2021
M.Sc.
First Semester
CORE – 02
PHYSICS
Course Code: MPHC 1.21
(Quantum Mechanics - I)

Total Mark: 70 *Pass Mark: 28*
Time: 3 hours

Answer five *questions, taking* one *from each unit.*

UNIT–I

1. (a) Obtain the Born's statistical interpretation of a wave function associated with a particle. 4
   (b) Obtain equation of continuity. Give its physical significance. 5
   (c) Consider the wave function of a particle

$$\psi(x) = A\left(1 - \frac{x}{a}\right), \text{ for } \frac{a}{2} < x < a$$

   Find the normalization constant A and also obtain $\langle x \rangle$ 5

2. (a) Find the probability current density if the wave function is

$$\psi(x) = Ae^{ikx}$$ 3

   (b) Show that $\frac{d\langle x \rangle}{dt} = \frac{\langle P_x \rangle}{m}$ 4

   (c) Establish the Schrödinger equation for a linear harmonic oscillator and solve it to obtain its eigenvalues and eigenfunctions. Discuss the significance of zero-point energy. 7

UNIT–II

3. (a) What are bound state and stationary state? A state may be bound state classically but not necessarily for quantum mechanical state. Justify the statement with examples. 7

   (b) Define delta potential. Show that the delta function potential has only one bound state. 7

4. (a) Define Hermitian operator. Show that the position and momentum operators are Hermitian operators. 7

   (b) Explain Hilbert space in detail. 7

UNIT–III

5. (a) Show that the commutator of position coordinate and the corresponding momentum component is non-vanishing and for the component which does not corresponds to it is zero. 5

   (b) Explain the coherent state of the harmonic oscillator. 5

   (c) Explain the Dirac Bra-Ket notation and give its properties. 4

6. (a) Discuss the Schrödinger equation for hydrogen atom qualitatively and obtain its solution for eigenvalues and eigenfunctions. 10

   (b) Calculate the expectation value of the potential energy in the ground state of the hydrogen atom. 4

UNIT–IV

7. (a) Prove that L_+ is a raising angular momentum operator, where

   $L_+ = L_x + iL_y$ 4

   (b) Obtain the Pauli spin matrices for spin ½ system. 5

   (c) Obtain Schrödinger equation for a rigid rotator with fixed axis and solve it to obtain the eigenvalues and eigenfunctions. 5

8. (a) Derive the recursion relation for Clebsch-Gordan coefficients. 7

(b) Find all the eigen states for a system of two particles having angular momentum $j_1 = 1$ and $j_2 = \frac{1}{2}$ and calculate the corresponding Clebsch-Gordan coefficients. 7

UNIT–V

9. (a) Obtain the mathematical formulation of Slater determinant. Find the overall wave function of ground state and first excited state for helium atom using Slater determinant. 9

(b) Show that the normalized wave functions of ortho helium is symmetric and anti-symmetric for para helium. Draw the singlet and triplet energy level diagram. 5

10. (a) Derive the Schrödinger time independent equation for two particle system. Obtain the ground state eigenfunctions and eigenvalues for identical bosons and fermions. 7

(b) Explain the mechanism of exchange forces for distinguishable particles and identical particles. 7

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