(AUTONOMOUS)

MSc DEGREE EXAMINATION MAY 2026
(First Semester)

Branch – **PHYSICS**

QUANTUM MECHANICS - I

Time: Three Hours Maximum: 75 Marks

SECTION-A (10 Marks)
Answer **ALL** questions
ALL questions carry **EQUAL** marks (10 × 1 = 10)

Module No.	Question No.	Question	K Level	CO
1	1	Which of the following is **not** one of the fundamental postulates of quantum mechanics? a. Physical states are represented by unit-norm vectors in a complex Hilbert space b. Observables correspond to Hermitian operators c. Measurement outcomes are given by eigenvalues of the observable and follow the Born rule d. Wavefunctions must always be real functions	K1	CO1
	2	Which of the following operators is not Hermitian? a. Position operator $\hat{x}$ b. Momentum operator $\hat{P} = -i\hbar\frac{d}{dx}$ c. Creation operator $a^{\dagger}$ for the quantum harmonic oscillator d. Hamiltonian $\hat{H}$ of a closed system	K2	CO1
2	3	When two angular momenta J_1 and J_2 are added, which of the following is a valid total angular momentum quantum number J? a. $J = J_1 + J_2$ b. $J = \|J_1 - J_2\|$ c. $J = J_1 X J_2$ d. $J = J_1 + J_2, J_1 + J_2 - 1 \ldots, \|J_1 - J_2\|$	K1	CO2
	4	For a spin-1/2 particle, what are the eigenvalues of the spin operator S_z? a. $\hbar, 2\hbar$ b. $\pm\frac{\hbar}{2}$ c. $0, \hbar$ d. $\pm\hbar$	K2	CO2
3	5	Which of the following best describes a non-degenerate energy level in quantum mechanics? a. An energy level that is always zero b. An energy level with only one associated eigenstate c. An energy level with multiple distinct eigenstates d. An energy level that depends on external fields	K1	CO3
	6	What is the primary reason the ground state of helium cannot be solved exactly using analytical methods? a. It has no electrons b. It involves strong relativistic effects c. It includes electron-electron interactions d. It is a degenerate state	K2	CO3
4	7	Einstein's A coefficient represents: a. Stimulated emission b. Spontaneous emission c. Population inversion d. Stimulated absorption	K1	CO4
	8	In Raman scattering, the scattered photon has: a. Lower and higher energy depending on vibrational transitions b. The same energy as the incident photon c. Zero energy d. Higher energy than the incident photon	K2	CO4
5	9	Which of the following correctly describes the Heisenberg picture? a. Operators evolve with time while states remain fixed b. Both operators and states evolve with time c. Operators are time-independent and states evolve d. Neither operators nor states evolve	K1	CO5
	10	What is the energy eigenvalue of the ground state of a quantum harmonic oscillator? a. $\frac{3}{2}\hbar\omega$ b. $\hbar\omega$ c. 0 d. $\frac{1}{2}\hbar\omega$	K2	CO5

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Answer **ALL** questions
ALL questions carry **EQUAL** Marks (5 × 7 = 35)

Module No.	Question No.	Question	K Level	CO
1	11.a.	Prove that the expectation value of a Hermitian operator is always real. Why are Hermitian operators used to represent observables in quantum mechanics?	K3	CO1
		(OR)		
	11.b.	Explain the Dirac bra–ket notation and demonstrate how it simplifies the representation of inner products, operators, and expectation values in quantum mechanics.		
2	12.a.	Show that the eigenvalues of L_z and L^2 are $\hbar m$ and $\hbar^2 l(l+1)$, respectively. Discuss the allowed values of ll and mm, and describe the degeneracy of energy levels in central potentials.	K4	CO2
		(OR)		
	12.b.	Explain the procedure for adding two angular momenta j_1 and j_2. Derive the possible values of the total angular momentum quantum number J, and discuss the role of Clebsch–Gordan coefficients.		
3	13.a.	Analyze the effect of an external electric field on the degenerate $n = 2$ state of the hydrogen atom. Explain how the Stark effect leads to energy level splitting and discuss the selection rules involved.	K4	CO3
		(OR)		
	13.b.	Discuss the effect of a weak external electric field on a non-degenerate ground state of an atom. Use the concept of the Stark effect to explain the energy shift and its dependence on the field strength.		
4	14.a.	Consider a quantum system subjected to a harmonic perturbation of the form $V(t) = V_0 \cos(\omega t)$. Derive the transition probability between two energy levels and explain the role of resonance in maximizing transition rates.	K3	CO4
		(OR)		
	14.b.	State and explain the selection rules for electric dipole transitions. Use parity and angular momentum conservation to justify allowed and forbidden transitions in atomic systems.		
5	15.a.	Define the interaction (Dirac) picture and explain its relevance in time-dependent perturbation theory. How does it interpolate between the Schrödinger and Heisenberg pictures?	K3	CO5
		(OR)		
	15.b.	Outline the method of second quantization for the harmonic oscillator. Define creation and annihilation operators and derive the Hamiltonian in terms of these operators.		

SECTION -C (30 Marks)

Answer **ANY THREE** questions
ALL questions carry **EQUAL** Marks (3 × 10 = 30)

Module No.	Question No.	Question	K Level	CO
1	16	Solve the eigenvalue problem for a given linear operator in a finite-dimensional Hilbert space. Discuss the conditions under which a complete set of eigenfunctions exists and explain the role of the spectral theorem in quantum mechanics.	K2	CO1
2	17	Define spin angular momentum for a spin-½ particle. Construct the spin operators S_x, S_y, S_z using Pauli matrices, and determine the eigenvalues and eigenvectors of S_z. Discuss the physical interpretation of spin measurements.	K3	CO2
3	18	Why the ground state of the helium atom cannot be solved exactly using analytical methods. Describe the role of electron–electron repulsion and outline how the variational method can be used to estimate the ground state energy. Include a sketch of the trial wavefunction and energy minimization approach.	K4	CO3
4	19	Derive the relations between Einstein's A and B coefficients using Planck's radiation law. Explain the physical significance of spontaneous and stimulated emission, and discuss how these coefficients govern radiative balance in thermal equilibrium.	K5	CO4
5	20	Starting from the Heisenberg equation of motion, derive the time evolution of a general observable $\hat{A}(t)$. Discuss the conditions under which the observable is conserved and relate this to symmetries in the Hamiltonian.	K5	CO5

Z-Z-Z END