2023

B.Sc. (Honours)

B.Sc. Fifth Semester End Examination - 2023

PHYSICS

PAPER - CC11T

Full Marks : 40 *Time : 2 hours*

The figures in the right-hand margin indicate marks.
Candidates are required to give their answers in their own words as far as practicable.
Illustrate the answers wherever necessary.

Group - A

1. **Answer any five questions :** **5×2=10**

(a) Prove that for any three operator $\hat{A}, \hat{B}, \hat{C}$

$$\left[\hat{A}, \hat{B}\hat{C}\right] = \left[\hat{A}, \hat{B}\right]\hat{C} + \hat{B}\left[\hat{A}, \hat{C}\right]$$

(b) Find the energy of second excited state of a particle of mass m trapped in one-dimentional box of length ℓ.

(c) What do you mean by "statonary states"?

(d) Consider the ground state wavefunction of hydrogen atom.

(Turn Over)

$\psi_0^{(x,t)} = Ae^{\dots}$

(e) Can Lithium (Z=3) give rise to Normal Zuman effect? Explain.

(f) Prove tht the eigen values of a Hermitian operator are real.

(g) In stern Gerlach experiment why is it necessary to use a beam of neutral atoms and not of ions?

(h) Find out the magnetic moment of an atom in the state $^2D_{3/2}$.

Group- B

Answer any four questions. **4×5=20**

2. Show that the uncertainty product of position and momentum for n^{th} stationary state of infinite square well is given by

$$\Delta x \Delta p = \frac{\hbar}{2}\sqrt{\frac{n^2\pi^2}{3} - 2}$$

3. A particle in the infinite square well has the initial wavefunction.

$$\psi(x, t=0) = A\sin^3\left(\frac{\pi x}{a}\right) \text{for } 0 \le x \le a$$

   1. Determine the normalization constant.
   2. Calculate the expectation value of position.

4. **A particle in an infinite potential box with walls at x=0 and x=a has following wavefunction at some initial time**

$$\psi(x,0) = \frac{1}{\sqrt{5a}}\sin\left(\frac{\pi x}{a}\right) + \frac{2}{\sqrt{5a}}\sin\left(\frac{3\pi x}{a}\right)$$

   (i) **Find the possible results of measurement of the system's energy and corresponding probablities.**

   (ii) Find the expectation value of energy. 2+3

5. State and prove the Ehrenfest Theorem. 1+4

6. What is Larmor Precession? Draw the relevant diagram and derive the expression for Larmor frequency. 1+1+3

7. What is spin orbit coupling? Explain the fine structure splitting in the energy levels due to this. 1+4

Group - C

Answer any one question. **1×10=10**

8. Consider a quantum ostillator of mass m which is kept in a potential

$$V(x) = \frac{1}{2}mw^2x^2$$

where w is classical angular frequency. Also consider two operators given by

$$\hat{a}_\pm = \frac{1}{\sqrt{2\hbar m w}}(\mp i\hat{p} + mw\hat{x})$$

1. Show that $\left[\hat{a}_-,\hat{a}_+\right]=1$
2. Prive that if Ψ satisfies the Schrodinger equation with energy E, then $\hat{a}_\pm\psi$ also satistifes the Schrodinger equation with energy $E\pm\hbar\omega$.
3. Show that the normalised ground state of this quantum harmonic oscillator is

$$\psi_{ground}=\left(\frac{mw}{\pi\hbar}\right)^{1/4}\exp\left\{-\frac{mw}{2\hbar}x^2\right\}$$

4. Show that the expectation value of potential energy in n^{th} state of the harmonic oscillator is given by

$$(V)=\frac{1}{2}\hbar w\left(n+\frac{1}{2}\right)$$

9. The normalized wave function for the ground state of hydrogen like atom is

$$\psi_{100}=\frac{1}{\sqrt{\pi}}\left(\frac{Z}{a_0}\right)^{3/2}e^{-Zr/a_0}$$

1. Calculate the most probable distance.
2. Sketch the radial probablity distribution function $P_{100}(r)$.
3. Calculate the average distance of the electron from the nucleus. 4+(3+1+2)