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Assignment-1

Q1 What would be the maximum thickness of thin film up to which one can see the interference pattern?

Ans) Condition for interference is that the path difference (Δ) between superimposing waves should be less than coherence length (l_{coh}) $= \dfrac{\lambda^2}{\Delta\lambda}$

$\Delta = 2\mu t \cos r - \lambda/2$.

$2\mu t \cos r - \dfrac{\lambda}{2} < \dfrac{\lambda^2}{\Delta\lambda}$ $\Rightarrow$ $2\mu t \cos r < \lambda\left(\dfrac{\lambda}{\Delta\lambda} + \dfrac{1}{2}\right)$

for normal incidence $\cos r = 1$ $(r = 0°)$ & $\lambda/\Delta\lambda >> \frac{1}{2}$

$\therefore$ $2\mu t < \lambda\left(\dfrac{\lambda}{\Delta\lambda} + \dfrac{1}{2}\right)$ $\boxed{t < \dfrac{\lambda^2}{2\mu\Delta\lambda}}$

Q2 What do you mean by the fringes of equal thickness & fringes of equal inclination?

Ans 2. Fringes of equal thickness are formed when path difference arises due to variation in thickness 't' of film. Thus each maxima & minima is a locus of constant film thickness.

Fringes of equal inclination are formed when rays which causes interference incidents at same angle & ~~cause~~ ~~interference~~ on the film and form a ~~film~~ fringe.

Q3. Derive expression for calculating the carrier concentration for intrinsic and the extrinsic semiconductor, also discuss the mobility and conductivity of intrinsic semicond.

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Ans 3 $n_e = \int_{E_c}^{\infty} D(E)\, dE\, f(E)$ $\qquad D_E = \frac{4\pi}{h^3}(2m)^{3/2}(E)^{1/2}$.

$$n_e = \int_{E_c}^{\infty} \frac{4\pi}{h^3}(2m)^{3/2}(E-E_c)^{1/2} \times \left(\frac{1}{e^{\frac{(E-E_f)}{KT}}+1}\right) dE.$$

$$= \frac{4\pi}{h^3}(2m)^{3/2} \int_{E_c}^{\infty} (E-E_c)^{1/2} \frac{1}{\left(e^{\frac{E-E_f}{KT}}+1\right)} dE. \qquad \left(\frac{E-E_f}{kT} > 1\right)$$

$$= \frac{4\pi}{h^3}(2m)^{3/2} \int_{E_c}^{\infty} (E-E_c)^{1/2}\, e^{\frac{E_f-E}{KT}}\, dE.$$

$$= \frac{4\pi}{h^3}(2m)^{3/2} \int_{E_c}^{\infty} (E-E_c)^{1/2} * e^{-\frac{(E_c-E+E_c-E_f)}{KT}}\, dE = \frac{4\pi}{h^3}(2m)^{3/2} e^{\frac{E_f-E_c}{KT}} \int_{E_c}^{\infty} (E-E_c)^{1/2} e^{-\frac{(E-E_c)}{KT}}\, dE$$

$$= \frac{4\pi}{h^3}(2m)^{3/2} e^{\frac{-\Delta E}{KT}} \int_{E_c}^{\infty} (KT)^{3/2}\sqrt{x}\, e^{-x}\, dx.$$

$$= \frac{4\pi}{h^3}(2m)^{3/2} e^{\frac{-\Delta E}{2KT}} (KT)^{3/2} \left(\frac{\sqrt{\pi}}{2}\right)$$

$$n_e = AT^{3/2} e^{\frac{-\Delta E}{2KT}}$$

For intrinsic $n_e n_h = n_i^2$ $\qquad n_e = n_h = n_i$

Mobility of is ratio of drift velocity to electric field.

In intrinsic semiconductor it is of order of $10^{-1}\ m^2/V.s$

Conductivity is of order 10^{4} to 10^{-4} s/m

$\sigma = n_e e \mu_e + n_h e \mu_h = e(n_e \mu_e + n_h \mu_h)$ $\qquad (n_e = n_h = n_i)$

$\therefore \sigma = e n_i (\mu_e + \mu_h)$.

Ques 4. Show that fermi energy lies between the valance band and conduction band in intrinsic semiconductor.

Ans 4. $f(E) = \frac{1}{\left(e^{\frac{E-E_f}{KT}}+1\right)}$ $\qquad f(E_v) + f(E_f) = 1$

$$\frac{1}{e^{\frac{E_c-E_f}{KT}}+1} = 1 - \frac{1}{e^{\frac{E_v-E_f}{KT}}+1} = \frac{e^{\frac{E_v-E_f}{KT}}}{e^{\frac{E_v-E_f}{KT}}+1} \qquad \left(e^{\frac{E_c-E_f}{KT}} >> 1\right) \quad \left(e^{\frac{E_v-E_f}{KT}} << 1\right)$$

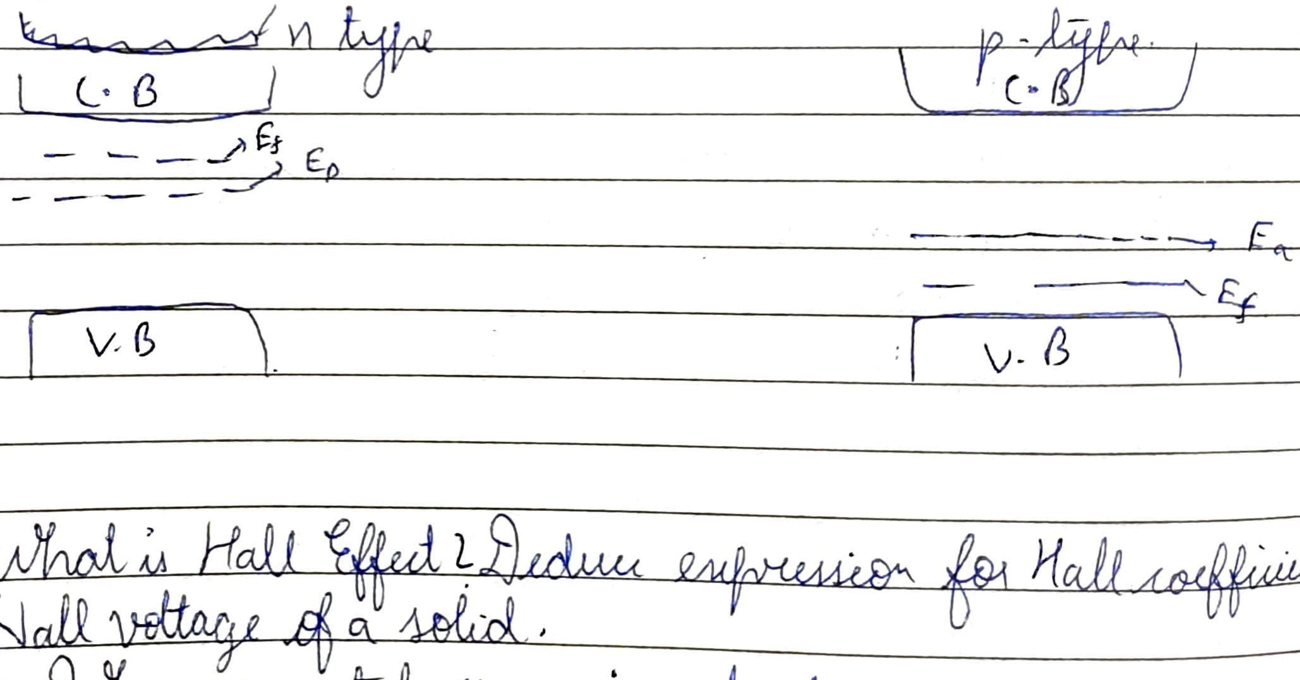
$$\frac{1}{e^{\frac{E_c-E_f}{kT}}} = \frac{e^{\frac{E_v-E_f}{kT}}}{1}$$

$$\therefore \frac{E_c-E_f}{\cancel{kT}} = \frac{E_f-E_v}{\cancel{kT}}$$

$$\boxed{E_f = \frac{E_c+E_v}{2}}$$

Q5. Explain with the help of diagram, the effect of doping on Fermi level of semiconductor.

Ans5. When a semiconductor is doped its conduction increases. When it is doped ~~with~~ to form n-type ~~atoms~~, fermi energy comes between donar level and conduction band & when it is doped to form p-type, fermi energy comes between ~~the~~ acceptor level and valance band. The forbidden gap decreases & conduction increases.



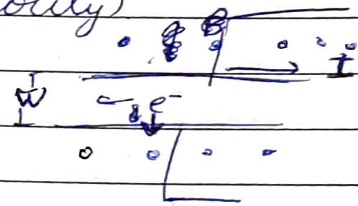
Q6. What is Hall Effect? Deduce expression for Hall coefficient & Hall voltage of a solid.

Ans6 When a metal or semiconductor carrying a current i is placed in transverse magnetic field B, a potential difference V_H is produced in a direction normal to both current i & magnetic field. This is known as Hall effect.

F_E = force of e^- due to electric field. F

$F_E = eE_H$

$F_B = eBV_d$ (V_d = drift velocity)



$F_E = F_B$

$eE_H = eV_dB$ $\left(E_H = \frac{V_H}{w} \text{ \& } V_d = \frac{J}{ne}\right)$

$\frac{V_H}{w} = \frac{BJ}{ne}$

$V_H = \frac{wBJ}{ne} = \frac{wBi}{neA} = \frac{Bi\cancel{l}}{ned \cdot \cancel{l}} = \frac{Bi}{ned}$.

Hall coefficient = R_H = Hall field per unit current density per unit magnetic induction.

$R_H = \frac{E_H}{J_x B} = \frac{V_H}{wJ_xB} = \frac{BJ_x}{neJ_xB} = \frac{1}{ne}$.

$V_H = R_H \frac{Bi}{d}$.

Q7 What is significance of wave function? Drive time-independent Schrodinger wave equation. What happens if the particle is free?

Ans 7. Wave function (ψ) has no physical siginficance. It is a complex quantity which relates coordinates i.e position & time. But product of wave function (ψ) & its complex conjugate (ψ^*) has physical significance i.e it tells probability density of locating the particle at a place.

$y = Ae^{i(kx-\omega t)} = Ae^{i\left(\frac{Px - Et}{\hbar}\right)}$

$\frac{dy}{dt} = \left(\frac{-Ei}{\hbar}\right)\psi$ $\qquad \frac{\partial y}{\partial x} = \frac{Pi}{\hbar}\psi$.

$\frac{\partial^2\psi}{\partial t^2} = \left(\frac{-Ei}{\hbar}\right)^2\psi$ $\qquad \frac{\partial^2 \psi}{\partial x^2} = \left(\frac{Pi}{\hbar}\right)^2\psi$ $\qquad \psi p^2 = -\hbar^2 \frac{\partial^2\psi}{\partial x^2}$.

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Total Energ E. = K.E + P.E

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

$$E\psi = \frac{p^2\psi}{2m} + V\psi.$$

$$\boxed{E\psi = -\frac{\hbar^2}{2m}\frac{\partial^2\psi}{\partial x} + V\psi}$$

For a free particle potential energy becomes constant V_0

$$E\psi = -\frac{\hbar^2}{2m}\frac{\partial^2\psi}{\partial x} + V_0\psi$$

Q8 Write the postulate of Quantum Mechanics. What is the tunnel effect? Explain alpha decay with the help of tunnel effect.

Ans. Fundamental postulates of quantum mechanics are:-

1. (a) The state of quantum mechanical system is described by a wave function $\psi(x,t)$. All constant multiple of ψ (given ψ) describes same state.

   (b) The state ψ of system can be built up by applying the principle of superposition.

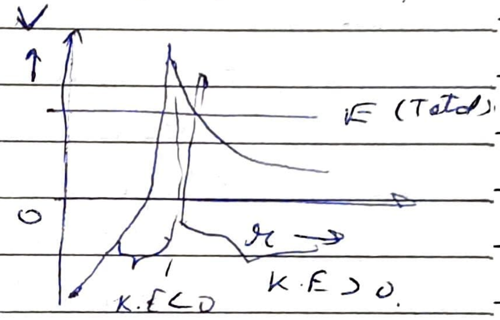
$$\psi = \sum_n C_n\psi_n \qquad (C_n = \text{complex no.})$$

2. Each dynamical variable $A(x,p)$ is represented by a linear operator in quantum mechanics.
3. If large no. of measurements of dynamical variable A are made on a system the results of measurement are distributed over an average value know as expectation value. $\langle A\rangle = \dfrac{\int \psi^* \hat{A}\psi\, dt}{\int \psi\psi^* dt}$.
4. Only possible results of measurements of dynamic variable A are the eign values of operator $\hat{A}$ satisfying the equantion :-

$$\hat{A}u_n = a_n u_n.$$

→ Classically, a particle striking a hard wall has no chance of leaking but quantum particle has possibility of getting partly reflected from the boundary of potential well & partly penetrating through barrier. This penetration by quantum particle is called tunnel effect.

→ For classical mechanics, alpha particle does not have enough energy to over come the barrier & come out. In forbidden region the K.E < 0 according to classical mechanics which is not possible. But quantum mechanically it is possible. The wave nature associated with it overlaps the energy gap. Thus alpha particle comes out.



Q9. Discuss the classical & quantum aspects of simple harmonic oscillator.

Ans 9 → Classically → in simple harmonic oscillator, can max amplitude is fixed $A = \sqrt{2E/k}$ & frequency $= (k/m)^{1/2}/2\pi$. K.E can not be negative & $E = K.E + P.E$. At some temp T avg. P.E & K.E are $\frac{K_B T}{2}$.

Quantum mechanically → amplitude can not have any value so energy can & thus is ~~continuous~~ discrete. If displacement $x > a$. K.E is ~~+ve~~ −ve probability of finding particle is finite in negative K.E

Schrodinger equ^n :-

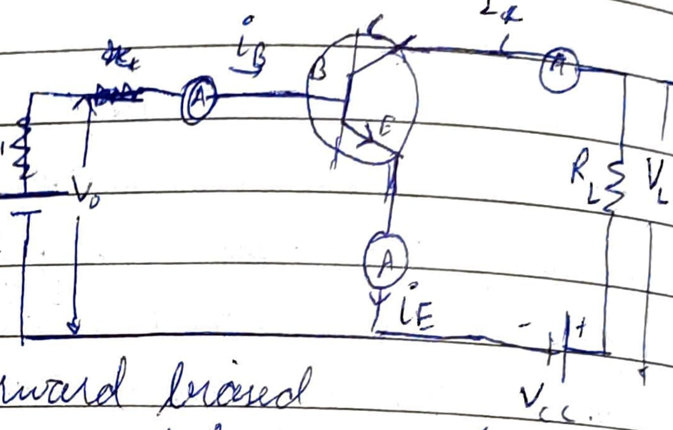
$$-\frac{\hbar^2}{2m}\frac{\partial^2\psi}{\partial x^2} + V\psi = E\psi \qquad V = \frac{1}{2}kx^2.$$

Solving we get.

$$E = \left(n + \frac{1}{2}\right)h\nu \qquad \left(\text{where } \nu = \frac{1}{2\pi}\sqrt{\frac{k}{m}}\right)$$

Q10 Explain the transistor action of NPN transistor, when it biased to operate in active region. Derive relation between transistor parameters α, β & γ.

Ans10 In active region transistor works as amplifier. It has 3 parts, base, emmitter & colletor. Here it has common emmitter.



Base-emmitter junction is forward biased & colletor-base junction is reversed biased. There is a load resistor R_L. Current i_B flows through base

$$\alpha = \frac{I_C}{I_E} \qquad \beta = \frac{I_C}{I_B} \qquad \gamma = \frac{I_E}{I_B}$$

$$I_E = I_C + I_B$$

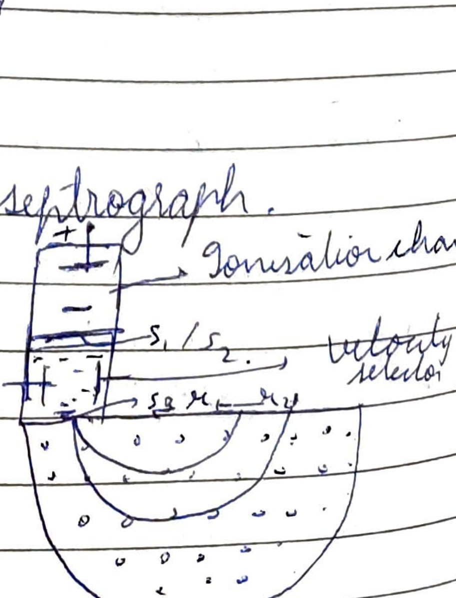
$$\frac{I_E}{I_B} = \frac{I_C}{I_B} + 1 \quad \Rightarrow \quad \boxed{\gamma = 1+\beta}$$

$$1 = \frac{I_C}{I_E} + \frac{I_B}{I_E} \qquad 1 = \alpha + \frac{1}{\gamma} \qquad 1-\alpha = \frac{1}{\gamma} \qquad \boxed{\gamma = \frac{1}{1-\alpha}}$$

$$\frac{1}{1-\alpha} = 1+\beta. \qquad \beta = \frac{1-1+\alpha}{1-\alpha} = \boxed{\frac{\alpha}{1+\alpha} = \beta}$$

Q11 Discuss working of Bainbridge mass septrograph.

Ans11. Element or isotope, whose mass needs to be determined is put into ionisation chamber where it turns into +ve ions of varying velocity. These are then put in velocity selector, where mutually perpendicular electric



& magnetic fields are applied.

$F = qE$ & $F = qvB$

$qvB = qE$

$v = \frac{E}{B}$.

here only those ion having velocity (E/B) pass through slit S_3 to vacuum chamber. Here another magnetic field B' is applied perpendicular to it. The ion comes out forming a semi circle & dark lines like spectra.

$\cancel{mvr = qvB'}$ $\frac{mv^2}{r} = B'qv$ $m = \frac{B'qR}{v}$.

$\cancel{m = \frac{qB'}{r}}$.

putting $v = E/B$ $\boxed{m = \frac{BB'qR}{E}}$

Q12. Describe Einstein's coefficients and significance of relation between them.

Ans12. Let there be 2 energy states E_1 & E_2.

→ Probable rate of absorption transition $1 \to 2$ depends on properties of states. & is proportional to energy density $u(\nu)$ of the radiation of frequency ν incident on atom: $P_{12} = B_{12}\, u(\nu)$ where B_{12} is Einstein's coefficient of absorption of radiation.

→ Probability of spontaneous emission $2 \to 1$ is determined only by properties of states. A_{21} : einstein's coefficient of spontaneous emission.

→ Probability of stimulated emission transition $2 \to 1$ is $\propto$ ~~energy~~ energy density $u(\nu)$ of stimulating radiation. $B_{21}\, u(\nu)$

B_{21} → einstein's coefficient of stimulated emission of radiation

Total probability $P_{21} = A_{21} + B_{21}\, u(\nu)$

→ Assume N_1 atoms in lower state & N_2 in higher state in thermal equilibrium.

$$\cancel{E_1 = E_2} \qquad N_1 P_{12} = N_2 P_{21}$$

$$N_1 B_{12} u(\nu) = N_2 [A_{21} + u(\nu) B_{21}]$$

$$u(\nu)[N_1 B_{12} - N_2 B_{21}] = N_2 A_{21}$$

$$u(\nu) = \frac{N_2 A_{21}}{[N_1 B_{12} - N_2 B_{21}]}$$

Thermodynamically $B_{12} = B_{21}$

$$u(\nu) = \frac{A_{21}}{B_{21}} \times \left(\frac{1}{\frac{N_1}{N_2} - 1}\right) \Rightarrow \frac{A_{21}}{B_{21}} \times \left(\frac{1}{e^{\frac{h\nu}{KT}} - 1}\right)$$

According to planck's radiation law $u(\nu) = \frac{8\pi h\nu^3}{c^3} \times \left(\frac{1}{e^{(\frac{h\nu}{KT})} - 1}\right)$

$$\therefore \frac{A_{21}}{B_{21}} = \frac{8\pi h\nu^3}{c^3}$$

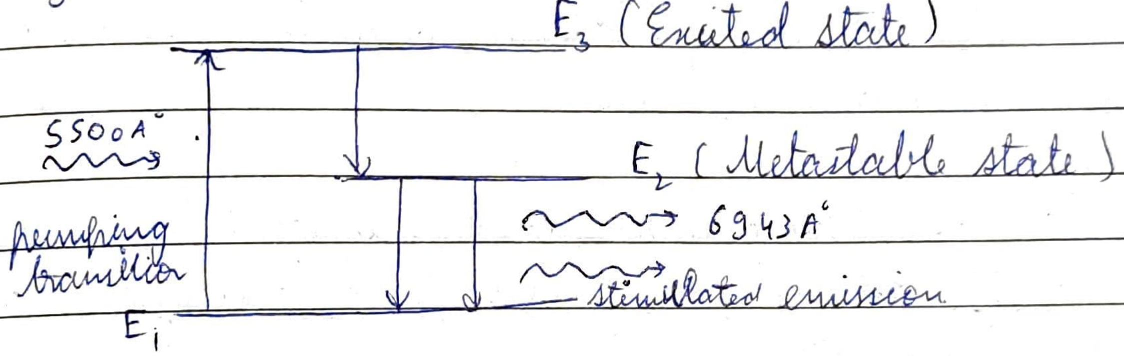
∴ ratio is directly proportional to cube of frequency thus Probability of spontaneous emission increases with increase in energy difference between two states.

Q13. Discuss the working of Ruby laser with proper energy level diagram.

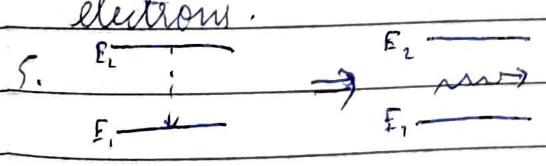
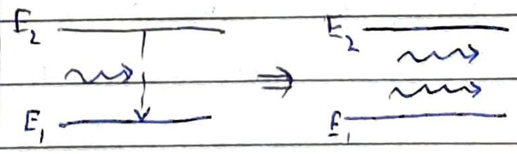
Ans13. Ruby laser belongs to class of solid-state laser.

1. Working part - ruby crystal rod.
2. A resonant cavity - 2 optical plates exactly parallel, one on left fully reflecting, other on right partially reflecting
3. Optical pumping - Xe helical flash tube with power supply source.
4. Cooling System - enclosed by glass tube & cold water is flown.

→ Ruby is basically Al_2O_3 with Cr^{+3} ions (0.05%) which are actual active centres. It uses 3-level pumping scheme. In figure E_1, E_2 & E_3 represent energy level of Cr^{+3} ion. Generally they are are E_1 but when ruby crystal is radiated by light transition $E_1 \rightarrow E_3$ occurs with absorption band ≠ 5500 Å. But due to collision atoms & come to metastable state E_2. No. of ions in E_1 decrease with pumping & increase in E_2 (life time 10^{-3} sec). One spontaneous emission from E_2 causes stimulated emission in others, thus photons travel along length of ruby rod & get repeatedly reflected. This results in amplified strong beam of wavelength 6945°A.



Q14. Write difference between spontaneous emission & stimulated emission.

Spontaneous	Stimulated
1. Occurs due to natural tendency of electron.	1. Occurs due to external agent (photons).
2. Used in LED, Fluorescent tube	2. Used in LASER beam mainly.
3. No external stimuli required	3. External stimuli is required.
4. No population inversion of electrons.	4. Population inversion by pumping
5. 	5. 

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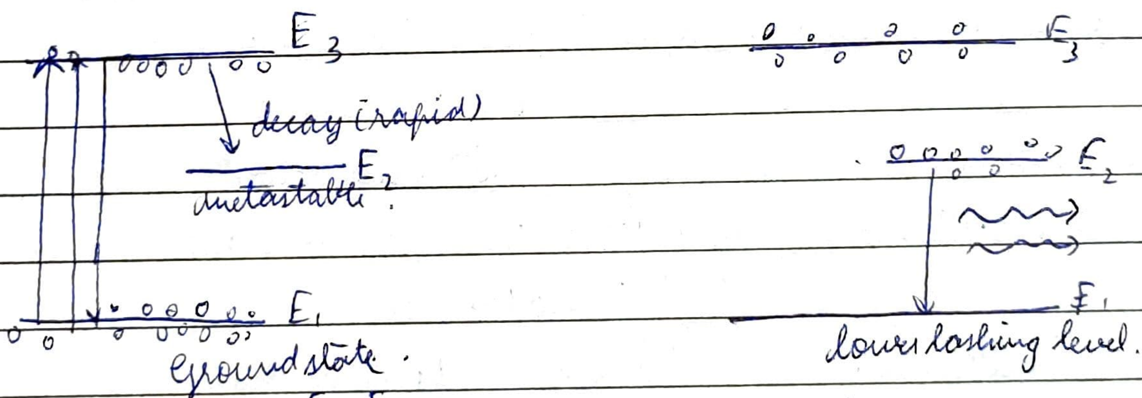
Q15. What is metastable state? What role do such states play in the operation of lasers.

Ans15. In order to ~~achive~~ achieve population inversion there is a state having long lifetime. Such energy states are metastable states. They allow accumulation of large number of excited atoms. Here they remain for appreciable time of order 10^{-6} to 10^{-3} sec. It's role is to allow population inversion and thus existence of LASER is possible.

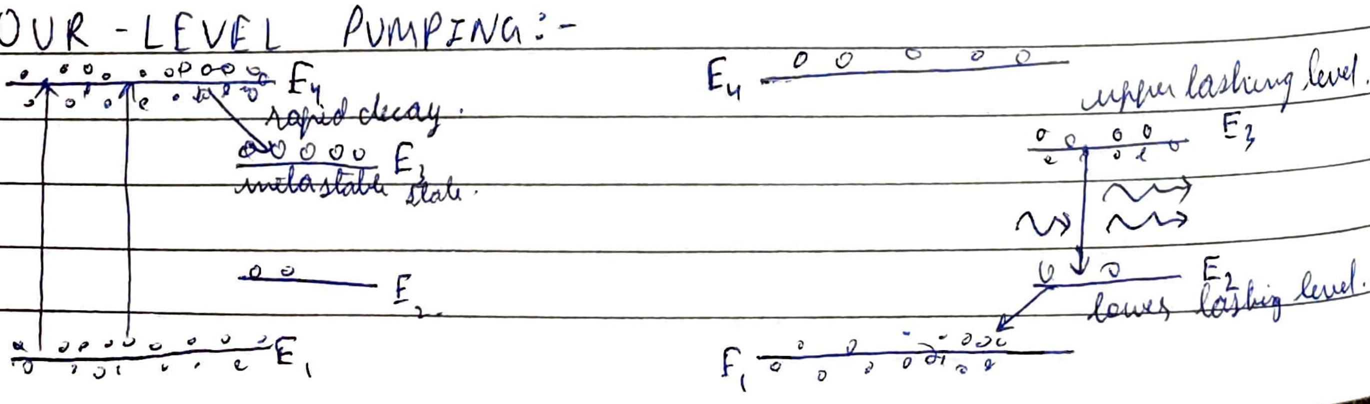
Q16. Explain the three level and four level laser system. What are the advantages of four level laser system over three level laser system?

Ans16 THREE-LEVEL PUMPING :-



When light of $\nu = \frac{E_3 - E_1}{h}$ is incident ~~at~~ on atom, some get excited to E_3. E_3 being unstable of lifetime 10^{-8} sec, atoms rapidly decay to E_2 metastable state of life time of order 10^{-3} sec. Due to pumping more atoms accumulate. Photons of energy $h\nu = E_2 - E_1$, trigger stimulated emission.

=) FOUR-LEVEL PUMPING :-



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Active centres are pumped from ground level E_1 to level E_4. Atoms fall rapidly to metastable state E_3. Accumulation occurs & population inversion is achieved between E_3 & E_2. Atom of energy $h\nu = (E_3 - E_2)$ trigger stimulated emission & bring to E_2. From E_2 atoms return to E_1 through non-radiative transition.

→ Four level pumping scheme requires smaller pumping power & smaller input power. Also it produces continuous wave output.

Q17 Describe the term 'holography' and its important application.

Ans17. Holography is lensless imaging process. It is made up of 2 words - holos means 'whole' & graphein' meaning 'to write'. Thus it means writing the complete image. It is recording of interference pattern formed between two beams of coherent light. In this process both amplitude & phase components of light waves are recorded on photographic plate.

Application of Holography :-

1. Security - for security & product authentication. They are proven as unsurpassed when attached to documents.
2. Three dimensional photography.
3. Microscopy - observing blood cells, cancer affected tissues etc.
4. Character recognition - identify fingerprints.
5. Data storage - in computers.
6. Photolithography - photographic masks to produce microelectronic circuit.
7. Holographic projection.
8. Holographic interferometry.
9. Acoustic Holography - to get image of organs.
10. Holographic optical element.

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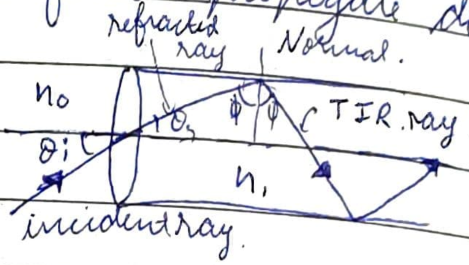
Q18. Deduce an expression for acceptance angle of an optical fibre.

Ans18. Acceptance angle is maximum angle that a light ray can have relative to the axis of the fibre & propogate down the figure.



Snell's law :-

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

for max value $\phi = \theta_c$

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

$\sin\theta_i = \frac{n_1}{n_0}\cos\phi$.

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

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

when $\theta_i = \theta_c$, $\sin(\theta_i\, max) = \frac{n_1}{n_0}\cos\phi_c$

$\sin(\theta_i\, max) = \frac{\sqrt{n_1^2 - n_2^2}}{n_0}$. for air $n_0 = 1$.

$\theta_i\, max = \sin^{-1}(\sqrt{n_1^2 - n_2^2})$

Q19. Difference between step index and graded index fibre.

Ans19

	Step index fibre		Graded index fibre.
1.	refractive index of core is uniform & abrupt at core cladding boundary.	1.	Refractive index of core vary gradually (max at centre)
2.	Path of light propogation (zig-zag)	2.	Path of light is helical.
3.	Attenuation is more for multimode step & less for single mode.	3.	Attenuation is less.
4.	Lower bandwidth	4.	Higher bandwidth.
5.	Meridional ray.	5.	Skew rays.
6.	No. of modes of propagation :- $N = \frac{V^2}{2}$	6.	$N = \frac{V^2}{4}$.

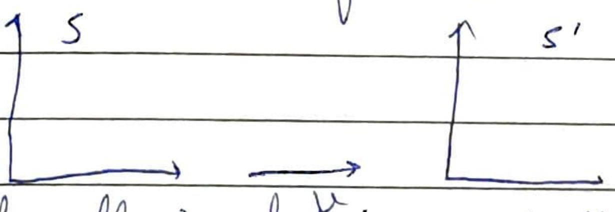
Q20. Write the postulates of special theory of relativity.

Ans20 Albert Einstein formulated Special theory of relativity in 1905 with two postulates.

1. The laws of physics have the same form in all inertial frames of refrence i.e the laws of physics are invariant to transformation between all inertial frames.
2. The speed of light in free space has the same value in all frames of refrences, regardless of their state of motion.

Q21 Derive the relativistic relation for variation of mass with velocity

Ans 21 Let us assume 2 frames having relative velocity v.



Let there be collision between 2 balls of same mass m & velocity u' in opposite direction in frame S'. After collision the come at rest w.r.t frame S'. But are moving with velocity v w.r.t frame S. Initial velocities u_1 & u_2 w.r.t frame S are:-

$$u_1 = \frac{(u'+v)}{(1+u'v/c^2)} \quad -①\qquad u_2 = \frac{(-u'+v)}{\left(1-\frac{u'v}{c^2}\right)} \quad -②$$

Applying conservation of momentum in frame S.

$$m_1 u_1 + m_2 u_2 = (m_1+m_2)v.$$

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

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

$$\frac{m_1}{m_2} = \frac{\left(1+\frac{u'v}{c^2}\right)}{\left(1-\frac{u'v}{c^2}\right)} \quad —③.$$

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$$1 - \frac{u_1^2}{c^2} = \left(1 + \frac{u'^2 v^2}{c^4} - \frac{u'^2}{c^2} - \frac{v^2}{c^2}\right) \Big/ \left(1 + \frac{u'v}{c^2}\right)^2 \quad — (4)$$

$$1 - \frac{u_2^2}{c^2} = \left(1 + \frac{u'^2 u^2}{c^4} - \frac{u'^2}{c^2} - \frac{v^2}{c^2}\right) \left(1 - \frac{u'v}{c^2}\right)^2 \quad — (5)$$

dividing them we get.

$$\frac{\left(1 - \frac{u_2^2}{c^2}\right)}{\left(1 - \frac{u_1^2}{c^2}\right)} = \frac{\left(1 + \frac{u'v}{c^2}\right)^2}{\left(1 - \frac{u'v}{c^2}\right)^2} \Rightarrow \sqrt{\frac{\left(1 - \frac{u_2^2}{c^2}\right)}{\left(1 - \frac{u_1^2}{c^2}\right)}} = \frac{\left(1 + \frac{u'v}{c^2}\right)}{\left(1 + \frac{u'v}{c^2}\right)} \quad — (6)$$

Comparing 3 & 6 we get.

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

Let us assume $u_2 = 0$ & $m_2 = m_0$.

$$\therefore \frac{m_1}{m_0} = \frac{1}{\sqrt{1 - \frac{u_1^2}{c^2}}} \qquad u_1 = v \qquad m_1 = m.$$

$$\therefore m = \frac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}}.$$

Q22. Derive Lorentz transformation equation

Ans 22 For 2 frames S' & S^*, moving with relative velocity v. Let co-ordinates of S be x, y, z & t, & S' be x', y', z', t'. Considering spherical wave front. & using galilean transformation

$x = vt$, $x' = a_1 x + a_2 t$, $y' = y$, $z' = z$, $t' = b_1 x + b_2 t$.

for $x' = 0$ $\quad x = -\frac{a_2}{a_1} t = vt$. $\quad \therefore -\frac{a_2}{a_1} = v$.

$$x'^2 + y'^2 + \cancel{z'^2} + c^2 t'^2 = x^2 + \cancel{y^2} + \cancel{z^2} + c^2 t^2$$

$$(a_1 x + a_2 t)^2 + c^2 (b_1 x + b_2 t)^2 = x^2 + c^2 t^2.$$

$$a_1^2 x^2 + a_2^2 t^2 + 2 a_1 a_2 x t - c^2 (b_1^2 x^2 + b_2^2 t^2 + 2 b_1 b_2 x t) = x^2 - c^2 t^2.$$

$$a_1^2 (x - vt)^2 - c^2 (b_1^2 x^2 + b_2^2 t^2 + 2 b_1 b_2 x t) = x^2 - c^2 t^2$$

$$a_1^2 x^2 + a_1^2 v^2 t^2 - 2 a_1^2 x v t - c^2 b_1^2 x^2 - c^2 b_2^2 t^2 - 2 b_1 b_2 x t c^2 = x^2 - c^2 t^2$$

Comparing coefficients we get.

$a_1^2 - c^2 b_1^2 = 1$ $\quad a_1^2 = 1 + c^2 b_1^2$ $\quad c^2 b_1^2 = a_1^2 - 1.$ ✓

$a_1^2 v^2 - c^2 b_2^2 = -c^2$ $\quad c^2 = \frac{a_1^2 v^2}{b_2^2 - 1}$ $\quad a_1^2 v^2 = c^2(b_2^2 - 1)$

$-2a_1^2 v = 2b_1 b_2 c^2$ ✓ $\quad c^2 = \frac{a_1 a_2}{b_1 b_2} = \frac{-a_1^2 v}{b_1 b_2} = \frac{-c^2(b_2^2-1)}{b_1 b_2}$

$1 = \frac{1 - b_2^2}{b_1 b_2} \Rightarrow b_1 b_2 = 1 - b_2^2$ $\quad b_2(b_1 + b_2) = 1$ $\quad b_1 = \frac{1 - b_2^2}{b_2}.$

$c^2 b_2^2 = a_1^2 v^2 + c^2.$ ✓

$b_1^2 b_2^2 c^4 = (a_1^2 v^2 + c^2)(a_1^2 - 1) = a_1^4 v^2.$

$\cancel{a_1^4 v^2} - a_1^2 v^2 + a_1^2 c^2 - c^2 = \cancel{a_1^4 v^2}$ $\quad c^2 = a_1^2(c^2 - v^2)$

$\therefore a_1^2 = \frac{1}{1 - \frac{v^2}{c^2}}$ $\quad a_1 = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}} = \gamma$

$a_2 = \frac{-v}{\sqrt{1 - \frac{v^2}{c^2}}}$ $\quad b_1 = \frac{-v}{c} \cdot \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$ $\quad b_2 = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}} = \gamma$

$\therefore x' = \gamma(x - vt)$ $\quad y' = y$ $\quad z' = z$ $\quad t' = \gamma(t - \frac{v}{c^2}x).$

Q23. Give the difference between inertial & non-inertial frames. Show that laws of physics are same in all inertial frame and why they can't be same in non-inertial frame?

Ans 23

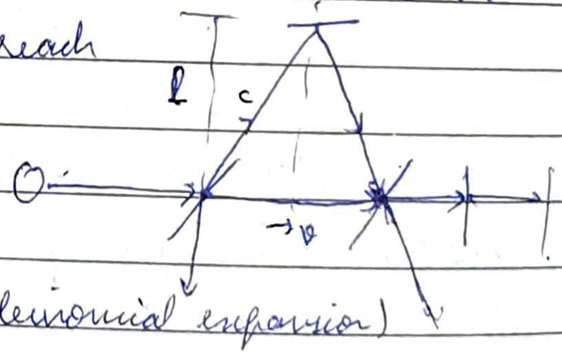
Inertial	Non-inertial
1. Is at rest or moving with con. velocity w.r.t other frame (uniform)	1. Is moving with non-uniform velocity w.r.t other frame.
2. Acceleration is 0.	2. There is some acceleration.
3. Newtons law of motion are vaild.	3. Newton's laws of motion are invalid.
4. Eg. Gravitational force.	4. Eg:- Coriolis force.

→ Let us take Newton's first law. Let us assume 2 frames having relative velocity v. A ball is moving with constant velocity u w.r.t first frame appears to be moving with constant velocity in second frame (or uniform velocity until an ~~entsal~~ external force is applied.

→ But if frames are non-inertial i.e one frame moves with acceleration. Then a ball moving with uniform velocity in one frame appears to move fast or slow with time. Thus laws are not obeyed in non-inertial frames.

Q24. Describe Michelson - Morley experiment and explain the physical significance of negative result.

Ans24. Michelson & Morley performed experiment to detect ether by modified michelson interferometer. A monochromatic light is hit on partially reflecting surface which divide it into 2 perpendicular rays. Time T_1 & T_2 to reach second plate are calculated.



$$(ct)^2 = l^2 + (vt)^2 \Rightarrow t = \frac{l}{c}\left(1 - \frac{v^2}{c^2}\right)^{-1/2}.$$

$$t_1 = 2t \approx \frac{2l}{c}\left(1 + \frac{v^2}{2c^2}\right)$$ (using binomial expansion)

$$t_2 = \frac{l}{c-v} + \frac{l}{c+v} = \frac{2l}{c}\left(1 - \frac{v^2}{c^2}\right)^{-1} \approx \frac{2l}{c}\left(1 + \frac{v^2}{c^2}\right).$$

Phase difference: $$\frac{\Delta t}{T} = \frac{c(t_2 - t_1)}{\lambda} = \frac{2l}{c} \times \frac{1}{2}\frac{v^2}{c^2}\frac{c}{\lambda} = \frac{l v^2}{\lambda c^2}$$

But no such phase difference was observed. Significance is to find reason which helped to know length contraction & also ether-drag theory.

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Q25. Explain length contraction & time dilation

Ans25. Length contraction: if there is a rod which is at rest w.r.t frame S. Length of rod is $l_0 = x_2 - x_1$. If a frame is moving with velocity v w.r.t S then length of same rod in that frame is given by l. According to Lorentz transformation

$$x_1 = \frac{x_1' + vt'}{\sqrt{1-v^2/c^2}} \qquad x_2 = \frac{x_2' + vt'}{\sqrt{1-v^2/c^2}}$$

$$\therefore l_0 = x_2 - x_1 = \frac{x_2' - x_1' + vt' - vt'}{\sqrt{1-v^2/c^2}} = \frac{x_2' - x_1'}{\sqrt{1-v^2/c^2}}$$

$\therefore l = l_0\sqrt{1-v^2/c^2}$ as $\frac{v^2}{c^2} < 1$ $\therefore l < l_0$.

Time dilation: Let us assume 2 frames S & S' moving with relative velocity 'v'. Consider 2 events happening at x_0' at time t_1' & t_2'. Then in S frame time interval is given by:-

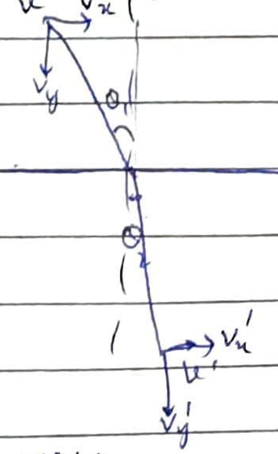
$$t_1 = \gamma(t_1' + vx_0'/c^2) \qquad t_2 = \gamma(t_2' + vx_0'/c^2)$$

$$t_2 - t_1 = \gamma(t_2' - t_1') . \qquad \left(\gamma = \sqrt{1-\frac{v^2}{c^2}}\right)$$

$$\Delta t = \gamma \Delta\tau$$

Q26 Explain Bethe's law of electron refraction.

Ans26 Motion of electron in non-uniform electric field can be explained by Bethe's law. Let us assume an equipotential surface. There is abrupt change in potential after the surface. Let us assume potential V_1 before surface boundary & V_2 after surface boundary. As electric field is $\perp$ $\therefore$ only y component changes.



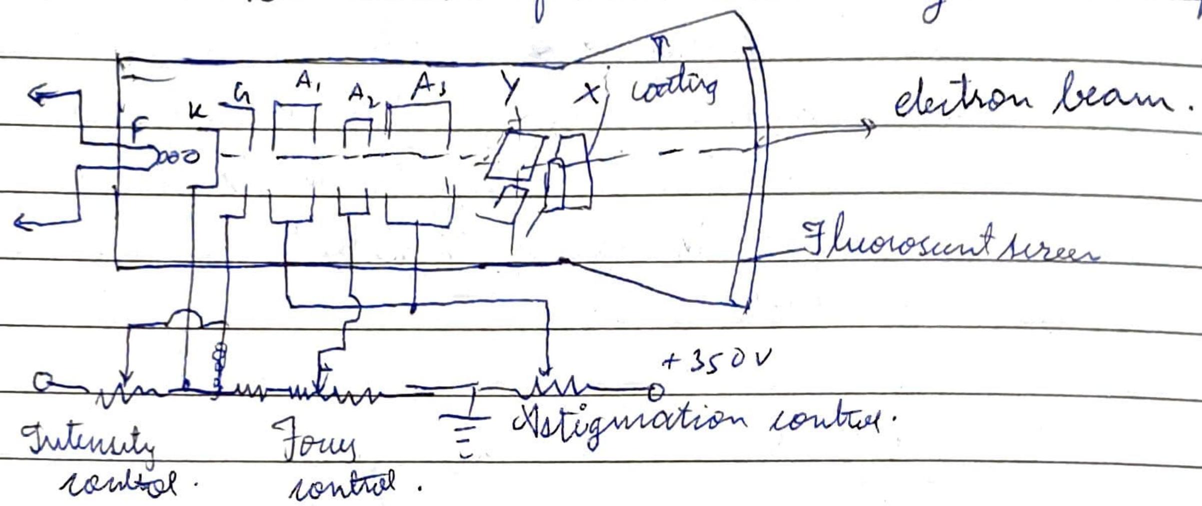
$\therefore v_x = v_x'$ $\qquad v \sin\theta_1 = v' \sin\theta_2$

$$\frac{\sin\theta_1}{\sin\theta_2} = \frac{v_2}{v_1} \qquad v = \sqrt{\frac{2eV}{m}}$$

$$\therefore \frac{\sin\theta_1}{\sin\theta_2} = \frac{\sqrt{\frac{2eV_2}{m}}}{\sqrt{\frac{2eV_1}{m}}} = \sqrt{\frac{V_2}{V_1}} = \left(\frac{V_1}{V_2}\right)^{1/2}.$$

If $V_2 > V_1$ electron bends towards normal & vice-versa.

Q27. Draw a schematic of a cathode ray tube & explain it.



1. Electron gun - we emits a beam of e^- from cathode which travel through grid and hit fluorescent screen. The intensity of flash depends on potential difference.
2. Deflection system - There are 2 set of plates one along x axis & other along y axis at the mouth of grip. When potential difference is applied between plates they deflect e^- beam one vertically & other horizontally. Due to 2 orthogonal forces. e^- beam deflects in direction of resultant force.
3. Flurosent screen - to make e^- effect visible. interior surface at end of CTR is covered with thin layer of phosphorus. It has property of emitting light when high-energy narrow particles strike the screen.
4. Acquadag coating - the e^- deflected by ~~so~~ screen are conducted away & Shortage of e^- is made up by this coating. Inner surface of flare is coated with conductive graphite (acquadag) & connected ~~onestar~~ internally at a +ve anode. e^- return to cathode via ground. It also shields CTR from external E.F.