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Section-F

Physics Assignment

Ans 1 We know that the interference colours are observed only in thin films but not in the thick plate since we know that the interference of waves occurs only when both the conditions of temporal and spatial coherence.

We have assumed that a monochromatic wave of infinite length is incident on film. In Reality, the incident light consist of wave trains of finite length and coherence extends over the length of each wave train only. Interference can occur only when parts of same group of wave trains overlap. Superposition of different wave trains cannot produce interference because they will be incoherent and do not maintain any constant phase relationship with each other.

Hence it implies that interference occurs only when the optical path difference Δ is less than the coherence length.

$$\Delta << l_{con}$$

$$2\mu t \cos r - \lambda/2 << l_{con} \qquad \text{Since, } L_{con} = \frac{\lambda^2}{\Delta\lambda}$$

$$2\mu t \cos r - \lambda/2 << \frac{\lambda^2}{\Delta\lambda}$$

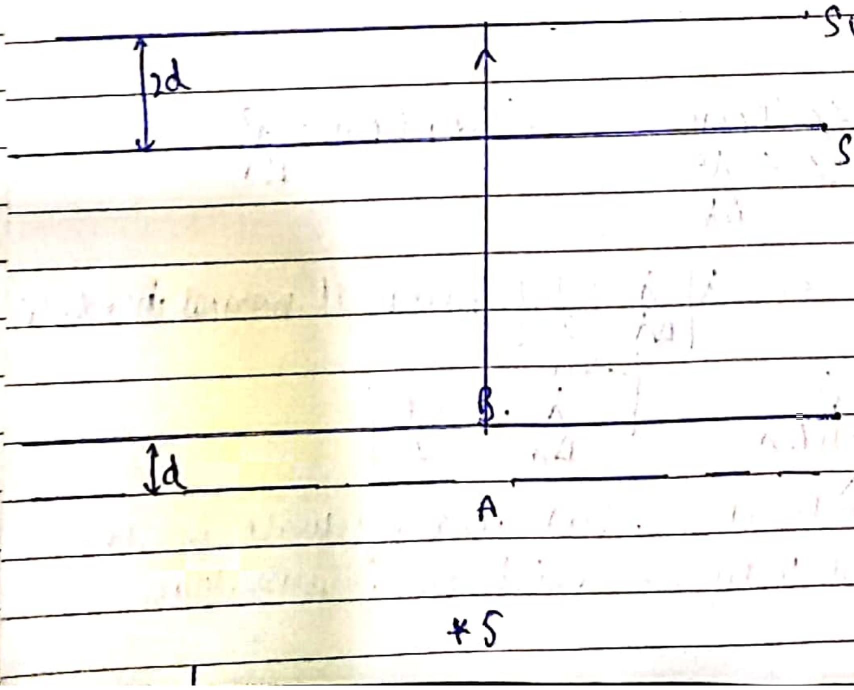
$$2\mu \cos r t << \lambda\left[\frac{\lambda}{\Delta\lambda} + \frac{1}{2}\right], \cos r = 1 \text{ (normal incidence)}$$

$$t < \frac{\lambda^2}{2\mu\Delta\lambda} \qquad \left[\text{since, } \frac{\lambda}{\Delta\lambda} >> \frac{1}{2}\right]$$

Above equation indicates that interference in thin film will be observed only if thickness is less than $\left[\frac{\lambda^2}{2\mu\Delta\lambda}\right]$

Ans2 Fringes of equal thickness → Newton rings are formed as result of interference between light waves reflected from the top and bottom surfaces of a thin air film enclosed between a plano convex lens and a plane glass plate. The occurrence of alternate bright and dark rings depends on optical path difference arising between the reflected rays. If the light falls normally on the air film the optical path difference between the waves reflected from two surfaces of the film is
$\Delta = 2t - \lambda/2$. It is seen that the path difference between the reflected rays arises due to variation in thickness 't' of air film. Reflected light will be of minimum intensity for those thickness for which the path difference is $m\lambda$ and maximum intensity for those thickness for which the path difference is $(2m+1)\,\lambda/2$. Thus, each maxima and minima is a locus of constant film thickness.

Fringes of equal inclination: In the Michelson Interferometer experiment, If one looks towards M_1 through T, one observes a virtual image of M_2 in G_1, parallel to M_1, say M'_2 act as two coherent sources formed by thin film of thickness



$S A = S_1 A = S_1 B + d$

$S_2 B = S B = S A + d$

$= S_1 B + 2d$

$* \; S_2 - S_1 = S_2 B - S_1 B = 2d$

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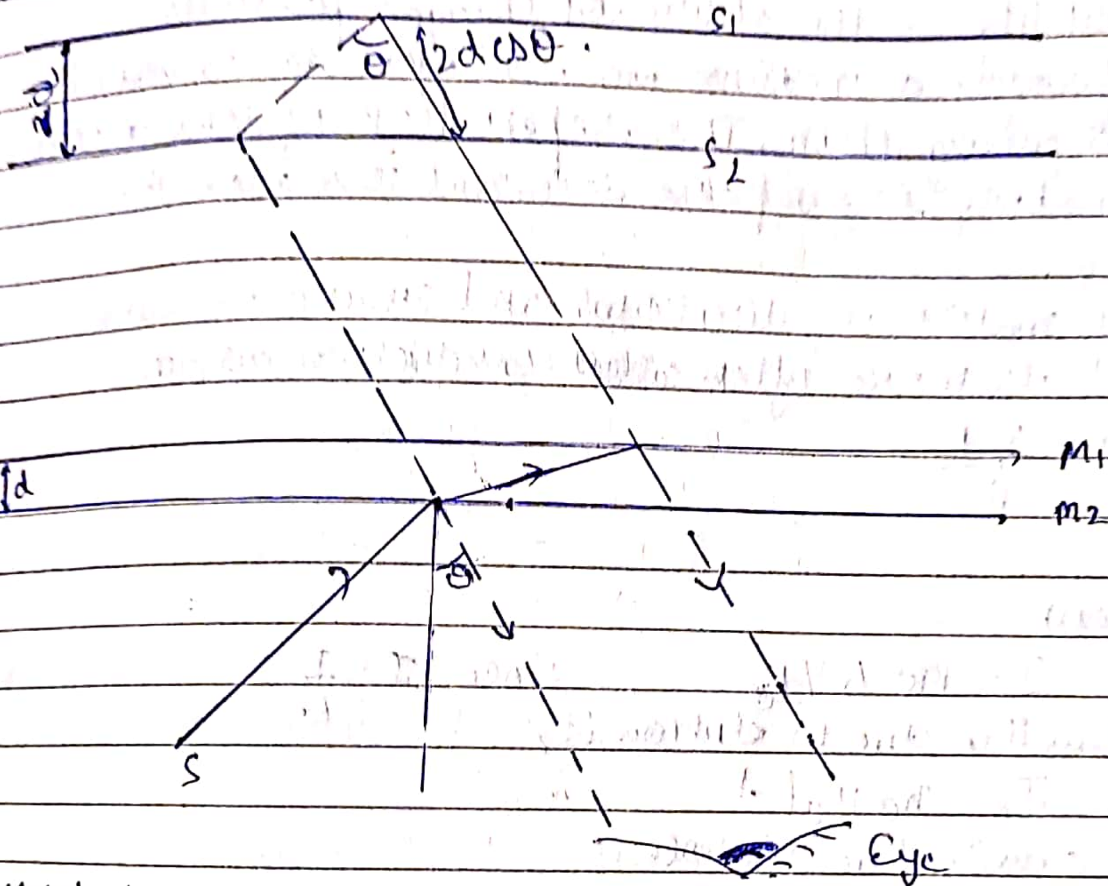
$M_1M_2' = G_1M_1 - G_1M_2' = G_1M_2 = (x_1 - x_2)$, If two arms are equal in length. $(M_2'M_1) = (x_1 - x_2) = d$. The virtual images are seperate by a distance 2d.



$M_1M_2' = (x_1 - x_2)$

If the observer looks into the system at angle θ, the path difference between the two beam will be $2d\cos\theta$. The light that comes from M_2 and goes to T undergoes rare to dense reflection and a phase change occurs. Hence total path difference is $D = 2d\cos\theta + \lambda/2$.

For a given seperation d, a given wavelength λ and order m angle θ is constant. This means fringes are of circular shape and they are called fringes of equal inclination.

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Ans 3

Mobility: Mobility is the ability of charged particles to move through a medium in response to an electric field that is pulling them. The seperation of ions according to their mobility in gas phase is called ion mobility spectrometry.

The drift motion is directional and causes drift current flow, which is more often called conduction current.

$$\mu = \frac{V_d}{E}$$

Since we know

$$I = neAV_{de} \qquad \text{Since } J = \frac{I}{A}$$

current density due to electron is,

$$J_e = n e \mu_e E$$

current density due to hole is

$$J_h = p e V_{dh} = p e \mu_h E$$

Comparing above expression with ohm's law, $J = \sigma E$

$$\sigma_e = n e \mu_e$$

$$\sigma_h = p e \mu_h$$

Total current in the semiconductor is due to both holes and electron hence $I = I_e + I_h$

$$J = \frac{I_e}{A} + \frac{I_h}{A}$$

$$J = J_e + J_h$$

$$= (n e \mu_e + p e \mu_h) E$$

$$\sigma = (n e \mu_e + p e \mu_h)$$

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As for semiconductor which is in intrinsic $n = p = n_i$
$\sigma = n_i e(\mu_e + \mu_h)$.

Carrier concentration: It is number of electrons in the conduction band per unit volume (n) and number of holes in valence band per unit volume (p) of material

Calculation : $dn = Z(E) f(E) dE$
On integrating
$$n = \int_{E_c}^{\infty} Z(E) f(E) dE$$

Since $Z(E) dE = \frac{4\pi}{h^3} (2 m_e^*)^{3/2} E^{1/2} dE$ for $E > E_C$ —(i)

$$f(E) = \frac{1}{1 + \exp[(E - E_f)/kT]} \quad \text{—(2)}$$

Using eq (i) and (ii)
$$n = \frac{4\pi}{h^3} (2 m_e^*)^{3/2} e^{(E_f - E_c)/kT} \int_{E_c}^{\infty} (E - E_c)^{1/2} e^{-(E - E_c)/kT} dE$$

On solving $n = \underbrace{2 \left[\frac{2\pi m_e^* kT}{h^2} \right]^{3/2}}_{N_c} e^{-(E_c - E_f)/kT}$

$$n = N_c e^{-(E_c - E_f)/kT}$$

Similarly for holes $p = N_V e^{-(E_f - E_V)/kT}$

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for intrinsic semiconductor

$$n_i^2 = np$$

$$n_i^2 = (N_C N_V)\, e^{-(E_C - E_V)/KT}$$

$$n_i = \sqrt{(N_C N_V)}\, e^{-(E_C - E_V)/KT}$$

Substituting value of N_C and N_V $\quad (E_C - E_V) = E_g$

$$n_i = 2\left[\frac{2\pi KT}{h^2}\right]^{3/2} (m_e^* m_h^*)^{3/4} e^{-E_g/2KT}$$

for extrinsic semiconductor:

1) In n type semiconductor. (In normal region $n_n = n_i$)

(In ionisation region) $n = N_D - N_D^0$.

$$n = \frac{N_D}{1 + e^{-(E_D - E_f)/KT}}$$

$$n = N_D\, e^{(E_D - E_f)/KT}$$

$$n = N_C\, e^{-(E_C - E_f)/KT}$$

Hence $E_f = \frac{E_D + E_C}{2} + \left(\frac{KT}{2}\right) \ln\left(\frac{N_D}{2(2\pi m_e^* KT/h^2)^{3/2}}\right)$

at $T = 0K$

$$E_f = \frac{E_D + E_C}{2}.$$

Hence on solving

$$n = (2N_D)^{1/2}\left[\frac{2\pi m_e^* KT}{h^2}\right]^{3/4} e^{-\frac{(E_C - E_D)}{2KT}}$$

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Similarly in p type (In normal region) $[P_p = n_i^2]$
[In ionised region] $E_f = \frac{E_V + E_A}{2}$

$$p = (2N_A)^{1/2}\left[\frac{2\pi m_h^* kT}{h^2}\right]^{3/4} \exp\left[\frac{(E_V - E_A)}{2kT}\right]$$

Ans 4

Fermi level in intrinsic semiconductor:

In a pure semiconductor, the electrons in the conduction band cluster very close to the bottom edge of a band, and we assume that electrons are located right at bottom edge of the conduction band.

Electron concentration in conduction band is

$$n = N_c e^{-(E_c - E_f)/kT}$$

hole concentration in valence band is

$$p = N_V e^{-(E_f - E_V)/kT}$$

In intrinsic semiconductor holes and electrons are equal (n=p)

$$N_c e^{-(E_c - E_f)/kT} = N_V e^{-(E_f - E_V)/kT}$$

Taking logarithm on both sides, we get

$$-\frac{(E_c - E_f)}{kT} = \ln\frac{N_V}{N_c} - \frac{(E_f - E_V)}{kT}$$

$$E_f - E_c = kT\ln\frac{N_V}{N_c} - E_f + E_V$$

$$E_f = \frac{E_c + E_V}{2} + \frac{1}{2}kT\ln\frac{N_V}{N_c}$$

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But . $N_c = 2\left[\frac{2\pi m_e^* kT}{h^2}\right]^{3/2}$ $N_V = 2\left[\frac{2\pi m_h^* kT}{h^2}\right]^{3/2}$

Hence $\ln\left(\frac{N_V}{N_c}\right) = \frac{3}{2}\ln\left(\frac{m_h^*}{m_e^*}\right)$

we can also write above equation as

$$E_F = \frac{E_C + E_V}{2} - \frac{3}{4}kT \ln\left(\frac{m_e^*}{m_h^*}\right)$$

If effective mass of a free electron is assumed to be equal to effective mass of a hole ie

$$m_h^* = m_e^*$$

$$\ln\left(\frac{m_h^*}{m_e^*}\right) = 0.$$

$$E_F = \frac{E_C + E_V}{2}$$

$$E_F = \frac{E_g}{2} + E_V$$

at top of valence band E_V as zero level $E_V = 0$

$$E_F = \frac{E_g}{2}$$

Ans 5 The fermi level is energy seperating occupied state (or levels) of the valency band from empty states (levels) of conduction band at the absolute temperature T=0.

The fermi level is an energy level characteristic of statistics which controls occupation of any energy state by a given particle : an electron or a hole in semiconductor.

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Electrons and holes are both fermion particles (with half values of spins) and both of them obey the fermi-Dirac statistics which becomes asymptotically the Boltzman statistics in dilute systems (with few electrons and or holes) or nondegenerate systems.

The position of the fermi level with respect to valence and or conduction bands depends on various parameters as the temperature, the effective masses of electrons and holes, number of free electrons and holes.

Variation of fermi level obeys two conditions.

- the "mass action law" which states that the number of particles of each type as well as the overall number of particles must conserve whatever is their distribution on the available energy levels
- The neutrality equation which states that the electrical neutrality has to be fulfilled ie the number of negative charges must be counterbalanced exactly by the same number of positive charges

In an extrinsic semiconductor (with added doping) in order to conserve number of particles (mass action) and to fulfill the overall electrical charge neutrality (neutrality equation), the fermi level has to move away from midgap position. It has to shift towards conduction band in an n type semiconductor (extrinsic semiconductor with

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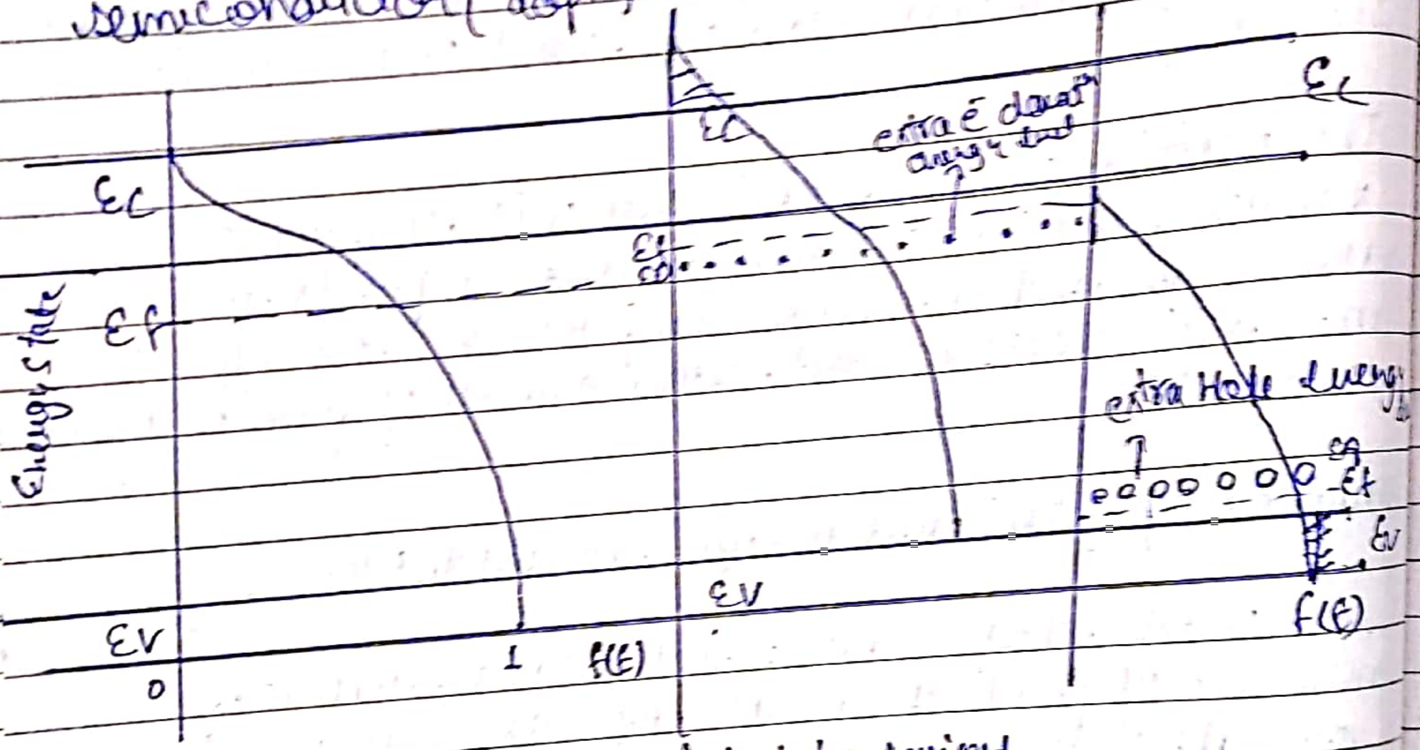
added doping impurities which are doners.

& It shifts towards valence band in a p type semiconductor (doping impurities which are accepters

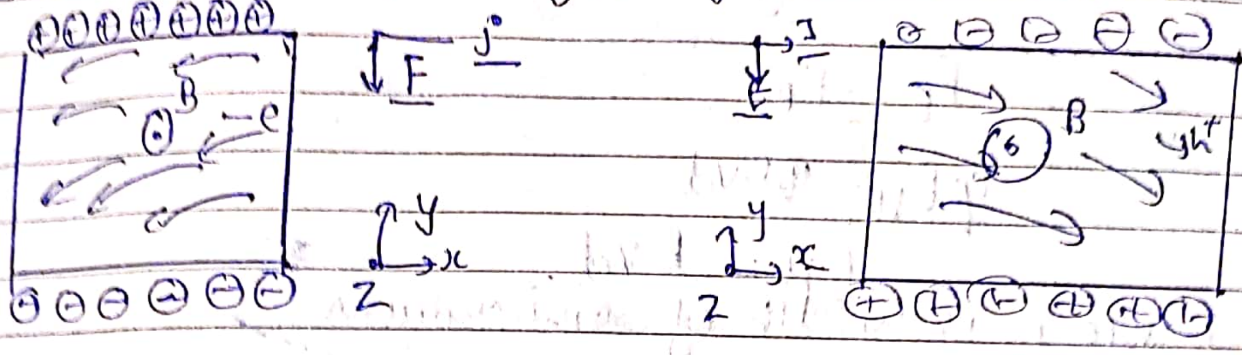


1) Intrinsic Semiconductor

2) n type semicond

Ans6
A static magnetic field has no effect on charges unless they are in motion. when the charge flow, a magnetic field directed perpendicular to direction of flow produces a mutually perpendic force on charges. When this happens electrons and holes will be seperated by opposite forces. This means that the current of carriers will be deflected from a straight line in y direction. In other words, there is a component of velocity in y direction and surfaces perpendicular

to the y direction will become charged as soon as the current for magnetic field is switched on.



They will in turn produce an electric field (E_h) which depends on the cross product of magnetic field intensity, H and current density, J

$$E_h = R J \times H$$

where R is called as Hall coefficient

Now, let us consider a bar of semiconductor, having dimension, x, y and z let J is directed along X and H along Z then E_H will be along Y. Then we could write

$$R = \frac{V_h/y}{JH} \quad , \quad R = \frac{V_H}{Ix} \times \frac{Z}{H}$$

where V_H is called Hall voltage appearing between two surfaces perpendicular to y.

Another way:

$$I = peAv_d$$

Since current density $J_x = \frac{I}{A} = pev_d$

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If equilibrium is attained that means forces both electric and magnetic field balance

$$F_E = F_B$$

$$qE_H = qBV_d$$

$$E_H = BV_d$$

Hence w is width of semiconductor

$$E_H = \frac{V_H}{w}$$

$$\frac{V_H}{w} = BV_d$$

we have $V_d = \frac{J_x}{\rho e}$

$$\frac{V_H}{w} = \frac{BJ_x}{\rho e}$$

$$V_H = \frac{wBI}{\rho eA}$$, If t is thickness of plate $A = wt$

$$V_H = \frac{BI}{\rho et}$$

Hall coefficient is defined as Hall field per unit current density per unit magnetic induction

$$R_H = \frac{V_H}{wJ_xB}$$

$$R_H = \frac{1}{\rho e}$$

Hall voltage, $V_H = \frac{R_H BI}{t}$

$$R_H = \frac{V_H t}{BI}$$

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Ans 7 Physical significance of wave function:
We cannot specify in similar way what is actually varying in de broglie waves. Since microparticles exhibit wave properties, it is assumed that a quantity ψ represent a de broglie wave. This quantity ψ is called wave function.

1) Born's Interpretation.

The wave function ψ itself has no physical significance but the square of absolute magnitude $|\psi|$ has significance when evaluated at a particular point and at particular time $|\psi^2|$ gives the probability of finding the particle there at that time.

The wave function $\psi(x,t)$ is quantity such that product

$$P(x,t) = \psi^*(x,t)\psi(x,t)$$

Is the probability per unit length of finding the particle at the position x at time t.

$P(x,t)$ is probability density and $\psi^2(x,t)$ is complex conjugate of $\psi(x,t)$.

Hence the probability of finding the particle is larger wherever ψ is large and vice versa

2) Normalization condition
The probability per unit length of finding the particle at position x and time t is

$$P = \psi^*(x,t)\psi(x,t)$$

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So, probability of finding particle in length dx is

$$P\,d(x) = \psi^*(x,t)\,\psi(x,t)\,dx$$

Total probability of finding particle

$$\int P\,d(x) = \psi^*(x,t)\,\psi(x,t)\,dx$$

If particle exist it may be somewhere on x axis, so total probability must be unity.

$$\int \psi^*(x,t)\,\psi(x,t)\,dx = 1$$

This is called normalization condition.

Probability
It can also be written as

$$P = |\psi(x,y,z)|^2\,dV$$

and Hence

$$\int_{-\infty}^{\infty} |\psi_N(x,y,z,t)|^2\,dx\,dy\,dz = 1$$

$$|c|^2 \int_{-\infty}^{\infty} |\psi(x,y,z,t)|^2\,dx\,dy\,dz$$

Here c is normalization constant.

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Time independent schroedinger wave :
In the stationary problems schroedinger equation can be simplified by seperating out time and position dependent parts.
Accordingly we can write the wave function as product of x, $\psi(x)$ and a function of t, $\phi(t)$.

Therefore

$$\Psi(x,t) = \psi(x)\,\phi(t).$$

Equation (20.56) may be written as

$$-\frac{\hbar^2}{2m}\frac{\partial^2}{\partial x^2}(\psi;\phi) + V\psi\phi = i\hbar\frac{\partial}{\partial t}(\psi,\phi)$$

$$-\frac{\hbar^2}{2m}\phi\frac{\partial^2}{\partial x^2}(\psi,\phi) + V\psi\phi = i\hbar\frac{\partial}{\partial t}(\psi,\phi)$$

Dividing above equat^n with $\psi\phi$

$$-\frac{\hbar^2}{2m}\frac{1}{\psi}\frac{\partial^2\psi}{\partial x^2} + V = i\hbar\frac{1}{\phi}\frac{d\phi}{dt}$$

If we assume potential energy V is a function of x only, the entire left hand side of eq (20.59) is a function of x only while the right hand side is function of t only. Since x and t are independent variables, both the function of x and t must be a constant. The constant that each side must equal is called seperation constant E, Thus

$$-\frac{\hbar^2}{2m}\frac{1}{\psi}\frac{d^2\psi}{dx^2} + V = E$$

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and

$$i \hbar \frac{1}{\phi} \frac{d\phi}{dt} = E$$

Hence

$$-\frac{\hbar^2}{2m} \frac{d^2\psi}{dx^2} + V\psi = E\psi \quad \text{--- eq (i)}$$

This equation is time independent schrodinger wave equation.

Eq(i) can be written as

$$-\frac{\hbar^2}{2m} \nabla^2 \psi + V\psi = 0$$

The free particle ⇒ when it is moving without being subjected to any external force in region of space. As the particle is moving freely with zero particle (potential) energy, it's total energy will be kinetic energy which is given by

$$E = \frac{p_x^2}{2m}$$

Where p_x is momentum along x direction.

Thus in equation $\frac{d^2\psi}{dx^2} + \frac{8\pi^2 m}{h^2} E\psi = 0$

It rewrites as

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

$$k^2 = \frac{8\pi^2 mE}{h^2}$$

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Ans 8

Postulates of quantum mechanics

Postulate - I

a) The state of a quantum mechanical system is described or represented by a wave function $\psi(x,t)$. All constant multiples of a given ψ describe one and same state.

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

Thus,

$$\psi = \sum_n C_n \psi_n$$

Where C_n are complex numbers.

Postulate - II

Each dynamical variable $A(x, p)$ is represented by a linear operator in quantum mechanics. dynamical variables in general do not commute with each other.

Postulate - III

If large number of measurements of a dynamical variable A are made on a system which is prepared to be in one and same state before each measurement results of measurements are distributed over an average value known as experimental value $\langle A \rangle$. The expectation value of dynamic variable is:

$$\langle A \rangle = \frac{\int \psi^* \hat{A} \psi \, d\tau}{\int \psi \psi^* \, d\tau}$$

Postulate - IV

Only possible result of measurement of

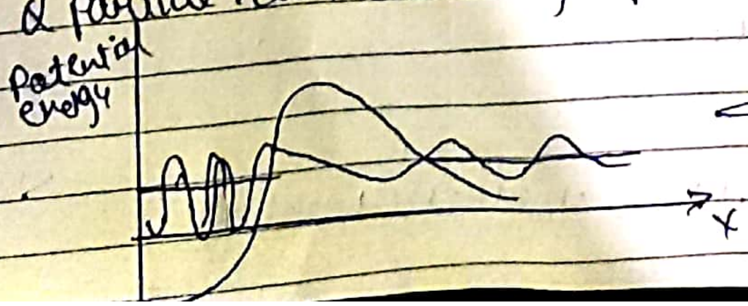
dynamical variable A are eigen value of operator $\hat{A}$ satisfying the eigen value equation. ($\hat{A}\psi_n = a_n \psi_n$) where ψ_n is eigenfunction of operator $\hat{A}$ belonging to eigen value a_n. Eigen value equation satisfied by Hamiltonian operator associated with the Hamiltonian function H can be written as

$$\hat{H}\psi_n = E_n \psi_n$$ where E_n is energy of system.

Tunnel effect: According to classical ideas, a particle striking a hard wall has no chance of leaking through it. But the behavior of a quantum particle is different owing to wave nature associated with it. De broglie wave also has a possibility of getting partly reflected from boundary of potential well and partly penetrating through barrier. The penetration of a barrier by quantum particle is called tunnelling.

Application of tunnelling

→ α decay → The quantum possibility of penetrating potential barrier is the basis of explanation of α decay of radioactive nuclei. In α decay, an unstable nucleus disintegrates into a lighter nucleus and an α particle. Ex → uranium nucleus ^{238}U undergoes α decay. In 1928 George Gamow explained α decay of unstable nuclei on basis of quantum tunneling. The forces in nuclear set up potential barrier of height of order 30MeV against α particle emission. Classically it would be trapped but according to quantum mechanics α particle tunnels through potential barrier.



→ Alpha particle having less energy than height of barrier tunnels through barrier.

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Ans 9 Harmonic oscillator: Atoms in solids execute harmonic vibrations about their equilibrium position and hence can be treated as simple harmonic oscillators. As atom displaces through a distance x from equilibrium position ($x=0$) a restoring force appears: $F=-kx$, Potential energy is given by $V=\frac{1}{2}kx^2$. The schrodinger equation for this case may be written as

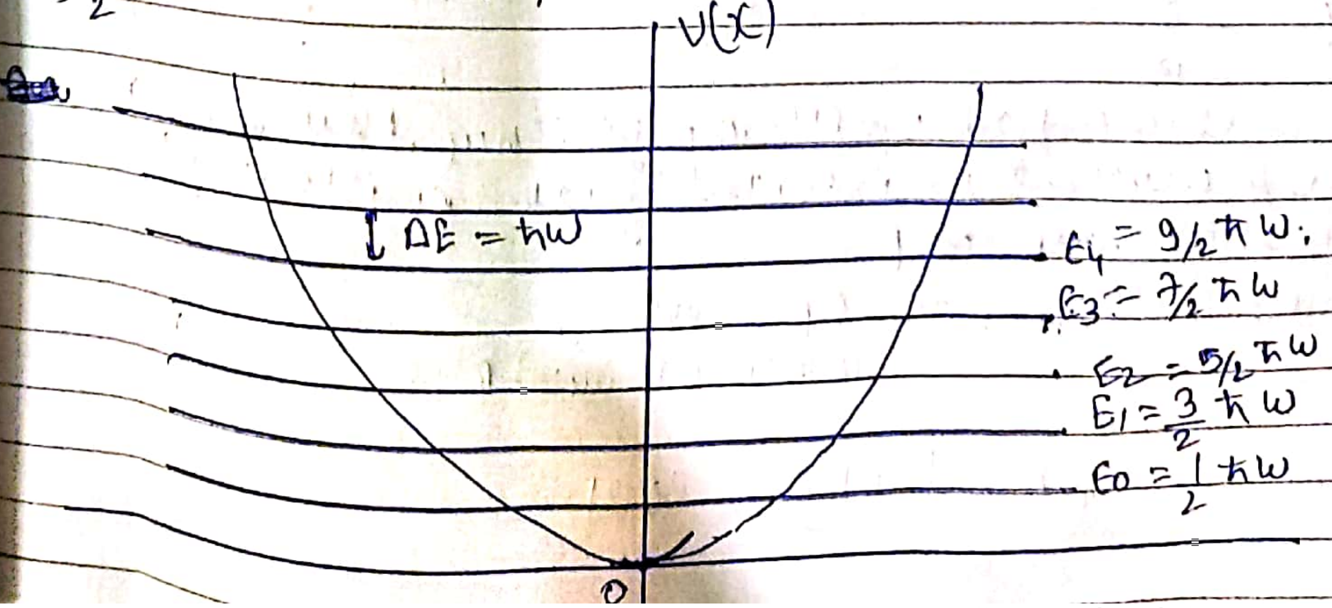
$$\frac{d^2\psi}{dx^2}+\frac{8\pi^2 m}{h^2}\left(E-\frac{1}{2}kx^2\right)\psi=0$$

This equation has a solution only at following values of energy $E_n=(n+\frac{1}{2})\hbar\omega$ where $n=0,1,2,3\ldots$

Thus energy levels of harmonic oscillators are quantized. lowest energy is $E_0=\frac{1}{2}\hbar\omega$

This level is ground state. E_0 is known as zero point energy as it does not vanish even at absolute zero temperature. The energy levels of harmonic oscillator are shown in figure. Energy levels are equidistant and separated by energy value $\Delta E=\hbar\omega$

Classically ⇒ It undergoes sinusoidal oscillation of amplitude $A=\sqrt{\frac{2E}{k}}$ and frequency $f=\left(\frac{k}{m}\right)^{1/2}/2\pi$. Kinetic and potential are equal to $\frac{k_BT}{2}$



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Ans 10 Alpha (α) : It is a large signal current gain in common base configuration. It is ratio of collector (output current) to emmitter current (input current)

$$\alpha = \frac{\text{collector current}}{\text{Emitter current}} \qquad \alpha = \frac{I_C}{I_E}$$

It is current gain in CB amplifier and it indicates that the amount of emitter current reaching to collector. It's value is unity ideally and practically less than unity.

Beta (β) : It is current gain factor in common emitter configuration. It is relation of collector current (output current) to base current (Input current)

$$\text{Beta} = \frac{I_C}{I_B}$$

(It is greater than 100 normally)

Gamma (γ) : It is current gain in common collector configuration and it is ratio of emitter current (output current) to base current (input current)

$$\gamma = \frac{I_E}{I_B}$$

It is also called emitter efficiency that how much current is injected from emitter to base. It's High than α, β.

Since, $I_E = I_C + I_B$ — eq (1)

Dividing by I_B

$$[\gamma = \beta + 1] \text{ — eq (2)}$$

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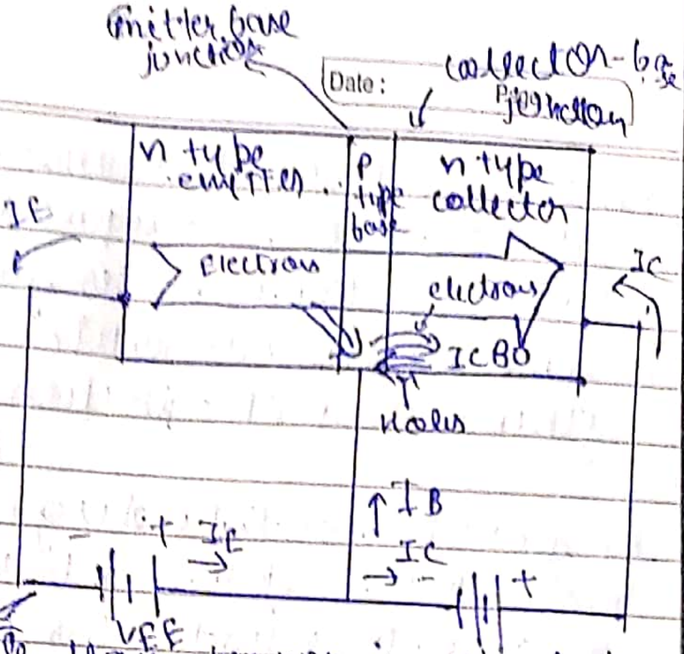
Dividing eq(1) by IE

$$1 = \alpha + \frac{1}{\gamma}$$

$$\boxed{1 - \frac{1}{\gamma} = \alpha} \quad \text{-- eq(3)}$$

from eq (2) and eq(3)

$$\boxed{\alpha = \frac{\beta}{\beta + 1}}$$



Principal particle flows when npn in active region or normal mode

Transistor action ⇒ Under forward bias, an intense injection of electron is not base region region take place and as a result the electron concentration in base region nearer to EB-junction steeply rises to a value many times higher than equilibrium value. Because of reverse bias at CB-junction, the electron concentration in the base region nearer to CB-junction is practically zero. Therefore a large concentration in base region is established pre.

Now the electrons in base region has two option:

1) One is that they may recombine with the holes in base causing huge base current. But due to light doping of base region, sufficient number of holes is not available recombination cannot take place in a large way. It is necessary that recombinations are precluded in base region, base current is very small.

2) As electron concentration is very high on emitter side and zero on collector side of base region, the possibility is that electrons swiftly diffuse towards the collector-base junction under the influence of concentration gradient across the base. The base region is narrow originally and is made further narrower due to the encroachment of depletion layers into the base and due to action of basies applied. Owing to this, electrons quickly reach the CB-junction. Once they arrive in the vicinity of the junction they will be acted upon by strong

electric field due to reverse bias and get swept into collector region. Consequently, a great majority of electrons emitted by emitter flow into the collector. It causes a large reverse current I_C which is nearly equal to I_E to flow accross CB-junction.

A small base current I_B is carried by few electrons that undergo recombination in the base. The emitter base junction is forward biased and therefore it has a low resistance. The collector-base junction is reverse biased and has a high resistance. Almost the same current flows through the two junctions. Thus the current is transferred from a low resistance to high resistance. Hence it is called trans-resistor (transistor).

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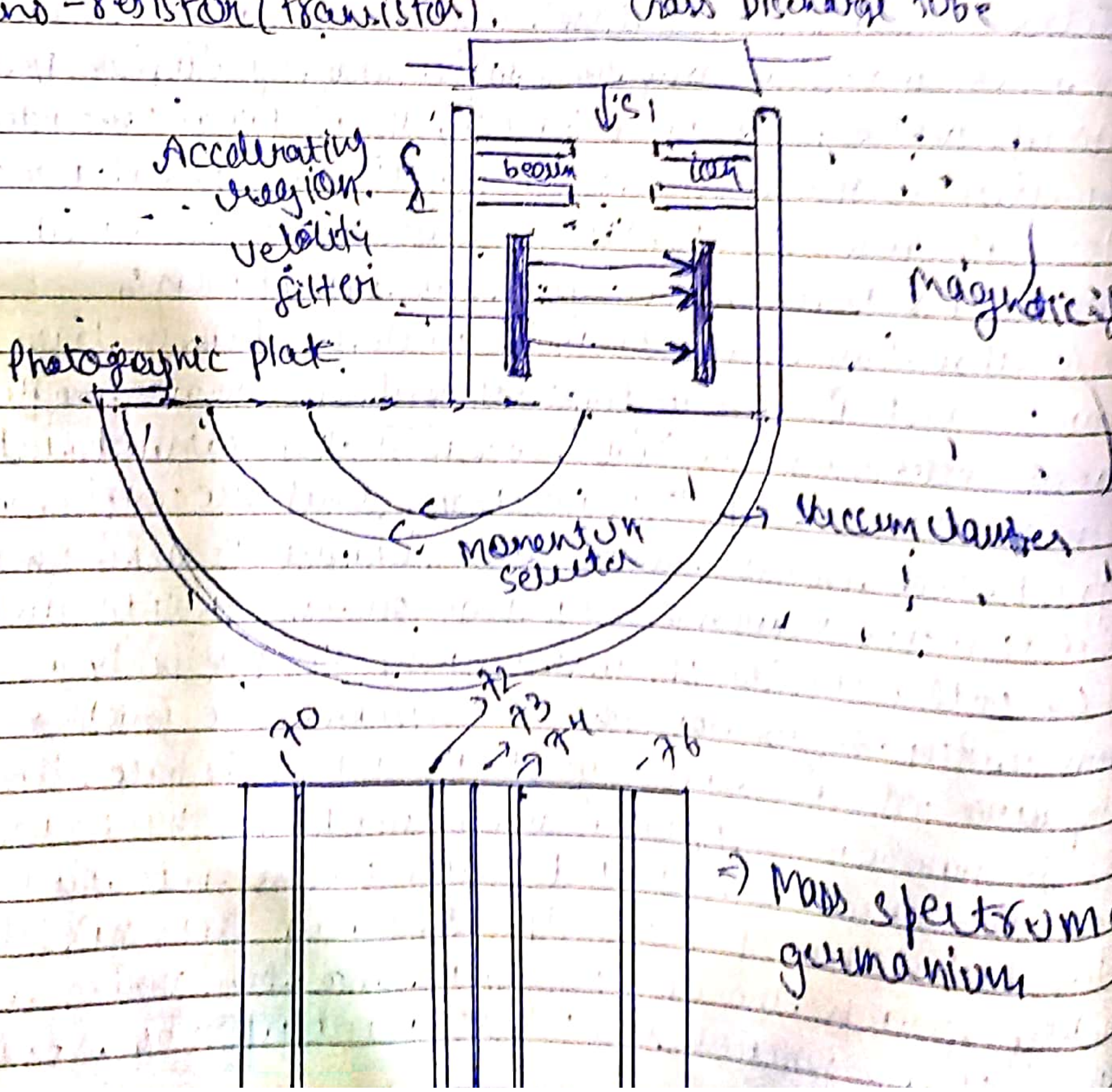

→ Mass spectrum of germanium

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Working :

The element under study is taken in form of gas and Introduced into a discharge tube. The gas is Ionized under the action of applied voltage and positive ions, which are formed in the discharge tube, are accelerated and conducted into the spectrograph through slits S_1 and S_2. Most of the positive ions formed will carry a charge of +1 because it is much more difficult to remove further electrons from an already positive ion. The ion beam, thus consisting of ions carrying a positive charge of +1, posses a wide range of velocities $V \pm \Delta V$. It is then passed through the velocity selector. It consists of combination of uniform electric and magnetic fields in crossed configuration. The electric field E is produced in horizontal direc^n by a set of charged parallel plates PQ and uniform magnetic field B is applied normal to E in same region. Both E and B act normal to ion path. Electric field produces a dispersion of ions with respect to velocity ($= E/B$). do not experience any net force and they continue to travel along the initial direction. Ions travelling with velocities differing from V are deflected sideways and are absorbed by metal plates. Therefore, a strictly mono velocity ion stream, having a velocity $v = E/B$, issues out of velocity selector. This beam of ribbon shape, then passes through the slit S_3 and enters analyzing chamber. The uniform magnetic field B acting on chamber plays the role of momentum selector. Ions of different mass are deflected along circular path of different radii depending on their momentum and strike plate after completion of semicircular movement. They leave vertical lines on plate, which resemble spectral lines formed by light. Hence it is called as mass spectrum. The number of lines on the plate correspond to number of isotopes. Considering isotope with a mass M_1, $R = \frac{MV}{Bq}$ but as $V = \frac{E}{B}$ than $R = \frac{ME}{qB^2}$

distance of line is x $\therefore x = 2R$

$$M = \frac{qB^2}{2E}x, \quad M = kx.$$

$M \propto x$

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the relation between M and x is known, mass can be obtained from E, B, x by proper calibration. Relative masses of two isotopes involve only measurement of x. If M_1 and M_2 are masses of two isotopes, x_1 and x_2 are distance from S_3

line separation $(\Delta x) = x_2 - x_1 = \frac{2E}{qB^2}(M_2 - M_1)$

Ans 12

Einstein coefficients: (1) The probability that an absorption transition occurs is given by $P_{12} = B_{12}\,\rho(\nu)$ where B_{12} is the constant of proportionality known as Einstein coefficient for induced absorption. It is constant characteristic of the atom and represent the properties of energy states E_1 and E_2.

(2) The probability that a spontaneous transition occurs is given by (P_{21}) spontaneous $= A_{21}$

where A_{21} is a constant known as the Einstein coefficient for spontaneous emission. A_{21} is a constant characteristics of the atom and is known as radioactive rate measured in unit of s^{-1} is the lifetime of upper state against decay to lower 21 state.

3) The probability that a stimulated transition occurs is given by (P_{21}) stimulated $= B_{21}\,\rho(\nu)$

where B_{21} is constant of proportionality known as Einstein coefficient for stimulated emission. It is constant characteristic of atom and represents properties of energy state E_1 and E_2.

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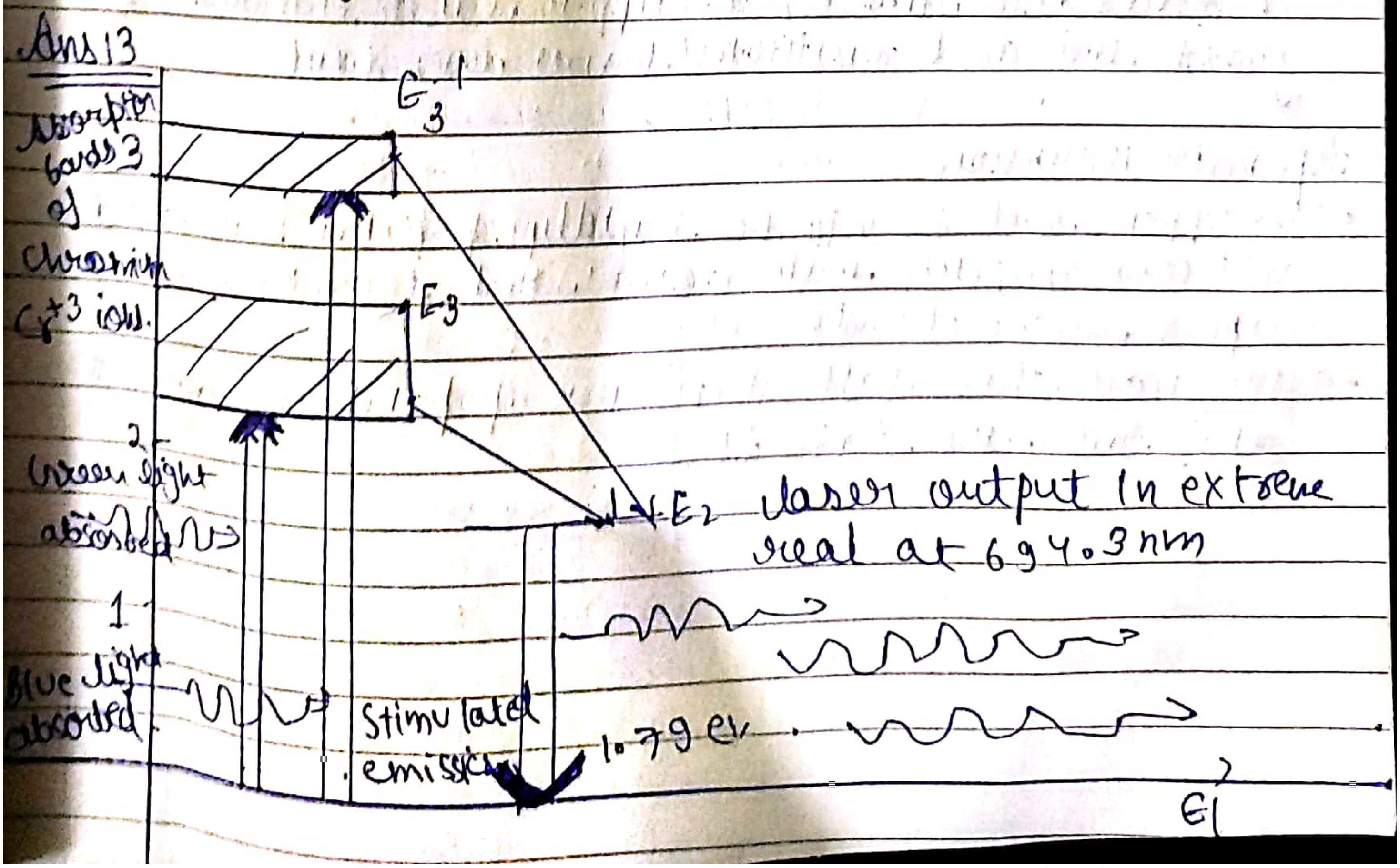
Relation: $B_{12} = B_{21} = \frac{c^3}{8\pi h \nu^3 \mu^3} A_{21}$

Significance: 1) The relation shows that the coefficient for both absorption and stimulated emission are equal. The equality implies that when an atom with two energy levels is placed in radiation field, the probability for an upward (absorption) transition is equal to probability for a downward transition

2) The relation shows that the ratio of coefficient of spontaneous versus stimulated emission is proportional to third power of frequency of radiation. This is why it is dificult to achieve laser action in high frequency ranges such as x rays.

Ans 13



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Working: The energy levels of Cr^{+3} ions in crystal lattice. The energy level structure of Cr^{+3} ions is characterized by two absorption bands and a metastable state.

The pumping Mechanism

- When the xenon flash lamp is switched on, the discharge generates an intense burst of white light lasting for a few milliseconds.
- The Cr^{+3} ions are excited to energy bands E_3 and E_3^+ by green and blue components of white light
- The Cr^{+3} ions undergo non-radiative transitions from the energy level to level E_2. E_2 is metastable state.
- The metastable state E_2 has a lifetime of approximately 100 times more than the lifetime of E_3 and E_3^+ level. Therefore Cr^{+3} ions accumulate at E_2 level.
- The metastable level E_2 is upper laser level while E_1 is ground level and constitutes lower laser level

Population inversion
- The upper level E_2 will be rapidly populated as excited Cr^{+3} ions quickly make downward transition from upper energy bands
- When more than half of Cr^{+3} ion population accumulates at E_2 level, the state of.

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Lasing

- A chance photon is produced when Cr^{3} ion make transition from E_2 to E_1 level
- This photon stimulates another excited ion to make a downward transition.
- This photon and initial photon trigger many excited ion to emit photons
- Red photons of wavelength 6943Å travelling along axis of ruby rod are repeatedly reflected at end mirrors and light amplification ocurs.
- On attaining sufficient energy, beam emerges out partially through mirror
- The laser becomes active once again when population state is reestablished and output of laser is not a continuous wave but occurs in form of pulses of microsecond duration

Ans 4

Spontaneous emission	Stimulated emission
1) Random and probabilistic process	Not a random process
2) Not amenable for control from outside	Amenable for control from outside
3) Photons are emitted haphazardly. Instant of emission, direction, polarization state are random	Stimulating photon imposes its characteristics on photon emitted
4) Photons are emitted uniformly in all direction.	4) Photons emitted in same direc^n as of stimulating photon.
5) Photons of slightly different frequencies are generated	Spread of photons frequencies is less, light is nearly monochromatic
6) Photons do not have any correlation in phases. (Incoherent)	Photons emitted by process are all in phase and therefore coherent
7) Light is unpolarized	Light is polarized
8) No amplification of light	Amplification of light takes place
9) Net intensity of generated light is given by $I_T = NI$ where N is number of atom emitting photons. I is intensity of photons	9) As all the photon are in phase. They constructively interfere and produce an intensity $I_T = N^2 I$

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Ans 15 Metastable states :- An atom can be excited to a higher level by supplying energy to it. Normally, excited atoms have short lifetimes and release their energy in a matter of nanoseconds (10^{-9} s) through spontaneous emission. It means that atoms do not stay long enough at excited state to be stimulated. As a result, even through the pumping agent continously raises the atoms to excited level, they undergo spontaneous transition and rapidy return to the lower energy level. Population inversion cannot be established under such circumstances. In order to establish the condition of population inversion the excited atoms are required to 'wait' at the upper energy level till a large number of atoms accumulate at that level. Such as opportunity would be provided by metastable state. Atoms excited to a metastable state remain excited for an appreciable time, which is order of 10^{-6} to 10^{-3} s. This is 10^3 to 10^6 times the lifetimes of ordinary excited energy levels. Therefore metastable state allows accumulation of large number of excited atoms at that level. The metastable state population can exceed the population at a lower level and establish the condition of population inversion in the lasing medium. It would be impossible to create state of population inversion without a metastable state. Metastable state can be readily obtained in crystal system containing impurity atom. These levels lie in forbidden band gap of host crystal. Population Inversion readily takes place as the lifetimes of these levels are large and secondly, there is no competion in filling these levels as they are localized levels. for example, Phosphorescent materials are made up of atoms with metastable states. There would be no population inversion hence no laser action, if metastable does not exist.

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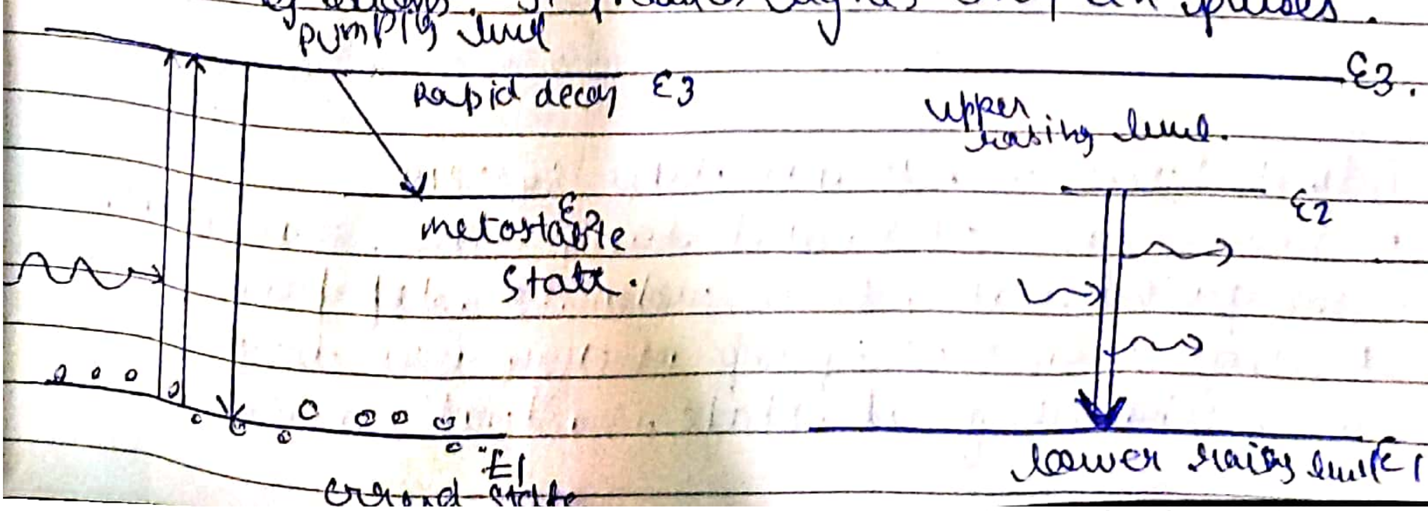
Role ⇒ The simplest conceivable system, such as the ammonia maser built by Townes has only two energy levels. More useful laser system involve three or four energy levels. In a three-level laser, the material is first excited to a short lived high energy state that spontaneously drops to a somewhat lower energy state with an unusually long lifetime (metastable state) It traps and holds excitation energy, building up a population inversion that can be further stimulated to emit radiation dropping species back to ground state. Ruby laser is an example

Ans 16 Three level laser system :⇒ The three level scheme first excites the atoms to be an excited state higher in energy than upper laser state. The atoms then quickly decay down into upper laser state. It is important for pumped state to have a short lifetime for spontaneous emission compared to upper laser state. When a medium is exposed to pump frequency radiation, a large number of atoms will be excited to E_3 level. However, they donot stay at that level but rapidly undergo downward transition to metastable state E_2 through non-radioactive transitions. The atoms are trapped at this state as spontaneous transition from level E_2 to E_1 is forbidden. The pumping continues and after short time there will be large accumulation of atoms. It produces lights only in pulses.



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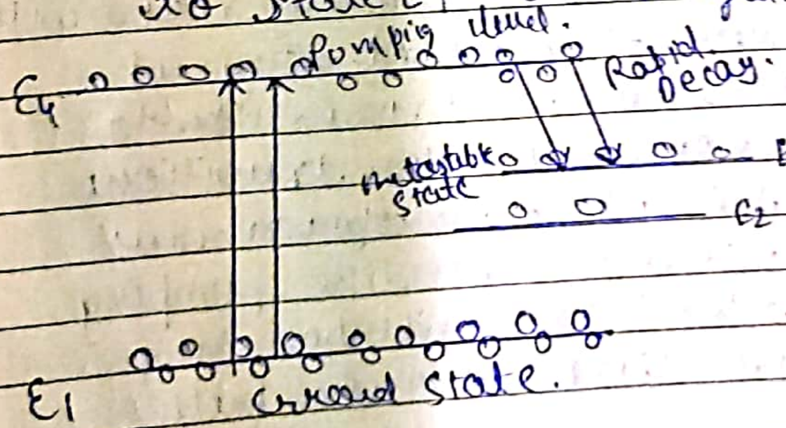
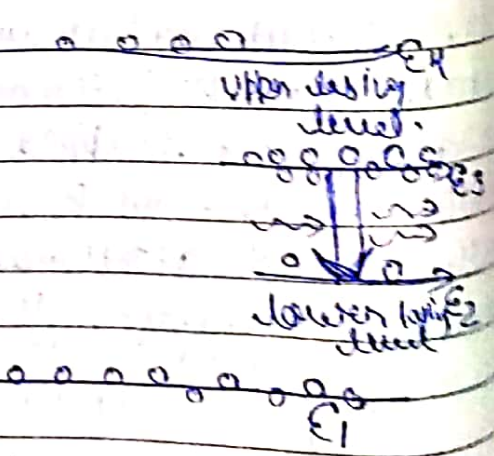
Four level system: E_1 is in ground state, E_4 is pumping level, E_3 is metastable upper lasing level, E_2 is lower lasing level. When light of pump frequency is incidence on lasing medium the active centres are readily excited from ground state to pumping level E_4. The atoms stay at the E_4 level for only about 10^{-8} s and quickly drop down to state E_3, As spontaneous transitions from level E_3 to level E_2 cannot take place, the atoms get trapped in E_3. The population at state E_3 grows rapidly. The level E_2 is well above ground state such that $E_2 - E_1 > kT$. Therefore at normal temperature atoms cannot jump to level E_2. As a result E_2 is empty. A chance photon of energy $h\nu = (E_3 - E_2)$ emitted spontaneously can start the chain and bring atoms to level E_2. From E_2 atoms go to state E_1 and once again available for excitation.





Advantages of using 4 level laser system.

- In the case of 3 level laser - the lower state is the ground state, so in order to depopulate it a large amount of pump energy must be put in so that the ground state is actually in lower

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concentration than exited state. The only way to depopulate the ground state is to put in more and more pump energy. In case of 4 level laser, only a modest pump energy may be sufficient to establish a population inversion between states 3 and 4. If state 3 is relatively long lived and state 4 is short lived.

- In 4 level laser with the help of pumping the atoms from ground state n_1 are raised to excited state n_4 from the n_4, the atoms decay to n_3 by spontaneous emission. The transition rate of atoms from n_4 to n_3 is much faster because of life time is very small.

- In 3 level laser atom can stay for longer lifetime than excited state (n_4) but dexcitation from n_3 to n_2 will slow down

Ans A

Holography: In 1948 dennis Gabor outlined a two step lensless imaging process. It is radically a new technique of photographing the object and is known as wave front reconstruction. The technique is also called holography. The word 'holography' is made by two words holo means whole and graphy means to write. Thus hollography means writing the complete image. It is actually a recording of interference pattern formed between two beams of coherent light coming from same source. In this process both the amplitude and phase component of light wave are recorded on a light sensitive media. Recording is known as hologram. Holography required an intense coherent source. Holographic technique came possible after invention of lasers.

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Application

1) Photolithography: Holography is used in production of photographic masks used to produce microelectronic circuits

2) Holographic projection is used to display flight information at the pilot's eye level in airplane cockpit.

3) Microscopy: Holography can be used in technique of microscopy. It is possible to obtain a magnified image. image of an object if recording is done with light of smaller wavelength and reconstruction with light of longer wavelength.

4) 3-D photography: One of most obvious applications of holography is production of 3-D photograph, with the distance and orientation of each point of object recorded in image

5) Data storage: Holograms can also be used for data storage devices and hence are of much use in computer technology. A large amount of information such as 1012 letters/ digits can be stored in cubic cm of volume Hologram.

In Medical.

Holography in Orthopedics: Holography offers an excellent tool for contactless study of orthopedic structures, specifically external fixtures to measure strains on fixation pins and rods. Such studies are important in osteosynthesis with external fixtures used for long bone fractures.

Diffractive bifocal intraocular lens: A very useful application of diffractive optics is in correct of refractive errors for old person.

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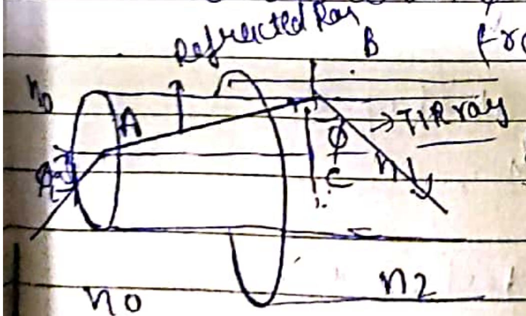
Ans 18 Acceptance angle: let us assume an optical fibre with outer zone having refractive index n_0, index of core be n_1 and cladding index be n_2.
Assume that a light ray enters the fibre at an angle θ_i to the axis of fibre. The ray refracts at an angle θ_r and strikes the core - cladding interface at an angle ϕ. If ϕ is greater than critical angle ϕ_c the ray undergoes (TIR) at interface, since $n_1 > n_2$. As long as angle ϕ is greater than ϕ_c, light will stay within the fibre

Applying snell's law

$$\frac{\sin\theta_1}{\sin\theta_r} = \frac{n_1}{n_0}$$

If θ_i is increased beyond a limit ϕ, will drop below critical value ϕ_c. The largest value of θ_1 occurs when $\phi = \phi_c$



from ΔABC.

$$\sin\theta_r = \cos\phi$$

Since $\sin\theta_1 = \frac{n_1}{n_0}\cos\phi$

$$\sin[\theta_{i\,max}] = \frac{n_1}{n_0}\cos\phi_c$$

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

$$\sin[\theta_i(max)] = \frac{\sqrt{n_1^2 - n_2^2}}{n_0}$$

$n_0 = 1$ (air medium)

$$\sin\theta_0 = \sqrt{n_1^2 - n_2^2}$$

$$\theta_0 = \sin^{-1}\sqrt{n_1^2 - n_2^2}$$

This θ_0 is acceptance angle. It is maximum angle that a light ray can have relative to axis of fibre

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Ans19

Step index fibre	Graded index fibre
1) Refractive index of core is uniform and there is a sharp decrease at cladding	1) Refractive index is maximum at centre core and it decreases towards core-cladding interface
2) It is found in two types • Mono mode • Multi-mode	2) It is found only of multi-mode fibre.
3) Index profile are in shape of step	3) Index profile is in shape of parabolic curve.
4) The light rays propagates in zig-zag manner inside the core	4) Light rays propagates in form of skew or hellical rays.
5) Fibre has lower bandwitch.	5) Fibre has higher bandwith
6) Signal distortion is more in case of high-angle rays in multimode step index fibre.	6) Signal distortion is very low even though rays travel with different speed.
7) Used for short distance communication.	7) Used for long distance communication
8) Diameter is 50-200μm in multimode and 10μm in single mode	8) Diameter is 50μm in case of multimode
9) Pulse broadcasting is present.	9) No pulse broadcasting available.

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Ans 20 Special theory of relativity is based on following Two postulates

1) The principle of relativity: All laws of physics are same in all inertial frame of reference
2) The principle of independence of velocity of light: Speed of light in vaccum is independent of motion of light source or reciever.

The term "special" implies that this theory considers phenomena only in inertial reference frame. The first postulate is, in effect a generalization of Galilean principle of relativity to cover all physical processes. All physical phenomena proceed identically in all reference frames. All physical laws are absolutely identical in all inertial systems. Basically, no experiment can distinguish one of the frames ~~as~~ as preferable. Thus, Einsteins principle of relativity establish complete equality of all inertial frame and rejects the Newton's ideas of absolute space and absolute motion.

The second postulates states that the velocity of light in vaccum has same value for all observers and is independent of their motion of light source. In contrast to all other velocities, which change on transition from one reference frame to another, velocity of light in vaccum is invariant. This invariance of velocity of light requires that we modify some of our intuitive, everyday notions of space and time.

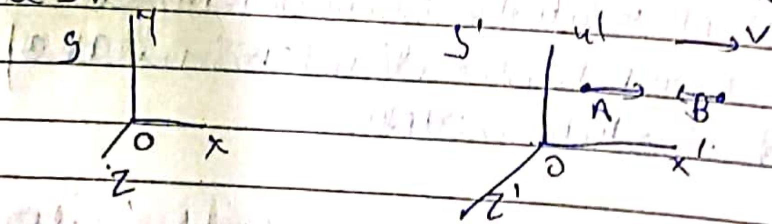
Ans 21

1) There is variation of mass with velocity in relativity that is mass varies with velocity when velocity is comparable with the velocity of light.

2) Let there are two inertial frames of refrences S and S_1. S is stationary frame of refrence and S' is moving frame of refrence. At time $t = t' = 0$ that is in the start, they are at the same position that is observer O and O' coincides. After that S' frame starts moving with a uniform velocity v along x axis

4 Suppose there are two particles moving in opposite direction in frame S', velocity of particle A will be u' and B will be -u' according to observer O'.

let us study the velocities and mass of these particles from frame S.



Velocity of A is u_1 and B is u_2 from frame S and these are given by

$$u_1 = \frac{(u'+v)}{1+u'v/c^2} \quad \text{--eq (1)}$$

$$u_2 = \frac{(-u'+v)}{(1-u'v/c^2)} \quad \text{- eq (2)}$$

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Let M_1 and M_2 are Mass of A and B from frame S respectively. As the particles are moving to each other at certain instant they will collide and momentarily came to rest. But even when they come to rest. But even when they come to rest, they travel with velocity of frame S' with v.

According to law of conservation of momentum.

$$m_1u_1+m_2u_2=(m_1+m_2)V=m_1V+m_2V$$

$$\text{or } m_1(u_1-V)=m_2(u_2-V).$$

Put eq (1) and (2) we get

$$m_1/m_2=\frac{(1+u'V/c^2)}{1-u'V/c^2}$$

Now square equation (1), then divide both sides by c^2 and subtract both sides by 1, we get

$$1-u_1^2/c^2=1-[(u'+V/c\,(1+u'V/c^2)]^2 \text{ -- eq (4)}$$

Similarily by squaring eq (2) and then dividing both side by c^2 and subtracting both sides by 1, we get

$$1-u_2^2/c^2=(1+u'^2V^2/c^4-u'^2/c^2-V^2/c^2)/(1-u'V/c^2)^2 \text{ -- eq (5)}$$

On dividing eq (5) by (4) we get

$$(1-u_2^2/c^2)/(1-u_1^2/c^2)=(1+u'V/c^2)^2/(1-u'V/c^2)^2$$

Take square root on both side.

$$(1-(u_2^2/c^2))^{1/2}/(1-u_1^2/c^2)^{1/2}=(1+u'V/c^2)(1-u'V/c^2) \text{ -- eq (6)}$$

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Now compare eq (3) and 6 we get

$$m_1/m_2 = (1-u_2^2/c^2)^{1/2} / (1-u_1^2/c^2)^{1/2} \quad eq(7).$$

let us assume, $u_2 = 0$

$m_2 = m_0$

where m_0 is rest mass of particle.

therefore eq (7) becomes,

$$m_1/m_0 = 1/(1-u_1^2/c^2)^{1/2}$$

4

assuming $u_1 = v$, $m_1 = m$.

$$m/m_0 = 1/(1-v^2/c^2)^{1/2}$$

$$\boxed{m = m_0/(1-v^2/c^2)^{1/2}}$$

This equation represent variation of mass with velocity

Ans22 Lorentz transformation: Equation that apply for all speeds up to c and incorporate the invariance of speed of light:

Let us consider two inertial reference frame S and S' in which standards for measuring distance and time are same. let reference systems be stationary while S' is moving with velocity v. let us assume $t = t' = 0$ and origin O and O' coincide. A light source is placed at origin emits a light pulse. light pulse travels in the form of a spherical wave at speed c in both frames

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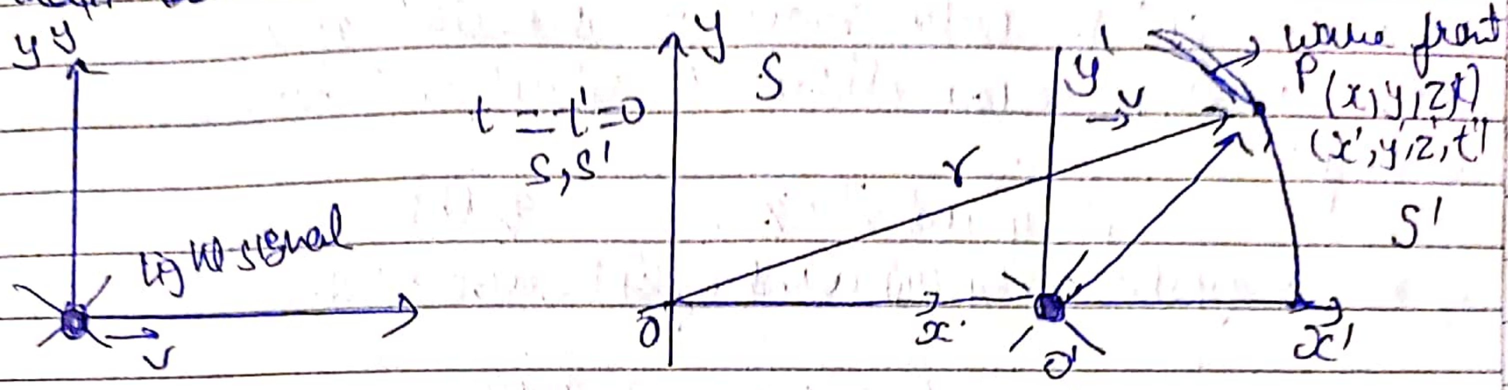
Then during time interval t' the light pulse travels distance ct and in 's' frame it travels 'ct'' during time interval t'. In both the frames the points reached by light pulse at t and t' respectively lie on spherical surface of radii ct and ct'.



$$r = ct \quad \text{--- eq (1)}$$

Thus, $r' = ct'$ --- eq (2)

The wave surface in frame S is described by equation

$$x^2 + y^2 + z^2 = r^2 = c^2 t^2 \quad \text{--- eq (3)}$$

and in frame S' by equation

$$(x')^2 + (y')^2 + (z')^2 = c^2 (t')^2 \quad \text{--- eq (4)}$$

As space and time are regarded as homogenous, the relation between the coordinates and time in different frames must be linear thus

$$x' = ax + bt = a\left[x + \left(\frac{b}{a}\right)t\right] \quad \text{--- eq (5)}$$

$$t' = fx + gt \quad \text{--- eq (6)}$$

At time t, the origin s' is at $x = vt$, for the position $x' = 0$,

$$0 = a[vt + (b/a)t]$$

$$b/a = -v.$$

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Hence we get

$$x' = a(x - vt) \quad \text{--- eq(7)}$$

Similiarily. $x = a(x' + vt')$ --- eq (8).

Since the system only move in direction of x and x' axes, the coordinates y, y' and z, z' does not changes

$$y' = y \text{ and } z' = z \quad \text{--- eq (9)}$$

from equation, eq (4) and eq (7) and eq (3)

$$x' = ct' = a(ct - vt) = act(1 - v/c) \quad \text{--- eq (10)}$$

$$x = ct = a(ct' - vt') = act'(1 - v/c) \quad \text{--- eq (11)}$$

from equation (10)

$$t' = at(1 - v/c)$$

using eq (11)

$$ct = ac[at(1 - v/c)](1 + v/c)$$

$$= a^2 ct(1 - v^2/c^2)$$

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

replacing a by γ $\Rightarrow$ $\gamma = \dfrac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$ --- eq (12)

using eq (7) and eq (12).

$$x' = \frac{x - vt}{\sqrt{1 - \frac{v^2}{c^2}}} \quad \text{--- eq (13)}$$

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$$t' = \frac{x'}{c} = \frac{\frac{x}{c} - \frac{vt}{c}}{\sqrt{1-\frac{v^2}{c^2}}}$$

but $x = ct$

$$t' = \frac{t - \frac{vx}{c^2}}{\sqrt{1-\frac{v^2}{c^2}}}$$

Thus, the equation for ~~[illegible]~~ transformation of coordinates from system S to system S' are.

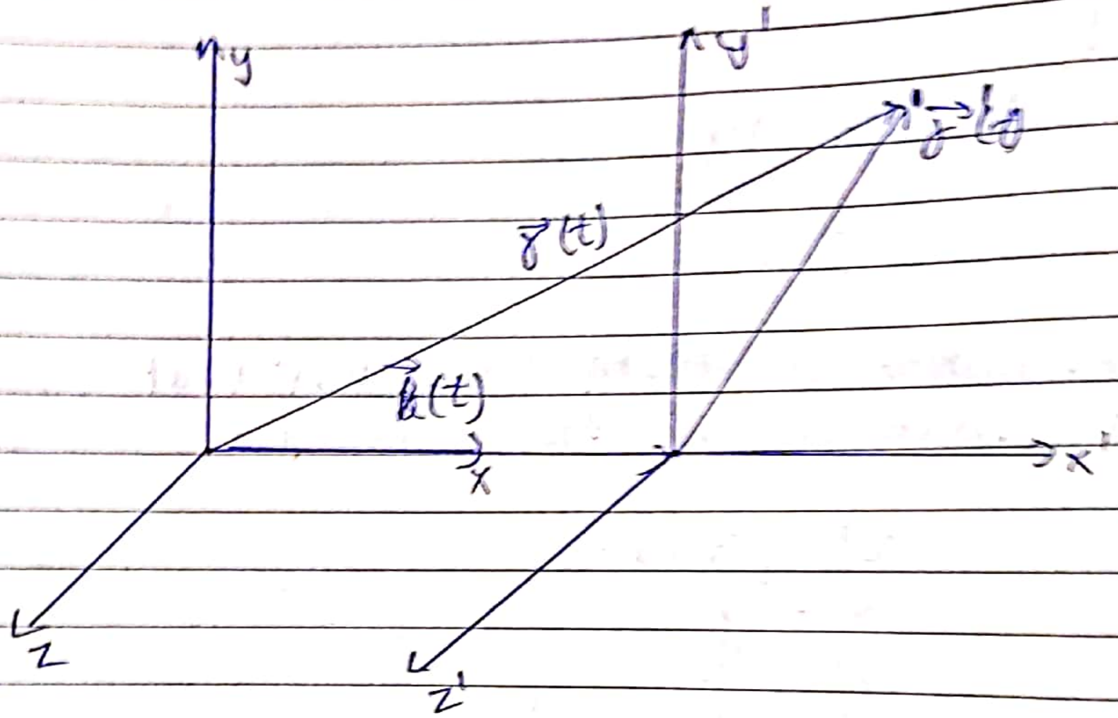
$$x' = \gamma(x+vt)$$
$$y' = y$$
$$z' = z$$
$$t' = \gamma\left(t - \frac{vx}{c^2}\right)$$

and $\gamma = \dfrac{1}{\sqrt{1-\frac{v^2}{c^2}}}$

Ans 23

Inertial frame	Non inertial frame
(Ex → train moving with uniform velocity)	Ex → free falling elevator.
1) A frame of refrence travelling with uniform velocity with respect to main ~~another~~ frame.	1) A frame of refrence travelling with non uniform velocity with respect to main frame.
2) Newton laws of motion are valid	2) Newton's laws of motion is not valid.
3) forces which depends upon distance difference ex: gravitational force, nuclear force are same.	3) forces which are additional due to newton's law is not valid helps in non inertial frame ex: centrifugal force, corioli's force

(b) S and S' be two inertial frames with relative velocity v_0 ~~and same~~.



Since $r(t) = R(t) + r'(t)$

by differentiating both side

$$\Delta r(t) = \Delta R(t) + \Delta r'(t)$$

Since relative velocity is always constant in inertial frames

$$v(t) = v_0 + v'(t)$$

again differentiating since acceleration between frames is zero

$$a = 0 + a'$$

$$\boxed{a = a'}$$

And since principle of relativity holds true all laws of physics is valid

Ans 24 is on last :

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Ans: 25 length contraction:

Let us consider a rigid rod at rest in a moving frame S'; say a spaceship or railcar moving along x axis with a speed v. The length of rod is equal to difference between coordinates of it's two end points. Thus an observer in spaceship measures length of rod to be

$$L_0 = x_2' - x_1'$$

L_0 is proper length (length of body measured in reference frame in which body is at rest).

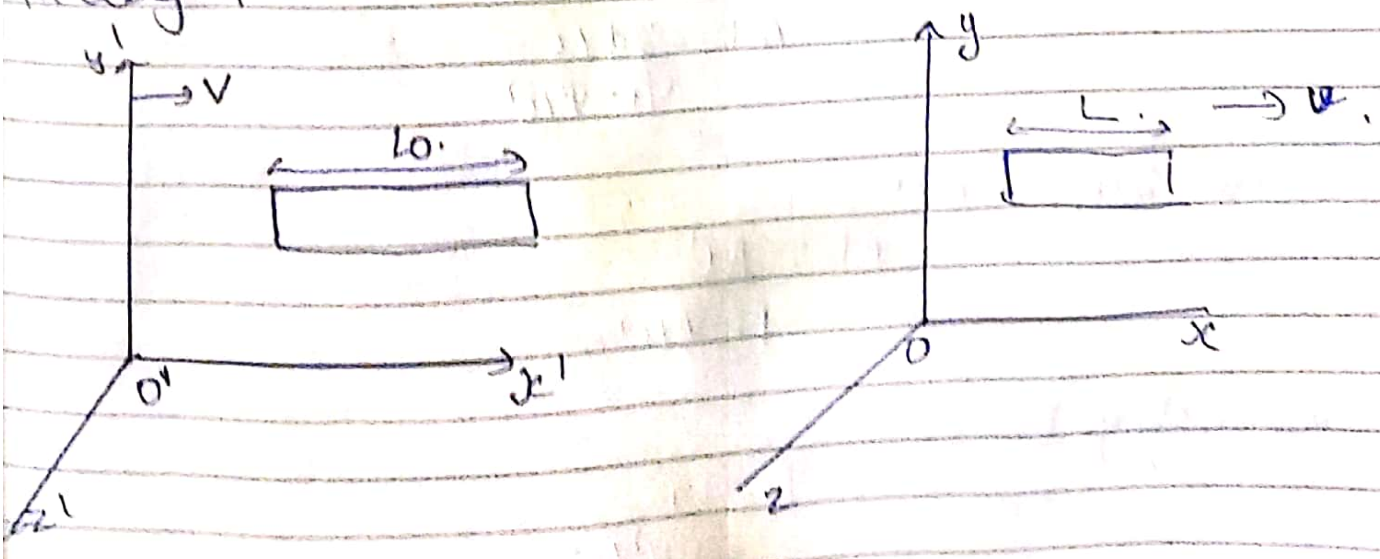
An observer on earth frame S will have to determine length of rod by marking the forward end position and rearward end position in frame S.

According to Lorentz coordinate transformation

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

$$L_0 = x_2 - x_1 = \frac{L}{\sqrt{1 - v^2/c^2}}$$

Hence the change in length is known as contraction in length



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Time dilation :

Let us consider a railcars moving to right with a speed v & let car have a mirror fixed to it's ceiling. An observer at rest in car sends off a light pulse at some instant towards the mirror. The light pulse travels (upward) at speed c gets reflected at mirror at top and comes back to observer. Observer measures time interval $\Delta t'$ for round trip of pulse with help of clock.

time t' is measured by stationary observer in s' frame then it's proper time T_0, $\Delta t' = 2d/c$.

where d is distance between source of light pulse.

From point of view of an observer on ground, the mirror and light source are moving to right with speed v, By time pulse hits the mirror, the mirror will have moved a distance equal to $v(\Delta t/2)$ where Δt is time taken by light pulse for its round trip from geometry

$$\left[\frac{c(\Delta t)}{2}\right]^2 = \left(\frac{v\Delta t}{2}\right)^2 + d^2$$

$$(c^2 - v^2)(\Delta t)^2 = 2d^2$$

$$\Delta t = \frac{2d/c}{\sqrt{1-v^2/c^2}}$$

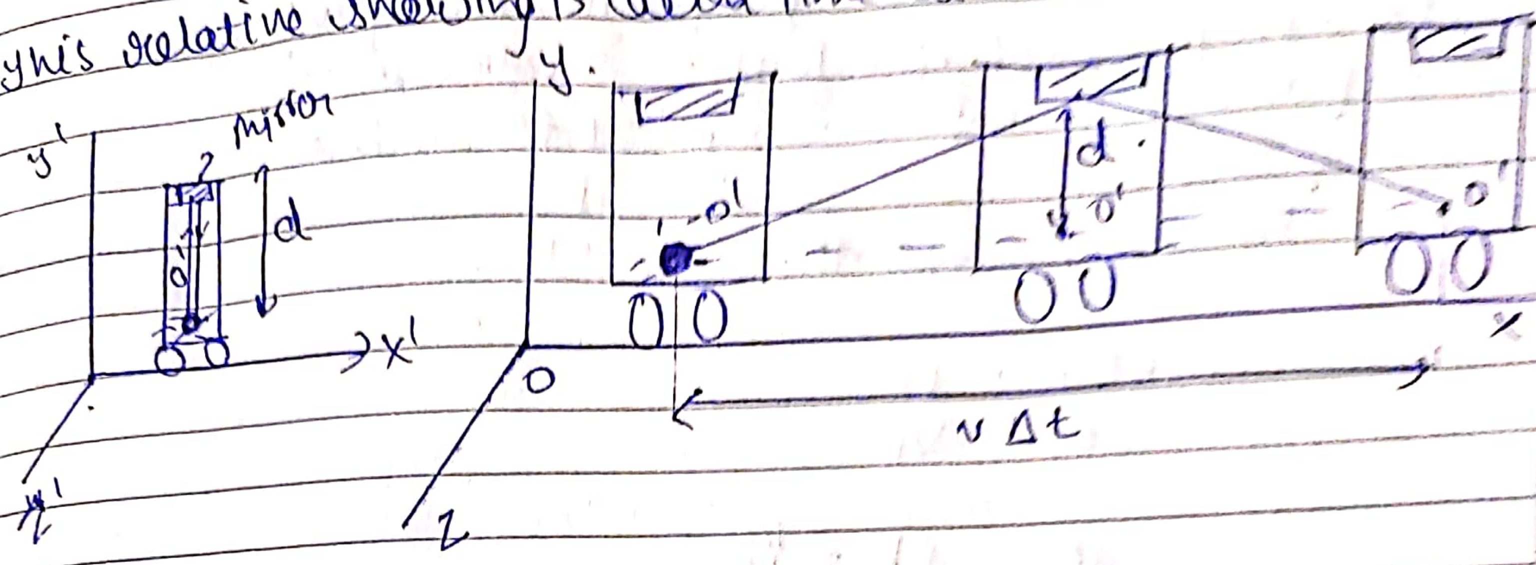
Since $2d/c = \Delta t'$

$$\Delta t = \frac{\Delta t'}{\sqrt{1-v^2/c^2}}$$

Designating $\Delta t = T$,

$$T = \frac{T_0}{\sqrt{1-v^2/c^2}}$$

This relative showing is called Time dilation



Ans 26

Bethe's law: The electron traveling in space bend and follow curved path when they travel through regions of different electric field strengths. The behavior is similar to light rays. By analogy the bending of electrons is called electron refracty.

On accont of nonuniform fields, equipotential surface shall be curved. Let potential on surface 1 will be V_1, potential on 2 will be V_2. let $V_2 > V_1$.

Electron starting from rest traveling in surface 1 has velocity v_1.

$$v_1 = \sqrt{\frac{2eV_1}{m}}$$

and on surface 2 it has velocity $v_2 = \sqrt{\frac{2eV_2}{m}}$

let angle b/w path of electron at it and normal to surface 1 be θ_1, and on surface 2 is θ_2.

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Tim — As electric field is proportionally perpendicular to equipotential surfaces; electron does not experience any force tangential to surface,

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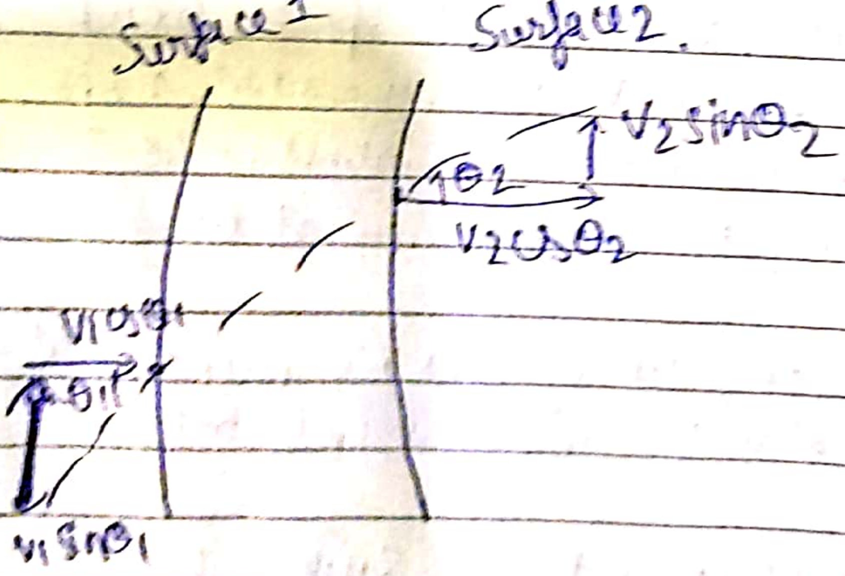
$$v_1 \sin\theta_1 = v_2 \sin\theta_2$$

$$\frac{\sin\theta_1}{\sin\theta_2} = \frac{v_2}{v_1}$$

$$\frac{\sin\theta_1}{\sin\theta_2} = \left[\frac{V_2}{V_1}\right]^{1/2}$$

This equation is known as bethe's law



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Ans 24 Michelson Morley ⇒ A collimated beam of light from source S is split into two beams by half silvered mirror M. Beam A travels to mirror M_1 and reflected back to M and is transmitted through M. Let us assume that earth travels through ether with speed v and light has speed c in ether. We assume that instrument is arranged such that two equal arms is parrallel to earth velocity V. Speed of beam A travelling from M to M_1 is $(C-V)$ relative to instrument and time required is $L/C-V$. Similarly speed of light beam is $(C+V)$. Time is $L/C+V$

Time for round trip

$$T_A = \frac{L}{C-V} + \frac{L}{C+V} = \frac{2L/C}{1-\frac{V^2}{C^2}}$$

The beam B is travelled towards mirror M_2 will get reflected at M_2 but mirror M has moved to a new position M'. The component of velocity of light in direction perpendicular to motion of instrument is $\sqrt{c^2-v^2}$.

$$T_B = \frac{2L/C}{\sqrt{1-\frac{v^2}{c^2}}}$$

Time difference is given by $\Delta T = T_A - T_B = \frac{2L}{c}\left[\frac{1}{1-\frac{v^2}{c^2}} - \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}\right]$

Since v is small compared to c

$$\frac{1}{1-\frac{V^2}{C^2}} = 1+\frac{v^2}{C^2} \quad \text{and} \quad \frac{1}{\sqrt{1-\frac{V^2}{C^2}}} = 1+\frac{v^2}{2c^2}$$

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$$\Delta T = \frac{2L}{c}\left[1+\frac{v^2}{c^2} - 1 - \frac{v^2}{2c^2}\right] = \frac{Lv^2}{c^3}$$

Now, if instrument is rotated through 90° role of path A and B are interchanged. Hence

$$T_A' = \frac{2L/c}{\sqrt{1-\frac{v^2}{c^2}}} \qquad T_B' = \frac{2L/c}{1-v^2/c^2}$$

$$\Delta T' = T_A' - T_B' = -\frac{Lv^2}{c^3}$$

$$\Delta T_{Total} = \frac{2Lv^2}{c^3}.$$

path difference introduced between beam component A and B is

$$\Delta = c(\Delta T_{Total}) = \frac{2Lv^2}{c^2}$$

The result was negative since we found no difference between speed of light in direction of movement through presumed ether and speed at right angles, more recent optical resonator experiences confirmed absence of any ether wind at 10^{-17} level

In Michelson Morley, $\lambda = 5500\,Å$, $v = 30\,km/s$

we obtain $N = \frac{2 \times 11\,m \cdot (3\times10^4)^2}{5500\times10^{-10}\times(3\times10^8)^2} = 0.4$

$\left[N = \text{Path difference} \right.$

$= \frac{2Lv^2}{\lambda c^2}$

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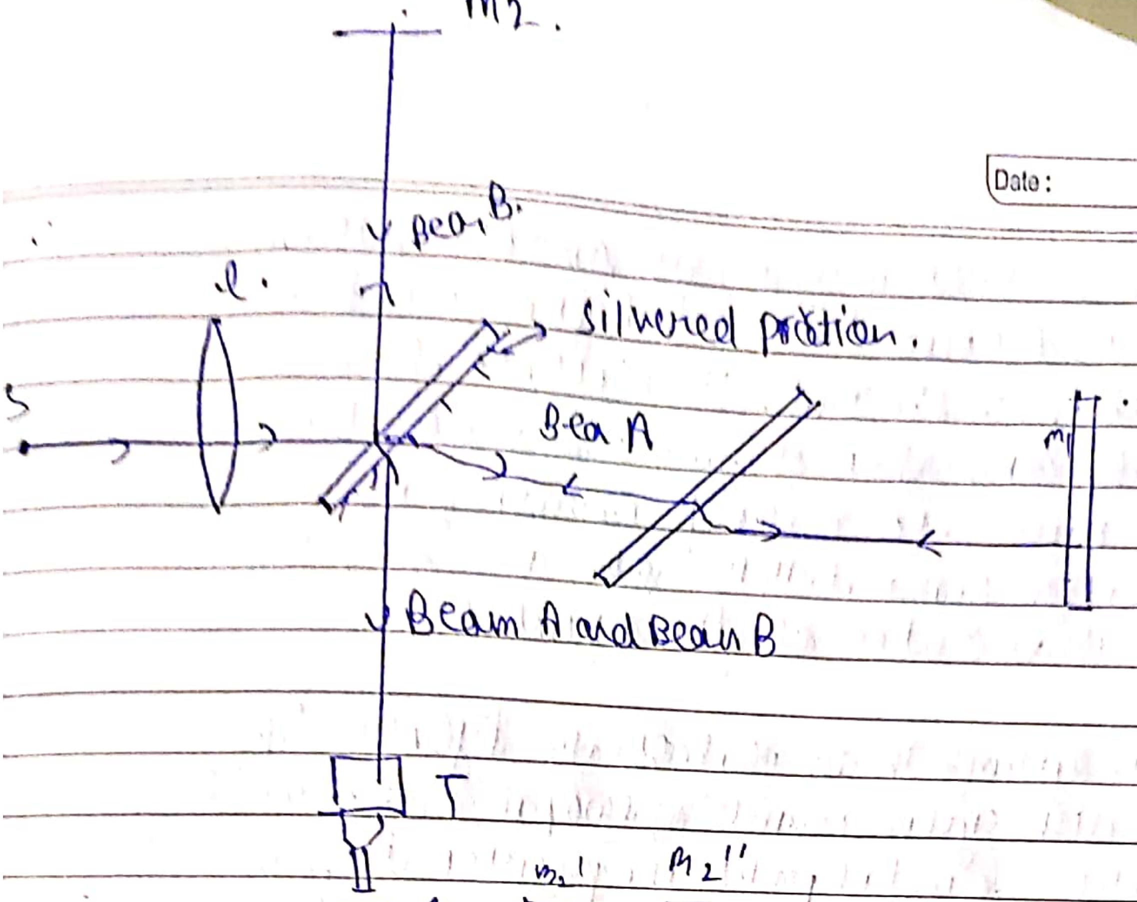
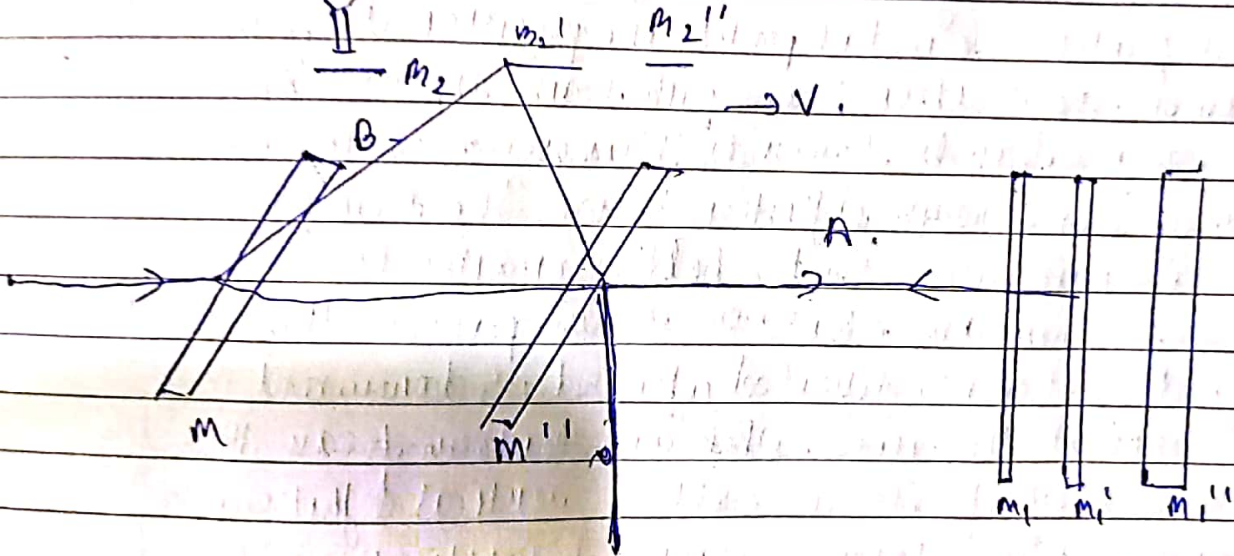




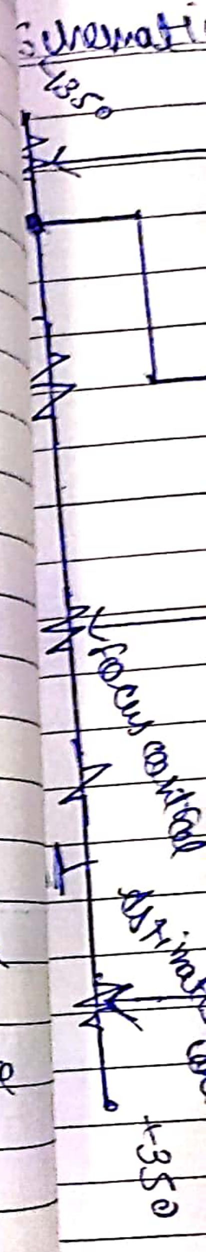
Ans 27 A cathode ray tube (CRT) is a specially designed vacum tube. It consist of three parts.

1) Electron gun: It consists of several electrodes and is mounted at one end of cathode ray tube. An indirectly heated cathode K emits the stream of electrons from it's front face. The electrons pass through control Grid G held at -ve potential. Effective size of aperture in grid varies depending upon the potential difference between grid and cathode. The number of electrons striking screen determines intensity

of glow produced at screen. Two anodes A_1 and A_2 are positioned beyond the control grid which are coaxial with the grid. The electron lens system formed by combination of grid and anodes focus electron rays into a sharp narrow pencil of beam. Electron beams travels along axis of tubes and strikes at centre of fluorescent tube.

2) Deflection system: In an electrostatic deflection type CRT, deflection system consists of two pairs of parallel metal plates. The metal plates are positioned symmetrically around the electron beam path. beam emitted by electron gun travels towards fluorescent coating and on way pass through deflection system. The two plates in each pair are strictly held parallel to each other. When an electron beam passes through the field, it gets deflected upward or downward in vertical direction. ~~When an electron beam~~ therefore this set of plates is called vertical deflection plates. Second set of plates is oriented vertically and when a potential difference is applied between the plates, it produces uniform electric field in horizontal direction.

3) Fluorescent screen: Electrons are invisible particles. However electron beam position can be located with help of fluorescent screen. The interior surface of circular front face of CRT is coated with a thin translucent layer of phosphor. Phosphorus have property of emitting light when particles hits them. The glow can be seen through thin glass face and marks the position of electron beam known



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Schematic diagram of cathode Ray tube.