Roll No. 

Total No. of Questions : 09

B.Tech. (AI&DS/AI&ML/Block Chain/CE/CSE/Cyber Security/ DS/IOT/CSD/EEE/EE/ECE/ETE/ECS/FT/IT/ME/Robotics & Artificial Intelligence/Internet of Things and Cyber Security including Block Chain Technology) (Sem-1,2)

# ENGINEERING PHYSICS

Subject Code : BTPH101-23

M.Code : 93794

Date of Examination : 14-06-2025

Time : 3 Hrs. Max. Marks : 60

**INSTRUCTIONS TO CANDIDATES :**

1. SECTION-A is COMPULSORY consisting of TEN questions carrying TWO marks each.
2. SECTION - B & C have FOUR questions each.
3. Attempt any FIVE questions from SECTION B & C carrying EIGHT marks each.
4. Select at least TWO questions from SECTION - B & C.

## SECTION - A

I. Write briefly :

a. Calculate the minimum wavelength of Continuous X-rays emitted from an X-ray tube whose operating voltage is 40 kV.

b. Show that at 0 K, the probability to find electron in an energy level above the fermi level is Zero.

c. Why superconductors cannot carry current beyond a certain limit?

d. Distinguish between diamagnetic and paramagnetic materials.

e. Show that Divergence of Curl of vector is zero.

f. Distinguish between Stimulated emission and spontaneous emission.

g. Write a note on four level lasers.

h. What are Carbon Nanotubes (CNTs)?

i. An electron has a speed of 400 m/s, correct upto 0.01%, with what minimum accuracy, can you locate the electron?

j. Distinguish between splicers and couplers.

## SECTION - B

2. What is Bragg's law? Explain the measurement of crystal spacing (d) using Bragg's spectrometer.

3. Distinguish between intrinsic and extrinsic semiconductors. Derive the expression for carrier concentration in n-type semiconductors.

4. What is Meissner effect? Explain it using London's equation.

5. a. Write the Maxwell's equations and discuss the physical significance of each equation.

   b. Define Poynting vector ($\vec{P}$). Show that $\vec{P} = < \vec{E} \times \vec{H} >$, where symbols have their usual meanings.

## SECTION - C

6. Explain the construction and working of Ruby laser with the help of energy level diagram. Explain why it is pulsed laser?

7. What are the various kinds of losses a light suffers while propagating through a fibre? Calculate the refractive index of core and clad of fibre where Numerical aperture is 0.40 and $\Delta = 0.020$.

8. Solve time independent Schrodinger wave equation for particle in a box and show that energy of particle is quantized.

9. Explain the synthesis of nanomaterials using sol-gel techniques. Why it is called bottom to top approach?

**NOTE : Disclosure of Identity by writing Mobile No. or Marking of passing request on any paper of Answer Sheet will lead to UMC against the Student.**

# Engineering Physics
## Paper- 14-06-2025

Section A:-

a Calculate the minimum wavelength of continuous X-rays emitted from an X-ray tube whose operating voltage is 40 KV.

→ $V = 40\ kV$
$= 40 \times 10^3\ V$

$E = eV$

$\lambda_{min} = \frac{hc}{eV}$

$\lambda_{min} = \frac{(6.62 \times 10^{-34}\ Js) \times (3 \times 10^{-8}\ m/s)}{(1.6 \times 10^{-19}\ C) \times 40,000}$

$\lambda_{min} \approx 3.10 \times 10^{-11}\ m.$

b). Show that at 0 K, the probability to find an electron in the energy level above the fermi level is zero?

- At 0 K, the probability of finding an electron in an energy level above the fermi level is zero. This is because at 0 K, all energy states below the fermi level are fully occupied and all states above the fermi level are empty.

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

where $f(E)$ is probability of occupancy, $E$ is energy level, $E_f$ is fermi level, $k$ is Boltzman constant and $T$ is temperature in Kelvin

At 0 K, the term $\left(\frac{E-E_f}{KT}\right)$ becomes either positive or negative infinity where E is above or below $E_f$

- If $E > E_f$ (above fermi level) the term becom positive infinity and $f(E)$ approaches 0.

c. Why superconductors cannot carry beyond a certain limit?

→ Superconductors cannot carry currents beyond a certain limit because exceeding this "critical current" disrupts the superconducting state. This disruption occurs due to the breaking of cooper pairs, the electron pairs responsible for superconductivity, or the material exceeding its critical magnetic field. The critical current and critical magnetic field are material specific properties. Therefore, the applicable range of superconducting materials is limited by these parameters

d. Distinguish between diamagnetic and paramagnetic materials?

| Diamagnetic | Paramagnetic |
|---|---|
| 1) Weakly repelled by magnetic field. | 1. Weakly attracted by magnetic field |
| 2) When placed in a M.F it is weakly magnetized in a direction opposite to that of B | 2. When placed in a M.F it is weakly magnetized in direction of applied field |
| 3) Permeability ($\mu$) is less than 1 | 3. Permeability is slightly more than 1. |
| 4) $\chi$ does not change with temperature | 4. $\chi$ varies inversely as temperature of substance |
| 5) $\chi_m$ has small negative value | 5. $\chi_m$ has small positive value |

e Show that the divergence of curl of vector is zero.

→ Let $\vec{F} = (f_x, f_y, f_z)$

$$\bar{F} = \nabla \times \bar{F} \begin{bmatrix} a_x & a_y & a_z \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ f_x & f_y & f_z \end{bmatrix}$$

$$= a_x \times \left( \frac{\partial f_z}{\partial y} - \frac{\partial f_x}{\partial z} \right) - a_y \left( \frac{\partial f_z}{\partial x} - \frac{\partial f_x}{\partial z} \right)$$

$$a_z \left( \frac{\partial f_y}{\partial x} - \frac{\partial f_x}{\partial y} \right)$$

Now div (curl $\bar{F}$) = $\nabla \cdot (\nabla \times F)$

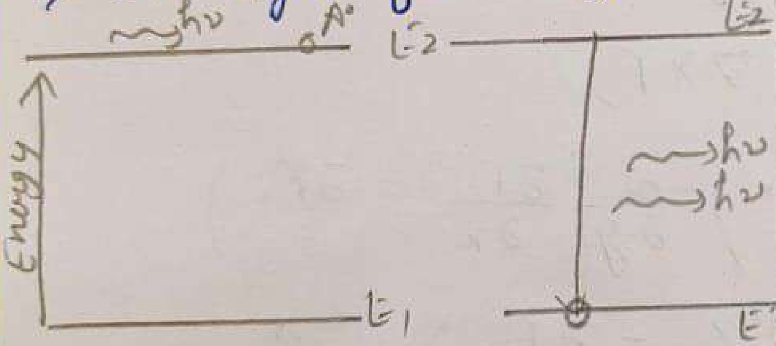
$$= \frac{\partial}{\partial x} \left( \frac{\partial f_z}{\partial y} - \frac{\partial f_x}{\partial z} \right) - \frac{\partial}{\partial y} \left( \frac{\partial f}{\partial x} - \frac{\partial f_x}{\partial z} \right)$$

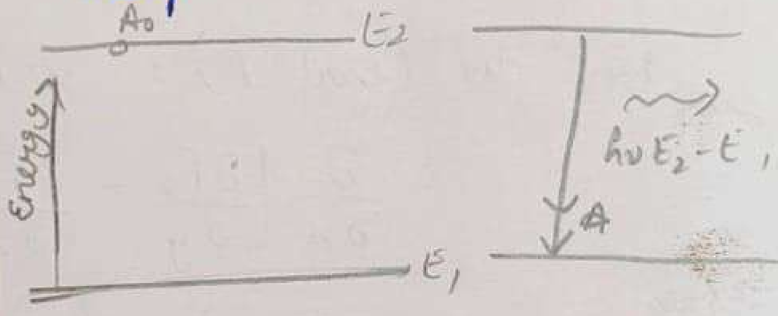
$$+ \frac{\partial}{\partial z} \left( \frac{\partial f_y}{\partial x} - \frac{\partial f_x}{\partial y} \right)$$

$$= 0$$

f) Distinguish between stimulated emission and spontaneous emission

| Stimulated Emission | Spontaneous Emission |
| --- | --- |
| 1). Emission takes place with the help of stimulus energy | Emission takes place without stimulated energy |
| 2). Two photons are emitted. | Single photon is emitted |
| 3). Coherent radiation | Incoherent radiation |
| 4) High intense and more directional. | Low intense and less directional |
| 5) Monochromatic radiation | Poly chromatic radiation |
| 6) Less angular spread | More angular spread |
| 7) Ex. Light from ruby laser | Ex. Light from sodium vapour lamp |




9. Write a note on four level lasers

Four level laser consists of four level. In the four level laser system the atoms from ground state E1 are raised to excited state E4 with the help of pumping. From the E4, the atoms decay to energy state E3 by spontaneous emission. The transition rate of atoms from E4 to E3 is much faster as compared to transition rate of atoms from $E_3$ to $E_2$. This is due to the reason that $E_4$ is an excited state with life time of the atoms of order $10^{-8}$ seconds. $E_3$ is metastable state. Thus the number of atoms in $E_3$ exceeds the number of atoms in $E_2$. The population inversion is achieved b/w $E_3$ and $E_2$. The laser action takes place between $E_3$ and $E_2$ by stimulated emission. The atoms from energy state $E_2$ get deexcited to $E_1$

h> What are carbon nanotubes (CNTs)?

→ A carbon nanotube is a tube made of Carbon with a diameter in the nanometer range They are one of the allotropes of carbon Two types of carbon nanotubes are recognized.

1). Single Walled Carbon nanotubes
2) Multi-walled carbon nanotubes

Carbon nanotubes can exhibit remarkeable properties, such as exceptional tensile strength and thermal conductivity because of their nanostructure and strength of the bonds between carbon atoms In addition carbon nanotubes can be chemically modified. These properties are expected to be valuable in areas such as electronics, optics, nanotechnology

i) An electron has a speed of 400 m/s corr upto 0.01%, with what minimum accuracy can you located the electron?

→ $v = 400\ m/s$

$\Delta v = 0.01\%$

$\Delta v = 0.01\% \times 400 = \frac{0.01}{100} \times 400 = 0.04\ m/s$

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

$\Delta p = m\,\Delta v$

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

$h = 6.63 \times 10^{-34}\ Js$

$$\Delta x = \frac{6.63 \times 10^{-34}}{4 \times 3.14 \times 9.1 \times 10^{-31} \times 0.04}$$

$$= 30.31 \times 10^{-3}\ m$$

ii) Difference between splicers and couplers.

| Splicers | Couplers |
|---|---|
| 1 a splice is a permanent or semipermanent joint between two optical fibers | Coupler is a device that distributes Light signals |
| 2) Splicers are typically used to create longer continuous fiber Runs | Couplers are used to split or combine signals for various applications. |

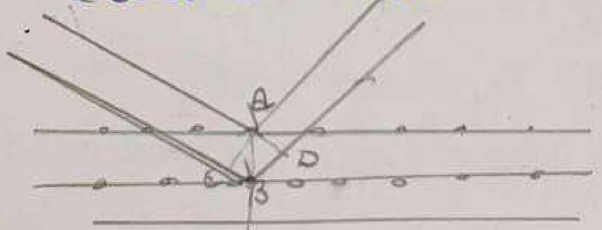
## Section-B

27) What is Bragg's law? Explain the measurement of crystal spacing (d) using bragg's spectrometer

Soln Bragg's law is a fundamental principle used to determine the atomic and molecular structure of a crystal. ~~It~~,

Consider a set of parallel planes called bragg's plane Each ~~plane~~ atom is acting as a scattering centre The intensity of the reflected beam at certain angles will be maximum when the path difference between two reflected waves from two adjacent planes in an integral multiple of $\lambda$.

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



Measurement of crystal spacing

Bragg's spectrometer is used to determine the spacing between crystal planes by analyzing the angles at which X rays are diffracted. This technique relies on Bragg's law which relates the wavelength of X-rays, the angle of incidence and the distance between crystal planes. By measuring the diffraction angles, knowing the X-ray wavelength the crystal's inter-planar distance can be calculated.

Bragg's law = $n\lambda = 2d\sin\theta$

$n$ = is an order of diffraction

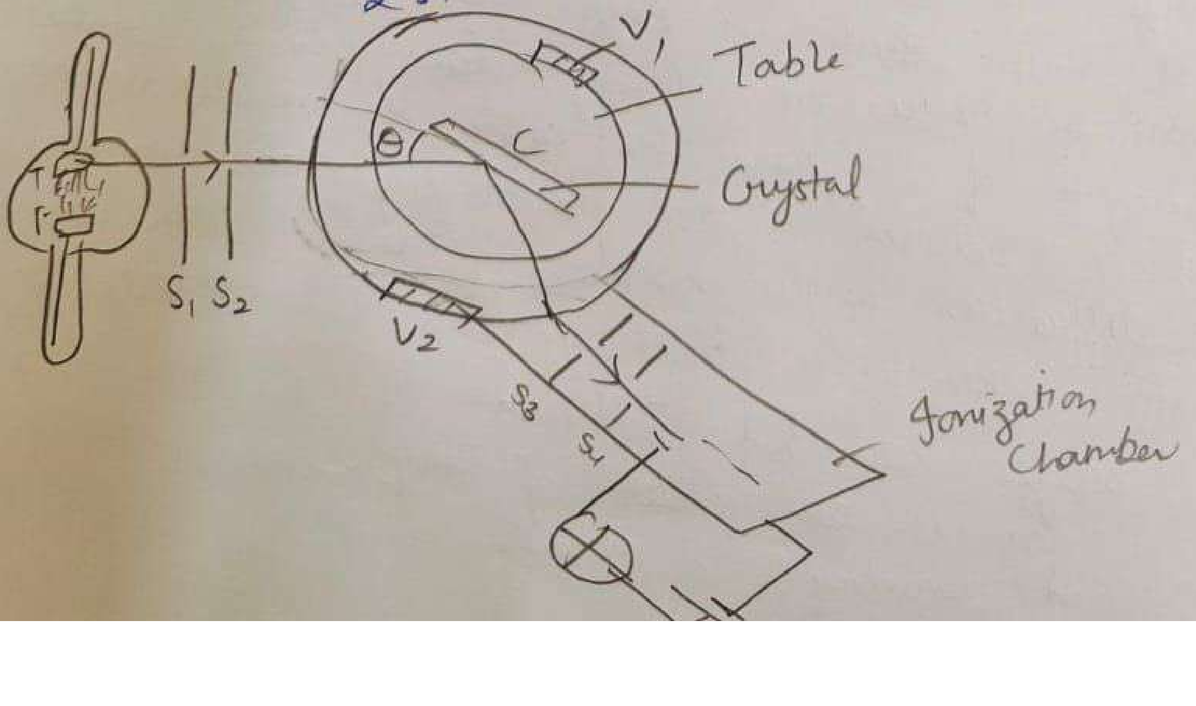
$\lambda$ = wavelength of X ray

$\theta$ is angle of incidence
d is spacing b/w crystal plane

Bragg's spectrometer

A beam of monochromatic X rays, is directed at a crystal mounted on a rotating table. The table is equipped with scale and vernier for precise angle measurement. An ionization chamber is fixed to longer arm. Now the crystal is rotated slowly. As the crystal rotates, the angle $\theta$ between the incident beam and the crystal plane changes when the bragg's condition is satisfied, a strong reflected X-ray beam is detected. The corresponding angle $\theta$ is measured using a scale on spectrometer. By knowing the wavelength $\lambda$, and measuring the angle $\theta$ at which the intensity peak occurs, you can compute the interplanar spacing d using

$$d = \frac{n\lambda}{2\sin\theta}.$$



) Distinguish between intrinsic and extrinsic semiconductors. Derive the expression for carrier concentration in n-type semiconductors

Soln

| Intrinsic Semiconductor | Extrinsic Semiconductors |
|---|---|
| 1) It is a pure semiconductor | 1 It is impure semiconductor |
| 2). Conductivity is Low | 2 Conductivity is high |
| 3) Number of free electrons ($n_e$) is equal to the number of holes ($n_h$) $n_e = n_h$ | 3. Number of free electrons ($n_e$) and number of holes ($n_h$) are unequal ($n_e \neq n_h$) |
| 4) Conductivity depends only on temperature | 4 Conductivity depends both on temperature and impurity added |
| 5). Conductivity due to electrons and holes is nearly equal | 5 Conductivity is due to majority charge carriers |
| 6) It does not conduct at zero Kelvin | 6 It conducts at 0 Kelvin |

(ii) Carrier concentration in n-type semiconductors

The donor level is just below the conduction band in n-type semiconductor

Density of electrons per unit volume in conduction band is

$$n = 2\left[\frac{2\pi m_e^* KT}{h^2}\right]^{3/2} e^{(E_F - E_c)/kT}$$

$E_c$ = Energy of conduction band

Density of ionised donor $= N_d\,[1 - F(E_d)]$

$F(E_d)$ is probability for finding electron.
$E_d$ = represents donor energy level.
$N_d$ · denotes donor concentration.

$$= N_d \left[ 1 - \frac{1}{1+e^{(E_F-E_c)/kT}} \right]$$

$$= N_d \left[ \frac{1+e^{(E_F-E_c)/kT} - 1}{1+e^{(E_F-E_c)/kT}} \right]$$

$$= \frac{N_d \, e^{(E_F-E_c)/kT}}{1+e^{(E_d-E_F)/kT}}$$

$e^{(E_D-E_F)/kT}$ is very small.

$$1+e^{(E_D-E_F)/kT} \simeq 1$$

Density of ionised donor $= N_d \, e^{(E_d-E_F)/kT}$

At equillibrium

$$2\left[\frac{2\pi m_e^* kT}{h^2}\right]^{3/2} e^{(E_F-E_c)/kT} = N_d \, e^{(E_D-E_F)/kT}$$

$$\frac{e^{(E_F-E_c/kT}}{e^{(E_D-E_F)/kT}} = \frac{N_d}{2\left(\frac{2\pi m_e^* kT}{h^2}\right)^{3/2}}$$

$$e^{(E_F-E_c+E_F-E_D)/kT} = \frac{N_d}{2\left(\frac{2\pi m_e^* kT}{h^2}\right)^{3/2}}$$

Taking log on both sides

$$= \log_e \left( \frac{N_d}{2\left(\frac{2\pi m_e^* kT}{h^2}\right)^{3/2}} \right)$$

$$2E_F - E_c - E_D = kT \left( \frac{N_d}{2\left(\frac{2\pi m_e^* kT}{h^2}\right)^{3/2}} \right)$$

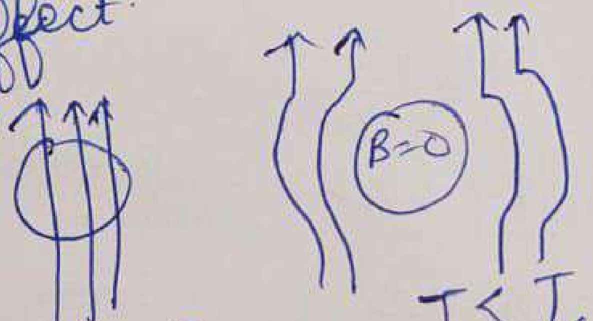
$$2E_F = E_D + E_c + kT \left( \frac{N_d h^2}{2\left(\frac{2\pi m_e^* kT}{h^2}\right)^{3/2}} \right)^{\cancel{3/2}}$$

$$E_F = \frac{E_D + E_C}{2} + \frac{KT}{2} \log_e \left[ \frac{N_d}{2\left(\frac{2\pi m_e^* k T}{h^2}\right)^{3/2}} \right]$$

4). What is Meisnerr effect? Explain it using London's equation

→ This phenomenona was discovered by German Physicist "Wather Meisner" & 'Robert Oschenfeld'.

When superconductor are cooled down below the Critical temperature Magnetic field expel and M.F do not allow to penetrate inside them. This phenomenona in superconductor is called Meisnerr effect.




$T > T_c$ $\quad$ $T < T_c$

$T_c$ = Critical Temperature

# London theory help us to understand the concept of superconductors.

There are two types of electrons in superconductor

$n = n_s + n_n$

$n_s$ = super electron

$n_n$ = Normal $e^-$

for superconductor $E = 0, B = 0$

Then below $T_c$

$J = J_s$ (Current density

$J = n_s e V_s$ — ①

$F = ma$

$eE = m \frac{dV_s}{dt}$

where $\frac{dV_s}{dt} = \frac{eE}{m}$ — ②

diff eqn. ① w.r.t. time

$\frac{dJ_s}{dt} = n_s e \frac{dV_s}{dt}$ — ③

Put $\frac{dV_s}{dt}$ in ③

$\frac{dJ_s}{dt} = \frac{n_s e^2 E}{m}$ — ④

This is first London's equation.-

by Maxwells eqn ③

$\nabla \times E = -\frac{dB}{dt}$

from London's ① eqn.

$\frac{dJ_s}{dt} = \frac{n_s e^2 E}{m}$

Taking curl on both sides.

$\nabla \times \frac{dJ_s}{dt} = \frac{n_s e^2}{m} \nabla \times E$

$\frac{d}{dt}(\nabla \times J_s) = \frac{n_s e^2}{m} - \frac{dB}{dt}$

integrating on both sides.

$\nabla \times J_s = \frac{n_s e^2}{m} B$ | london's second eqn) if $B = 0$

$$\nabla \times \vec{J}_s = 0$$

Hence Magnetic field expel out.

5. (a) Write Maxwell's equation and discuss the physical significance

1) Maxwells first Equation

$$\nabla \cdot D = \rho$$

It signifies that the total electric displacement through the surface enclosing a volume is equal to the charge within the volume.

2) Maxwells second equation

$$\nabla \cdot B = 0$$

The net magnetic flux emerging through any closed surface is zero.

3). $\nabla \times \vec{E} = \dfrac{-\partial B}{\partial t}$ (Maxwell's third Equation)

The electromotive force around a closed path is equal to the time derivative of the magnetic displacement through any surface bounded by the path

4) Maxwell's fourth Equation

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

The magnetomotive force around a closed path is equal to the conduction current plus the displacement through any surface bounded by path.

6 Define Poynting Vector ($\vec{P}$). Show that $\vec{P} = \langle \vec{E} \times \vec{H} \rangle$ whe symbol have there usual meanings.

→ Poynting vector denoted by $\vec{P}$ (or $\vec{S}$) represents the directional energy flux of an electromagnetic field. It describes the rate of energy flow per unit area in an electromagnetic wave.

Derivation

By using Maxwell's equation

$$\vec{\nabla} \times \vec{H} = \vec{J} + \frac{\partial \vec{D}}{\partial t} \quad -(1)$$

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

Taking dot product on both sides of equation with E and H respectively

$$\vec{E} \cdot \nabla \times \vec{H} = \vec{E} \cdot \vec{J} + \vec{E} \cdot \frac{\partial D}{\partial t}$$

$$E \cdot \nabla \times \vec{H} = \vec{E} \cdot \vec{J} + \frac{\partial}{\partial t}\left(\frac{1}{2} \epsilon E^2\right) \quad -(3)$$

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

$$\vec{H} \cdot \vec{\nabla} \times \vec{E} = -\frac{\partial}{\partial t}\left(\frac{1}{2} \mu H^2\right) \quad -(4)$$

Subtract (4) from (3)

$$\vec{E} \cdot \vec{\nabla} \times \vec{H} - \vec{H} \cdot \vec{\nabla} \times \vec{E} = \vec{E} \cdot \vec{J} + \frac{\partial}{\partial t}\left(\frac{1}{2} \epsilon E^2\right) + \frac{\partial}{\partial t}\left(\frac{1}{2} \mu H^2\right)$$

$$E \cdot \vec{\nabla} \times \vec{H} - \vec{H} \times \vec{\nabla} \times \vec{E} = \vec{E} \cdot \vec{J} + \frac{\partial}{\partial t}\left[\frac{1}{2} \varepsilon E^2 + \frac{1}{2} \mu H^2\right]$$

$$-\int_V \vec{\nabla}(\vec{E} \times \vec{H})\, dV = \int_V \vec{E} \cdot \vec{J}\, dV + \int_V \frac{\partial}{\partial t}\left(\frac{1}{2} \epsilon E^2 + \frac{1}{2} \mu H^2\right) dV \quad -(5)$$

Formula $H(\nabla \times E) - E(\nabla \times H) = \vec{\nabla}(\vec{E} \times \vec{H})$

$$\oint_V \nabla (E \times \vec{H}) dv = \oint_S \vec{E} \times \vec{H}\, ds \quad -(6)$$

Put (6) in (5)

$$\oint_S \vec{E} \times \vec{H}\, dv = -\frac{\partial}{\partial t} \int_V \left(\frac{\mu H^2}{2} + \epsilon \frac{E^2}{2}\right) dv - \int_V \vec{E} \cdot J dv$$

$p \rightarrow$ Poynting vector

where $-\frac{\partial}{\partial t} \int_V \left(\frac{\mu H^2}{2} + \epsilon \frac{E^2}{2}\right) dV$ represents the rate of decrease of energy stored in volume V.

$-\int (E \times \vec{J}) dv \rightarrow$ represents the rate at which at ~~which~~ electromagnetic energy is lost.

$\vec{E} \times \vec{H}$ gives rate of flow of energy through unit area enclosing the volume V. This is denoted by $\vec{P}$

$$\boxed{\vec{P} = \vec{E} \times \vec{H}}$$

h.

## Section - C

6) Explain the construction and working of Ruby laser with the help of energy level diagram. Explain why it is pulsated laser?

$\rightarrow$ Ruby laser is based on three level laser

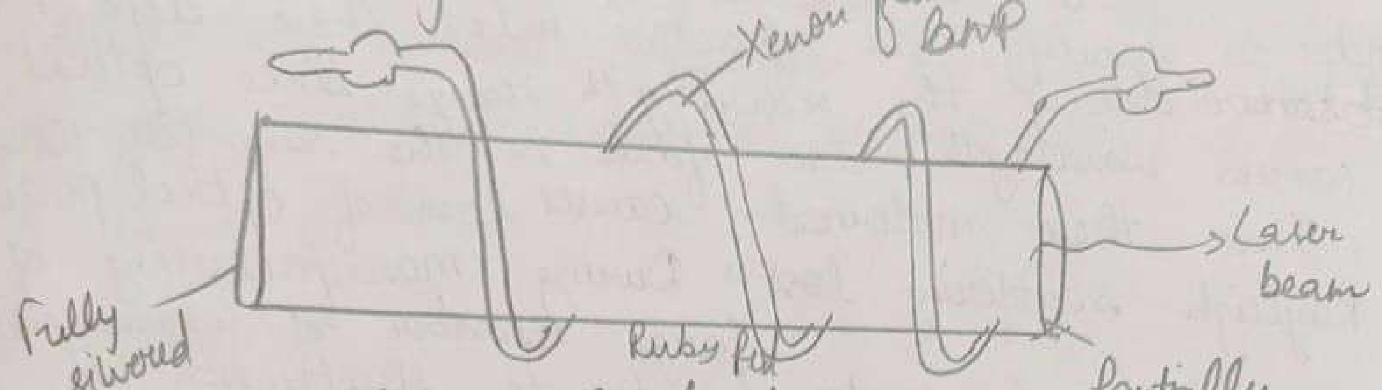
Constructions This laser consists of pink ruby cylindrical rod whose ends are optically flat and parallel. One end is fully silvered and other end is partially silvered. Upon the rod is wound a coiled flash lamp filled with Xenon gas. The ruby rod is basically $Al_2O_3$ crystal doped with 0.05% of chromium oxide ($Cr_2O_3$). The $Al^{3+}$ ions are replaced by $Cr^{3+}$ ions.

Working → The energy levels of $Cr^{3+}$ ions on the crystal lattice. It consists of three levels. Upper level is short lived. $E_3$ above the ground energy level $E_1$. There is an intermediate energy level $E_2$ which is metastable having a life time of $3 \times 10^{-3}$ sec.

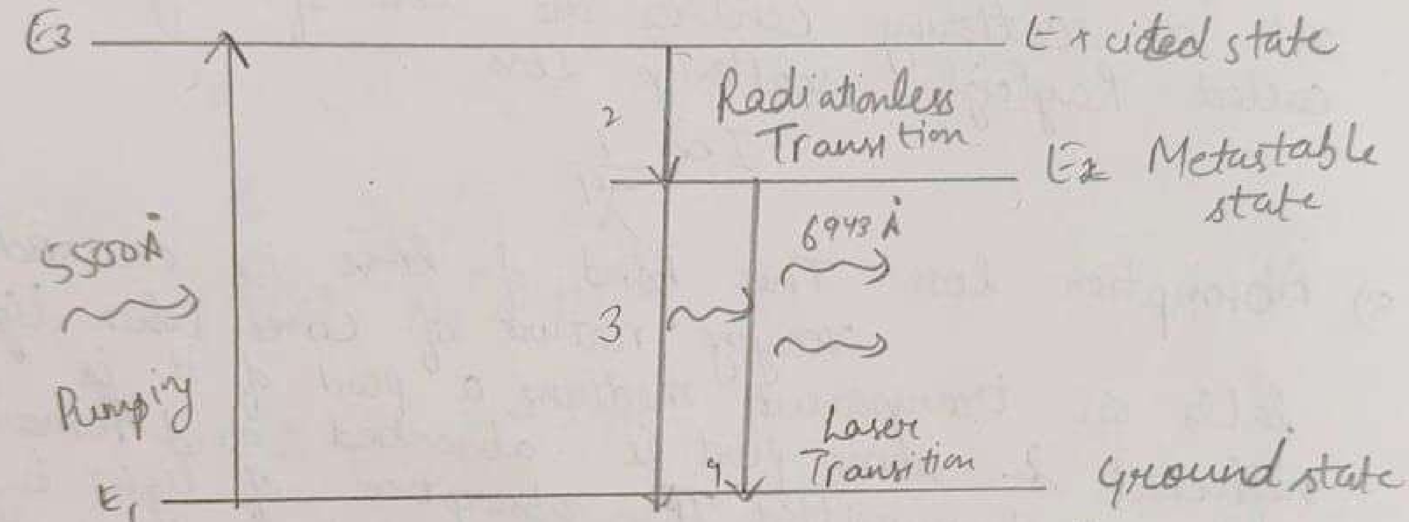
Most of $Cr^{3+}$ are in ground state $E_1$. When a flash of light falls on ruby rod, the 5500 Å radiation photons are absorbed by the $Cr^{3+}$ ions which are pumped to excited state $E_3$. The transition from $E_1$ to $E_3$ is optical pumping. Now the $Cr^{3+}$ ions on the excited ions give a part of their energy to the crystal decay and $E_3$ to $E_2$ is a radiation less transition. Then population inversion is established between metastable and ground state.

A spontaneous photon emitted by $Cr^{3+}$ ion at $E_2$ level initiates the stimulated emission by other $Cr^{3+}$ ions. The wavelength of photon is 6943 Å. Some of the axial photons are repeatedly reflected.

Ruby laser




Energy level diagram




- The output of ruby laser is not continous but occurs in the form of pulses of microsecond duration. That is why it is called pulsated laser

7) What are the various kind of losses a light suffers while propagating through a fibre? Calculate the refractive index of core and clad of fibre where Numerical aperture is 0.40 and $\Delta = 0.020$?

Soln → Attenuation of an optical fibre means loss of optical power in the fibre. It is defined as optical power output obtained from a fibre of given length to the optical power input fed into the fibre

1 Material loss → In fabrication of various types of optical fib[illegible] we use $GeO_2$, $P_2O_5$ etc as a dopant in order to modify its refractive index. These dopant [illegible] observe the wavelength range. Since optical carrier wavelength also falls in the range (800 - 1300[illegible] thus these material causes loss of optical pow[illegible]

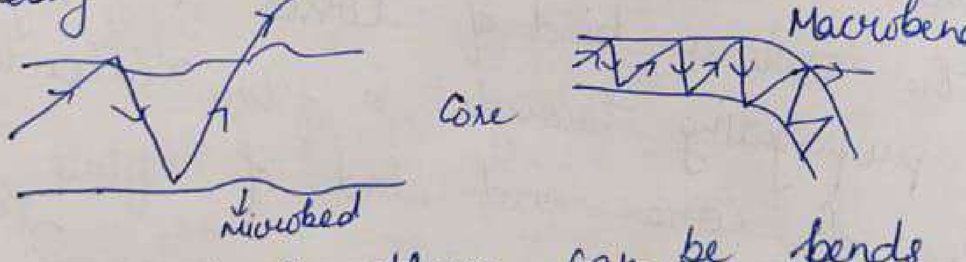
2 Rayleigh scattering loss → During manufacturing of [illegible] large number of inhomogene[illegible] appear in the material due to fluctuation in density, & presence of impurity atom. These inhomogene[illegible] act as scattering centres. The loss of signal is called Rayleigh scattering loss

$$I \propto \frac{1}{\lambda^4}$$

3) Absorption loss → This kind of loss is caused [illegible] varying nature of core. When light falls on transparent medium, a part of it is reflected & some part is absorbed and remaini[illegible] part is transmitted. The absorption of light by [illegible] core medium can take place via three mechanism[illegible]

(i) Ultraviolet absorption
(ii) Infrared absorption
(iii) Ion Resonance

4) Bending Losses →




As shown in fig, there can be bends in the optical fibres instead of the same diameter. Some of the signals may loss depends on the size of the bend whether it is microbend or macrobend

Temperature dependent losses → If the temp. of fibre is less than $-10°C$ then differential thermal expansion b/w polymer coating & glass causes stress, which results in microbend & causes stress.

(b) Numerical

$NA = 0.40$

$\Delta = 0.020$

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

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

$(NA)^2 = n_1^2 - n_2^2$

$2\Delta n_1^2 = n_1^2 - n_2^2$

$(NA)^2 = 2\Delta n_1^2$

$n_1^2 = \frac{(0.40)^2}{2 \times 0.020}$

$n_1^2 = \frac{0.16}{0.04} = 4.0$

$\boxed{n_1 = 2.0}$

$0.16 = 4 - n_2^2$

$n_2^2 = 4 - 0.16$

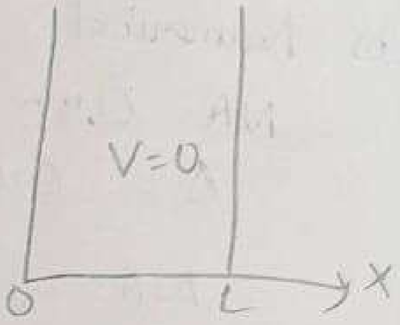
$\boxed{n_2 \approx 1.96}$

8). Solve time independent Schrodinger wave equation for particle in a box and show that energy of particle is quantized.

Soln. Consider a particle moving inside a box along x direction The particle is bouncing back and forth between the walls of the box $L$ is the width of box

$$V = 0 \quad \text{for } 0 < x < L$$
$$V = \infty \quad \text{for } x \leq 0 \text{ and } x \geq L$$

Within the box, Schrodinger wave equation becomes




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

$$\frac{d^2\psi}{dx^2} + k^2\psi = 0$$

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

The general solution is

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

Using boundary conditions

$$\psi = 0 \text{ at } x = 0$$
$$0 = A\sin 0 + B$$
$$B = 0$$
$$\psi = 0 \quad x = L$$
$$\cancel{\sin} \quad 0 = A\sin kL \qquad A \neq 0$$
$$\sin n\pi = \sin kL$$
$$k = \frac{n\pi}{L}$$

$$\psi_n = A\sin\frac{n\pi x}{L} \quad \text{where } n = 1, 2, 3$$

$$E_n = \frac{k^2\hbar^2}{2m}$$

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

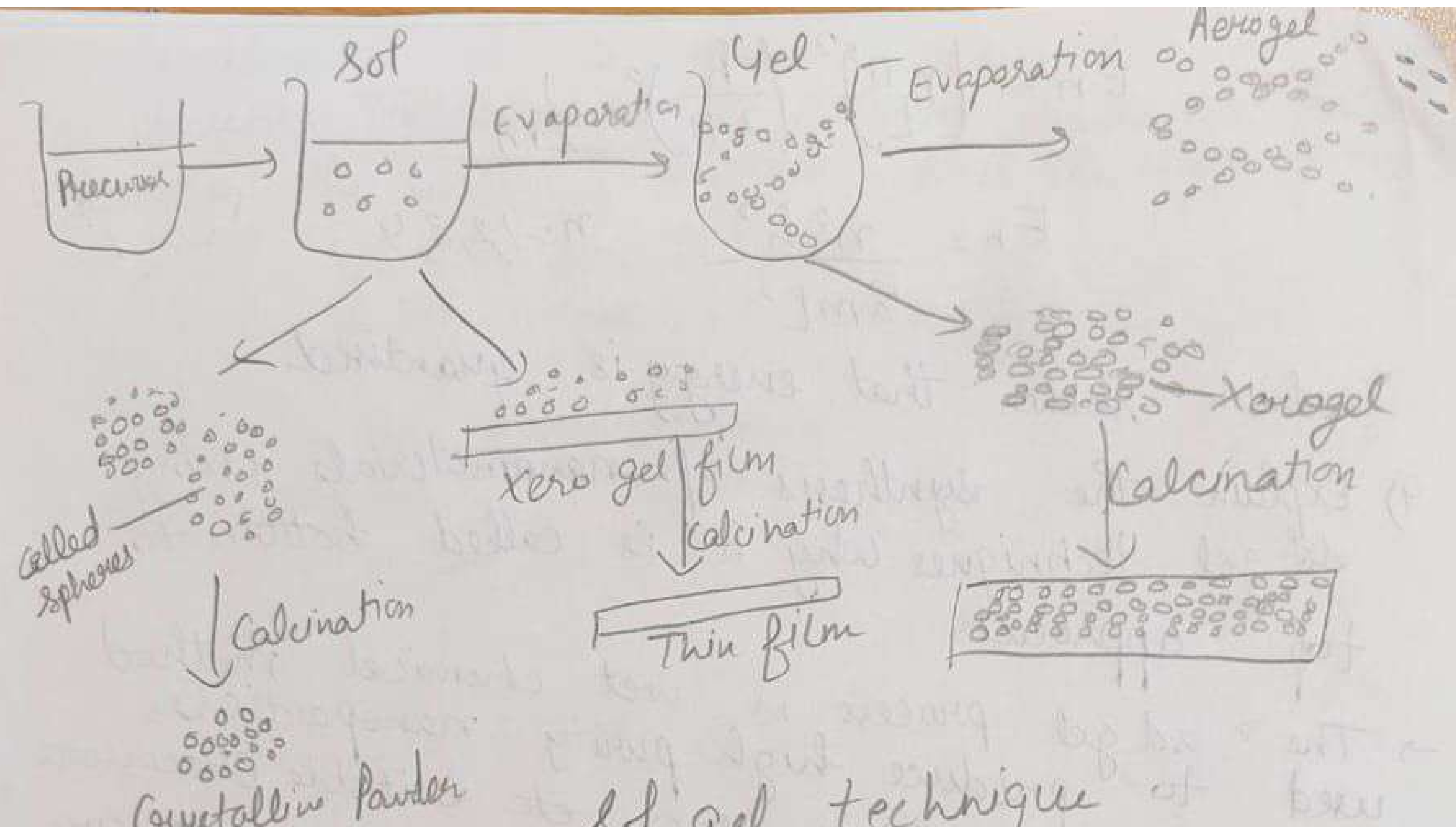
$$E_n = \left(\frac{n\pi}{L}\right)^2 \left(\frac{h}{2\pi}\right)^2 \frac{1}{2m}$$

$$E_n = \frac{n^2 h^2}{8mL^2} \quad n = 1, 2, 3, 4$$

which shows that energy is quantised.

9) Explain the synthesis of nanomaterials using sol-gel techniques. why it is called bottom to top approach

→ The sol gel process is wet chemical method used to produce high purity nanoparticles such as $TiO_2$, $ZnO$, $MgO$ etc. Suitable precursors in the form of nitrates/acetates/carbonates are taken and then dissolved in deionized water. The solutions are kept at suitable temperatures. The starting material is used to produce a colloidal suspension known as sol. Then a gelling like agent PVA is added. This will produce a gel. A thin film coating is made on a substrate such as glass or tin or Ni sheets. depending upon the requirements using sol-gel dip coating or spin coating. To make a uniform coating the pH, temperature and viscosity should be controlled Then the film is annealed at suitable temperature
Instead of forming a thin film coating, crystalline powders are also produced by suitably calcinating the gel




Sol gel technique

Merits ⇒ 1) It is a low-cost method used to produce large quantities

2) It can be done at low temperature

3) This method produces homogeneous substances

* The sol-gel technique is called a bottom up approach because it builds materials starting from atoms or molecules gradually assembling them into more complex structures