



## Avinashilingam Institute for Home Science and Higher Education for Women

Deemed to be University Estd. u/s 3 of UGC Act 1956, Category A by MHRD (now MoE)

Re-accredited with A++ Grade by NAAC. CGPA 3.65/4, Category I by UGC

Coimbatore - 641 043, Tamil Nadu, India

### Master's Degree Examination – May 2025

#### II Semester

Class : I P.G.  
Major : Physics

Time: 3 Hours  
Max. Marks: 100

#### 23MPHC07 Quantum Mechanics I

##### Course Outcomes:

CO1: Explain the evolution of quantum theory

CO2: Enumerate properties of operators in quantum mechanics.

CO3: Describe about linear vector spaces, Hilbert space, concepts of basis and operators

CO4: Solve Schrödinger equations for various potentials and apply to hydrogen atom

CO5: Analyze orbital and spin angular momentum matrices and calculate Clebsh-Gordan Coefficient

##### Part A

10 x 1 = 10

##### Choose the Correct Answer

1. The quantity  $|\Psi^2|$  is called CO1K2
  - a. Probability density
  - b. probability current density
  - c. Propagation density
  - d. Normalized density
2. A free particle is best described by CO1K1
  - a. wave packet
  - b. plane wave
  - c. exponential form
  - d. wave function
3. Which of the following is true about eigenfunctions of a Hermitian operator? CO2K2
  - a. They are always real
  - b. They form a complete orthonormal set
  - c. They correspond to non-degenerate eigen values only
  - d. They are not normalizable
4. The time evolution of a quantum state is governed by which operator? CO2K2
  - a. The position operator
  - b. The Hamiltonian operator
  - c. The momentum operator
  - d. The lowering operator
5. Which of the following is true about Hermitian matrices? CO3K1
  - a. Their eigenvalues are always complex
  - b. They are equal to their transpose
  - c. They are equal to their conjugate transpose
  - d. They are always unitary
6. The Hilbert space in quantum mechanics is: CO3K2
  - a. A finite-dimensional vector space
  - b. A complete vector space of square-integrable functions
  - c. A space of operators
  - d. A space of classical states
7. For an unbound system of a free particle CO4K1
  - a.  $E=0$
  - b.  $E=V_0$
  - c.  $E < V_0$
  - d.  $E > V_0$
8. For a hydrogen-like atom, the principal quantum number  $n$  determines: CO4K2
  - a. The shape of the orbital
  - b. The orientation of the orbital
  - c. The energy of the electron
  - d. The spin of the electron
9. The time-independent Schrödinger equation for a particle in a potential  $V(x)$  is: CO5K2
  - a.  $(i\hbar)\partial\psi/\partial t = (-\hbar^2/2m)\nabla^2\psi + V\psi$
  - b.  $(-\hbar^2/2m)\nabla^2\psi + V\psi = E\psi$
  - c.  $(-\hbar^2/2m)d^2\psi/dx^2 = E\psi$
  - d.  $i\hbar(d\psi/dt) = E\psi$
10. In quantum mechanics, the total angular momentum  $J$  is given by: CO5K1
  - a.  $L/S$
  - b.  $L \times S$
  - c.  $L-S$
  - d.  $L+S$

**Part B****5 x 6 = 30****Answer ALL questions****Each answer should not exceed 400 words or two pages**

- 11.a. State and prove correspondence principle. CO1K2  
(or)
- 11.b. How does the superposition principle contribute to the construction of wave packets and what role do phase and group velocities play in their propagation? CO1K2
- 12.a. Define operator and linear operator. Mention the properties of linear operator. CO2K2  
(or)
- 12.b. Give the analogy between commutator bracket and Poisson bracket. CO2K2
- 13.a. Explain Schmidt's orthogonalization method. CO3K2  
(or)
- 13.b. Write a note on Dirac's notation. CO3K2
- 14.a. A particle in an infinitely deep potential well is in a state described by the wave function  $\psi(x) = Ax(a - x)$ , where  $a$  is the well depth and  $A$  is a constant. Find the probability distribution for the different energies of the particle and also the average value and the dispersion of the energy. CO4K3  
(or)
- 14.b. The energy of a linear harmonic oscillator in third excited state is 0.1eV. Find the frequency of vibration. CO4K3
- 15.a. State the commutation relations obeyed by the components of angular momentum and express them in vector notation. CO5K2  
(or)
- 15.b. For a spin  $\frac{1}{2}$  system, state the matrices for  $S_x$ ,  $S_y$  and  $S_z$ . List their eigen values with the corresponding eigen vectors. CO5K2

**Part C****5 x 12 = 60****Answer ALL questions****Each answer should not exceed 800 words or four pages**

- 16.a. Show that the average motion of a wave packet corresponding to a particle of mass  $m$  satisfies the equation  $\frac{d}{dx} \langle x \rangle = \frac{\langle p_x \rangle}{m}$  and  $\frac{d \langle p_x \rangle}{dt} = - \langle \frac{\partial V}{\partial x} \rangle$  CO1K2  
(or)
- 16.b. Arrive at the time dependant and time independent Schrodinger equation from the equation of motion of a wave packet. CO1K2
- 17.a. What is a Hermitian operator? Give its properties and show that the momentum operator  $\frac{\hbar}{i} \frac{\partial}{\partial x}$  is Hermitian. CO2K3  
(or)
- 17.b. What is Schwarz's inequality? Derive Heisenberg's uncertainty relations from operators. CO2K3
- 18.a. Elaborate Schrodinger and Heisenberg picture. CO3K2  
(or)
- 18.b. Discuss the matrix theory of Harmonic oscillator. CO3K2
- 19.a. Write the Schrodinger's equation for the hydrogen atom and separate it into radial and angular part. CO4K2  
(or)
- 19.b. Explain the problem of the leakage of a particle through a rectangular potential barrier of finite width and explain the theory of  $\alpha$ - particle decay. CO4K2
- 20.a. What is the significance of addition of angular momentum? What are Clebsh-Gordan coefficients? Deduce the recursion relation between CG coefficients. CO5K3  
(or)
- 20.b. Obtain the Clebsh-Gordan coefficients for a system having  $j_1=1$  and  $j_2=1/2$ . CO5K3

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