EXAMINATION NOV-DEC 2023

B.Tech. FIRST YEAR (All BRANCHES) PH10017 : PHYSICS

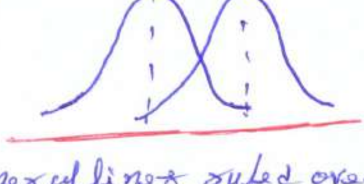
1a.- Define the following terms

(i) Coherence of light and sustained interference (02)

(ii) Rayleigh criterion and resolving power (02)

i) Path diff. remain constant w.r.t. time/space if time Then temoral if same Then spacial coherence. for sustaind interference The two or more Then two coherent wave must be genrated from two distinct, fine, closely spaced sources illuminated by monochromatic source.

ii) Diffraction max of one object/wavelength lies on the min. of other object/wavelength. Resolving power is the ability of optical instrument two see two distinct object/wavelength distinctly.



for telescope $= d/D$

for gratting $= \frac{\lambda}{\Delta\lambda} = nN$ → Number of lines ruled over the gratting/inch. (n: order)

1b.- Identify the number of lines ruled on transmission grating that just resolved the 589.592 nm and 588.995 nm wavelengths. (03)

$\lambda_1 = 589.592,\ \lambda_2 = 588.995;\ \Delta\lambda = \lambda_1 \sim \lambda_2 = 0.597\ nm$

$\lambda = \frac{\lambda_1 + \lambda_2}{2} = 589.294\ nm$

Resolving Power of gratting $= \frac{\lambda}{\Delta\lambda} = nN$

for first order resolution $N = \frac{\lambda}{\Delta\lambda} = \frac{589.294}{.597}$

$= 987$ lines/inch.

$N = 987$ lines/inch

1c.- Drive the expression for maxima and minima of light diffracted by a plane transmission grating also plot the diffraction pattern (05+02)

OR

Discuss Newton's ring experiment. Drive the expression for the refractive index of the medium of air film. **(03+04)**

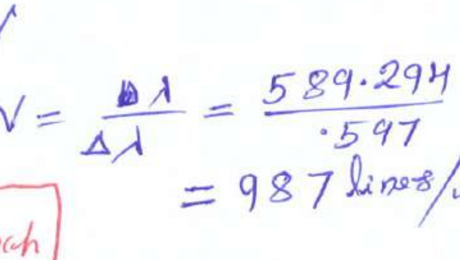
(a) for gratting $I = I_0 \frac{\sin^2\alpha}{\alpha^2} \cdot \frac{\sin^2 N\beta}{\beta^2}$ $\alpha = \frac{\pi}{\lambda} e \sin\theta$ → gratting width.

$\beta = \frac{\pi}{\lambda}(e+d)\sin\theta$ → spacing b/w lines.

Principle maxima

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

Primary minima $N(e+d)\sin\theta = \pm m\lambda$



(b) Explain The physics for the formation of rings by NR experiment and drive $D_n^2 \propto n$ Then drive the expression $\lambda\mu = \frac{D_{n+p}^2 - D_n^2}{4pR}$

$\mu = \frac{(D_{n+p}^2 - D_n^2)_{medium}}{(D_{n+p}^2 - D_n^2)_{air}}$

2a.- Give suitable explanation for the following

(i) Population inversion is a negative temperature state.

(ii) Each optical fiber is a multimode fiber. (02)

(02)

(i) Population inversion means $N_2 > N_1$ ∵ $N \propto e^{-\mathcal{E}/kT}$

$N_1 \propto e^{-\mathcal{E}_1/kT}$ & $N_2 \propto e^{-\mathcal{E}_2/kT} \Rightarrow \boxed{\frac{N_2}{N_1} = e^{-\frac{(\mathcal{E}_2-\mathcal{E}_1)}{kT}} = e^{-\frac{h\nu}{kT}}}$

if $\boxed{T<0} \Rightarrow \frac{N_2}{N_1} > 1 \Rightarrow N_2 > N_1$ i.e. population inversion seems to be a -ive temperature state.

(ii) The value of $V = \frac{2\pi a}{\lambda} NA$; parameter define modes of fiber if $V < 2.408$ it is single mode otherwise multimode. Since $V \propto 1/\lambda$ means each fiber can behave like a multimode fiber for a particular wavelength. More over Electric & magnetic modes will always propogate. i.e. each fiber is a Multimode fiber

2b.- If the cut-off angle for light entering a step index (SIN) fiber ($n_{core} = 1.425$) from air is 8.50^o find the values of Numerical aperture of the fiber (03)

NA. of fiber $n_0 \sin\theta_{max} = \sqrt{n_{core}^2 - n_{cld}^2} = NA$.

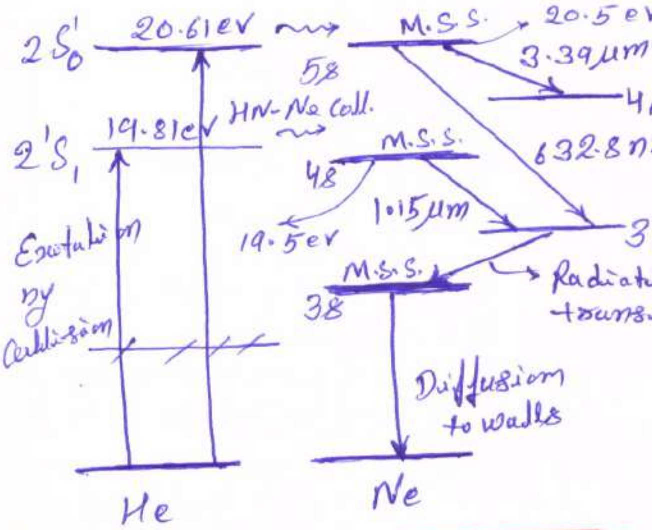
let the fiber is kept in air $NA = \sin\theta_{max}$ $n_0 = 1$

$$\boxed{NA = \sin(8.5) = 0.15}$$

2c.- Draw energy level transitions of He-Ne laser, mark the energy values and write the corresponding lasing wavelength. Also, discuss the significance of He:Ne ratio, tube diameter and length of the optical cavity. (04+03)

OR

Drive the expression for numerical aperture and acceptance angle of optical fiber. On the basis of mode of fiber and type of index, which fiber will you prefer for long distance communication and why? (04+03)



* He-Ne ratio decide the population of 5S & 4S state of. Ne atoms
* tube diameter used to diffuse the $\bar{e}$ trapped in 3S state that in turn ensure the continious lasing.
* Length of the cavity used to resonate a particulare wave length ∵ $\boxed{L \propto 1/\lambda}$

(b) multi mode fibe is prefer for long distance communication → graded index; because the coupling is easy and large also losses are minimum.

3a.- Prove the following

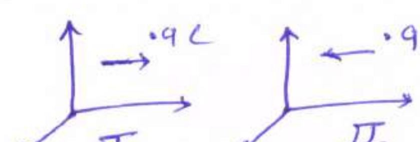
(i) Photon is a mass less particle. (02)

(ii) $x^2 + y^2 + z^2 = c^2t^2$ is invariant under Lorentz transformation. Let the moving frame of reference have the velocity along +x-axis only. (02)

(i) Photon is a particle that have K.E. only P.E. is zero.. means if somehow we bring. The photon at rest it means energy of photon is zero. ∵ $E = mc^2 = h\nu = pc$
$\Rightarrow m = E/c^2$ if $E = 0 \Rightarrow m = 0$ i.e. rest mass of the photon is zero.

(ii) Lorentz transformation $x' = \gamma(x - vt)$; $y' = y$; $z' = z$.
or $x = \gamma(x' + vt')$; $y' = y$; $z' = z$ $t = \gamma(t' + x'v/c^2)$
given $\gamma = 1/\sqrt{1 - v^2/c^2}$
$x^2 + y^2 + z^2 - c^2t^2 = 0$ substituting Lor. Trans. eqn.
$\gamma^2(x' + vt')^2 - c^2\gamma^2(t' + x'v/c^2)^2 = \gamma^2(x' + vt')^2 - \frac{\gamma^2(c^2t' + x'v)^2}{c^2}$
by solving $= x'^2 + y'^2 + z'^2 - c^2t'^2 = 0$

3b.- In laboratory frame of reference, there are two particles each having velocity 0.9c in opposite direction. Find the relative velocity of one with respect to other. (03)



Let us calculate the velocity of II particle w.r.to I
i.e. Velocity of partical $= -0.9c = u$
Velocity of FOR $= 0.9c = v$

by the relativistic addition of velocity.

$$u' = \frac{v + u}{1 + \frac{vu}{c^2}} = \frac{1.8c}{1.81} = 0.995c$$

3c.- State fundamental postulates of special theory of relativity and deduce the relativistic expression of length contraction and time dilation. (02+2.5+2.5)

OR

A particle have rest mass m_o, when it moves with the velocity v its mass appears to be m. Drive the relativistic relation between m and m_o. (07)

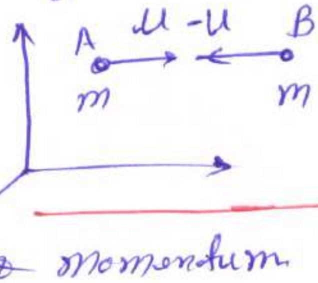
(a) Postulate of SOR. (i) Velocity of ligth is universal constant
(ii) Law of physics holds good in all inertial FOR
(iii) Time is also variable.

time dilation $t < t_o$ or $t = \gamma t_o$.

Length Contraction $L < L_o$
$L = \gamma L_o$; L_o actual length observed by observer w.r.to the moving observer / w.r.to the moving FOR

$\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$ to actual time w.r. to moving FOR

(b) Drive $m = \frac{m_o}{\sqrt{1 - v^2/c^2}}$



by Considering to masses approaching each other with equal velocity
use theory of conservation of Energy & momentum

4a.- Discuss the following

(i) Any one application of Heisenberg uncertainty principle. (02)

(ii) Properties of well behaved eigenfunction. (02)

(i) use $\Delta x \Delta p \geq \hbar/2$ to show that e^- cannot exist inside the nucleus - if it exist $\Delta x \approx 1 Å$ $\Delta p \approx \frac{\hbar}{2} \times 10^{10} \Rightarrow \boxed{\Delta E = \frac{\Delta p^2}{2m} = 31.5\ eV}$

31.5 eV energy is very large as compared to the energy of β particle.

ii) Well behaved eigenfunction ① Single valued and continious ② first order derivative exist and continious; ③ Normalized within the given boundary. $\psi(r,t) = A e^{i(\vec{k}\cdot\vec{r} - \omega t)}$ $\boxed{\int_{-\infty}^{+\infty} |\psi|^2 d\tau = 1}$

4b.- If the peak power of a star occurs at the middle of visible spectra, what is the approximate surface temperature of the star? (03)

Edges of visible spectra is 400nm & 700nm, wavelength at the middle is $= \frac{400+700}{2} = 550\,nm$.

Wein's Displacement law $\boxed{\lambda T = 3\ mmK}$

$$T = \frac{3 \times 10^{-3}}{550 \times 10^{-9}} = \frac{300}{55} \times 10^3 = \frac{60}{11} \times 10^3$$

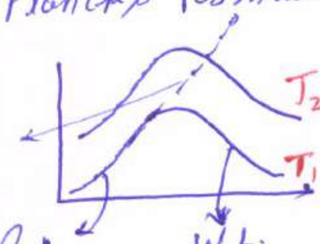
$$\boxed{T = 5454\ K}$$

4c.- What do you understand by ultraviolet catastrophe? Discuss Planck's formula for explaining black body radiation spectra. (02+05)

OR

What is Compton effect? Why the effect is significant only for microscopic particles? Drive the expression for Compton shift and angle of recoil. (01+01+03+02)

① Planck's formula $\boxed{U(\nu,T) = \frac{8\pi h\nu}{c^3} \frac{1}{e^{\frac{h\nu}{kT}} - 1}} = \frac{8\pi hc}{\lambda^5} \frac{1}{e^{\frac{hc}{\lambda kT}} - 1}$

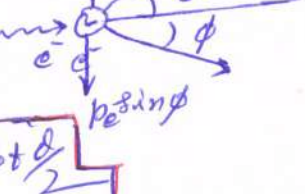


Rayleigh law $U(\nu,T) = \frac{8\pi\nu^3}{c^3} \cdot kT \Rightarrow \nu \to \infty, U \to \infty$ Ultraviolet Catastrophy

Wein's law $U(\nu,T) = \frac{8\pi h\nu^2}{c^3} \cdot e^{-\frac{h\nu}{kT}}$

② Shift in wavelength by the scattering from a microscopic particle.

$\boxed{\Delta\lambda = \frac{h}{m_e c}(1 - \cos\theta) = 4\pi\lambda_c \sin^2\frac{\theta}{2}}$; θ = scattering angle. $\lambda_c = \frac{\hbar}{m_e c} = 3.86 \times 10^{-13} m$



$\Rightarrow \boxed{\sin\phi = \frac{p'}{p_e} \sin\theta}$ or $\boxed{\tan\phi\left(1 + \frac{h\nu}{m_e c^2}\right) = \cot\frac{\theta}{2}}$

5a.- For a thermodynamic system define the following terms

(i) State, Equilibrium, Process and Properties. (02)

(ii) Heat and Work (02)

(i) State characterized by the definite values for each Thermodynamic properties.
Equilibrium means no internal change or no unbalance force, no reactive gases no change in temperature.
When a system undergoes a change of state due to interaction with surrounding, it termed as system is going to a Thermodynamic process. The change in the Thermodynamic parameters like temp., press, volume etc. define it's properties.

(ii) Heat & work → Heat is the mode of energy b/w transfer b/w the system and surroundings only if $\Delta T \neq 0$. While work is the mode of energy transfer b/w system & surrounding if if $\Delta T = 0$.

5b.- A closed system, consisting of 2 kg substance, undergoes from stage 1 to 2 by the work done of -2200J. The specific internal energy (u), velocity (v) and elevation above sea level (z) of the two states are $u_1 = 16\text{kJ/kg}$, $u_2 = 20\text{kJ/kg}$, $v_1 = 120\text{m/s}$, $v_2 = 215\text{m/s}$, $z_1 = 1500\text{m}$ $z_2 = 300\text{m}$, respectively. Determine the total energy of system, magnitude and direction of heat transfer during the process. (03)

given

State-1: $m = 2\ kg$, $u_1 = 16\ kJ/kg$, $V_1 = 120\ m/s$, $z_1 = 1500\ m$

$W_{1-2} = -2200\ J$ →

State-2: $m = 2\ kg$, $u_2 = 20\ kJ\cdot kg^{-1}$, $V_2 = 215\ m/s$, $z_2 = 300\ m$

$$E_1 = m[u_1 + \tfrac{1}{2}V_1^2 + gz_1] = 75.83\ kJ$$

$$E_2 = m[u_2 + \tfrac{1}{2}V_2^2 + gz_2] = 92.11\ kJ$$

$$Q_{1\text{-}2} = W_{1\text{-}2} + (E_2 - E_1) = 14.08\ kJ$$

5c.- With the help of one example of each discuss the first law of thermodynamics for (i) cyclic process of closed system and (ii) study state flow of open system. (3.5+3.5)

OR

Explain second law of thermodynamics for cyclic process. Discuss the thermal efficiency of direct and reversible heat engine. (02+2.5+2.5)

(a) When a closed system undergoes a cyclic process, The net work done by the system is directly proportional to the net heat transfer to the system.

$$\sum_{i=1}^{n} Q_i = \sum_{i=1}^{n} W_i$$

for non cyclic process $\sum_{i=1}^{n} Q_i - \sum_{i=1}^{n} W_i = dE \Rightarrow \delta Q - \delta W = dE$

(i) for open system conservation of energy & mass

(b) it is impossible to construct a device which works continiously in a cyclic process, absorbs a finite quantity of energy as heat from a Thermal reservior and converts all of it's into useful work without the aid of an external energy. Thermal efficiency $\eta = 1 - \frac{Q_2}{Q_1}$