PHYSICS

Roll No. 24E045 Scholar No. 24112011143

SESSIONAL PAPERS

ASSIGNMENT-02

Q.1 Calculate the de-Broglie wavelength of an electron having a kinetic energy of 1kev. Compare the result with the wavelength of X-rays having the same energy.

→ For an electron -

$$\lambda = \frac{h}{p} = \frac{h}{mv} = \frac{h}{\sqrt{2mK.E.}}$$

Given that:-

K.E. (Kinetic Energy) = 1 kev
$= 10^3 \, eV$
$= 10^3 \times 1.602 \times 10^{-19} J$
$= 1.602 \times 10^{-16} J$

$$\Rightarrow \lambda = \frac{6.626 \times 10^{-34}}{\sqrt{2 \times 9.1 \times 10^{-31} \times 1.602 \times 10^{-16}}}$$

Here, $h \rightarrow$ Planck's constant (6.626×10^{-34})
$m \rightarrow$ mass of an electron $(9.1 \times 10^{-31} \, kg)$

$$\Rightarrow \lambda = \frac{6.626 \times 10^{-34}}{\sqrt{29156.4 \times 10^{-50}}}$$

$$\Rightarrow \lambda = \frac{6.626 \times 10^{-37}}{170.8 \times 10^{-25}}$$

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$\Rightarrow \lambda = 38.79 \times 10^{-12}$ m

$\boxed{\lambda = 3.88 \times 10^{-11} \text{ m}}$ (Ans)

For x-rays photon,

$$E = \frac{hc}{\lambda}$$

$$\Rightarrow \lambda = \frac{hc}{E}$$

$$\Rightarrow \lambda = \frac{6.626 \times 10^{-34} \times 3 \times 10^{8}}{1.602 \times 10^{-16}}$$

$$\Rightarrow \lambda = \frac{12.40 \times 10^{-26}}{10^{-16}}$$

$\Rightarrow \boxed{\lambda = 1.24 \times 10^{-9} \text{ m}}$ (Ans)

$\therefore$ de-Broglie wavelength of electron, $\lambda = 3.88 \times 10^{-11}$ m.
de-Broglie wavelength of x-rays, $\lambda = 1.24 \times 10^{-9}$ m.

Q.2 Why the wave nature of matter is not apparent in our daily observations?

→ Wave nature of matter, as described by de Broglie's theory is not appearent in everyday life because the de Broglie wavelength of macroscopic objects is extremely small and effectively undetectable.

For objects in our daily use, their masses are very large compared to atomic or subatomic particles. Since, the de-Broglie wavelength λ is inversely proportional to the objects momentum p (i.e. $\lambda = \frac{h}{p}$), objects with large masses and everyday velocities have extremely small wavelengths.

Q.3 Consider a mass-spring system where a 4 kg mass is attached to a mass less spring of constant $K = 196\ Nm^{-1}$; the system is set to oscillate on a frictionless, horizontal table. The mass is pull 25 cm away from the equilibrium position and then released.

(a). Use classical mechanics to find the total energy and frequency of oscillation of the system.

→ Given that,

mass (m) = 4 kg

spring constant (K) = 196 N/m

Amplitude (A) = 0.25 m

We know that,

Total Energy (E) of a mass - spring system undergoing simple harmonic motion is:-

$$E = \frac{1}{2} KA^2$$

$$\Rightarrow E = \frac{1}{2} \times 196 \times \left(\frac{1}{4}\right)^2$$

$$\Rightarrow E = \frac{1}{2} \times 196 \times \frac{1}{4} \times \frac{1}{4}$$

$$\boxed{E = 6.125 \text{ J}}$$

$\therefore$ We know that,

$$\text{Frequency } (f) = \frac{\omega}{2\pi} = \frac{1}{2\pi}\sqrt{\frac{K}{m}}$$

$$\Rightarrow f = \frac{1}{2\pi}\sqrt{\frac{196}{4}} = \frac{1}{2\pi}\sqrt{49}$$

$$f = \frac{7}{2\pi} \text{ Hz} = 1.11 \text{ Hz}$$

$\therefore$ Total energy of system, $E = 6.125$ J (Ans).
and frequency of system, $f = 1.11$ Hz (Ans).

(b). Treating the oscillator with quantum theory, find the energy spacing between two consecutive energy levels and the total number of quanta involved. Are the quantum effects important in this system?

→ Energy spacing between two consecutive energy levels $(\Delta E) = E_{n+1} - E_n$

$$\Delta E = \hbar\omega$$

$$\Rightarrow \Delta E = (1.0545718 \times 10^{-34} \text{ Js})\ (7 \text{ rad/s})$$

$$\boxed{\Delta E \approx 7.38 \times 10^{-34} \text{ J}}\quad \text{(Ans)}$$

Also,

The number of quanta n can be estimated by dividing the total energy (E) by the energy spacing (ΔE).

$$\Rightarrow n = \frac{E}{\Delta E} = \frac{6.125}{7.38 \times 10^{-34}}$$

$$\Rightarrow \boxed{n \approx 8.3 \times 10^{33}} \quad \text{(Ans)}$$

Since, the number of quanta n is extremely large (about 10^{33} quanta), the energy levels are extremely closely spaced, making the system behave essentially as a continous system rather than a quantized one. Therefore, quantum effects are negligible for this system, and classical mechanics is sufficient to describe the motion.

Q.4 Calculate the group and phase velocities for the wave packet corresponding to a relativistic particle?

→ For a relativistic particle, the total energy E and momentum p are related by:-

$$E^2 = (pc)^2 + (m_0 c^2)^2$$

Here,

$c \rightarrow$ speed of light (3×10^8 m/s)

$m_0 \rightarrow$ particles rest mass

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$E = \hbar \omega$ ($\omega \rightarrow$ angular frequency of wave)
$p = \hbar K$ ($K \rightarrow$ wave number)

Solving for the energy in terms of momentum:-

$$E = \sqrt{(pc)^2 + (m_0c^2)^2}$$

We know that,

$$\text{Phase velocity } (V_{phase}) = \frac{E}{p}$$

$$\Rightarrow V_{phase} = \frac{\sqrt{(pc)^2 + (m_0c^2)^2}}{p}$$

$$\Rightarrow V_{phase} = c\sqrt{1 + \left(\frac{m_0c}{p}\right)^2}$$

$$\therefore \text{Group velocity } (V_{group}) = \frac{dE}{dp}$$

$$\Rightarrow V_{group} = \frac{pc^2}{\sqrt{(pc)^2 + (m_0c^2)^2}} = \frac{c^2p}{E}$$

$$\Rightarrow V_{group} = \frac{c^2}{V_{phase}}$$

$$\therefore \boxed{V_{group} \cdot V_{phase} = c^2}$$

Phase velocity : V_{phase} is typically greater than 'c' for a ~~ton~~ relativistic particle.

Group velocity : V_{group} is less than 'c' and corresponds to the actual speed of the particle.

Q.5 Assuming the potential seen by a neutron in a nucleus to be schematically represented by a one-dimensional, infinite rigid walls potential of width 10 fm. Estimate the minimum kinetic energy of the neutron.

→ For a neutron in a nucleus modeled as a particle confined in a one-dimensional box of width L=10 fm, we can use the quantization condition to estimate its minimum kinetic energy.

For a particle of mass m in a 1D infinite potential of width L, the energy levels are given by :-

$$E_n = \frac{n^2h^2}{8mL^2}$$

where,

$n = 1, 2, 3, \ldots$ is the quantum number.

h = planck's constant

m = mass of the neutron

L = width of potential well

Here,

(1). $L = 10\,fm$

$\Rightarrow L = 10 \times 10^{-15} m = 10^{-14} m$

(2). $h = 6.626 \times 10^{-34}$ Js

(3). $m = 1.675 \times 10^{-27}$ kg

For minimum kinetic energy, $n=1$.

$$\Rightarrow E_{min} = \frac{(6.626 \times 10^{-34})^2}{8 \times (1.675 \times 10^{-27}) \times (10^{-14})^2}$$

$$\Rightarrow E_{min} = \frac{43.9 \times 10^{-68}}{13.4 \times 10^{-27} \times 10^{-28}}$$

$$\Rightarrow E_{min} = \frac{43.9 \times 10^{-68}}{13.4 \times 10^{-55}}$$

$\boxed{E_{min} = 3.276 \times 10^{-13} J}$ (Ans)

$\therefore$ Minimum kinetic energy of the neutron is 3.276×10^{-13} J.

Q.6 Calculate the energy required for an electron to jump from ground state to the second excited state in a potential well of width L.

→ For an electron in a One-dimensional infinite potential well of width L, the energy levels are given by:

$$E_n = \frac{n^2h^2}{8mL^2}$$

∴ Energy level of ground state ($n=1$):-

$$E_1 = \frac{h^2}{8mL^2}$$

∴ Energy level of second excited state ($n=3$):-

$$E_3 = \frac{9h^2}{8mL^2}$$

⇒ The energy difference is the energy required to excite the electron from the ground state to the second excited state.

$$\therefore \Delta E = E_3 - E_1 = \frac{9h^2}{8mL^2} - \frac{h^2}{8mL^2}$$

$$\Rightarrow \Delta E = \frac{8h^2}{8mL^2}$$

$$\Rightarrow \boxed{\Delta E = \frac{h^2}{mL^2}}$$

So, the energy required for the transition is $\frac{h^2}{mL^2}$. (Ans)

Q 7 The wave function.

$$\psi(x) = A\sin(n\pi x/L)$$

describes a state of a particle. Calculate the normalization constant A.

→ To find the normalisation constant A, we need to ensure that the wave function $\psi(x) = A\sin\left(\frac{n\pi x}{L}\right)$ is normalized. It means that the probability of finding the particle in the interval $0 \le x \le L$ must be 1.

$$\Rightarrow \int_0^L |\psi(x)|^2 dx = 1$$

$$\because \psi(x) = A\sin\left(\frac{n\pi x}{L}\right)$$

$$\Rightarrow |\psi(x)|^2 = A^2 \sin^2\left(\frac{n\pi x}{L}\right)$$

$$\Rightarrow \int_0^L A^2 \sin^2\left(\frac{n\pi x}{L}\right) dx = 1$$

we know that,

$$\sin^2\theta = \frac{1-\cos(2\theta)}{2}$$

$$\Rightarrow A^2 \int_0^L \frac{1-\cos(2n\pi x/L)}{2} dx = 1$$

$$\Rightarrow \frac{A^2}{2}\int_0^L 1\,dx - \frac{A^2}{2}\underbrace{\int_0^L \cos\left(\frac{2n\pi x}{L}\right) dx}_{} = 1$$

→ This integral evaluates to zero because the cosine function completes an integer number of half periods over $0 \le x \le L$.

$$\Rightarrow \frac{A^2}{2} \cdot L = 1$$

$$\Rightarrow A^2 = \frac{2}{L}$$

$$\Rightarrow \boxed{A = \sqrt{\frac{2}{L}}}$$

$\therefore$ Normalization constant (A) is $\sqrt{\frac{2}{L}}$ (Ans).

Q.8 Find the probability of finding a particle in a box of length in the region from $0.45L$ to $0.55L$ for the ground state?

→ The Ground state wave function for a particle in a box with length L is given by:-

$$\psi_1(x) = \sqrt{\frac{2}{L}} \sin\left(\frac{\pi x}{L}\right)$$

where, $\psi_1(x)$ is the ground state wave function.

Probability of finding the particle between $x = 0.45L$ and $x = 0.55L$ is given by integrating the probability density $|\psi_1(x)|^2$

$$P(0.45L \le x \le 0.55L) = \int_{0.45L}^{0.55L} |\psi_1(x)|^2 dx$$

$$P(0.45L \le x \le 0.55L) = \int_{0.45L}^{0.55L} \frac{2}{L} \sin^2\left(\frac{n\pi x}{L}\right) dx$$

$$P(0.45L \le x \le 0.55L) = \frac{2}{L} \int_{0.45L}^{0.55L} \frac{1 - \cos(2\pi x/L)}{2} dx$$

$$\Rightarrow P(0.45L \le x \le 0.55L) = \frac{1}{L} \int_{0.45L}^{0.55L} dx - \frac{2}{L} \int_{0.45L}^{0.55L} \cos\left(\frac{2\pi x}{L}\right) dx$$

On solving, we get -

Probability of finding particle in the region from 0.45L to 0.55L for the ground state is approximately,

$\boxed{0.198}$ or $\boxed{19.8\%}$ (Ans).

Q.9 Calculate the energy required for a quantum particle to jump from ground state to the second excited state when it is oscillating quantum mechanically with frequency ω.

→ For a quantum harmonic oscillator, the energy levels are quantized and given by:-

$$E_n = \left(n + \frac{1}{2}\right) \hbar \omega$$

where,

$n \rightarrow$ quantum number

$\hbar = \frac{h}{2\pi}$, $h \rightarrow$ planck's constant

$\omega \rightarrow$ angular frequency of oscillation

∴ Ground state energy E_0 is :-

$$E_0 = \left(0+\frac{1}{2}\right)\hbar\omega = \frac{1}{2}\hbar\omega$$

∴ Energy of the second excited state E_2 is :-

$$E_2 = \left(2+\frac{1}{2}\right)\hbar\omega = \frac{5}{2}\hbar\omega$$

⇒ Energy required for the particle to jump from the ground state to the second excited state is :-

$$\Delta E = E_2 - E_0$$

$$\Rightarrow \Delta E = \frac{5}{2}\hbar\omega - \frac{1}{2}\hbar\omega = 2\hbar\omega$$

$$\Rightarrow \Delta E = 2 \times \frac{h}{2\pi}\omega = \boxed{\frac{h\omega}{\pi}}$$

So, the energy required for this transition is $\frac{h\omega}{\pi}$ (Ans).

PHYSICS

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ASSIGNMENT - 3

Q.1 The current gain in CB mode of a NPN transistors is 0.98 and the collector base leakage current I_{CBO} is $12 \mu A$. Calculate ①. The collector current (I_C) ②. The base current I_B for the emitter current $I_E = 2mA$.

→ Current gain, $\alpha = 0.98$

$I_{CBO} = \cancel{12\mu A}\ 12 \mu A$

$I_E = 2mA$

①. We know, $I_C = \alpha I_E + I_{CBO}$

$I_C = 0.98 \times 2 \times 10^{-3} + 12 \times 10^{-6}$

$I_C = 1.972 \times 10^{-3}$

$\boxed{I_C \approx 1.972\ mA}$

②. $I_E = I_C + I_B$

$I_B = I_E - I_C$

$I_B = 2 - 1.972 = 0.028\ mA$

$\boxed{I_B = 28 \mu A}$

Q.2 In the common base mode a transistor the emitter current is 1mA. When the emitter circuit is open the collector current is $50 \mu A$. If $\alpha = 0.92$, calculate the total collector current.

→ $I_E = 1mA$

$I_{CBO} = 50 \mu A$

$\alpha = 0.92$

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$\therefore$ Total collector current $(I_C) = \alpha I_E + I_{CBO}$

$$= 0.92 \times 1 \times 10^{-3} + 50 \times 10^{-6}$$

$$\approx 9.7 \times 10^{-4}$$

$$\boxed{I_C = 970\ \mu A}$$

Q.3 1.0 Ampere current flow in a silver strip of length 5mm and width 0.1mm, along its length. The strip is placed in a magnetic field of strength 1.0 tesla along its width of the strip. (Atomic weight of silver = 108 and density = 10.5×10^3 kg/m³).

$\rightarrow$ $I = 1.0\,A$

$B = 1.0\,T$

$t = 0.1\,mm$

Hall voltage, $V_H = \frac{R_H IB}{t} = \frac{1}{ne}\frac{IB}{t}$

$$n = \frac{\rho N_A}{A} = \frac{\cancel{10\times}\ 10.5 \times 10^3 \times 6.022 \times 10^{23}}{108}$$

$$\boxed{n \approx 5.85 \times 10^{22}\ m^{-3}}$$

Now, $V_H = \frac{1 \times 1}{5.85 \times 10^{22} \times 1.602 \times 10^{-19} \times 0.1 \times 10^{-3}}$

$$\boxed{V_H \approx 10.7\ \mu V}$$

Q.4 A current of 1 μA flows in copper strip of length 10 cm and width 0.1cm along its length. The strip is placed in a magnetic field of strength 3×10^{-6} wb/m²

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perpendicular to its length. If Hall coefficient of copper is 0.55×10^{10} volt m^3 per Aw, find the Hall voltage developed in it.

→ $I = 1\mu A$

$l = 10\,cm$

$B = 3 \times 10^{-6}\,wb/m^2$

$R_H = 0.55 \times 10^{10}\ Vm^3/Aw$

$$V_H = \frac{R_H I B}{t}$$

$$= \frac{0.55 \times 10^{10} \times 1 \times 10^{-6} \times 3 \times 10^{-6}}{10 \times 10^{-2}}$$

$$\boxed{V_H = 1650\,mV = 1.65\,\mu V}$$

Q.5 What is the difference between drift current and diffusion current?

Drift Current	Diffusion Current
• Caused by an external electric field	• Caused by an concentration gradient on charge carriers.
• In the direction of electric field for positive carriers and opposite for negative carriers.	• From the region of high concentration to low concentration.
• Charge carriers move due to electric force	• Charge carriers move due to random thermal motion and concentration gradient

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- $J_{drift} = qn\mu E$
- J_{drift}

$J_{diffusion} = qD\frac{dn}{dx}$

Q.6 What is the reverse saturation current in transistors? Explain I_{CBO} and I_{CEO}.

→ Reverse saturation current always also known as the reverse leakage current, is the small current that flows through a transistor when it is reverse-biased. The current is caused by the thermal energy that excites electrons in the semiconductor material, allowing them to flow through the device.

I_{CBO} - I_{CBO} is the collector-base leakage current, A very small current that flows when the base is open and the collector-base junction is reverse biased.

I_{CEO} - I_{CEO} is the collector-emitter leakage current, A small current that flows between collector and emitter terminal when the emitter is open and the base-emitter junction is forward biased.

Q.7 What do you mean or understand by classically forbidden region? Explain α-decay and quantum harmonic oscillator in this context.

→ A clasically forbidden region refers to a region where, a particle or system cannot exist or pass through, because the particle's energy is insufficient to overcome the potential energy barrier.

but according to quantum mechanics, particles can tunnel through or exist in classically forbidden regions due to wave-particles duality and uncertainity principle.

α-decay :- A quantum process where an alpha-particle escapes the nucleus by tunnelling through a classically forbidden region created by the nuclear potential barrier.

Quantum Harmonic Oscillator :- A quantum harmonic oscillator is a system that exhibits simple harmonic motion, but with the quantum mechanics effects. In quantum harmonic oscillator, the particle can exist in states where its energy is less than the potential energy at certain points allowing it to tunner through classically forbidden regions.

Q.-8 The wave function for the one-dimentional motion of a particle is $\psi = Ax$ when $0 \le x \le 1$. Calculate (i) the value of A (ii). the probability of finding a particle in the range $x=0$ to $x=0.5$ (iii) the expectation value of x.

→ (i). $\psi(x) = Ax$ $\quad 0 \le x \le 1$

The wave function must be normalized so that the probability of finding the particle in space is equal to 1.

$$\int_{-\infty}^{\infty} |\psi(x)|^2 dx = 1$$

since, $\psi(x) = Ax$ only exists for $0 \le x \le 1$.

$$\int_0^1 |Ax|^2 dx = 1$$

$$\int_0^1 A^2x^2 dx = 1$$

$$\Rightarrow A^2 \int_0^1 x^2 dx = 1$$

$$A^2 \left[\frac{x^3}{3}\right]_0^1 = 1$$

$$A^2 \times \frac{1}{3} = 1$$

$$\boxed{A = \sqrt{3}}$$

$\therefore$ The value of normalisation constant A is $\sqrt{3}$.

(ii). The probability of finding the particle in Range $0 \le x \le 0.5$ is given by integral of $|\psi(x)|^2$.

$$P(0 \le x \le 0.5) = \int_0^{0.5} |\psi(x)|^2 dx$$

$$P(0 \le x \le 0.5) = \int_0^{0.5} (\sqrt{3}x)^2 dx = \int_0^{0.5} 3x^2 dx$$

$$= 3\left[\frac{x^3}{3}\right]_0^{0.5} = x^3\Big|_0^{0.5}$$

$$\boxed{= \frac{1}{8}}$$

∴ the probability of finding the particle in the range $0 \le x \le 0.5$ is $\frac{1}{8}$.

(iii). The expectation value of x, $\langle x \rangle$ is given by,

$$\langle x \rangle = \int_0^1 x |\psi(x)|^2 dx$$

$$= \int_0^1 x (\sqrt{3}x)^2 dx$$

$$= \int_0^1 3x^3 dx$$

$$= \left[\frac{3x^4}{4}\right]_0^1 = \frac{3}{4}$$

∴ The expectation value of x is $\langle x \rangle = \frac{3}{4}$

Q.9 Calculate the energy required for an electron to jump from ground state to the second excited state in a potential well of width L.

→ For a particle in a one-dimentional infinite potential well of width L, the energy levels are given by,

$$E_n = \frac{n^2 h^2}{8mL^2}$$

L → width of potential well.
m → mass of electrons
n → Quantum number

for ground state, $(n=1)$

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$$E_1 = \frac{1^2h^2}{8mL^2} = \frac{h^2}{8mL^2}$$

for second state (excited) $(n=3)$;

$$E_3 = \frac{3^2h^2}{8mL^2} = \frac{9h^2}{8mL^2}$$

Energy require for jump, $\Delta E = E_3 - E_1$

$$\Rightarrow \frac{9h^2}{8mL^2} - \frac{h^2}{8mL^2}$$

$$\boxed{\Delta E = \frac{h^2}{mL^2}}$$

∴ the energy required for the electrons to Jump from ground state to the second excited state in a potential well of width L is $\frac{h^2}{mL^2}$.

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ASSIGNMENT - 04

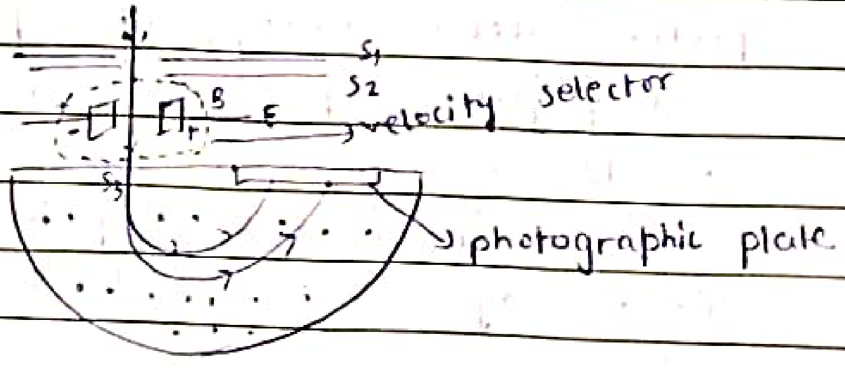
Q.1 What do you mean by spectograph? Give the working spectograph in detail.

→ Spectrograph - A device that separates a signal into its component wavelengths.

Bainbridge mass spectrometer - A device that uses a spectrograph to determine atomic masses by separating ions of different masses.

A beam of positive ions produced in a discharge tube is collimated into a fine beam by two narrowslits S_1 and S_2. This fine beam enters into a velocity selector. The velocity selector consists of two plane parallel plates P_1 and P_2 which produces a uniform electric field E and an electromagnet to produce uniform magnetic field B. The electric and magnetic field are so adjusted that the deflection produced by one field is nullified by the other, so that the ions do not suffer any deflection. These ions passed into next chamber where another magnetic field B' at right angle is acted. These ions are deflected along circular path of radius R and strike photographic plate. Ions with different mass trace semi-circular paths of different radii and produce dark curves on plates.

Bain bridge mass spectrometer



$$B'qv = \frac{mv^2}{R}$$

$$\Rightarrow \quad v = \frac{B'qR}{m}, \quad \boxed{v = \frac{E}{B}}$$

$$\Rightarrow \quad \boxed{m = \frac{B'qR \cdot B}{E}}$$

Q.2 Discuss the working and limitation of cyclotron and how the problem of cyclotron has been resolved by synchrocyclotron?

→ The charged particles are injected by the ion source into gap between the dees. The protons are accelerated by the r.f. electric field existing in the gap toward the dee, which is at a negative potential at that instant. However, the magnetic field that is acting perpendicular, deflects them along a circular path. The protons travel in the hollow region of the dee and come back into the gap after completion of one half revolution. The protons will be further accelerated if the dees reverse their polarity at the instant when the protons emerge into the gap. The protons travel further and reach other gap in time T/2. The process is repeated over and over again. During each revolution, proton receives energy of 2qV electron volts. At the end of journey proton beam is pulled out of its circular by negatively charged deflector plate.

The maximum energy of the particle beam is limited by magnetic field B and it cannot be increased beyond a specefic value. Also as time taken to complete the revolution increases because of relativity, so the particle fail to reach gap at right moment because of which instead of acceleration, it starts to deaccelerate.

This is solved by synchrotron as in a synchrotron the particle remains in resonance as the frequency of the generation is decreased. So particle is in resonance with hf voltage. Instead of other ~~dep~~ dees, It has a metal plate, which allows to extract the particle easily.

Q.3 Deuterons in a cyclotron describe a circle of radius 0.32m just before emerging from the dees. The frequency of the applied emf is 10MHz. Find the flux density of the magnetic field and velocity of deuterons emerging out of the cyclotron. Mass of deuterium $= 3.32 \times 10^{-27}$ kg ; $e = 1.6 \times 10^{-19}$C.

→ As we know, $f = \dfrac{qB}{2\pi m}$

Given:
$m = 3.32 \times 10^{-27}$
$f = 10MHz$
$q = 1.6 \times 10^{-19}C$
$r = 0.32m$

$$10 \times 10^{6} = \frac{1.6 \times 10^{-19} \times B}{2 \times 3.14 \times 3.32 \times 10^{-27}}$$

$$B = 1.3 \times 10^{8+19-27}\ T$$

$$\boxed{B = 1.3\,T}$$

Now, we know that, $v = \frac{qBr}{m}$

$$v = \frac{1.6\times10^{-19} \times 1.3 \times 0.32}{3.32\times10^{-27}}$$

$$\boxed{v = 2\times10^{8}\ ms^{-1}}$$

Q.4 In a Betatron B_{max} applied $0.5\ wb/m^2$ with orbital diameter 1.5 m. If the electromagnet is energized at 50 Hz, calculate average energy gained by electrons in a revolution. Also calculate the total time of flight of electrons.

→ $B_{max} = 0.5\ wb/m^2$

$f = 50\ Hz$

$r = \frac{1.5}{2}\ m$

$d = 1.5\ m$

Now, Energy gaine per revolution $= \frac{Berc}{c} \times 4\omega r$

$$\boxed{= 4Ber^2\omega}$$

$$E = \frac{4\times0.5\times1.6\times10^{-19}\times1.5\times1.5\times2\times3.14\times50}{2\times2}$$

$$\boxed{E = 565.5\times10^{-19}\ J}$$

$$\boxed{E = 353.25\ eV}$$

Time of flight $(T) = \frac{1}{f}$

$T = \frac{1}{50}$

$\boxed{T = 0.02 \text{ seconds}}$

$\therefore$ the total time of flight of an electron is 0.02 sec.

Q.5 Explain three level and four level pumping scheme. which one is better and why?

→ The three level scheme first excites the atoms to an excited state higher in energy than the upper laser state. The atoms then quickly decay down into the upper laser state. This scheme requires very high power as ~~p~~ for population inversion is achieved only when more than half of ground state atoms are pumped and it produces light only in pulses.

The four level pumping scheme excites atom to a pumping level and comes to metastable upper lasing level. It can operate on low power to achieve population inversion and it operates in continous wave mode.

Therefore, 4 level pumping is better than 3 level.

Q.6 what do you mean by Bethe's law? Also, discuss electrostatic lens using Bethe's law.

Q.7 In a laser action due to transition from the excited to the ground state, a beam of wavelength 6930 Å is obtained. Assuming the energy of ground state to be zero. Find the energy of the excited state.

→ Given :- Wavelength $(\lambda) = 6930 Å = 6930 \times 10^{-10}$ m
Energy of ground state $(E_1 = 0)$

$$E = \frac{hc}{\lambda}$$

$$= \frac{6.626 \times 10^{-34} \times 3 \times 10^{8}}{6930 \times 10^{-10}}$$

$$\boxed{E = 2.86 \times 10^{-19} J}$$

Since, the energy of the ground state is zero, the energy of the excited state (E_2).

Q.8 A three level laser emits light of wavelength 550nm
(a) What is the ratio of population of the upper level (E_2) to that of E_1 laser transition, at 300 k ?
(b). At what temperature the ratio of the population of E_2 to that of E_1 becomes half?

→ (a). Ratio of population of the upper level (E_2) to that of the lower (E_1) at 300 k.

$$E_2 - E_1 = \frac{hc}{\lambda}$$

$$= \frac{6.626 \times 10^{-34} \times 3 \times 10^{8}}{5.50 \times 10^{-9}}$$

$= 3.61 \times 10^{-19}$ J

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

$= e^{-(3.61 \times 10^{-19})/(1.38 \times 10^{-23} \times 300)}$

$\approx e^{-87.2} \approx 0$

at 300 K, the population ratio $\frac{N_2}{N_1}$ is extremely small, meaning most of the atoms are in the lower energy state.

Q.9 A Ruby laser emits photon of wavelength 694.4nm. If the energy release per pulse is 150 mJ and lasts for 12.0 ps. Calculate the (i) length of the pulse. (ii) the number of photons in each pulse.

→

(i) Length of the pulse,

$L_{pulse} = c \cdot t_{pulse}$

$L_{pulse} = (3 \times 10^8)(12 \times 10^{-12})$ m

$\boxed{L_{pulse} = 3.6 \text{ mm}}$

(ii) Energy of single photon,

$E_{photon} = \frac{hc}{\lambda}$

$E = \frac{6.626 \times 10^{-34} \times (3 \times 10^8)}{694.4 \times 10^{-9}}$ J

$\boxed{E = 2.86 \times 10^{-19} \text{ J}}$

Number of photons (N) in each pulse,

$$N = \frac{E_{pulse}}{E_{photon}}$$

$$N = \frac{150 \times 10^{-3}}{2.86 \times 10^{-19}} \quad \boxed{= 5.24 \times 10^{17}}$$

Q-10 He - Ne laser emits light of wavelength of 632.8nm and has an output power of 2.3 mW. How many photons are emitted each minute by this laser when operating?

→ Energy of each photon $(E) = \frac{hc}{\lambda}$

$$E = \frac{6.626 \times 10^{-34} \times 3 \times 10^{8}}{632.8 \times 10^{-19}}$$

$$E = 3.14 \times 10^{-19} J$$

Total energy output per minute = power × time

$= 2.3 \times 10^{-3} \times 60$

$= 0.138 J$

Number of photons emitted per minute

$= \frac{\text{Total energy output}}{\text{energy per photon}}$

$$= \frac{0.138}{3.14 \times 10^{-19}}$$

$= \boxed{4.39 \times 10^{17} \text{ photon per minute}}$

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PHYSICS

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ASSIGNMENT - 05

Q.1 Discuss Galilean and Lorentz transformation equations. Give a comparative study of these two transformations.

→ • Galilean transformations - For two intertial reference frames, S (stationary) and S′ (moving at a constant velocity v relative to S) ; $x' = x - vt$, $y' = y$, $z' = z$, $t' = t$.

• Lorentz transformations - For two inertial reference frames ; S and S′ where S′ moves with velocity v along the x-axis relative to S.

$$x' = \frac{x - vt}{\sqrt{1 - \frac{v^2}{c^2}}}, \quad y' = y, \quad z' = z, \quad t' = \frac{t - vx/c^2}{\sqrt{t - \frac{v^2}{c^2}}}$$

Comparative study :-

	Galilean transformations	Lorentz transformations
Nature of time	Absolute ; same for all observers ($t' = t$)	Relative ; depends ($t' \neq t$) on thes relative velocity.
Speed of light	Not invarient ; depends on the relative motion of source & observer	Invarient , c is constant in all inertial frames.

Applicability	valid for v<<<c (low speeds	valid for all speeds especially v≈c.
length contraction	Does not account for length contraction.	Accounts for length contraction. $l' = l\sqrt{1-v^2/c^2}$
Time Dilation	No time dilation effects	Predicts time dilation $\Delta t' = \Delta t / \sqrt{1-v^2/c^2}$
Principal of relativity	Holds only in newtonian mechanics	consistent with einstein's special relativity.

Q.2 Write short notes on:-

a). Postulates of Einstein's special theory of relativity:-

(i). All the fundamental laws of physics retain the same form of all the inertial frames of references.

(ii) The velocity of light in free space is constant and is independent of the relative motion of the source.

b). Relevance of negative result of michelson-morley experiment.

- failure to detect the ether: The experiment aimed to detect the presence of an 'ether' that was thought to be the medium through which light waves propagated.

- Led to the development of special relativity: Einstein special theory of relativity: which postulates that the speed of light is constant and unchanging was in part a response to the michelson - morley experiment.

c). zero rest mass particle.

A particle with zero rest mass always travels at the speed of light and has energy and momentum, but no mass.

Examples :- photons, gluons and gravitons.

d). zero rest mass.

- A property of a particle having no mass when it is at rest.
- Implifications : Particles with zero rest mass always travel at the speed of light and have energy and momentum, but no mass.

Q.3 Explain length contraction and time dilation.

- Length contraction : Length contraction is the phenomenon in which the length of an object moving relative to an observer is measured to be shorter than its proper length (the length measured in the objects rest frame).

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

$L \rightarrow$ length of the object observed in the moving frame.
$L_0 \rightarrow$ proper length (length in the rest frame).
$v \rightarrow$ Relative velocity.

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- Time Dilation: Time Dilation is the phenomenon where a clock moving relative to an observer ticks more slowly compared to a stationary clock in the observer's frame of reference.

$$\Delta t = \frac{\Delta t_0}{\sqrt{1-\frac{v^2}{c^2}}}$$

$\Delta t \rightarrow$ time interval measured in the observer's frame.

$\Delta t_0 \rightarrow$ proper time interval.

Q.4 An observer is moving with velocity 0.6c making an angle 30° with a rod of length 5m. Calculate the length and the inclination of the rod w.r.t. the observer.

$\rightarrow$ $v = 0.6c$ and $L_0 = 5m$.

component of the length of the rod along x-direction will be,

$$L'_x = L_0 \cos 30^\circ = \frac{5\sqrt{3}}{2}$$

$$= 3.464$$

$$L'_y = L_0 \sin 30^\circ = \frac{L_0}{2} = 2.5$$

The length of the rod in a moving frame (L')

$$L' = \sqrt{L_x'^2 + L_y'^2} = \sqrt{(3.464)^2 + (2.5)^2}$$

$$= 4.27m$$

The orientation of the rod is given by angle θ,

$$\tan\theta = \frac{L'_y}{L'_x} = \frac{2.5}{3.464} = 0.72$$

$$= 35.75^\circ$$

Q.5 Prove that $x^2+y^2+z^2-c^2t^2$ is invarient under Lorentz transformation.

→ $x' = \dfrac{x-vt}{\sqrt{1-\frac{v^2}{c^2}}}$, $y'=y$, $z'=z$

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

$$\therefore\ x'^2+y'^2+z'^2-c^2t'^2 = \left[\frac{x-vt}{\sqrt{1-v^2/c^2}}\right]^2 + y^2+z^2 - c^2\left[\frac{t-vx/c^2}{\sqrt{1-v^2/c^2}}\right]^2$$

$$= \frac{(x-vt)^2 - c^2(t-vx/c)^2}{1-\frac{v^2}{c^2}} + y^2+z^2$$

$$= \frac{x^2+v^2t^2-2xvt - c^2t^2 - v^2x^2/c^2 + 2xvt}{1-v^2/c^2} + y^2+z^2$$

$$= \frac{x^2(1-v^2/c^2) - c^2t^2(1-v^2/c^2)}{(1-v^2/c^2)} + y^2+z^2$$

$$\boxed{= x^2+y^2+z^2-c^2t^2}$$

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Q.6 At what speed is a partical moving if the mass is equal to three times its rest mass?

→ we know, $m = \frac{m_0}{\sqrt{1-\frac{v^2}{c^2}}}$.

$m = 3m_0$

$3m_0 = \frac{m_0}{\sqrt{1-\frac{v^2}{c^2}}}$

$3 = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}} \Rightarrow 1-\frac{v^2}{c^2} = \frac{1}{9}$

$\frac{v^2}{c^2} = \frac{8}{9}$

$v = c\sqrt{\frac{8}{9}} = \frac{c\sqrt{8}}{3} = \frac{2\sqrt{2}c}{3}$

$\Rightarrow 0.943 \times 3\times10^8$

$\boxed{v = 2.829 \times 10^8 m/s}$

Q.7 The proper life of π^- meson is $2.5\times10^{-8}s$ what is the velocity of these mesons if the observed mean life is 2.5×10^7 sec.

→ $t = \frac{\tau}{\sqrt{1-\frac{v^2}{c^2}}} \Rightarrow \sqrt{1-\frac{v^2}{c^2}} = \frac{\tau}{t}$

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$$\sqrt{1-\frac{v^2}{c^2}} = \frac{2.5\times10^{-8}}{2.5\times10^{-7}} = 0.1$$

$$1-\frac{v^2}{c^2} = (0.1)^2 = 0.01$$

$$\frac{v^2}{c^2} = 1-0.01 = 0.99$$

$$v = c\sqrt{0.99} \Rightarrow 3\times10^{8}\times\sqrt{0.99}$$

$$\boxed{v \approx 2.985\times10^{8}\,m/s}$$

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