B.Tech.

First Semester Examination, 2009-2010

Physics-1 (PHY-101-F)

Note : Attempt five questions in all. First question is compulsory **and** select one question from each Section. First question **contain** ten sub-questions, each sub-question carries equal marks.

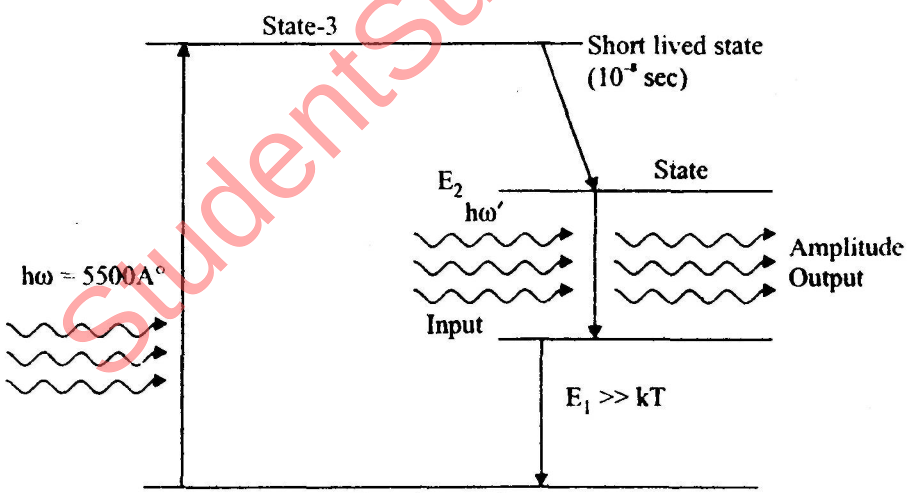
Q. 1. (a) What is optical pumping?

Ans. Optical Pumping: In optical pumping the medium is excited by supplying luminous energy from a light source. The base of the use of optical pumping (achieving population inversion) is used in Ruby Laser. Where the pumping is brought about by three-level scheme, or four level laser scheme

In three level scheme the population is transferred from the ground level E_0 to the level-3 by optical excitation and the inversion is achieved between the level-3 and an intermediate metastablc state-2' of energy value E'_2 from which the laser action occurs. The level-3 with the energy value E_3 , is a short lived excited state with the mean life time order of 10^8 sec.

In general, to have modest requirement on the pump source spectral frequency is desirable that the absorption bands used to optical pumping be broad and have strong absorption over the spectrum of the pump source.

Hence the optical pumping of gases required much high spectral lines, which are normal available only with lasers.



Four level scheme

Q. 1. (b) State Brewster's law.

Ans. Brewster's Law : The tangent of the angle of polarisation is numerically equal to the refraction index of the reflecting medium.

$$\mu = \tan i_P$$

$$i_P = \text{Angle of polarisation}$$

$$\mu = \tan i_P = \frac{\sin i_P}{\cos i_P} = \frac{\sin i_P}{\sin r}$$

$$\frac{\sin i_P}{\sin\left(\frac{\pi}{2} - i_P\right)} = \frac{\sin i_P}{\sin r}$$

$$\frac{\pi}{2} - i_P = r$$

$$i_P = \frac{\pi}{2} + r$$

$$i_P + r + \angle RQS = \pi$$

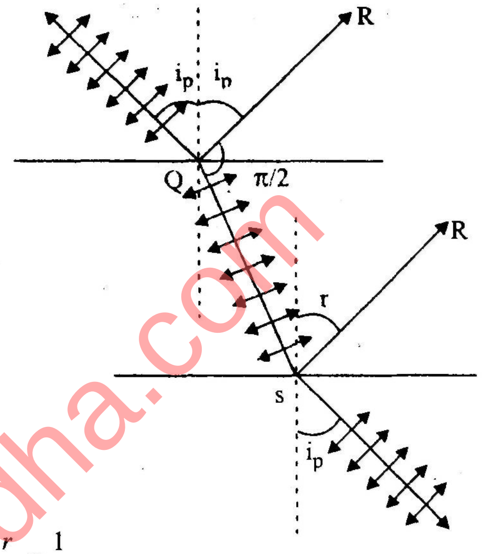
$$\angle RQS = \pi - i_P - r$$

$$= \pi - \frac{\pi}{2} = \frac{\pi}{2}$$

$$\tan r = \frac{\sin r}{\cos r}$$

$$= \frac{\sin r}{\cos\left(\frac{\pi}{2} - i_P\right)} = \frac{\sin r}{\sin i_P} = \frac{1}{\mu}$$

$$\left[\tan r = \frac{1}{\mu}\right]$$



Q. 1. (c) On what **factors the** width **of central** maxima **depends?**

Ans. The width of central maxima depends. According to this criterion, two nearby point objects are just resolved by an optical instrument, when the principal maximum in the diffraction pattern of one falls over the first minimum in the diffraction pattern of other.

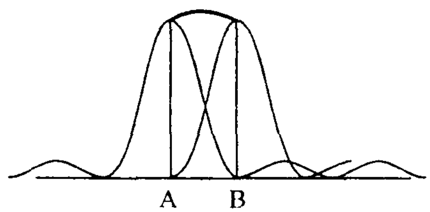
$$I = I_{max} \frac{\sin^2 \alpha}{\alpha^2}$$

$$\alpha = \pi$$

$$I_{min} = 2I_{max} \frac{\sin^2 \pi/2}{(\pi/2)^2}$$

$$I_{mid} = \frac{8}{\pi^2} I_{max}$$

$$I_{mid} = 0.81 I_{max}$$



Lines are just resolved of the intensity at the dip in the middle is 0.81 time the intensity at either of the central maximum.

Q. 1. (d) What do you **mean** by division of wave front?

Ans. Division of Wave Front: In the propagation of a wave the locus of particle vibrating in the same phase is in the wave front of the wave.

For interference two coherent sources are needed. These sources are derived from the same source either by division of wave front or division of amplitude. As such we may have two classes of interference depending on formation of coherent sources.

Example, Young's exp, Fresnal biprjsm.

Q. 1. (e) Can more than one signal be transmitted through optical fibre? Explain.

Ans. **Optical Fibre** : A cable containing one or more fibre is called optical fibre cable. In practical, cladding is usually coated with resin buffer layer of plastic, which is further surrounded by a jacket layer. The dispersion in multimode propagation may also be reduced by considering propagation in graded index fibre. Since the refractive index core in a graded index fibre decreases continuously as one move away from the centre of the core towards the interface, a ray of light entering the fibre is continuously a medium of lower refractive index and hence bands away from the normal, that is, it band towards the axis of the fibre, it is obvious, that light waves with large angle of incidence travel longer path than those with small angles. As we know $r = c/\mu$ higher than refractive index, slower the velocity of light traveling through the fibre. Thus, all the propagation that waves will reach the end point of the fibre at the same time.

Q. 1. (f) What is Meissner effect?

Ans. Meissner Effect: The magnetic properties of superconductor are equally dramatic. A bulk superconductor in a weak magnetic field acts as a perfect diamagnet, with magnetic induction in the interior. In l933, Meissner observed that if a superconductor material is placed in a magnetic field and then cooled to below its critical temperature, it expels all originally present magnetic flux from its interior. This is called 'Meissner effect.'

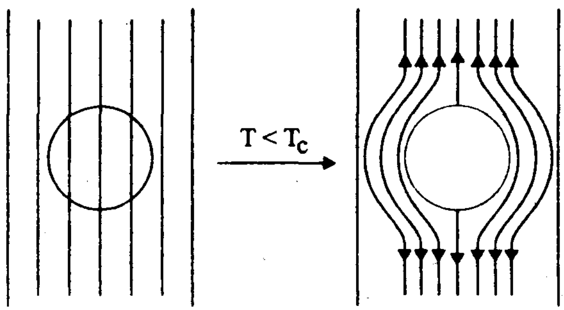
This mean that the magnetic induction B inside the superconductor is always zero, as long as it is in the superconducting state.

$$B = \mu_0 (H + M) = 0$$

$$\chi_m = \frac{M}{H} = -1$$

$$|\chi_m| << 1$$

That a superconductor is an ideal super diamagnetics



Q. 1. (g) What do you understand by inertial frame and non-inertial frame?

Ans. **(i) Inertial Frame** : Thus, the unaccelerated reference frames in uniformation of translation relative to each other are inertial frames.

"Law of physics are identical in all inertial frame."

Such Galilean invanance is known as "Classical" or Newtonian-relativity.

(ii) Non-Inertial Frame : Those frame of reference are those frames in which 'Newton's law of motion do not hold true, all the reference frames according relative to an inertial frame are non-inertial frames.

Q. 1. (h) The mass of moving electron is 11 times its rest mass. Find its Kinetic energy.

Ans.

$$m = \frac{m_0}{\sqrt{v^2/c^2}}$$

According to the variation at mass

$$m = 11m_0 \text{ (say)}$$

$$11m_0 = \frac{m_0}{\sqrt{\frac{1-v^2}{c^2}}}$$

$$11 = \frac{1}{\sqrt{\frac{1-v^2}{c^2}}}$$

$$\sqrt{1-\frac{v^2}{c^2}} = \frac{1}{11}$$

$$1-\frac{v^2}{c^2} = \frac{1}{121}$$

$$\frac{v^2}{c^2} = 1-\frac{1}{121}$$

$$v^2 = c^2\left(1-\frac{1}{121}\right)$$

$$K = (m-m_0)c^2$$

$$= (11m_0 - m_0)c^2$$

$$K = 10m_0c^2$$

$$K = 10\times m_0c^2$$

$$m_0 = 9.11\times 10^{-31}\text{ kg}$$

$$K = 10\times 9.1\times 10^{-31}\times(3\times 10^8)^2$$

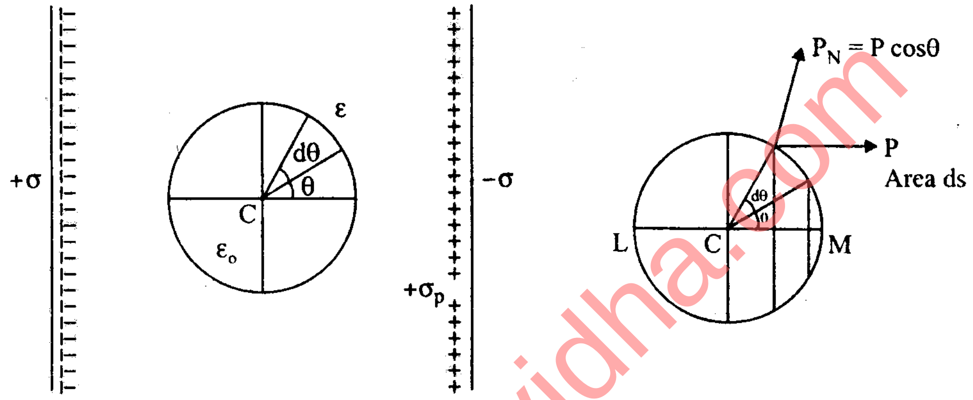
$$K = 91 \times 10^{-31} \times 10^{16} \times 9$$

$$K = 189 \times 10^{-15}$$

$$K = 189 \text{ Fm-J} \quad \textbf{Ans.}$$

Q. 1. (i) Write the Clausius-Mossotti equation.

Ans. Clausius Mossotti Relation : The electric field which is responsible for polarising a molecule of the dielectric is called the molecular field.



$$E_{in} = E_1 + E_2 + E_3 + E_4$$

E_1 = Field between two plates with no dielectric $= \dfrac{\sigma}{\varepsilon_0}$

E_2 = Field at C due to polarized charges on the plane surfaces of the dielectric facing the capacitor plates and is given by $E_2 = \dfrac{\sigma_P}{\varepsilon_0}$

E_3 = Field at C due to polarised charge on the surface of cavity, to be calculated.

E_4 = Field due to permanent dipoles, but no n-polar isotropic dielectric $E_4 = 0$

$$E_3 = P_N = P\cos\theta$$

Surface charge per unit area

ds to provide flux normal to $\quad ds = P\cos\theta\, ds$

$$E = \frac{P\cos\theta\, ds}{4\pi E_0 r^2}$$

Along the axis $\quad = \dfrac{P\cos\theta ds}{4\pi\varepsilon_0 r^2}\cos\theta$

Perpendicular to axis $\quad = \dfrac{P\cos\theta ds}{4\pi\varepsilon_0 r^2}\sin\theta$

$$ds = 2\pi r\sin\theta\, r d\theta$$

$$= 2\pi r^2 \sin\theta d\theta$$

Intensity at C
$$= \frac{P\cos^2\theta}{4\pi\varepsilon_0 r^2} 2\pi r^2 \sin\theta d\theta$$

$$= \frac{P\cos^2\theta}{4\pi\varepsilon_0 r^2} 2\pi r^2 \sin\theta d\theta$$

$$= \frac{P}{2\varepsilon_0}\cos^2\theta\sin\theta d\theta$$

$$E_3 = \frac{P}{2\varepsilon_0}\int_0^\pi \cos^2\theta\sin\theta d\theta = \frac{P}{2\varepsilon_0}\frac{2}{3} = \frac{P}{3\varepsilon_0}$$

$$E_{in} = \frac{\sigma}{\varepsilon_0} - \frac{\sigma_P}{\varepsilon_0} + \frac{P}{3\varepsilon_0} = E + \frac{P}{3\varepsilon_0}$$

$$E_{in} = E + \frac{P}{3\varepsilon_0}$$

$$D = \varepsilon E = \varepsilon_0 E + P$$

$$P = D - \varepsilon_0 E = (\varepsilon - \varepsilon_0)E$$

$$E = \frac{P}{\varepsilon - \varepsilon_0}$$

$$E_{in} = \frac{P}{\varepsilon - \varepsilon_0} + \frac{P}{3\varepsilon_0} = \frac{P}{3\varepsilon_0}\left[\frac{\varepsilon + 2\varepsilon_0}{\varepsilon - \varepsilon_0}\right)$$

$$P = n \propto E_{in}$$

n = Number of molecules per unit nm

α = Molecular polarizability

$$\frac{P}{3\varepsilon_0}\left(\frac{\varepsilon + 2\varepsilon_0}{\varepsilon - \varepsilon_0}\right) = \frac{P}{n\alpha}$$

$$\frac{n\alpha}{3\varepsilon_0} = \frac{\varepsilon - \varepsilon_0}{\varepsilon + 2\varepsilon_0} = \frac{\varepsilon/\varepsilon_0 - 1}{\varepsilon/\varepsilon_0 + 2} = \frac{\varepsilon_r - 1}{\varepsilon_r + 2}$$

$\varepsilon_r \rightarrow$ dielectric constant

$$\frac{n\alpha}{3\varepsilon_0} = \frac{\varepsilon_r - 1}{\varepsilon_r + 2}$$

$$\varepsilon_r = \mu_g^2$$

C-M equation
$$\left(\frac{n\alpha}{3\varepsilon_0} = \frac{\mu_g^2 - 1}{\mu_g^2 + 2}\right)$$ **Ans.**

Q. 1. (j) What is Rayleigh's limit of resolution?

Ans. Rayleigh's Limit of Resolution : Two nearby point objects are just resolved by an optical instrument when the principal maximum in the diffraction pattern of one falls over the first minimum in the diffraction pattern of other.

$$I = I_{max} \frac{\sin^2 \alpha}{\alpha^2}$$

$$\alpha = \pi$$

Thus, midway between two central maximum of figure (b) the intensity can be obtained as

$$I_{mid} = 2I_{max} \frac{\sin^2(\pi/2)}{(\pi/2)^2}$$

$$= \frac{8}{\pi^2} I_{max}$$

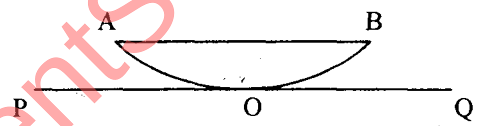
$$= 0.81 I_{max}$$

Thus, the lines are just resolved if the intensity at the dip in the middle is 0.81 times the intensity at either of the central maximum.

Section—(A)

Q. 2. (a) What are Newton's rings? Explain the formation of Newton's'ring in reflected light?

Ans. Newton's **Rings** : When a planoconvex lens and plane glass plate are suitable joined, then air film be created in the gap, this circular types of rings is called Newton's Ring. As the results, an alternate dark and bright circular rings concentric around the point at contact are seen.



Newton's Rings Due to Reflected Light : The formation of Newton's Rings was explain by Young's. According to him, these rings are formed due to interference of light rays reflected from the upper and lower surface of air/film formed between the convex surface of the plano-convex lens and glass plate.

For normal incidence r = 0 for very small angle of wedge

$$\cos(r+\theta) \cong \cos\theta = 1$$

The effective path difference $= 2\mu t + \lambda/2$

$\because$ $\nabla = 2\mu t \cos(r+\theta) + \lambda/2$

At the point of contact $t = 0$

The effective path difference $= \lambda/2$

The central spot of the rings system appears dark for constructive

$$= 2n\lambda_{12} = n\lambda$$

$$2\mu t + \frac{\lambda}{2} = n\lambda$$

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

$$2\mu t = (2n-1)\lambda_{12} \quad n = 1, 2, 3, 4......$$

$$2\mu t = (2n+1)\lambda_{12} \quad n = 0, 1, 2, 3, 4.....$$

For destructive interference

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

$$2\mu t = n\lambda \qquad n = 0, 1, 2, 3......$$

This fringes are due to equal thickness in the shape of constructive rings with point at contact of the film at the centre of the ring.

Q. 2. (b) In a Newton's ring experiment the diameter of the 15th ring was **found to** be 0.59×10^{-2} **m and that of the 5th ring was 0.336×10^{-2} m. If the radius of the piano convex lens is 1 m, calculate the wavelength of light used.**

$$D_{15}^{th} = 0.59 \times 10^{-2} \text{ m}$$

$$D_5{}^{th} = 0.336 \times 10^{-2} \text{ m}$$

$$R = 1\text{m}$$

$$\lambda = 2$$

$$P = D_{15}^{th} - D_5^{th} = 15 - 5 = 10$$

$$P = 10$$

$$l = \frac{D_{n+P}^2 - D_n^2}{4PR} = \frac{(0.59 \times 10^{-2})^2 - (.336 \times 10^{-2})^2}{4 \times 10 \times 1}$$

$$\lambda = \frac{[(0.59 + .336)10^{-4}][0.59 - .33] \times 10^{-4}}{40}$$

$$l = 58.93 \text{ A}° = 5893 \times 10^{-10} \text{ M} \quad \textbf{Ans.}$$

Q. 3. (a) What is a grating? Explain the spectra formed by a plane transmission diffraction grating and also discuss that the intensity of principal maxima decreases with the increase of order.

Ans. Diffraction Grating: A plane diffraction grating is an arrangement consisting of a large no. of close, parallel, straight transparent and equidistant slits, each of equal width a, with neighbouring slits being separated by an opaque regipn of width *b*. The spacing $(a + b)$between adjacent slits is called the diffraction element or grating element.

$$(e + d)\sin\theta = n\lambda$$

Grating element $\qquad (e + d) = \frac{2.54}{N}$

N = No. of rulling lines

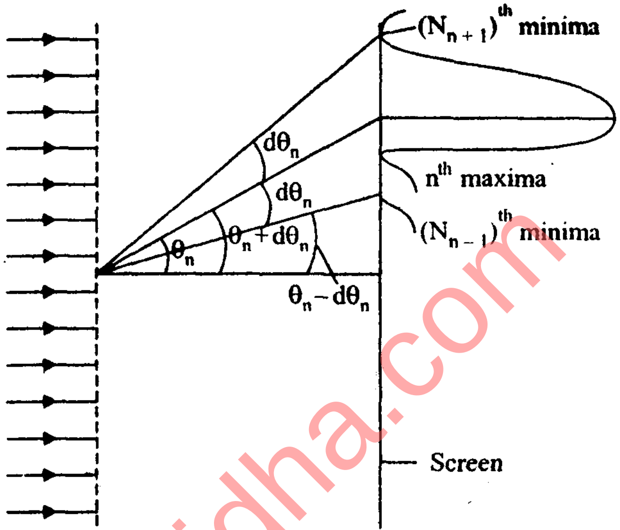
λ = Wavelength of light

θ = Diffraction angle

Width of the Principal Maximum :

The n^{th} order $(a+b)\sin\theta = n\lambda$

$N(a+b)\sin\theta = n\lambda$
$m = (nN + 1)$



$$N(a+b)\sin(\theta_n \pm d\theta_n) = (nN \pm 1)\lambda$$

$$N(a+b)(\sin\theta_n \cos d\theta_n \pm \cos\theta_n \sin d\theta_n) = (nN \pm 1)\lambda$$

As $d\theta_n$ = small $\qquad$ $\sin d\theta_n = d\theta_n$

$$N(a+b)[\sin\theta_n \pm \cos\theta_n d\theta_n] = (nN+1)\lambda$$

$$N(a+b)\sin\theta_n \pm N(a+b)\cos\theta_n d\theta_n = n\lambda N \pm \lambda$$

Multiply both N $\qquad$ $N(a+b)\sin\theta_n = Nn\lambda$

$$N(a+b)\cos\theta_n d\theta_n = \lambda$$

$$d\theta_n = \frac{\lambda}{N(a+b)\cos\theta_n}$$

Angular width (half) of principle maxima

$$d\theta_n = \frac{1}{Nn\cot\theta_n}$$

The width of n^{th} order principle maxima

$$2d\theta_n = \frac{2\lambda}{N(a+b)\cos\theta_n}$$

As N increases width of the maxima decreases.

Q. 3. (b) Derive expressions for dispersive power.

Ans. Dispersive Power: The dispersive power of a grating is defined as the ratio of change of the angle of diffraction with the change in the wavelength of light used.

$$(a+b)\sin\theta = n\lambda \qquad \text{... (i)}$$

$(a+b)$ = Grating element

θ = Angle of diffraction

Differentiate equation (i) $(a+b)\cos\theta \frac{d\theta}{d\lambda} = n$

$$\frac{d\theta}{d\lambda} = \frac{n}{(a+b)(1-\sin^2\theta)^{1/2}}$$

$$\sin\theta = \frac{n\lambda}{(a+b)}$$

$$\frac{d\theta}{d\lambda} = \frac{n}{(a+b)\sqrt{1-\left(\frac{n\lambda}{a+b}\right)^2}}$$

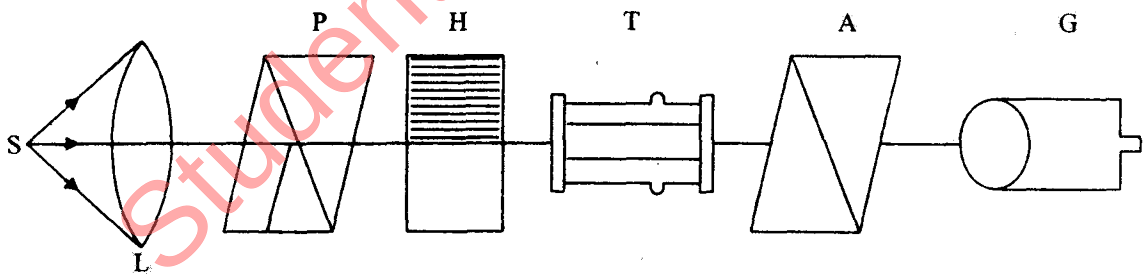
$$\frac{d\theta}{d\lambda} = \frac{1}{\sqrt{\frac{(a+b)^2}{n^2}-\lambda^2}}$$

The angular separation is independent of the width of the spectral lines and the total number of railing on the ruled surface.

Section-(B)

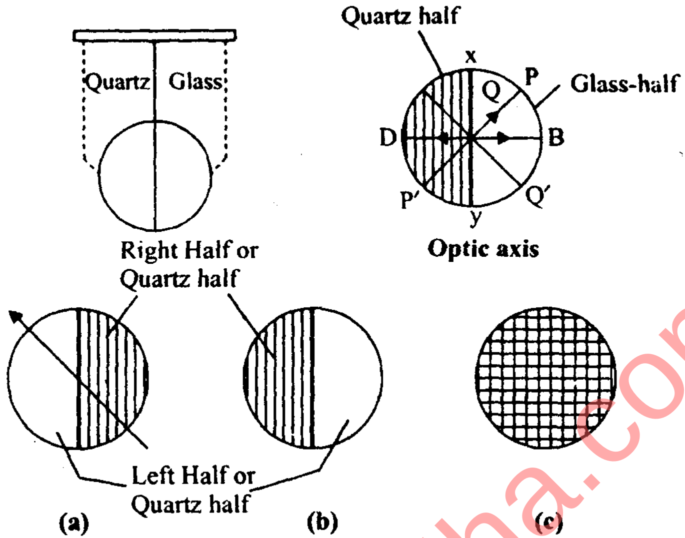
Q. 4. (a) Give **the construction and working of Lorentz half** shade polarimeter. What is its main drawback?

Ans. **Lorentz Half Shade Polarimeter** :

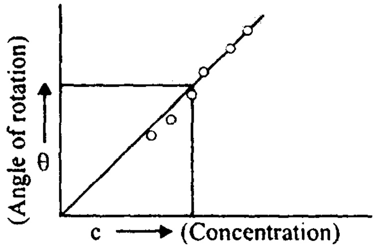


It consist of two separate nicole P (called polariser) and A (called analyser) mounted in brass tubes placed same distance apart and capable of rotation about a common axis. A glass tube T having a larger diameter in middle contains the active solution under examination. Monochromatic light of wavelength lambda from a source S, rendered parallel by a convex lens *L* falls on a nicole prism *P*. After passing through *P* the light become plane polarised. This plane polarised light now passes through a half shade device *H* and then through the solution whose specific rotations is to be determined and filled in the tube *T*. The transmitted light passes through analysing nicole *A* which can be rotated about the direction of propagation of light. The emerging light from nicole *A* is viewed through telescope *G*.

Action of Lorentz Half Shade Plate :



Determination of specific rotation of sugar solution :



$$\alpha_\lambda = \frac{10\theta}{lc}$$

l = Length of tube in cm

c = Concentration of solution.

Q. 4. (b) A polarimeter hibe of 25 cm containing a sugar solution rotates the plane of polarization through 10°. If the specific rotation of sugar is 60°. Calculate the strength of sugar solution.

Ans. $l = 25\,\text{cm}$

$\theta' = 10° = \alpha$

$\theta = 60°$

Strength of sugar solution $S = \frac{10\theta}{lc}$

$$S_1 = \frac{10\theta_1}{l_1 c} \qquad S_2 = \frac{10\theta_2}{l_2 c}$$

θ in rotation, C concentration

$$\alpha = \frac{\theta}{lc}$$

$$\alpha = \theta' = 10°$$

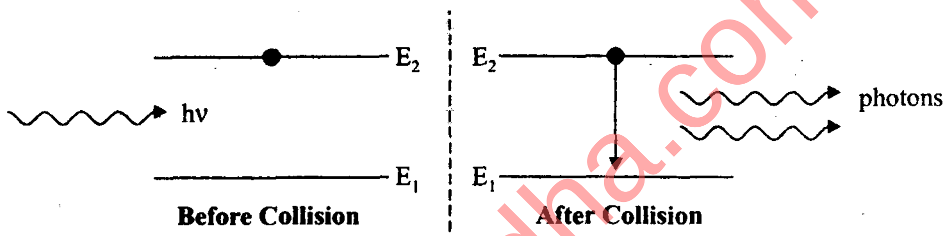
$$c = \frac{\theta}{l.\alpha} = \frac{60°}{10 \times 25}$$

$$= \frac{6 \times 4}{25 \times 4} = 24\%$$

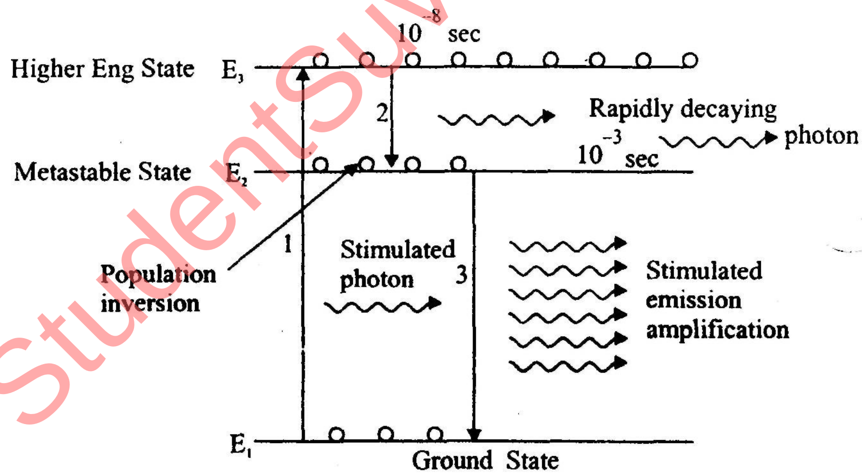
$$= 24\% \quad \textbf{Ans.}$$

Q. 5. Explain the terms stimulated emission of radiation and optical pumping. Explain how lasers can be produced by He-Ne gas. How it is superior to Ruby laser?

Ans. Stimulated Emission of Radiation : Suppose the atom is in excited energy state E_2 and a photon of energy exactly equal to E_2 E_1 is incident on it. The incident photon interact with the atom and then it induces, the atom to come down to ground state E_1. A fresh photon is emitted in the process. Thus. when an atom ejects a photon due to its interaction with a photon incident on it. The process is called stimulated emission.



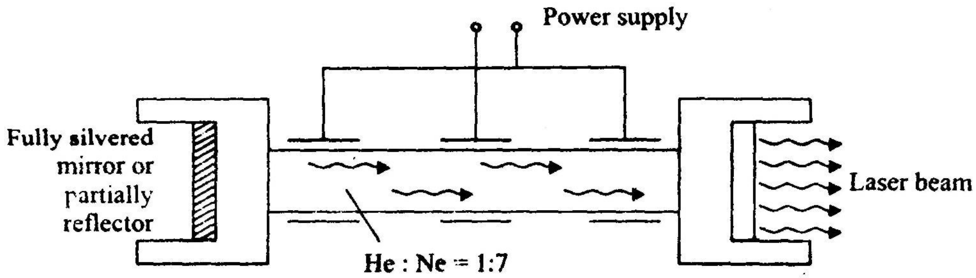
Optical pumping & the process by which atoms are brought from lower energy state to higher energy state and maintained is called optical pumping.



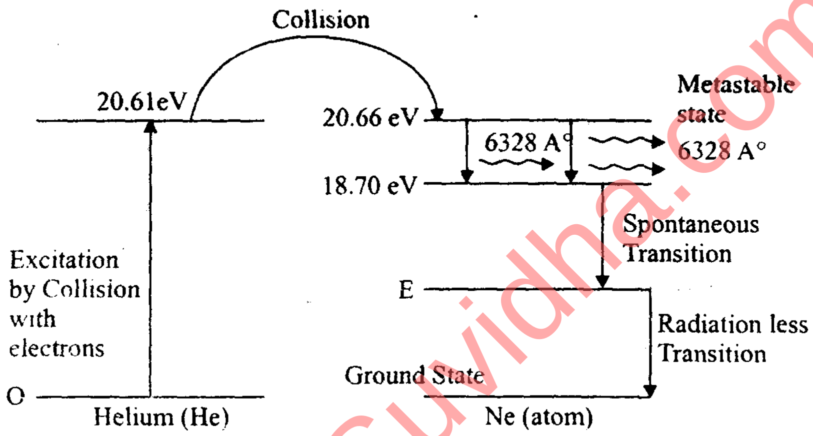
He-Ne Laser : It is a gas laser that are three level energy diagram. The first few energy levels of He- and Ne atoms are shown in figure, when an electric discharge passes through the gas, the electron in the discharge tube collide with the He- atoms and excite or pumped tube them to the metastable state 20.61 eV and 20.60 eV respectively above the G state.

When an excited Ne- atom drop do,wn spontaneously from the metastable state at 20.66 eV to lower energy state at 18.70 eV, at emits a 6328A° photon in the visible region, the photons emitted spontaneously which do not move parallel to the axis of the escape through the side of the tube.

The stimulated transition from 20.66 eV level to 18.70 eV level is the laser transition.



The Ne atoms drop down from the 18.70 eV level to metastable state, through spontaneously emission emitting incoherent light.



A gas laser has several advantages over the solid state lasers or ruby laser.

The light is produced as a continuous beam rather than in ultra-short pulse as in the ruby laser. The remarkable spectral purity of the stimulated radiation, the narrow spectral width of the emission, the large power output per unit band width are the other feature of the gas lasers. Its highly monochromatic and highly directicnal. The gas laser are capable of operating continuously without any need o. cooling. Therefore He-Ne laser is superior than Ruby laser.

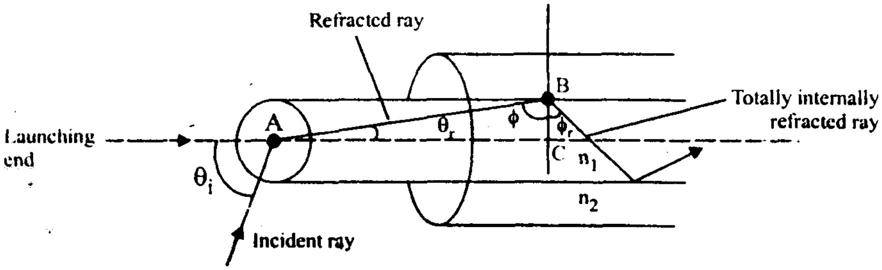
Section—(C)

Q. 6. Give **the principle of optical fibres. How the terms angle of acceptance and numerical** aperture are used **in optical fibres? Mow optical fibres can be used in medical and communication** fields?

Ans. Principle of Optical Fibres : Let us consider light propagate in an optical fibre. The end at which the light enters the fibre is called the launching end. Let us refracting index of the core n_1 and refractive index of cascading be n_2 ($n_2 < n_1$). Let outside medium from which the light is launched into the fibre have a refractive index n_0.

Apply Snell's law $\qquad \dfrac{\sin\theta_1}{\sin\theta_r} = \dfrac{n_1}{n_0}$

.v larger value of θ_i $\qquad \theta = \phi_c$



ΔABC $$\sin\theta_r = \sin(90°-\phi) = \cos\phi$$

$$\sin\theta_i = \sin\theta_r \frac{n_1}{n_0}$$

$$\sin\theta_r = \frac{n_1}{n_0}\cos\phi$$

$\phi = \phi_c$, we get $$\sin\theta_{max} = \frac{n_1}{n_2}\cos\phi_c$$

$$\sin\phi_c = \frac{n_2}{n_1}$$

∵ $$\cos\phi_c = \frac{\sqrt{n_1^2 - n_2^2}}{n_1}$$

$$\sin\theta_{max} = \frac{\sqrt{n_1^2 - n_2^2}}{n_0}$$

If $n_1^2 - n_2^2 \geq n_0^2$, θ_i, total internal reflection will occur

$$n_0 = 1$$

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

$$\theta_m = \sin^{-1}\sqrt{n_1^2 - n_2^2}$$

θ_m angle of acceptance angle of the fibre.

Numerical aperture (NA) $$NA = \sin\theta_m = \sqrt{n_1^2 - n_2^2}$$

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

∵ $$n_1^2 - n_2^2 = (n_1 + n_2)(n_1 - n_2)$$

$$= \frac{(n_1 + n_2)}{2}\frac{(n_1 - n_2)}{n_1} = n_1$$

$$\frac{n_1 + n_2}{2} = n_1, \quad n_1^2 - n_2^2 = 2n_1^2 D$$

Optical fibres can be used in medical and communication field.

Q. 7. (a) Derive **an expression for the energy density of electric field established in a** dielectric medium.

Ans. Energy Density of **Electric Field** : Power density associated with em field at the given point, it may be interpreted **as** the power **flux,** energy **crossing unit area, placed perpendicular to *P*, per** unii time.

The Poynting vector points along the direction of flow of radiation, for time varying field (E x *H)* gives the instant rows vector as Poynting **vector. Let us consider the time varying field as real parts of** complex fields.

$$E_C = E_0 e^{i\omega t} \qquad H_C = H_0 e^{i\omega t}$$

$$E = R_e E_C \qquad H = R_e H_C$$

$$R_e = \text{'Real part of}$$

$$E = R_e[E_{OR} + iE_{OI}(\cos\omega t + i\sin\omega t)]$$

$$E = E_{OR}\cos\omega t - E_{OJ}\sin\omega t$$

$$P = E \times H$$

$$= (E_{OR} \times H_{OR})\cos^2\omega t + (E_{OI} \times H_{OI})\sin^2\omega t$$

$$-(E_{OR} \times H_{OR})\cos\omega t + \sin\omega t - (E_{OI} \times H_{OR})\sin\omega t\cos\omega t$$

$$<P> = \frac{1}{2}[(E_{OR} \times H_{OR}) + (E_{OI} + H_{OI})]$$

$$<P> = \frac{1}{2}R_e[E \times H^x]$$

Average electrostatic energy density

$$<u> = <u_e> + <u_m>$$

$$<u_e> = \left\langle \frac{1}{2}\varepsilon E^2 \right\rangle = \frac{1}{4}\varepsilon E E^x$$

$$<u_m> = \left\langle \frac{1}{2}\varepsilon H^2 \right\rangle = \frac{1}{4}\mu H H^x$$

$$<u> = \frac{\varepsilon|H|^2 + \mu|H|^2}{4}$$

Q. 7. **(b) What are three electric vectors in dielectrics? Name and find relationship between** them.

Ans. Three Electric **Field : (i) Electric Intensity** : The electric field strength at any point in the electric field is defined as the force experienced per unit infinitesimal positive charge q_0.

$$E = \lim_{q_0 \to 0} \frac{F}{q_0}$$

The direction of £ is along the direction of force.

Electric. Polarisation : The polarisation may also be defined as the square density of charge appearing at faces perpendicular to the direction of applied field.

$$P = Q_P$$

Electric Displacement Vector D: The polarisation of a dielectric slab placed between the plates of parallel plate capacitor.

$$E = \frac{\sigma_{free}}{\varepsilon_o} \qquad E' = \frac{\sigma_P}{\varepsilon_o}$$

$$E = E_0 - E' = \frac{\sigma_{free}}{\varepsilon_o} - \frac{\sigma_P}{\varepsilon_o}$$

$$\varepsilon_o E = \sigma_{free} - \sigma_P$$

$$[\sigma_{free} = \varepsilon_o E + \sigma_P]$$

$$\boxed{D = \varepsilon_o E + D}$$

(ii) We have dielectric displacement $D = \varepsilon_o E + P$

$$D = \varepsilon E \quad P = \varepsilon_o X_e E$$

$$\varepsilon E = \varepsilon_o E + \varepsilon_o X_e E$$

$$\varepsilon = \varepsilon_n + \varepsilon_o X_e$$

$$\frac{\varepsilon}{\varepsilon_o} = 1 + X_e$$

$$\frac{\varepsilon}{\varepsilon_o} = \text{Relative permittivity, } \varepsilon_r$$

$$\varepsilon_r = 1 + X_e$$

This is required relation $X_e = 0$

$$\varepsilon_r = 1$$

$$\varepsilon_r = 1 + \frac{P}{\varepsilon_o E}$$

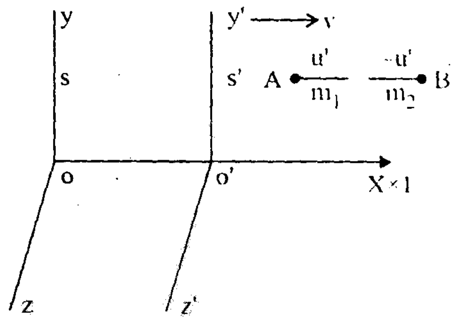
$$P = \varepsilon_o [\varepsilon_r - 1] E \quad \textbf{Ans.}$$

Q. 8. (a) Derive expression of variation of mass with velocity.

Ans. Variation of Mass with Velocity : The mass of **a** body moving at very high speed $(v \cong c)$ relative to an observer is larger than its mass when it is rest by a factor $\frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$

$$m = \frac{m_o}{\sqrt{1-\frac{v^2}{c^2}}}$$

Proof : xyz and $x'y'z'$ are inertial frame.



$$u_1 = \frac{u'+v}{1+\frac{u'v}{c^2}}$$

$$u_2 = -\frac{u'+v}{1-\frac{u'v}{c^2}}$$

u' = Velocity of particle A

$-u'$ = Velocity of particle B.

Principle of Conservation :

Momentum before impact = Moment of after

$$m_1u_1 + m_2u_2 = (m_1+m_2)v$$

$$m_1\left[\frac{u'+v}{1+\frac{u'v}{c^2}}\right] + m_2\left[\frac{-u'+v}{1-\frac{u'v}{c^2}}\right] = (m_1+m_2)v$$

$$\frac{m_1}{m_2} = \frac{1+\frac{u'v}{c^2}}{1-\frac{u'v}{c^2}}$$

$$u_1^2 = \left[\frac{u'+v}{1+\left(\frac{u'v}{c^2}\right)}\right]^2$$

$$1-\frac{u_1^2}{c^2} = 1-\frac{1}{c^2}\left[\frac{u'+v}{1+\left(\frac{u'v}{c^2}\right)}\right]^2$$

$$1-\frac{u_1^2}{c^2} = \frac{\left(1-\frac{v^2}{c^2}\right)\left(1-\frac{u'^2}{c^2}\right)}{\left(1+\frac{u'v}{c^2}\right)^2}$$

$$1+\frac{u'v}{c^2} = \sqrt{\frac{\left(1-\frac{v^2}{c^2}\right)\left(1-\frac{u'^2}{c^2}\right)}{1-\left(\frac{u_1^2}{c^2}\right)}}$$

$$1-\frac{u'v}{c^2}=\sqrt{\frac{\left(1-\frac{v^2}{c^2}\right)\left(1-\frac{u'^2}{c^2}\right)}{1-\frac{u_2^2}{c^2}}}$$

$$\frac{m_1}{m_2}=\sqrt{\frac{\left(1-\frac{u_2^2}{c^2}\right)}{\left(1-\frac{u_1^2}{c^2}\right)}}$$

If the body B is rest or moving with zero velocity.

$$u_2=0$$

$$m_1=\frac{m_o}{\sqrt{1-\frac{u_1^2}{c^2}}}$$

$$v=c$$

$$m\to\infty$$

No material particle c on travel with a velocity equal to or greater than the velocity of light in vacuum.

So it is impossible for a material particle to move faster than the velocity of light in free space.

Q. 8. (b) State and prove the law of equivalence of mass and energy.

Ans. Low of Equivalence of Mass & Energy : (Einstein's Mass-Energy Relation)

According to this the mass is convertible into energy, and energy into mass.

If a force F displaces the particle through a small distance ds, than work done, dw is stored by the particle as K.E dK.

$$dw=dK=Fds$$

According to Newton's law $$F=\frac{dp}{dt}=\frac{d}{dt}(mv)$$

$$F=\frac{mdv}{dt}+v\frac{dm}{dt}$$

$$dK=m\frac{dv}{dt}ds+v\frac{dm}{dt}ds$$

$$dK=mvdv+v^2dm$$

$$\frac{ds}{dt}=v$$

According to
$$m = \frac{m_o}{\sqrt{1-\frac{v^2}{c^2}}} = m_o\left(1-\frac{v^2}{c^2}\right)^{-1/2}$$

$$dm = m_o\left(\frac{-1}{2}\right)\left(1-\frac{v^2}{c^2}\right)^{-3/2}\left(\frac{-2v}{c^2}dv\right)$$

$$m_o = m\left(1-\frac{v^2}{c^2}\right)^{1/2}$$

$$dm = \frac{mvdv}{(c^2-v^2)}$$

$$mvdv = (c^2-v^2)dm$$

$$dK = (c^2-v^2)dm + v^2 dm$$

$$dK = c^2 dm$$

Change in K.E. of the particle be K
$$K = \int dK = \int_{m_o}^{m} c^2 dm = c^2(m-m_o)$$

$$K = c^2(m-m_o)$$

Total energy. E = Rest Energy + K.E. Energy

$$E = m_o c^2 + (m-m_o)c^2$$

$$[E = mc^2]$$

Einstein mass-Energy relation.

Q. 9. (a) Derive the London equations and discuss how its solution explains Meissner effect and flux penetration?

Ans. **London's** Theory **of Superconductivity** : Meissner's effect can very well be explained on the basic of London's classical theory of superconductivity.

Total current density J consists of normal-current density J_u and super current density J_s

$$J = J_n + J_s$$

Below
$$J = J_c$$

$$F = m_e a$$

$$eE = m_e a$$

Let u be the mi. of superconducting electron per unit volume and v be their average velocity then the current density

$$J_s = n_e v$$

$$\frac{dJ_s}{d_t} = n_e\frac{dv}{dt} = nea$$

$$= n\frac{e^2E}{m_e} = \frac{E}{\lambda}$$

$$\lambda = m_e / n_e^2$$

Constant characteristic of the superconductor

$$\nabla \times E = -\frac{\mu \partial H}{\partial t}$$

μ = Permeability of medium

$$\nabla \times E = \lambda \frac{d}{dt}(\nabla \times J) = \lambda \frac{d}{dt}(\nabla \times I_s)$$

$$\lambda(\nabla \times J_s) = -\mu H$$

Maxwell's $[\nabla \times H = J_s]$

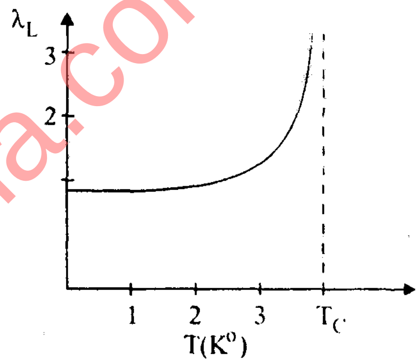
Taking curl both sides $\nabla \times (\nabla \times H) = \text{curl } J_s = \frac{-\mu}{\lambda} H$

$$\text{grad div } H - \nabla^2 H = -\frac{\mu}{\lambda} H$$

$$\nabla^2 H = \frac{H}{\lambda_L^2}$$

$$H = H_0 e^{-x/\lambda_L}$$

H_0 = Magnetic field at the surface



Q. 9. (b) Mention some important properties changes that occur in materials when they **change from normal to super conducting state.**

Ans. Important properties changes that occur in materials when they change from normal to super conducting state :

(i) Critical Temperature : Heavier superconducting ions possess lower transition temperature.

(ii) Thermal Behaviour: Specific heat and thermal conductivity of a substance change abruptly.

(iii) Critical Magnetic Field : $H_{C1} < H < H_{C2}$

(iv) Penetration depth (Screening length).

(v) **Critical Current Density** : It is the density of current carried by a superconductor such that the magnetic field of produce is equal to H_C

(vi) Energy Band Gap : $\Delta \propto T_C$

$$\Delta = 3.52\, kT_C$$

The energy gap is of the order of 10^{-3} eV. Just below T_C the energy gap rises steeply from zero.

$$\Delta T = 3.52kT_C\left[1 - \frac{T}{T_C}\right]^{1/2}$$