(AUTONOMOUS)

MSc DEGREE EXAMINATION MAY 2026

(Second Semester)

Branch – **PHYSICS**

QUANTUM MECHANICS - II

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	The Rayleigh-Ritz method is primarily used to: (i) Solve time-dependent Schrödinger equations. (ii) Approximate eigenvalues by expanding the trial wavefunction in a finite basis set. (iii) Determine exact solutions for multi-electron atoms. (iv) Calculate transition probabilities between states.	K1	CO1
	2	The binding energy of the deuteron ground state is primarily due to: (i) Coulomb attraction between proton and neutron. (ii) Strong nuclear force between proton and neutron. (iii) Exchange interaction between electrons. (iv) Spin-spin interaction of nucleons only.	K2	CO1
2	3	In the classically forbidden region (E < V), the WKB wavefunction behaves as: (i) Oscillatory with constant amplitude (ii) Purely imaginary (iii) Exponentially growing or decaying (iv) Constant	K1	CO2
	4	Gamow's theory of alpha emission using WKB predicts that the decay rate depends: (i) Linearly on the atomic number Z (ii) Exponentially on Z and the energy of the alpha particle (iii) Only on the nuclear radius (iv) Inversely on the nuclear mass	K2	CO2
3	5	The differential scattering cross-section $d\sigma/d\Omega$ is defined as: (i) The total number of particles scattered per second (ii) The ratio of scattered flux per unit solid angle to the incident flux per unit area (iii) The area of the target nucleus presented to the beam (iv) The probability that a particle is absorbed by the target	K1	CO3
	6	The phase shift δ_l in quantum scattering represents: (i) The energy lost by the particle during scattering (ii) The shift in phase of the radial wavefunction relative to the free-particle solution due to the scattering potential (iii) The angular deflection of the particle trajectory (iv) The time delay of the scattered wave packet	K2	CO3
4	7	The Klein–Gordon equation is primarily used to describe: (i) Spin-½ particles (ii) Spin-0 particles (iii) Spin-1 particles (iv) Spin-2 particles	K1	CO4
	8	Spin–orbit interaction arises due to: (i) Interaction of spin with external magnetic field (ii) Coupling between electron's spin and orbital angular momentum in the presence of electric field (iii) Interaction of spin with photon polarization (iv) Interaction of spin with gravitational field	K1	CO4
5	9	The Hamiltonian density is obtained from the Lagrangian density by: (i) Legendre transformation (ii) Fourier transformation (iii) Laplace transformation (iv) Taylor expansion	K1	CO5
	10	The number operator's eigenvalue represents: (i) Energy of the system (ii) Momentum of the particle (iii) Number of particles in the state (iv) Spin of the particle	K1	CO5

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SECTION - B (35 Marks)

Answer **ALL** questions

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

Module No.	Question No.	Question	K Level	CO
1	11.a.	Describe the Rayleigh-Ritz linear variational method and derive the secular equation.	K3	CO1
		(OR)		
	11.b.	State and explain the Hellmann–Feynman theorem. How can this theorem be applied to evaluate forces in quantum systems?		
2	12.a.	Starting from the time-independent Schrödinger equation, develop the WKB solutions for classically allowed and forbidden regions. Using Airy functions, derive the connection formulae at a turning point and state their physical interpretation.	K3	CO2
		(OR)		
	12.b.	Apply the WKB approximation to derive the Gamow formula for the alpha-decay rate. Explain the Geiger–Nuttall law and show how it follows from the WKB result. Discuss why heavier nuclei have longer half-lives.		
3	13.a.	Derive the expression for the scattering amplitude using partial wave analysis for a particle scattered by a central potential. Explain how phase shifts enter into the formulation.	K4	CO3
		(OR)		
	13.b.	Apply the Born approximation to the Coulomb potential and discuss why it fails. Contrast this with the exact Rutherford scattering result.		
4	14.a.	Derive the Dirac equation and explain its significance compared to the Klein–Gordon equation.	K4	CO4
		(OR)		
	14.b.	Discuss the origin and physical meaning of spin–orbit interaction in atomic systems.		
5	15.a.	Write the Lagrangian density for a scalar field and explain its significance.	K3	CO5
		(OR)		
	15.b.	Define creation and annihilation operators and state their commutation relations.		

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	Discuss the variational method for a one-dimensional harmonic oscillator using the Gaussian trial function $\varphi(x) = \exp(-\alpha x^2)$.	K3	CO1
2	17	Using the WKB approximation, derive the tunnelling transmission coefficient through an arbitrary potential barrier and discuss its physical consequences.	K4	CO2
3	18	Derive scattering amplitude using partial waves, explain scattering length in s-wave limit, outline Born approximation, and compare its validity for short-range vs Coulomb potentials	K5	CO3
4	19	Derive the Dirac equation in covariant form, explain the role of Dirac matrices, and show how the theory leads to a conserved probability density.	K5	CO4
5	20	Derive the quantization of the non-relativistic Schrödinger equation. Explain how the wavefunction is promoted to an operator in second quantization.	K5	CO5

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