2023
M.Sc.
First Semester
CORE – 02
PHYSICS
Course Code: MPHC 1.11
(Quantum Mechanics - I)

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

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

UNIT–I

1. (a) Write the Schrödinger equations for a particle. What is the physical significance of the wave function? Explain the interpretation by Born. 5

   (b) Normalize the wave function $\psi_1 = A_1 e^{-\alpha x^2}$ and $\psi_2 = A_2 x e^{-\alpha x^2}$ in the interval $-\infty \le x \le \infty$. Are the wave function orthogonal in this interval. 4

   (c) State and prove the Ehrenfest's second theorem. 5

2. (a) Obtain the energy eigen value and eigen function of one dimensional harmonic oscillator using analytical method. 8

   (b) Show that the normalized wave function associated with a Gaussian wave packet is $\psi = \left(\frac{2a^2}{\pi}\right)^{\frac{1}{4}} e^{-\alpha^2 x^2}$ 6

UNIT –II

3. (a) Define delta function potential. Show that the delta function potential has only one bound state. 8

   (b) Explain Hilbert space and Dirac notation. 6

4. (a) Prove that the eigen functions of a Hermitian operator corresponding to different eigen values are orthogonal. 4

(b) Obtain the Heisenberg uncertainty principle using Hermitian operator. 7

(c) Using mathematical induction, show that $\left[x^n , p \right] = i\hbar n x^{n-1}$. 3

UNIT–III

5. (a) Derive the expression for the coherent state of linear harmonic oscillator. 7

(b) What is the azimuthal component of the Schrödinger equation? Solve this equation and find the normalized eigen functions. 7

6. (a) Solve the Schrödinger equation for the radial wave function and find the allowed energies of the electron in the hydrogen atom. 8

(b) What are spherical harmonics? Express their values for the ground state of the hydrogen atom. 2

(c) Show that the commutator of position coordinate and the corresponding momentum operator is non-vanishing and has eigen value $i\hbar$. 4

UNIT–IV

7. (a) Explain the concept of parity. Show that eigen values of parity operators are +1 and –1. 7

(b) Describe Stern-Gerlach experiment. How does it explain the space quantization and electron spin? 7

8. (a) Derive the relation between total magnetic moment and total angular momentum. 7

(b) Obtain the Clebsch-Gordan coefficient for a system having $j_1 = \frac{1}{2}$ and $j_2 = \frac{1}{2}$. 7

UNIT–V

9. (a) Explain exchange forces between two identical particles. 7
   (b) For a symmetric wave function, two particles can simultaneously exist in the same quantum state, while for an anti-symmetric wave function, two particles cannot be in the same quantum state. Justify the statement with examples. 7

10. (a) Write a short note on positronium hydrogen. Show that the positronium energy is half of the hydrogen atom. 7
    (b) Draw the energy level diagram for para and ortho helium. 2
    (c) Explain Hund's three rules with examples. 5
