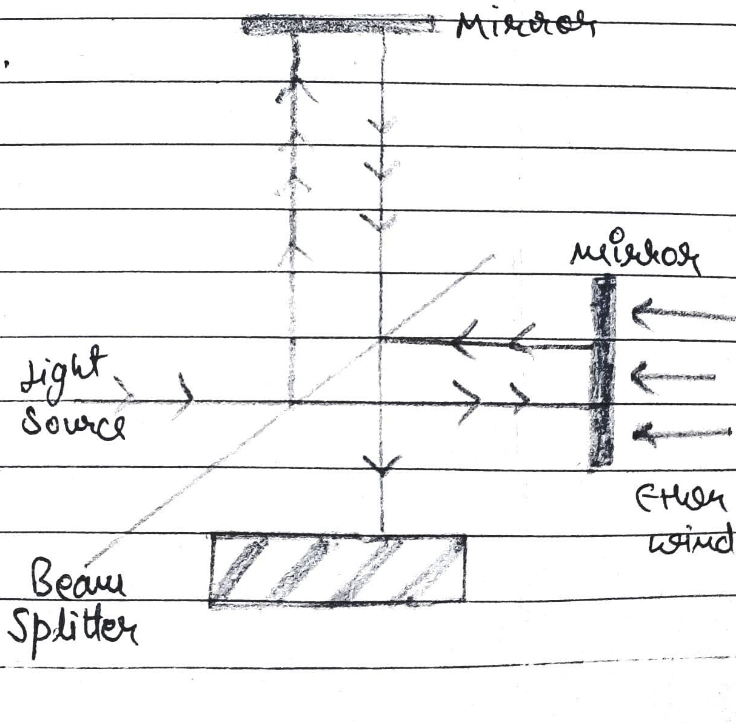
APPLIED PHYSICS AP ~~[illegible]~~ - 202

Ans Q1

a) The main objective of this Michelson-Morley experiment being conducted was to attempt the existence of light luminiferous aether, a supposed medium permeating space that was thought to be the carrier of light waves

Aim was supposed to be compleated by mesuring ~~the~~ the velocity of earth with respect to ether.
Earth being supposed to propagate through stationary ether with uniform velocity and if beam of light is sent in direction of motion of earth then it takes more time if sent in opposite directions.
Eventually time difference [if calculated] would lead to calculation of relative velocity.

Waves interfere at A and interference fringes can be observed through telescope
Apprates was arranged to move along the direction of earth's orbit with the velocity of earth is V.



Experiment

Let the distance $AM_1 = AM_2 = D$
Light Velocity [in direction of motion of earth] $= C-V$
Light Velocity [in opposite direction] $= C+V$

T_1 be the time taken, from A to M_2
T_2 from M_2' to A' so,

Total oscillation time $\Rightarrow T = T_1 + T_2 = \frac{D}{C-V} + \frac{D}{C+V} - \frac{2DC}{C^2-V^2}$ — (1)

Total Distance by light $\Rightarrow x_1 = T \times C = \frac{2DC^2}{C^2-V^2} \simeq 2D\left(1+\frac{V^2}{C^2}\right)$ — (2)

Let time by light to travel A to M_1' be T'. during this time M_1 is shifted to M_1' and A to R

Distance $AR = VT'$

$$C^2T'^2 = D^2 + V^2T^2$$

$$T' = \frac{D}{\sqrt{C^2-V^2}} = \frac{D}{C\sqrt{1-\frac{V^2}{C^2}}} = \frac{D}{C}\left(1+\frac{V^2}{2C^2}\right)$$

Time taken by light in going from A to M_1' and back to A'

$$T = 2T' = \frac{2D}{C}\left(1+\frac{V^2}{2C^2}\right)$$

Distance travelled $x_2 = ct$

$$x_2 = 2D\left(1+\frac{1}{2}\frac{V^2}{C^2}\right) \quad \text{— (3)}$$

From ② and ③ path difference is →

$$x_1 - x_2 = \frac{2D}{c}\left(1+\frac{1}{2}\frac{v^2}{c^2}\right) - 2D\left(1+\frac{v^2}{2c^2}\right)$$

$$\Delta x = \frac{2Dv^2}{c^2} \quad \text{—— ④}$$

Path difference in eq ④ corresponds shifting fringes ⇒

$$\Delta x = n\lambda \quad \text{or} \quad n = \frac{\Delta x}{\lambda} = \frac{Dv^2}{c^2\lambda}$$

Ans. Q.1

b) As the theoretical results of Michelson – Morley experiment did not match with experiment result. Even then scientists of that time had convictions that ether exists and each moves with respect to it. then there was lot of debate and discussion regarding this as why there were negative results.

1. Ether Drag Hypothesis: Then scientist assumed that ether exists and it is attached with the earth. Thus it will be dragged with the earth so the relative velocity of ether and earth will be zero. If this is taken then theory and experimental will get matched. But this hypothesis is discarded as there was no proof for this.

2. Lorentz - Fitzgerald Hypothesis: Lorentz told that the length of the arm towards the transmitted side should be but not L. If this is taken then theory and experimental will get matched. But this hypothesis was discarded due to no proof.

Ans Q.2

a) Difference between inertial and non inertial frames of reference.

Inertial frame of reference → Body moves with constant Velocity
→ Body does not accelerate
→ Real force are acted on body
→ follow newton's law

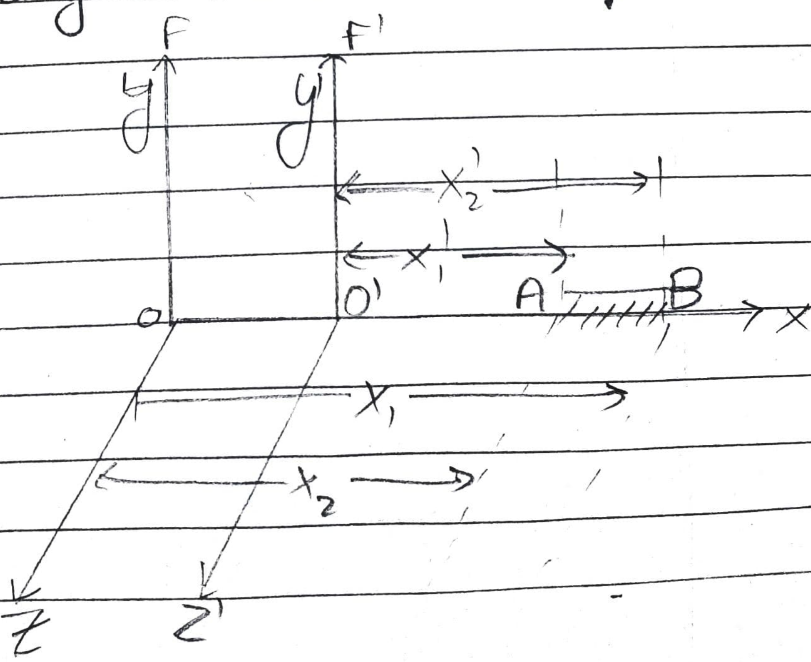
Non Inertial frame of reference → moves with variable speed/velocity
→ Body undergoes acceleration
→ pseudo force is acted on body
→ does not follow newton's law

Length Contraction.

Considering two inertial system F and F'

F' moving with velocity v' relative to F along x axis

AB is rod at rest in moving system F' relative to observer O' and l_0 is length of rod in frame measured by observer at any instant.



So $l_o = x_2' - x_1'$ — (1)

l is the length of rod mesured by the observer O is stationary frame F

$$L = x_2 - x_1 \quad -(2)$$

As per lorentz transformation.

$$x_1' = \frac{x_1 - vt}{\sqrt{1 - v^2/c^2}} \quad -(3)$$

$$x_2' = \frac{x_2 - vt}{\sqrt{1 - v^2/c^2}} \quad -(4)$$

Substracting eq (3) from (4)

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

From (1) and (2) $\Rightarrow l_o = \frac{L}{\sqrt{1 - v^2/c^2}} \Rightarrow L = l_o\sqrt{1 - \frac{v^2}{c^2}}$

as $L < L_o$, the length reduced in the ratio $\sqrt{1 - \frac{v^2}{c^2}} : 1$ as measured by the observer moving with velocity 'v' with respect to the rod.

Time Dialation.

Consider F and F' as [F' is moving with velocity 'v' along the x-axis relative to F let a gun placed at position (x', y', z') in F' frame.

Two shots fired at time interval t_1' and t_2' mesured from F'

let t_0 = proper time interval

$$t_0 = t_2' - t_1' \quad \text{——— (1)}$$

assuming that F is moving with velocity $-v$ along the $+x$ axis relative to F.

In frame F, the observer two shots at time t_1 and t_2 then time interval t.

$$t = t_2 - t_1 \quad \text{—— (2)}$$

By Lorentz transformation equation

$$t_1 = \frac{t_1' + vx'/c^2}{\sqrt{1 - v^2/c^2}} \quad \text{—— (3)}$$

$$t_2 = \frac{t_2' + vx'/c^2}{\sqrt{1 - v^2/c^2}} \quad \text{—— (4)}$$

From (3) and (4)

$$t = t_2 - t_1$$

$$t = \frac{t_2' - t_1'}{\sqrt{1 - v^2/c^2}} \Rightarrow \boxed{t = \frac{t_0}{\sqrt{1 - v^2/c^2}}}$$

Ans
Q.2
b) An object at a speed v related to an observer will appear to contract from both frames of reference through with the object's frame of reference it is the observer being contracted. This happens all the time but the speeds are always too slow. to have any noticeable effect, only being noticeable at relativistic speeds.

$$L = L_0\sqrt{1 - \frac{v^2}{c^2}}$$, where, L = new length (m)
L_0 = original length (m)
v = speed of object (ms^{-1})
c = speed of light.

$$L = \sqrt{1 - \frac{(0.6c)^2}{c^2}}$$

$$L = \sqrt{1 - (0.6)^2}$$

$$L = \sqrt{1 - 0.36} \Rightarrow \sqrt{0.64} \quad \boxed{L = 0.8m}$$

Ans
Q.3
a) Let us assume that electrons exist in the nucleus and radius is $10^{-14}m$ approx. If the electron is to exist inside the nucleus, then uncertainity in the position of the electron is given by –

$$\Delta x = 10^{-14}m$$

According to uncertainity principle,

$$\Delta x \, \Delta p x = h/2\pi$$

Thus $\Delta p_x = h/2\pi\Delta x$

$\Delta p_x = 6.62 \times 10^{-34} / 2 \times 3.14 \times 10^{-14}$

$\Delta p_x = 1.05 \times 10^{-20}$ kg m/sec

An e^- having this much momentum must have a velocity comparable to the velocity of light. Thus its energy should be calculated by the following relistic formula

$$E = \sqrt{m_0^2 c^4 + p^2 c^2}$$

$$E = \sqrt{(9.1 \times 10^{-31})^2 \times (3 \times 10^8)^4 + (1.05 \times 10^{-20}) \times (3 \times 10^8)^2}$$

$$= \sqrt{9.9267 \times 10^{-24}}$$

$$E = 3.15 \times 10^{-12} J = \frac{3.15 \times 10^{-12}}{1.6 \times 10^{-19}} = eV$$

$$= 19.6 \times 10^6 \ eV$$

$$\underline{\underline{E = 19.6 \ MeV.}}$$

Ans
Q-3
b) In thermal equilibrium at temprature T, with radiation frequency ν and energy density $u(\nu)$ let N_1 and N_2 be the no. of atoms in energy states 1 and 2 respectively at any instant. The number of atoms in state 1 absorbs a photon and give rise to absorption per unit time.

For equilibrium $P_{12} = P_{21}$

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

$$u(\nu) = \frac{N_2 A_{21}}{N_1 B_{12} - N_2 B_{21}} \quad \text{——— (1)}$$

According to Boltzmann distribution law number of atoms N_1 and N_2 in energy states E_1 and E_2 in thermal equilibrium at temperature T are given by

$$\rightarrow \frac{N_1}{N_2} = \frac{e^{-E_1/kT}}{e^{-E_2/kT}}$$

$$\frac{N_1}{N_2} = e^{\frac{-(E_1 - E_2)}{kT}} = e^{hc/kT} \quad \text{——— (2)}$$

Substituting N_1/N_2 in Eq (1), we get.

$$u(\nu) = \frac{A_{21}}{B_{21}} \frac{N_2}{e^{\frac{h\nu}{kT}} \left(\frac{B_{12}}{B_{21}}\right) - 1}$$

Comparing it with Plank's Radiation law

$$u(\nu) = \frac{8\pi h \nu^3}{c^3} \frac{1}{e^{\frac{h\nu}{kT}} - 1}$$

we get,

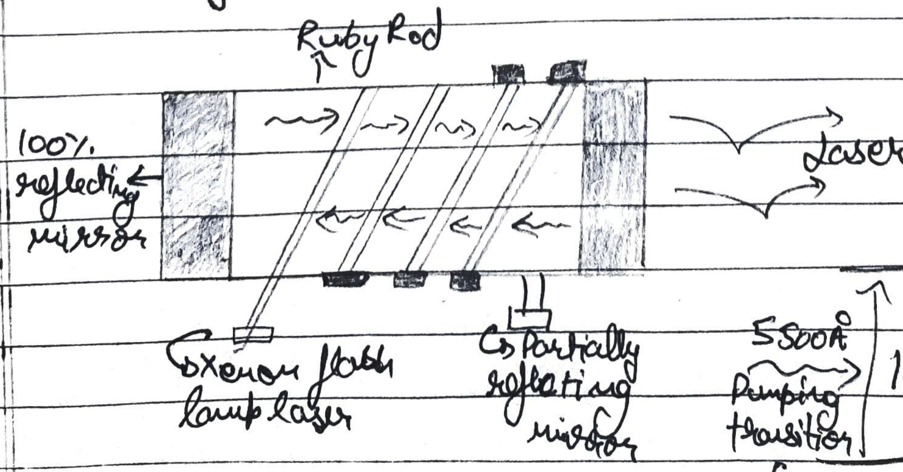
(1) $\frac{B_{12}}{B_{21}} = 1$; $B_{12} = B_{21}$, The probability of spontaneous emission is same as that of induced absorption

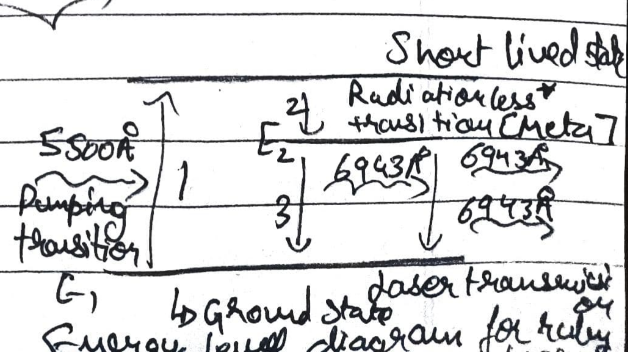
(ii) $\frac{A_{21}}{B_{21}} = \frac{8\pi h \nu^3}{c^3}$, The ratio of spontaneous emission is stimulated emission is proportional to ν^3

Ans
Q-4
a) Principle: A ruby laser is a solid state laser that uses the synthetic ruby crystal as its laser medium. Ruby laser is one of the few solid state lasers that produce visible light.

Working: The ruby laser consists of a single crystal of ruby rod of length 10 cm and 0.8 cm in diameter. A ruby is a crystal of Aluminium oxide Al_2O_3, in which some of Aluminium ions (Al^{3+}) are replaced by chromium ions (Cr^{3+}). Ends are flat and parallel; Ends being fully silvered and partially silvered each.
Ruby rod is surrounded by helical Xenon flash tube which provides the pumping light to raise the chromium ions to upper energy level. In the xenon flash tube, each flash lasts several milliseconds and in each flash a few thousand joules of energy is consumed.

The simplified energy level diagram of chromium ions in a ruby laser is given at the end of this answer. In normal state, most of the chromium ions are in the ground state E_1. When the ruby rod is irradiated by a flash of light, the 5500Å radiation (green colour) photons are absorbed by the chromium ions which are pumped to the Excited state E_3. The excited ion give up a part of it's energy to the crystal lattice and decay without giving any radiation to the meta stable state E_2. Since, the state E_2 has much longer lifetime (10^{-3}s), the no of ions in this state goes on increasing thus population inversion is acieved between the states E_2 and E_1. When the excited ion from the metastable state E_2 drops down to state E_1, it emits a photon of wavelength 6943Å. This photon travels through the silvered ends until it stimulates other excited ions and causes it to emit a fresh photon in phase with stimulating photon. Thus reflection will amount in additional stimulated emission. — Amplification. This stimulated emission is the laser transition. Finally, a pulse of red light of wavelength 6943Å emerges through the partially silvered end of crystal.





Ans
04

b) When a material makes the transition from the normal to super conducting state, it actively excludes magnetic fields from its mirror, this is called Meissner effect.

This constraint to zero magnetic field inside a super conductive is distinct from the perfect diamagnetic which would arise from its zero electrical resistance. Zero resistance would imply that if you tried to magnetize a superconductor current loops would be generated to exactly cancel this imposet field (lenz's law). But if the material already had a steady magnetic field through it when it was cooled through the super conducting transitions, the magnetic field would be expected to remain. If there were no change in the applied magnetic field there would be no generated Voltage (Farday's) to desire counts. even in perfect conductor hence the active exclusion of magnetic field must be considered to be an effective distinct from just zero. resistance. A mixed state meissner effective occur with type II material.

One of the theoritical explanations of the meissner effect comes from the london eqn. It shows that the magnetic field decays exponentially inside the superconductor over a dissemer of 20-40 nm

It is described in forms of a parameter called the london penetration depth

Ans 8
Q.5
a) $T = 400K$ $m = 6.7 \times 10^{-27}$ kg
$K = 1.38 \times 10^{-23}$ J/K

The mean velocity

$$V_{mean} = \sqrt{\frac{8KT}{\pi m}}$$

$$V_{mean} = \sqrt{\frac{8 \times 1.38 \times 10^{-23} \times 400}{3.14 \times 6.7 \times 10^{-27}}}$$

$V_{mean} = 1455.3$ m/s.

de broglie wavelength $\lambda = \frac{h}{m v_{mean}}$.

$$\lambda = \frac{6.62 \times 10^{-34}}{6.7 \times 10^{-27} \times 1455.3}$$

$\lambda = 7 \times 10^{-11}$

Ans
Q.5
b) (a) $m = 1 \times 10^{-15}$ kg $V = 2$ mm/s
$= 2 \times 10^{-3}$ m/s

de broglie wavelength $\lambda = \frac{h}{mv}$

$$\lambda = \frac{6.626 \times 10^{-34}}{1 \times 10^{-15} \times 2 \times 10^{-3}}$$

$$\boxed{\lambda = 3.313 \times 10^{-16} m}$$

(b) KE $= 120 ev$

mass of electron $(m) = 9.1 \times 10^{-31}$ kg

de broglie wavelength $\lambda = \frac{h}{\sqrt{2m(KE)}}$

$$\lambda = \frac{6.626 \times 10^{-34}}{\sqrt{2 \times 9.1 \times 10^{-31} \times 120}}$$

$$\lambda = \frac{6.6 \times 10^{-34}}{59.1 \times 10^{-25}} = 0.112 \times 10^{-9} m$$