FIRST SEMESTER B.TECH DEGREE EXAMINATION
JANUARY 2016

Course Code: PH 100

Course Name: ENGINEERING PHYSICS

Max. Mark: 100

Part A

1 What do you mean by quality factor of an oscillator?

It defines the quality or efficiency of the oscillator. OR, It is defined as 2π times the energy stored to the energy dissipated per cycle.

$$Q = 2\pi \times \frac{\text{Energy stored}}{\text{Energy dissipated per cycle}}$$

OR,

quality factor is also defined as the ratio of amplitude at resonance to the amplitude at zero driven frequency.

ie, $$Q = \frac{\text{Amplitude at resonance}}{\text{Amplitude at zero driven frequency}}$$

$$Q = \frac{\omega_0}{2r}$$

2 What is the relation between path difference and phase difference in wave motion?

λ Path difference $= 2\pi$ phase difference.

1 path difference $= \frac{2\pi}{\lambda}$ Phase difference.

x path difference $= \frac{2\pi}{\lambda} x$ Phase difference

$$\boxed{\Delta\phi = \frac{2\pi}{\lambda}\Delta x}$$

$\Delta\phi \to$ phase diff

$\Delta x \to$ path diff.

3 Two independent sources of light cannot produce interference fringes. Why?

It is not possible to have two independent sources are coherent, because, even if they two sources produce light waves of same amplitude and frequency, they may undergo random changes in their Phases. So two independent sources cannot produce interference pattern

4 Define dispersive power of a grating.

It is the ratio of change in angle of diffraction to the change in wave length.

Dispersive power, $\frac{d\theta}{d\lambda} = \frac{nN}{\cos\theta}$

$\theta \rightarrow$ angle of diffraction.

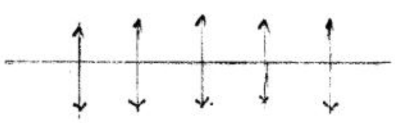
$\lambda \rightarrow$ wavelength.

$N \rightarrow$ No. of lines/unit length.

$n \rightarrow$ order of the spectrum.

5 Distiguish b/w plane polarized light and unpolarised light.

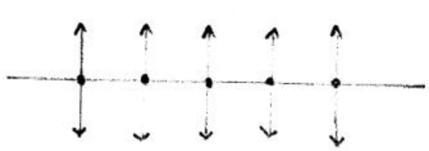
In plane polarized light electric field vector $\vec{E}$ is vibrating in a single $\perp r$ to the direction of propagation of wave.



$\Rightarrow$ plane polarized light, having vibrations parallel to the plane of paper.

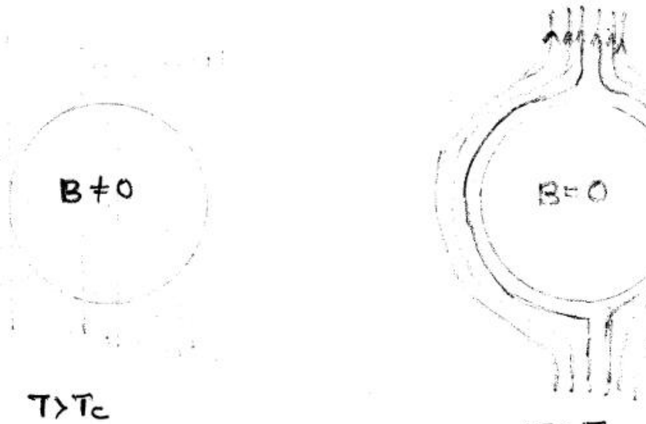
$\Rightarrow$ plane polarized light, having vibrations $\perp r$ to the plane of paper.

In unpolarised light electric field vector $\vec{E}$ vibrates in all direction $\perp r$ to the direction of propagation.



6 What is Meissner effect?

When a superconductor is cooled below the critical temperature (T_c) in an external magnetic field ($H < H_c$), then the magnetic field lines are expelled out of the superconductor, so field inside the super conductor is zero. This phenomenon is called Meissner effect.



$T > T_c$
$H > H_c$
Normal conductor.

$T < T_c$
$H < H_c$
super conductor.

9 What is the relation connecting reverberation time and total absorption

$$T = \frac{0.163V}{A} = \frac{0.163V}{\alpha S}$$

Where $T \rightarrow$ reverberation time

$V \rightarrow$ volume of the hall

$A = \sum_i \alpha_i s_i \rightarrow$ total absorption.

α = absorption coefficient

S = surface area.

10 What is magnetostriction effect?

When a ferromagnetic rod is subjected to a magnetic field parallel to its length, the length increases or decreases. This effect is called Magnetostriction effect.

9 ~~What is the relation connecting reverberation time and total absorption?~~

11 Write any two advantages of Hologram over photographic image.

- It produces a three dimensional image.
- It requires monochromatic coherent source.

- Hologram is sensitive to record both intensity variation & phase variations.
- The entire image can be reconstructed using a small broken piece of hologram.
- We can record several images on a single hologram.

7 What is phase space.

It is a six dimensional space with six mutually perpendicular coordinates x, y, z, p_x, p_y, p_z used to describe a single particle

Here $x, y, z \rightarrow$ Position coordinates.

$p_x, p_y, p_z \rightarrow$ momentum coordinates.

8 What is the probability interpretation of wave function?

If a particle exists in a given region of space, the total probability of finding the particle in that region is one

ie, $\int \psi \psi^* \, dv = 1$

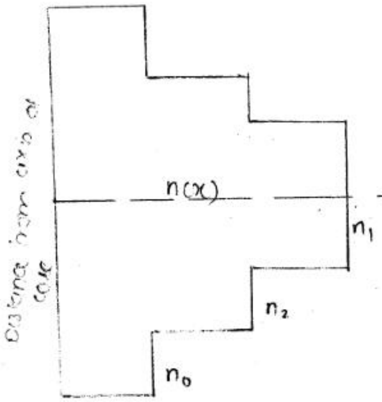
where $dv \rightarrow$ volume

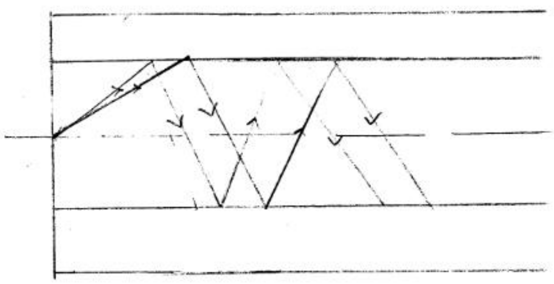
$\psi \psi^*$ probability density.

12 Distinguish b/w step index fibre and Graded index fibre.

Step index fibre.

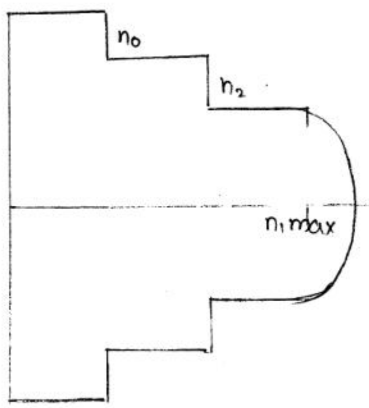
- Here core is thick, allow large no. of modes for transmission.
- n_1 & n_2 are constant & $n_1 > n_2 \Rightarrow$ hence the shape of index profile is step like.

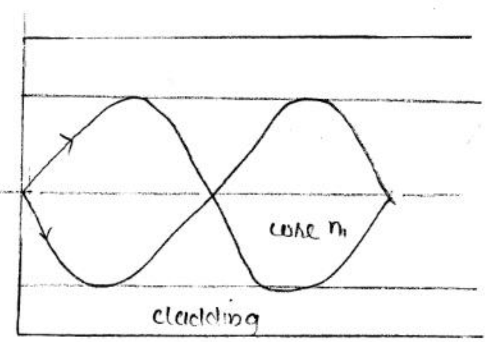




Graded index fibre.

- Here n_1 is varying and n_2 is constant & $n_1 > n_2$
- n_1 is maximum at axis of the core and decreases radially outwards.
- Light is travelling in parabolic path.





Part B

13 compare an electrical and mechanical oscillator

Mechanical Oscillator	Electrical oscillators
Mass (m)	Inductance (L)
Displacement (x)	charge (Q)
velocity (dx/dt)	current $I = \frac{dQ}{dt}$.
Damping coefficient (γ)	Electrical resistance (R)
Force constant (k)	Reciprocal of capacitance ($1/c$)
Resonant angular frequency $\omega_0 = \sqrt{k/m}$	Resonant angular frequency in the case of LCR circuit $\omega_0 = \frac{1}{\sqrt{LC}}$
So resonance frequency $\nu_0 = \frac{1}{2\pi}\sqrt{k/m}$	Resonant frequency $\nu_0 = \frac{1}{2\pi\sqrt{LC}}$
Q-factor $= \frac{\omega_0}{2\gamma} = \frac{\sqrt{k/m}}{2\gamma}$	Q Factor $= \frac{1}{2R}\sqrt{\frac{1}{LC}}$
Potential energy $= \frac{1}{2}kx^2$	Energy stored in capacitor $= \frac{q^2}{2C} = \frac{1}{2}CV^2$
kinetic energy $= \frac{1}{2}mv^2$	Energy stored in inductor $= \frac{1}{2}LI^2$
Differential eqn $\frac{d^2x}{dt^2} + 2\gamma\frac{dx}{dt} + \omega_0^2 x = 0$	Differential eqn $\frac{d^2Q}{dt^2} + \frac{R}{L}\frac{dQ}{dt} + \frac{Q}{LC} = 0$.

14 A transverse wave on a stretched string is described by $y(x,t) = 4.0\sin(25t + 0.016x + \pi/3)$ where x & Y are in cm and t is in second. obtain the.

(i) ~~amplitude~~ . Speed .

(ii) Amplitude

(iii) Frequency and

(iv) Initial phase at the origin

$$y = 4.0 \sin(25t + 0.016x + \pi/3)$$

we have

$$y = A\sin(kx + \omega t + \phi)$$

$\omega = 25$

$k = 0.016$

Amplitude, $A = 4$ cm.

Speed $V = \frac{\omega}{k} = \frac{25}{0.016}$

$= 1562.5$ cm/s.

frequency, $\nu = \frac{\omega}{2\pi} = \frac{25}{2\pi} = 3.978$ Hz

Initial phase at $t=0 \Rightarrow \phi = \pi/3$.

15 With Newton's rings arrangement, n^{th} dark ring formed by light of wave-length 6000 A° coincides with the $(n+1)^{th}$ dark ring for the light of wave length 4500 A°. If the radius of curvature of the convex surface is 90 cm. find the diameter of the n^{th} ring of light wavelength 6000 Å.

$\lambda_1 = 6000\,A^\circ = 6000\times10^{-10}$ m

$\lambda_2 = 4500\,A^\circ = 4500\times10^{-10}$ m

$R = 90$ cm $= 90\times10^{-2}$ m.

here the ring coincide with each other

ie, $r_1 = r_2$.

$$\sqrt{90\times10^{-2}\times n\times6000\times10^{-10}} = \sqrt{90\times10^{-2}(n+1)\,4500\times10^{-10}}$$

$$n(6000\times10^{-10}) = (n+1)\,4500\times10^{-10}$$

$$\frac{n+1}{n} = \frac{6000\times10^{-10}}{4500\times10^{-10}}$$

$$\frac{n+1}{n} = \frac{4}{3}$$

$$3n+3 = 4n$$

$$n = 3$$

$$\therefore D_n = 2\sqrt{Rn\lambda_1}$$

$$= 2\sqrt{90\times10^{-2} \times 3 \times 5000\times10^{-10}}$$

$$= 2.545 \times 10^{-3}\,m$$

16 A plane transmission grating has 6000/cm. Find the angular seperation between two wavelength 500nm & 510nm in the 3rd order

$n = 3$

$\lambda_1 = 500\times10^{-9}\,m$

$\lambda_2 = 510\times10^{-9}\,m$

$N = 6000/cm = 6000\times10^{2}\,/m$

$\sin\theta_1 = nN\lambda_1 = 3\times6000\times10^{2}\times500\times10^{-9} = 0.9$

$\theta_1 = 64.15$

$\sin\theta_2 = nN\lambda_2 = 3\times6000\times10^{2}\times510\times10^{-9} = 0.918$

$\theta_2 = 66.63$

$\theta_2 - \theta_1 = 2.48 = 2^\circ 28' 48''$

17 The refractive index of calcite is 1.658 for ordinary ray and it is 1.486 for extraordinary ray. A slice having thickness 0.9×10^{-4} cm is cut from the crystal. For what wavelengths this slice will act as a

(i) Quarter wave plate.

(ii) Half wave plate

$\mu_o = 1.658$

$\mu_e = 1.486$

$t = 0.9\times10^{-4}\,cm = 0.9\times10^{-6}\,m$

(i) For quarter wave plate.

$$t = \frac{\lambda}{4(\mu_0 - \mu_e)}$$

$$\therefore \lambda = 4t(\mu_0 - \mu_e)$$

$$= 4 \times 0.9 \times 10^{-6} (1.658 - 1.486)$$

$$= 6.192 \times 10^{-7} m.$$

(ii) For half wave plate.

$$t = \frac{\lambda}{2(\mu_0 - \mu_e)}$$

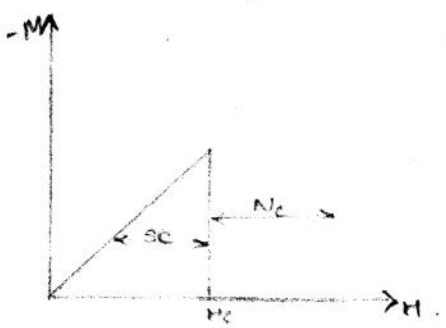
$$\lambda = 2t(\mu_0 - \mu_e)$$

$$= 2 \times 0.9 \times 10^{-6}(1.658 - 1.486)$$

$$= 3.096 \times 10^{-7} m.$$

18 Distinguish between type I & type II super conductors with examples.

Type I superconductor



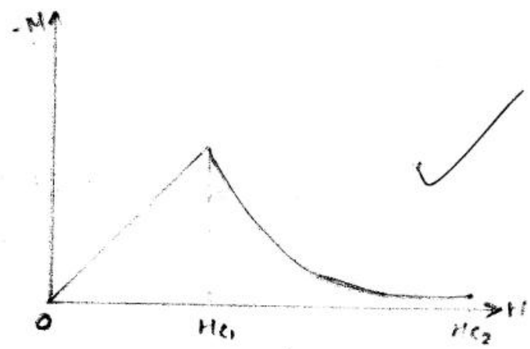
When field H increases, magnetisation M also increases linearly up to Hc

At critical field Hc, M suddenly decreases to zero and material changed to normal conductor.

Transition from superconducting state to normal state is a sudden process.

Hc is very small $H_c \simeq 0.1T$ to $0.2T$, so a small magnetic field is ~~req~~ required to destroy super conducting

Type II superconductor.



When external field H increases, M also increases linearly up to H_{c1} (lower critical field)

Beyond H_{c1}, magnetic field lines slowly penetrating through the specimen so, magnetisation M, gradually decreases and is equal to zero at H_{c2} (upper critical field)

So from 0 to H_{c2}, the material act as a super conductor.

The value of H_{c2} is high; $H_{c2} \simeq 10T$ to $20T$. So high magnetic field is

nature. Hence type I superconductor is also called soft superconductors. eg: Lead, Tin, Al, Mg, Hg.	required to destroy super conducting nature; so type II s c is called hard super conductor. Beyond H_{c2}, the material changes to normal conductor. eg: Niobium, Niobium-tin

21 The Volume of a hall is $3000\ m^3$. It has a total absorption of $100\ m^2$ sabine. If the hall is filled with audience who add another $80\ m^2$ sabine then find the difference in reverberation time.

$V = 3000\ m^3$.

$A_1 = 100\ m^2$ sabine

$A_2 = (100+80)\ m^2$ sabine

$T_1 = \frac{0.163V}{A_1}$, $T_2 = \frac{0.163V}{A_2}$.

$$T_2 - T_1 = 0.163\ V\left[\frac{1}{A_2} - \frac{1}{A_1}\right]$$

$$= 0.163 \times 3000\left[\frac{1}{180} - \frac{1}{100}\right]$$

$$= \underline{\underline{2.17\ \text{sec.}}}$$

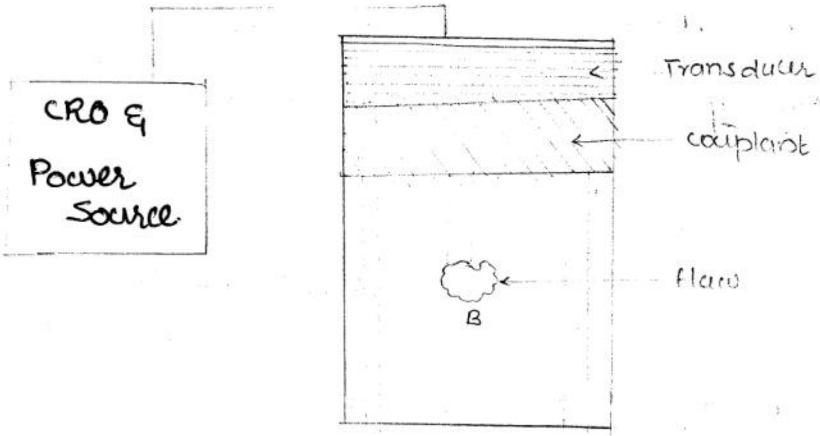
22 What is NDT? How ultrasonic wave is used for NDT.

NDT (Non destructive testing)

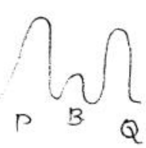
When no changes takes place in the properties of materials during the process of testing is called Non destructive testing (NDT)

a 1. Pulse-echo method

- It is used to detect the flaws, cracks, breakings, cavity etc.



- Transducer emits an ultrasonic ~~pulse~~ waves in the specimen.
- At the same instant, the ultrasonic pulse passes directly to the CRO produces a high peak 'P'
- The ultrasonic waves are reflected from the other end of the material are also sent to the CRO produces a high peak Q as same as P.
- When there is a flaw in the specimen, partial reflection takes place. in CRO.
- From the position of the additional peaks in the CRO the exact location of flaw can be estimated.



23 What is the difference b/w spontaneous emission and stimulated emission.

Spontaneous emission	Stimulated emission
An excited atom spontaneously jump from higher energy level to lower energy level without the help of any external agency	An external photon is incident on the excited atom and stimulate it to jump from the higher energy level to the lower energy level. (An external photon is needed for stimulated emission)

• During this transition a single photon is produced (Here no photon multiplication)	Here two photons are emitted during one transition (There is a photon multiplication).
• The emerging beam is not coherent	Emerging beam is coherent.
• Rate of emission depends no. of atoms in excited state. (so beam is not highly intense)	Rate of emission depends (i) no. of atoms in the excited state. (ii) density of photon. (beam is highly intense)
• Emission is not due to population inversion	Emission is due to population inversion.
• This is uncontrolled random process	controlled regular process.
• Spectrum is broad & wide	spectrum is very narrow & sharp
• Travelling in different direction (diverging)	Travelling in a particular direction.

20 Distinguish b/w Macrostate & Microstate of a system.

Macrostate:-

• It describes Macroscopic or overall behaviour of a system.

Eg:-

If a gas enclosed in a vessel, then its state is completely described by its volume, pressure and temperature are called macro states.

Microstates:-

It gives a detailed description about the individual properties of a system.

Energy of electron in a conductor

Energy of molecule in a gas.

Eg:-

The system of a single particle can be explained by its position coordinates (x, y, z) and momentum coordinates (p_x, p_y, p_z)

For N particle it requires 3N no. of generalised coordinates $q_1, q_2, \dots q_N$ and '3N' no. of momentum coordinates $p_1, p_2 \cdots p_N$

- These coordinates are called microstate of the system.

19 Calculate the de-Broglie wavelength of electron whose kinetic energy is 10 keV.

$KE = 10 keV$

$= 10\times10^{3} eV$

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

$$= \frac{6.62\times10^{-34}}{\sqrt{2\times9.1\times10^{-31}\times10\times10^{3}\times1.6\times10^{-19}}}$$

$= 1.226\times10^{-11} m$

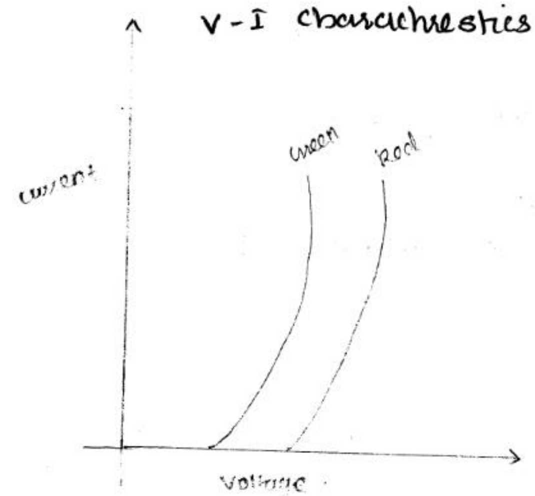
24 What is a LED? Give its working principle?

Light emitting diode (LED)

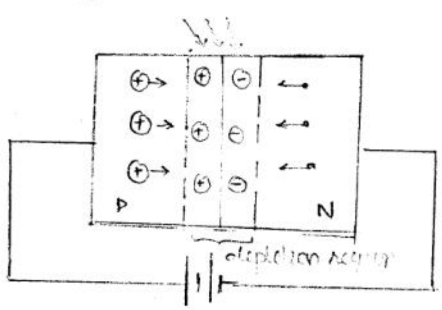
- LED is a semiconductor PN junction diode which convert electrical energy in to light energy under forward biasing

Symbol.

V-I characteristics



Block diagram



working:-

- During forward bias free $\bar{e}$s from the ~~conduction~~ conduction band of N side & holes from the valence band of P side moving towards Depletion region, And recombine each other.
- During recombination electro magnetic radiations (light) is emitted with

energy equal to band gap energy.

ie, $h\nu = E_g$.

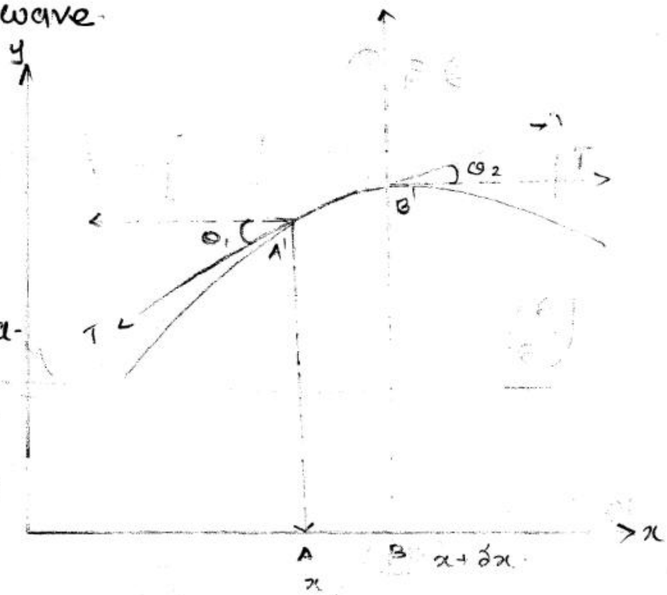
$$\nu = \frac{E_g}{h}$$

$E_g \rightarrow$ band ~~ey~~ gap energy

For visible light its value is 1.5 eV to 1.8 eV.

Part 'C'

25 Considering the transverse vibration in a stretched string. Derive the differential equation of one dimensional wave.



consider an infinitely long thin, uniform string stretched between A & B by a constant tension T,

Let the string be slightly displaced along the Y axis and released, then transverse vibrations are formed in the string

Let a small element AB of length $= \partial x$

Magnitude of the tension will be same ~~evergy~~ every where

($\because$ the string is perfectly flexible)

Tension T acts tangentially at every point.

At A', tension T makes an angle θ_2 with horizontal.

The net force acting along x & Y direction is

$$F_x = T\cos\theta_2 - T\cos\theta_1 \longrightarrow (1)$$

$$F_y = T\sin\theta_2 - T\sin\theta_1 \longrightarrow (2)$$

For small oscillations, θ_1 & θ_2 are very small

So $\cos\theta_1 \simeq \cos\theta_2 = 1$

& $\sin\theta_1 \simeq \tan\theta_1$ & $\sin\theta_2 \simeq \tan\theta_2$.

$\therefore$ (1) $\Rightarrow$ $F_x = 0$.

& (2) $\Rightarrow$ $F_y = T\left[\tan\theta_2 - \tan\theta_1\right]$

$$= T\left[\left(\frac{\partial y}{\partial x}\right)_{x+\partial x} - \left(\frac{\partial y}{\partial x}\right)_x\right] \longrightarrow (3)$$

From Newton's second law of motion,

$$F = ma$$
$$= \mu\, \delta x \, \frac{\partial^2 y}{\partial t^2} \longrightarrow (4)$$

$a = \frac{\partial^2 y}{\partial t^2}$

μ = linear mass density

mass of the string, $AB = \mu\, \delta x$.

From (3) & (4)

$$T\left[\left(\frac{\partial y}{\partial x}\right)_{x+\delta x} - \left(\frac{\partial y}{\partial x}\right)_x\right] = \mu\, \delta x \, \frac{\partial^2 y}{\partial t^2}$$

$$\frac{\left(\frac{\partial y}{\partial x}\right)_{x+\delta x} - \left(\frac{\partial y}{\partial x}\right)_x}{\delta x} = \frac{\mu}{T}\frac{\partial^2 y}{\partial t^2}$$

In the

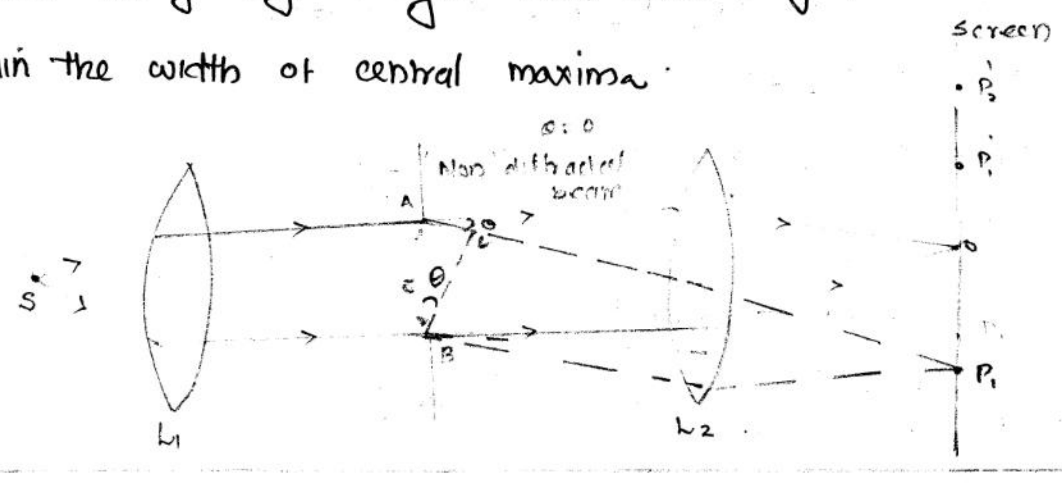
$$\lim_{\delta x \to 0} \frac{\left(\frac{\partial y}{\partial x}\right)_{x+\delta x} - \left(\frac{\partial y}{\partial x}\right)_x}{\delta x} = \frac{\partial^2 y}{\partial x^2}$$

Therefore the above equation becomes.

$$\frac{\partial^2 y}{\partial x^2} = \frac{\mu}{T}\frac{\partial^2 y}{\partial t^2}.$$

This is the wave equation (D.E) in the case of wave in a stretched string.

26 Light from a monochromatic source is allowed to fall on a single slit. Two lenses are given. With the help of a neat diagram write the experimental set up for obtaining the diffraction pattern. Deduce the condition for getting bright and dark regions on the screen. Also obtain the width of central maxima.



$\theta \rightarrow$ angle of diffraction.

$a \rightarrow$ slit width.

When a monochromatic light is incident normally on a slit of width 'a' The diffracted light is focused by a convex lens & diffraction pattern is obtained on the screen, consists of a central maxima & no. of principal maxima.

Central maxima: At the point 'O' all the waves reaching 'O' from slit having same path length, so path difference $= 0$. Hence we get a brightest maxima called central maxima.

consider the point at P_1

Let the path difference b/w the waves emerging from the extreme point A & B $= AC = AB \sin\theta = a \sin\theta$.

Let this path difference $= 1\lambda$

Divide the aperture in to two halves, then the waves from corresponding points from each halves will differ in Path difference of $\lambda/2$. They will destructively interfere and cancelled out. so we get 1st minimum at P_1.

$a \sin\theta = \lambda \longrightarrow$ 1st minimum.

consider the P_2

Let the path difference b/w the waves emerging from the extreme points A & $B = 2\lambda$

Then aperture is divided in to 4 equal parts waves from corresponding points from each part in upper & lower half suffer a path difference of $\lambda/2$.

Here also all waves are cancelled out so we get second minimum

For minimum

$$a \sin\theta = 2n\,\lambda/2 = n\lambda$$

If path diffrence b/w the waves emerging from the extreme point A & B is an even multiple of $\lambda/2$. Then we get minima

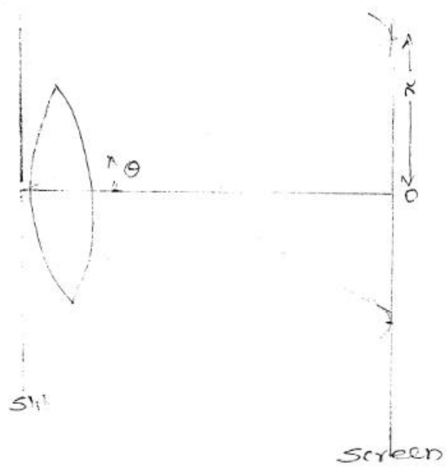
Now we consider, if the path diffrence b/w the waves emerging from extreme point $= \frac{3}{2}\lambda$. Then we divide the slit into 3 equal parts. Then waves from either 1st & second parts or 2nd & 3rd part will cancelled out. So remaining part will reach at the screen. So we get 1st maximum.

so $a\sin\theta = (2n+1)\lambda/2$. $\Rightarrow$ Maximum.

If the path diffrence b/w the waves emerging from the extreme point A & B is an odd multiple of $\lambda/2$, then we get maxima.

Width of central maxima.

It is distance b/w the first order minima on either side of central maxima.



$x \rightarrow$ distance of 1st minimum from 'O'

$f \rightarrow$ Focal length of lens.

For 1st order minima

$a \sin\theta = \lambda$

From the figure

$\sin\theta = x/f$

$\frac{x}{f} = \frac{\lambda}{a} \Rightarrow x = \frac{f\lambda}{a}$.

$\therefore$ width of central maxima,

$$2x = \frac{2f\lambda}{a}.$$

27 How a Nicol can be constructed from a calcite crystal? How can it be used as a polariser and as an analyser.

Nicol prism

construction:-

step-1

consider a rhombohedron calcite crystal whose $l > 3b$, having 6 parallelogram faces with angles 102° & 78°

step-2

cut through the principal section, having angles 109° & 71°

step-3

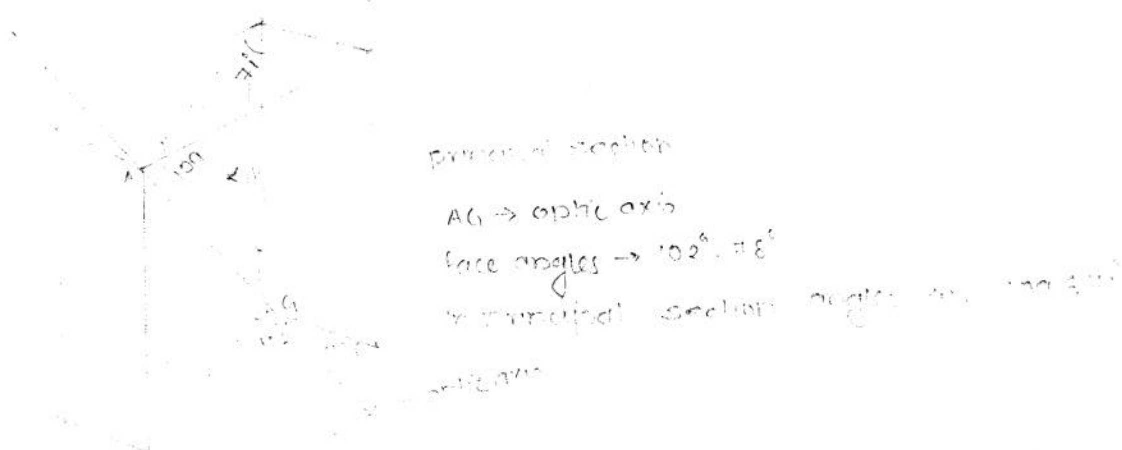
The end sides are grinded till the angles reaches 112°, 68°

step-4

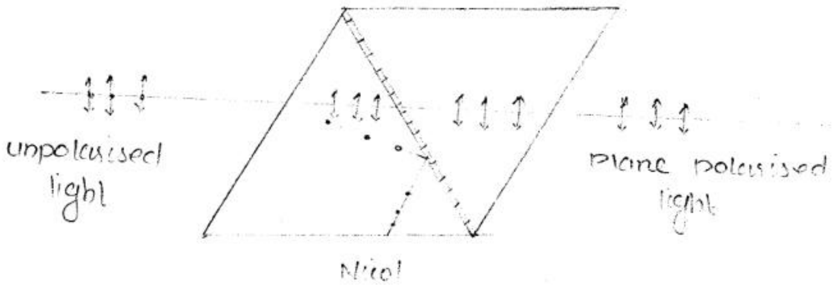
cut the prism into two along the newly formed optic axis.

step-5

These two pieces are cemented by a transparent material ($\mu_{CB} = 1.54$) called canada balsm. Now Nicol is formed.



Nicol acts as a polarizer:-



$\mu_o = 1.66$
$\mu_{CB} = 1.54$
$\mu_e = 1.49$

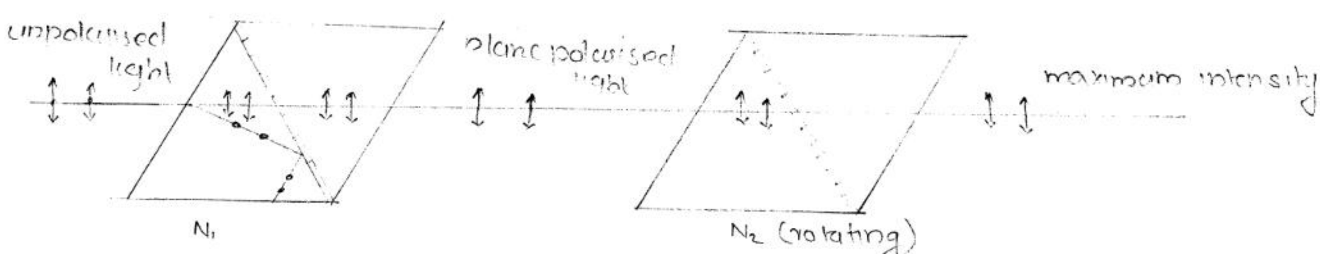
→ When an unpolarised light is passed through a nicol, inside the nicol it splits into two, o-ray & e-ray (double refraction)

→ For o-ray, it travels from denser to ($\mu_o = 1.66$) rarer ($\mu_{CB} = 1.54$), so o-ray undergoes total internal reflection and reflected back to the same medium. & it is absorbed by the back surface.

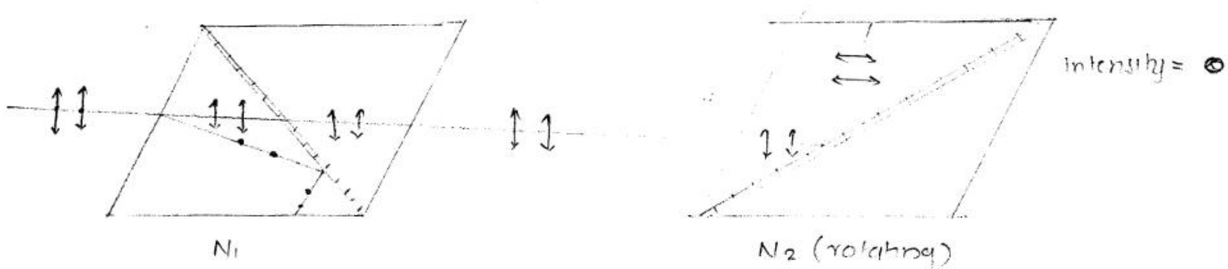
→ But e-ray travels from rarer (1.49) to denser ($\mu_{CB} = 1.54$) medium. so e-ray is refracted through the crystal.

→ So we get plane polarised light. hence Nicol act as an polarizer.

Nicol acts as an analyser:-



Angle b/w N_1 & N_2 $(\theta) = 0$, so we get maximum intensity.



Angle b/w N_1 & $N_2 = 90^\circ \Rightarrow$ intensity $= 0$

→ For Analysing, the light from N_1 is allowed to passed. Through rotating Nicol (N_2), when N_1 & N_2 are parallel ($\theta = 0$), intensity is maximum and & when $N_1 \perp r\ N_2$, then we get zero intensity.

→ Reason:- When $N_1 \perp r\ N_2$ the refractive index reaches a value $\mu_E = \mu_0 = 1.66$, so e-ray travels from denser to rarer and undergoes total internal reflection.

→ Now Nicol acts as an analyser.

28 Formulate schrodinger's time dependent equation stating from a plane wave equation by using de-Broglie's formula and Einstein's relation for photon energy.

consider a particle of mass 'm' moving in +ve x direction

then the wave function is given by

$$\psi(x,t) = A e^{i(kx - \omega t)} \longrightarrow ①$$

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

we have $E = h\nu$

$$= \frac{h\nu\, 2\pi}{2\pi} = \hbar\omega$$

$$P = \frac{h}{\lambda} = \frac{h\, 2\pi}{\lambda\, 2\pi} = \hbar k.$$

$$\therefore ① \Rightarrow \psi(x,t) = A e^{i/\hbar (Px - Et)} \longrightarrow ②$$

Partial differentiation of ψ w.r.t x is

$$\frac{\partial\psi}{\partial x} = A e^{i/\hbar (Px - Et)} \times \frac{iP}{\hbar}$$

$$= \frac{iP}{\hbar}\psi$$

$$\frac{\partial^2\psi}{\partial x^2} = \frac{iP}{\hbar} A e^{i/\hbar (Px - Et)} \times \frac{iP}{\hbar}$$

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

$$\therefore P^2\psi = -\hbar^2 \frac{\partial^2 \psi}{\partial x^2} \longrightarrow ③$$

$$P\psi = -i\hbar \frac{\partial \psi}{\partial x}.$$

$$\hat{P} = -i\hbar \frac{\partial}{\partial x}$$

$\Downarrow$

momentum operator.

Differentiating w.r.t time

$$\frac{\partial \psi}{\partial t} = A e^{i/\hbar (Px - Et)} \times \frac{-iE}{\hbar}$$

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

$$\therefore E\psi = \frac{-\hbar}{i} \frac{\partial \psi}{\partial t} = i\hbar \frac{\partial \psi}{\partial t} \longrightarrow ④$$

$$E\psi = i\hbar \frac{\partial \psi}{\partial t}.$$

$$\hat{E} = i\hbar \frac{\partial}{\partial t}$$

$\Downarrow$

energy operator

We have total energy is

$$E = KE + PE.$$

$$E = \frac{P^2}{2m} + V$$

ie, $E\psi = \frac{P^2\psi}{2m} + V\psi \longrightarrow ⑤$

sub ③ & ④ in ⑤, we get

$$⑤ \Rightarrow \quad i\hbar \frac{\partial \psi}{\partial t} = \frac{-\hbar^2}{2m} \frac{\partial^2 \psi}{\partial x^2} + V\psi$$

$\Rightarrow$ one dimensional time dependent Schrodinger eqn

In 3D

$$i\hbar \frac{\partial \psi}{\partial t} = \frac{-\hbar^2}{2m} \left[\frac{\partial^2 \psi}{\partial x^2} + \frac{\partial^2 \psi}{\partial y^2} + \frac{\partial^2 \psi}{\partial z^2}\right] + V\psi$$

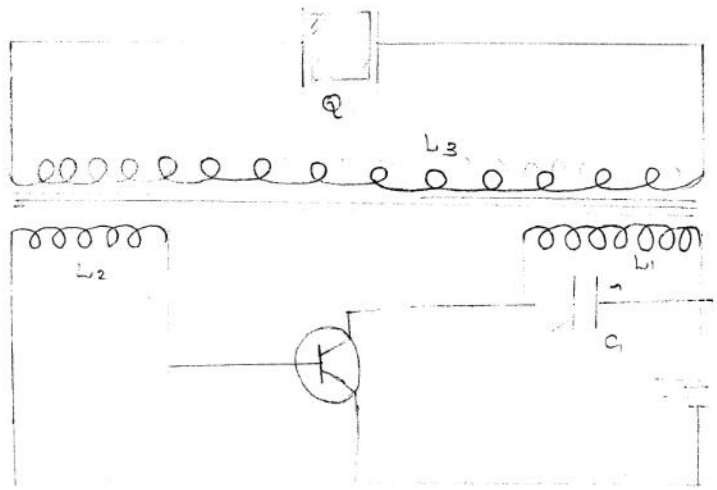
$$i\hbar \frac{\partial \psi}{\partial t} = \frac{-\hbar^2}{2m} \nabla^2 \psi + V\psi$$

where

$$\nabla^2 \psi = \frac{\partial^2 \psi}{\partial x^2} + \frac{\partial^2 \psi}{\partial y^2} + \frac{\partial^2 \psi}{\partial z^2}$$

Part - D

29 With a neat diagram explain how ultrasonic waves are produced by piezoelectric oscillator.



→ Here Q be the quartz crystal
→ L_1C_1 be the oscillator circuit (tank circuit)
→ When the oscillator is switched on, the tank circuit produce oscillation.
→ Due to this oscillations, an ac emf (ac voltage) is produced, and it is applied across is two opposite faces of crystal.
→ Then crystals vibrates in perpendicular directions by inverse piezo electric effect.
→ When the frequency of oscillations produced by the oscillator equals the natural frequency of crystals, then resonance takes place, and crystal vibrates with maximum amplitude, as a result ultrasonic waves are produced
→ Here ultrasonic waves with frequency 500 MHz can be produced.
→ frequency $f = \frac{1}{2l}\sqrt{Y/\rho}$

l → thickness of crystal.
Y → Young's modulus.
ρ → density.

30 What are the factors affecting the acoustics of a building?

1. Reverberation :-

- For good acoustics, the reverberation time should neither be too small, nor too large. (Reverberation time should have an optimum value.)
- If reverberation time is too small, sound will dies in short time, this gives a dead silence in the hall.
- If T is very large, sound persists for a long time, resulting in overlapping of successive sounds, this result in loss of clarity.
- So reverberation time must be an optimum value.

We have $T = \frac{0.163V}{\sum_i \alpha_i S_i} = \frac{0.163V}{A}$

- Reverberation time can be controlled by.

* By providing proper doors and windows at proper places.
* Having full audience in the hall.
* Using thick curtains.
* covering the floors with carpets.
* Providing suitable sounds absorbers on the walls.

2. Echoes :-

- Echo is the repeatation of sound waves due to multiple reflections from the walls, ceilings etc.
- Echo is heard, when direct and reflected sound waves coming from the same source reach the listener in a time interval of 1/4 sec which causes confusion.

* Echo can be minimized by ~~con~~ covering distant walls with sound absorbing materials.
* Providing thick curtains with folding.
* Instead of parallel walls, splayed side walls are used.

* Faint echo is necessary for music hall.

3. Focusing surface:-

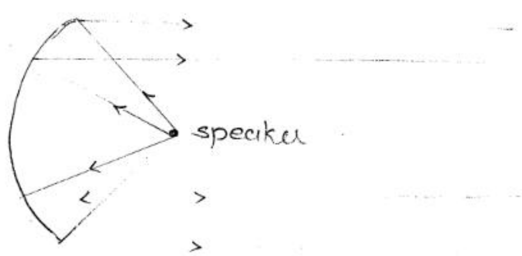
- The presence of focussing surfaces such as concave, spherical, cylindrical and parabolic produces the concentration of sound in some region, so which causes less sound in some other region. so sound distribution is not uniform.

- For uniform distribution.

→ There should not be any curved surfaces on the walls, ceilings, floor etc. If curved surfaces are present they must be covered with suitable sound absorbing materials.

→ Ceiling must be low

→ A parabolic surface may be arranged with the speaker at its focus. This send out a uniform sound energy in the entire hall.



Parabolic surface with the speaker at the focus.

4. Sufficient Loudness.

- An ~~arrangement~~ average person would be able to detect a 30dB sound at 1000Hz as reasonably sound. But 30dB sound at 50Hz would not be hear at all.

- so for satisfactory hearing, sufficient loudness throughout the hall is necessary.

- For sufficient loudness.

→ By setting up load speakers at different position in the hall.

→ Low ceiling of suitable shape can also solve the purpose by reflecting sound energy ~~forward~~ towards the audience.

→ By keeping large sounding boards behind the speakers and facing the audience

5. Resonance effect:-

- Hollows, cavities, air pockets in the walls and ceiling will contains air columns. These air column selects the natural frequency from the incident sound & this will produce resonance.
- In some cases windows - panes, section of wooden portions etc. will vibrate and produce sound waves. This will also produce resonance.
- sometimes created sound will make interference with the original sound.
- These resonance and interference produces distortion and losses the clarity of original sound.
- To avoid this

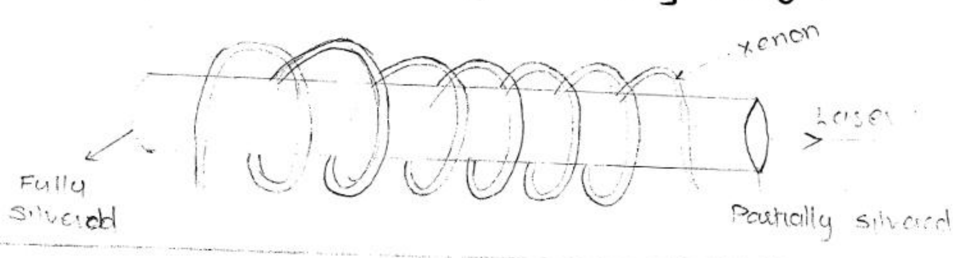
→ hollow cavities, air packets must be avoided or covered with sound absorbing materials.

6. Echelon effect:-

- Regular spacing of reflecting surfaces and railings may produces additional musical notes due to the regular repitition of echoes. This is called echelon effect.
- This makes the original sound confusion and unintelligible.
- For avoid this

Such equally spaced steps, ceilings, pillars etc should be covered with sound absorping materials.

31 Outline the principle and working of Ruby laser.



Ruby laser : (Three level laser)

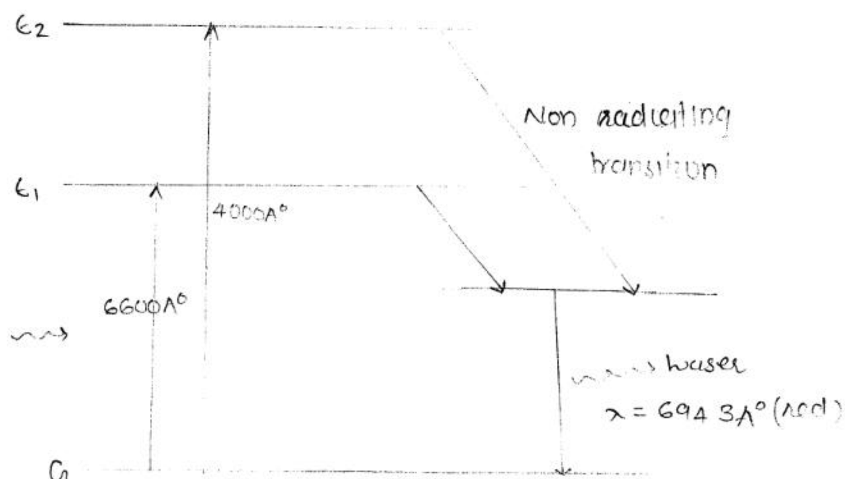
- It is a solid state laser
- It was the first laser fabricated by maiman in 1960
- It is a three level laser
- Ruby is aluminium oxide crystal (Al_2O_3) doped with 0.05 % of chromium oxide (Cr_2O_3)

Energy source : xenon flash tube

Pumping : Optical pumping

Lasing medium : Ruby rod

Optical resonator :- Two end faces of the ruby rod, one is fully silvered, and the other is partially silvered.



Energy level diagram of Cr^{3+} ion

Working :-

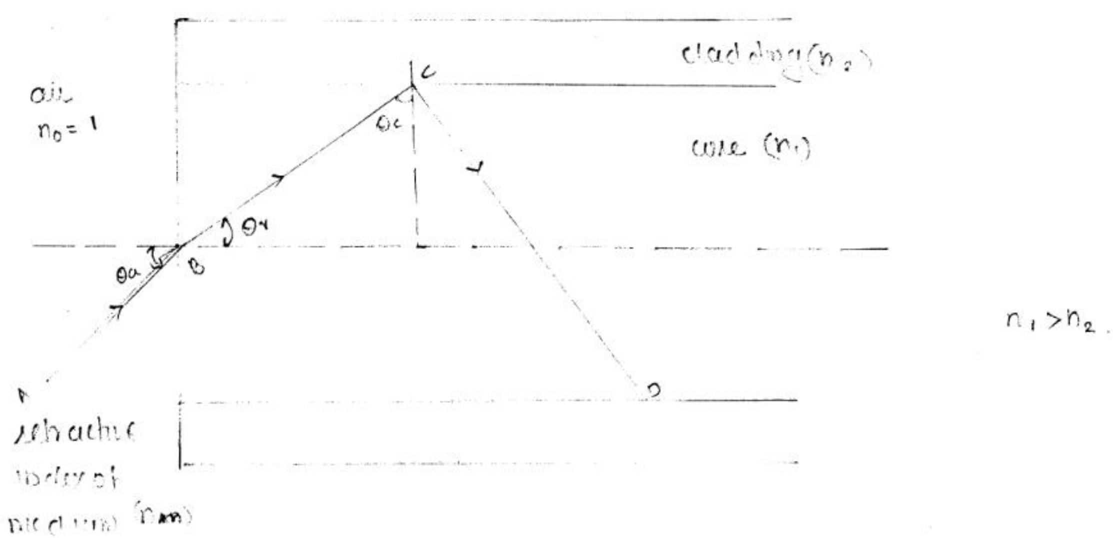
- When Xenon flash tube is on, the Cr^{3+} ions absorbs the energy and get excited to higher energy E_1 and E_2 ⇒ Induced absorption
- Since the life time of E_1 & E_2 is too small (10^{-9}sec). they are suddenly jumps to metastable state ⇒ Non radiative transition.
- Since the life time of meta stable state is 10^{-3} sec, no. of chromium ion gets increased and populations inversion is achieved.

- The spontaneously emitted photons in the system, stimulated the laser action.
- Large number of photons are emitted by stimulated emissions from metastable state to ground state.
- These photons are shuttled b/w two ends faces of the rod, then highly coherent laser beam is produced
- wavelength of laser o/p ⇒ 6943 A°.

32 Define numerical aperture of an optical fibre and derive an expression for NA of a step index fibre.

- Numerical aperture is the light gathering power of an optic fibre.
- It is the sine of acceptance angle.
- It measures the amount of light accepted by the fibre.
- NA represents the sensibility or figure of merit of the fibre

$$NA = \sin\theta_a = \sqrt{n_1^2 - n_2^2}$$



- A light ray AB is incident at an angle θ_a (acceptance angle)
- It is refracted along BC at θ_r called critical propagation angle.
- This ray is incident at C, at an angle just greater than the critical angle, hence it undergoes total internal reflection.

At B, by Snell's law

$$\frac{\sin \theta_a}{\sin \theta_r} = \frac{n_1}{n_m} \rightarrow ①$$

$$n_m \sin \theta_a = n_1 \sin \theta_r$$

$$\sin \theta_a = \frac{n_1}{n_m} \sin \theta_r \longrightarrow ①$$

in ΔBCN;

$$\cos \theta_r = \frac{BN}{BC}$$

$$\sin \theta_c = \frac{BN}{BC}$$

$$\cos \theta_r = \sin \theta_c \longrightarrow ②$$

At critical angle ; $\frac{\sin \theta_c}{\sin 90} = \frac{n_2}{n_1}$

Or $\sin \theta_c = \frac{n_2}{n_1} \longrightarrow ③$

We have

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

$$= 1 - \sin^2 \theta_c \quad ; \text{ from } ② \text{ \& } ③$$

$$= 1 - \frac{n_2^2}{n_1^2}$$

$$= \frac{n_1^2 - n_2^2}{n_1^2}$$

$$n_1^2 \sin^2 \theta_r = n_1^2 - n_2^2$$

$$n_1 \sin^2 \theta_r = \sqrt{n_1^2 - n_2^2}$$

$① \Rightarrow$ $$N_A = \sin \theta_a = \frac{\sqrt{n_1^2 - n_2^2}}{n_m}$$

for air medium ; $n_m = n_0 = 1$

$$\therefore NA = \sin \theta_a = \sqrt{n_1^2 - n_2^2}$$