May 2025
M.Sc.
Second Semester
CORE – 06
PHYSICS
Course Code: MPHC 2.21
(Quantum Mechanics - II)

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

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

UNIT–I

1. (a) Derive the expression for energy shift in the fine structure of hydrogen atom due to relativistic correction. 7

   (b) If the perturbation $H' = ax + bx^2$ is added to the infinite square well potential $V(x) = \begin{cases} 0 & \text{for } 0 \le x \le \pi \\ \infty & \text{otherwise} \end{cases}$, obtain the first order correction to the ground state energy. 4

   (c) Explain spin-orbit interaction in brief. 3

2. (a) Derive the fundamental result of two-fold degenerate perturbation theory. 7

   (b) The Hamiltonian matrix of a system is $H = \begin{pmatrix} 1 & \varepsilon & 0 \\ \varepsilon & 1 & 0 \\ 0 & 0 & 2 \end{pmatrix}$. Find the energy eigenvalues to first order perturbation. 3

   (c) What is Zeeman effect? Give a brief account on the strong Zeeman splitting for the ground state of H-atom. 4

UNIT–II

3. (a) Obtain the solutions of two-level systems for time dependent perturbation theory. 8

   (b) Deduce the transition probability for sinusoidal perturbations. 6

4. (a) What is an adiabatic process? Prove the adiabatic theorem. 7
   (b) Establish the relations between the Einstein coefficients. 7

UNIT–III

5. (a) Obtain the solution of the hydrogen molecule ion using variational principle. 9
   (b) Find the ground state energy of a particle of mass m in potential $V(x) = \frac{\hbar^2 \beta x^2}{6m}$, and a trial wave function $\Psi(x) = \left(\frac{\alpha}{\pi}\right)^{1/4} e^{-\alpha x^2/2}$. 5

6. (a) Show that the variational principle gives a more realistic theoretical value to the ground state energy of helium atom. 9
   (b) Use the variational method to estimate the energy ground state of a 1-D harmonic oscillator that has a trial wave function $\Psi_0 = Ae^{-\alpha}$. 5

UNIT–IV

7. (a) Explain the condition for the validity of WKB approximation. Obtain the WKB solution for classically allowed region, classically forbidden region and show that WKB method blows up at the classically turning point. 8
   (b) Show that the tunnelling transmission probability through a barrier is given by $T \cong e^{-2\gamma}$. 6

8. (a) Derive the connection formula for WKB approximation. 8
   (b) Obtain the energy eigenvalue for potential well with two vertical walls using WKB method. 6

UNIT–V

9. (a) Using the method of partial wave, obtain the cross-section for scattering by a perfectly rigid sphere. 8
   (b) Deduce the Rayleigh formula for quantum scattering. 6

10. (a) Explain quantum scattering theory. Prove that $\sigma(\theta, \Phi) = |f(\theta, \Phi)|^2$. 6

(b) Show that for a quantum hard sphere scattering, the total scattering cross-section for low energy scattering is twice the total scattering cross-section for high energy scattering. 8