This question paper contains 4 printed pages.

Your Roll No. ....

Sl. No. of Ques. Paper: **107**

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Unique Paper Code	**: 32221501**
Name of Paper	**: Quantum Mechanics and Applications**
Name of Course	**: B.Sc. (Hons.) Physics**
Semester	**: V**
Duration	**: 3 hours**
Maximum Marks	**: 75**

(Write your Roll No. on the top immediately on receipt of this question paper.)

Attempt five questions in all.
Q. No. 1 is compulsory.
All questions carry equal marks.

Non-programmable calculators are allowed.

1. Attempt any *five* of the following:

   (a) State linearity and superposition principle.

   (b) Prove that:

   $$[x^n, \hat{p}] = -in\hbar x^{n-1}.$$

   (c) What are stationary states? Why are they called so?

   (d) What are the conditions for a wavefunction to be physically acceptable?

(e) What do you mean by space quantization? Explain.

(f) Write the quantum numbers for the state represented by:

$$3^2 D_{3/2}.$$

(g) Define group velocity and phase velocity.

5×3=15

2. (a) Set up the time dependent Schrödinger equation and hence derive the time independent Schrödinger equation.

(b) Derive the expressions for probability density and probability current densities in three dimensions and hence derive the equation of continuity. 7,8

3. (a) Give the theory to explain spreading of a Gaussian wave packet for a free particle in one dimension.

(b) Normalize the following wave function for a particle in one dimension:

$$\begin{cases} A \sin\left(\frac{\pi x}{a}\right) & 0<x<a \\ 0 & \text{outside} \end{cases}$$

10,5

4. (a) Solve the Schrödinger equation for a Linear Harmonic Oscillator to show that the energy eigenvalues are:

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

(b) A Harmonic Oscillator has a wave function which is superposition of its ground state and first excited state normalized eigenfunctions are given by:

$$\Psi(x) = \frac{1}{\sqrt{2}} [\psi_0(x)+\psi_1(x)].$$

Find the expectation value of the energy. 10,5

5. Write the Schrödinger equation for a 3D hydrogen atom in spherical polar coordinates. Derive three separate equations for r, θ, φ using the method of separation of variables. Solve the equation for φ to obtain the normalized eigenfunctions and show that they are orthogonal. 15

6. (a) Describe Stern Gerlach experiment with necessary theory. What does it demonstrate?

(b) Explain Normal Zeeman Effect with examples and energy diagram. 8,7

7. (a) What is spin orbit coupling? Calculate the change in the energy levels due to this.

(b) Show the result of an LS coupling of two non-equivalent p-electrons. 10,5