(FOR THE CANDIDATES ADMITTED DURING THE ACADEMIC YEARS 2024-26 ONLY)

SUBJECT CODE 24PPS204

REG.NO.

N.G.M.COLLEGE (AUTONOMOUS) : POLLACHI

END-OF-SEMESTER EXAMINATIONS : MAY – 2025

M.Sc.-PHYSICS **MAXIMUM MARKS: 75**

II SEMESTER **TIME : 3 HOURS**

QUANTUM MECHANICS I

SECTION – A (10 X 1 = 10 MARKS)

ANSWER THE FOLLOWING QUESTIONS. (K1)

1. The Hermitian conjugate of $\lambda A|\psi_1><\psi_1|B^+$ is ………
   (a) $B^+ <\psi_2|\psi_1> A\lambda$ (b) $B^+ <\psi_2|\psi_1> A^+\lambda$
   (c) $\lambda^* B|\psi_2><\psi_1|A^+$ (d) $\lambda^* B|\psi_1><\psi_2|A$

2. For a particle of mass m in a one-dimensional box of length L, the average momentum P_x for the ground state is……………
   (a) 0 (b) $\frac{h}{2L}$ (c) $\frac{h}{L}$ (d) $\frac{h}{2\pi L}$

3. The value of $[\widehat{L_x^2} + L_y^2, L_z]$ will be **…………….**
   (a) $(\widehat{L_y} + \widehat{L_x})i\hbar$ (b) $(\widehat{L_y} - \widehat{L_x})i\hbar$
   (c) $i\hbar\widehat{L_z}$ (d) 0

4. The WKB method applies to the system whose……………….
   (a) potential energy is equal to zero (b) kinetic energy is equal to zero
   (c) potential energy is slowly varying (d) kinetic energy is slowly varying

5. If a quantum system is subjected to a weak, time-independent perturbation, the probability of transition to a continuum of final states is directly proportional to …………….
   (a) The square root of the transition energy
   (b) The energy difference between initial and final states
   (c) The square of the perturbation matrix element
   (d) The cube of the density of final states

ANSWER THE FOLLOWING IN ONE (OR) TWO SENTENCES. (K2)

6. State Ehrenfest theorem.
7. Does the zero-point energy of a quantum harmonic oscillator arise as a consequence of the Heisenberg Uncertainty principle?
8. Why can electrons with Parallel Spins not Occupy the Same State?
9. What does the Hellmann-Feynman theorem state about the relationship between the total energy of a quantum system and the nuclear positions?
10. Mention the condition under which the Fermi Golden Rule remains valid for describing transition probabilities

(CONTD …. 2)

SECTION – B (5 X 5 = 25 MARKS)

ANSWER EITHER (a) OR (b) IN EACH OF THE FOLLOWING QUESTIONS.

(K3)

11. a) Deduce the value of
(i) $[x^2, p^2]$
(ii) $[\alpha, \cos x]$, with $\alpha = x + \frac{d}{dx}$

(OR)

b) Let the normalized eigenstates of the Hamiltonian $H = \begin{pmatrix} 2 & 1 & 0 \\ 1 & 2 & 0 \\ 0 & 0 & 2 \end{pmatrix}$ be $|\psi_1>$, $|\psi_2>$, and $|\psi_3>$. Calculate the expectation value of $<H>$ and the variance of H in the state $|\psi> = \frac{1}{\sqrt{3}}(|\psi_1> + |\psi_2> - i|\psi_3>)$.

12. a) Obtain the eigenvalue and eigenfunction of a rigid rotator.

(OR)

b) The wavefunction of the electron in a Hydrogen atom is $\psi(r) = \frac{1}{\sqrt{6}}\Phi_{200}(r) + \sqrt{\frac{2}{3}}\Phi_{21-1}(r) - \frac{1}{\sqrt{6}}\Phi_{100}(r)$. Where $\Phi_{nlm}(r)$ is the eigenstate of the Hamiltonian.

Calculate the expectation value of energy in this state.

13. a) Show that
(i) $[L_x, L_y]2i\hbar L_z$
(ii) $[L_z, L_+] = \hbar[L_x + iL_y]$

(OR)

b) State the Pauli exclusion principle and explain how it arises from the antisymmetry of the wave function.

14. a) Explain the perturbation method for a degenerate system.

(OR)

b) How is the variational principle used to get the approximate solution to Schrodinger's equation?

15. a) Using constant perturbation, deduce Fermi golden rule.

(OR)

b) Write short on
(i) Sudden approximation
(ii) Harmonic perturbation

SECTION – C (5 X 8 = 40 MARKS)

ANSWER EITHER (a) OR (b) IN EACH OF THE FOLLOWING QUESTIONS.

(K4 (Or) K5)

16. a) State and explain the postulates of Quantum mechanics.

(OR)

b) Explain the Heisenberg and Dirac representations with equations of motion and operators.

(CONTD …. 3)

17. a) Obtain the angular and radial solutions for the Hydrogen atom using the Schrodinger equation.

(OR)

b) Using the analytic method, obtain the eigenvalue and eigenfunction for the Linear Harmonic oscillator.

18. a) Findthe eigenvalue of J^2, J_z.

(OR)

b) Derive Clebsch-Gordon coefficients and obtain the selection rule and recursion relations.

19. a) Discuss the formulation of non-degenerate perturbation theory; derive the first and second-order corrections to the eigenfunction and eigenvalue.

(OR)

b) How is the perturbation method used to study the ground state of the He atom and anharmonic oscillator?

20. a) Explain first-order time-dependent perturbation theory.

(OR)

b) Obtain the scattering amplitude for a beam of particles of mass m travelling along the z-axis with velocity v and scattered by a scattering potential V centered at the origin. Assume the scattering angle to be θ.

ETHICAL PAPER

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