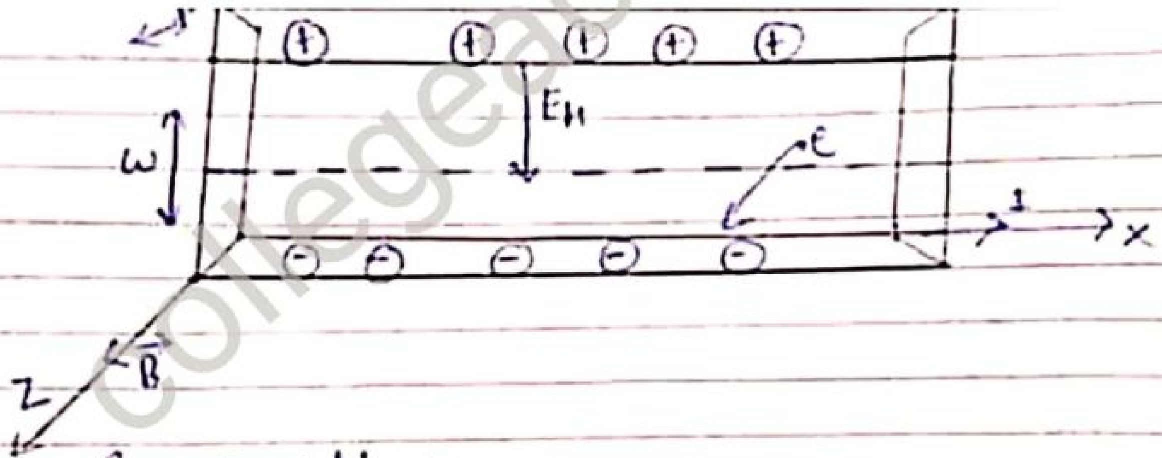

In equilibrium

$evB \sin\theta = eE_H$

$\because \theta = 90^\circ$

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$\because$ eq. (1) becomes

$$\boxed{E_H = \frac{B_0 I}{new t}} \text{ --- (4)}$$

$\because$ This is Hall E.F

Hall Voltage

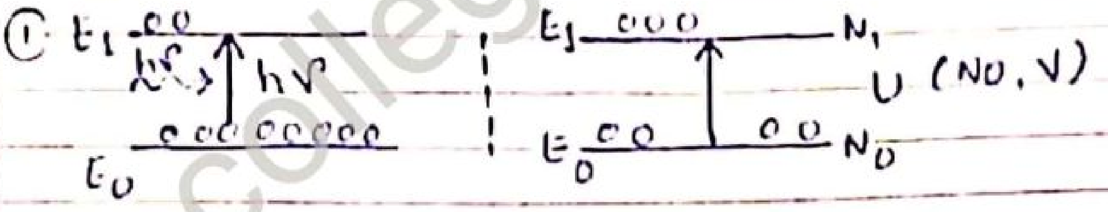
$$V_H = E\omega$$

$$= \frac{BI}{new t} \times \omega$$

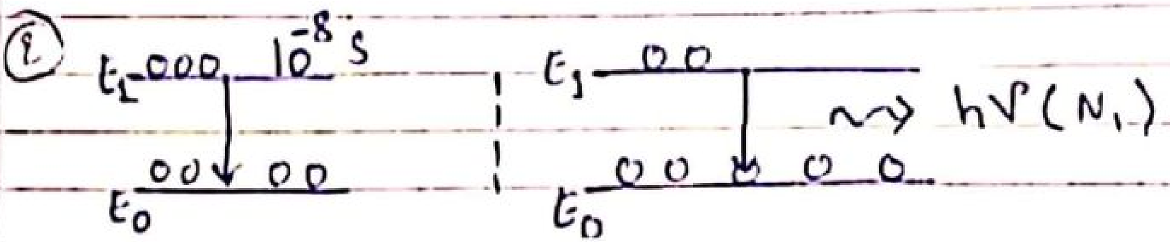
$$\boxed{V_H = \frac{BI}{net}} \text{ --- (5)} \qquad \frac{1}{ne} = R_H$$

(Hall Coffiesc

To explain Absorption emission of radion let's Consider an atomic System having the two energy level E_0 and E_1 with energy difference ($h\nu$) is then we have

① 

(a) absorption

② 

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2. As α increase the width of allowed energy band also increases.

3. ① If P is large if the free electron has a single energy.

② If P = 0 then electron has continous value inside the Solid

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Applying the boundary Condition we get;

$$\psi_1(x) = \psi_2(x)$$

$$\frac{mV_0 b}{\alpha \hbar^2} \cdot \sin\alpha a + \cos\alpha a = \cos Ka$$

$$\left(\frac{mV_0 ab}{\hbar^2}\right)\left(\frac{\sin\alpha a}{\alpha a}\right) + \cos\alpha a = \cos Ka$$

$$P = \left(\frac{mV_0 ab}{\hbar^2}\right) \text{ (Says)}$$

$$P\left(\frac{\sin\alpha a}{\alpha a}\right) + \cos\alpha a = \cos Ka = y \text{ (Say)}$$

$$y = \left[P\left(\frac{\sin\alpha a}{\alpha a}\right) + \cos\alpha a\right] \quad \text{—— (7)}$$

$$\& \; y = \cos Ka$$

$$= \cos\left(\frac{n\pi}{a} \cdot a\right)$$

$$y = \cos(n\pi) \quad \text{—— (8)}$$

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In region Sch. wave eq^n

$$\frac{d^2\psi_1}{dx^2} + \left(\frac{2m}{\hbar^2}(E)\right)\psi_1 = 0 \quad \text{---} \quad (3)$$

In IInd region

fig (3.8) (a) for single atom

(b)

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let's consider A Solid of atomic no Z, then the potiental energy of a free electron will be (If the subriation (S)

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(b). Derive De-Broglie Wavelength

The De Broglie wavelength is the wave length λ, associated with a object and is related to its momentum and mass.

De Broglie derived his equation Using well established theories through the following series of substituting.

De Broglie first used Einstein's famous equation relating Matter and energy

$$[E = mc^2] \quad \text{--- } (1)$$

with,

- E = Energy,
- m = mass,
- c = speed of light.

Using planck's theory which states every quantum of a wave has a discrete amount of energy given by planck's equa

$$[E = h\nu] \quad \text{--- } (2)$$

with,

- E = energy,
- h = plank's Constant. (6.62607×10^{-34} J
- ν = frequency

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Since de Broglie belived particles and wave have the same traits, he hypothesized that the two energies would be equal.

$$\left[mc^2 = h\nu \right] \longrightarrow (3)$$

Because real particles donot travel at the speed of light, De Broglie submitted velocity (v) for the speed of light (c).

$$\left[mv^2 = h\nu \right] \longrightarrow (4)$$

Through the equation λ, de Broglie substituted v/λ for ν and arrived at the final expression that relates wavelength and particle with speed.

$$\left[mv^2 = \frac{hv}{\lambda} \right] \longrightarrow (5)$$

Hence,

$$\lambda = \frac{hv}{mv^2} = \frac{h}{mv}$$

$$\therefore \left[\lambda = \frac{h}{mv} \right] \leftarrow \text{Ans.}$$