October 2025
B.A./B.Sc.
Fifth Semester
CORE – 11
PHYSICS
Course Code: PHC 5.11
(Quantum Mechanics & Applications)

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

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

UNIT–I

1. (a) What is an eigenvalue equation? Show that the time-dependent Schrödinger equation is an example of eigenvalue equation. 6
   (b) Normalise the wave function and find the probability of finding the particle in the region described by the Gaussian wave packet, $\psi(x) = Ae^{\frac{\alpha^2 x^2}{2^{e^{jkx}}}}$ in the region $-\infty$ to $+\infty$. 4
   (c) What is a wave function? Discuss its physical significance and requirements of a wave functions. 4

2. (a) What are the basic operators of quantum mechanics? Show that the commutator of position coordinates and momentum component which does not correspond to it is always zero. 6
   (b) A particle is confined in the region $0 < x < a$, in 1-D infinite square well. If the particle is in the first excited state, then find the maximum probability of finding the particle in the 1-D box. 3
   (c) Prove that the average motion of wave packet agrees with the motion of the corresponding classical motion of particle obeying Newton's second law of motion. 5

UNIT–II

3. (a) Obtain the energy eigenvalues and the normalized eigenfunctions equation for a particle in a one-dimensional infinite square well potential 7

   (b) Calculate the zero-point energy of a mass of 5×10^{-4} kg connected to a fixed point by a spring, which is stretched 0.01 m by a force of 10^{-2} N. The particle is constrained to move along x-axis. 2

   (c) Discuss potential barrier qualitatively for $E > 0$. 5

4. (a) Show that the probability of finding the particle outside the classical limits is approximately 16%, assuming that the oscillator is in its normal state. 5

   (b) Find the energy of the first excited state of an electron confined to move in a one-dimension potential box of 1 Å.
   (Given $m = 9.11\times10^{-31}$ kg, $\hbar = 1.054\times10^{-34}$ Js) 2

   (c) What is meant by barrier penetration? Deduce the expression for reflection and transmission coefficient for a step potential. 7

UNIT–III

5. (a) Solve the Schrödinger equation for the radial wave function and find the allowed energies of the electron of the hydrogen atom. 8

   (b) What is spherically symmetric potential? Obtain the solution of the Schrödinger equation for spherically symmetric potentials by separation of variables 6

6. (a) What are spherical harmonics? Find the spherical harmonics for the ground state and first excited state of the hydrogen atom. 5

   (b) Explain the physical significance of the following: 6
   (i) Principal quantum number (n)
   (ii) Orbital quantum number (l)
   (iii) Magnetic quantum number (m_l)

   (c) Calculate the most probable radius r for an electron in the ground state of the hydrogen atom. 3

UNIT–IV

7. (a) What is Larmor precession? Obtain an expression for Larmor frequency. 6

   (b) Discuss the quantum mechanical theory of anomalous Zeeman effect, with special reference to Zeeman pattern for D_1 lines of sodium. Draw the neat diagram to illustrate Zeeman splitting of D_1 lines of sodium. 8

8. (a) What is magnetic dipole moment? Prove the space quantization of spin magnetic moment. 7

   (b) Describe Stern-Gerlach experiment. How does it explain the space quantization and electron spin? 7

UNIT–V

9. (a) Explain the symmetric and anti-symmetric wave functions. Show that no two electrons can occupy the same quantum state. 7

   (b) Explain spin orbit coupling. Prove that the magnetic field observed by the electron depends on its own orbital angular momentum. 7

10. (a) Give a detailed account of Bohr's explanation of atomic spectra of hydrogen atom. 8

    (b) What is LS coupling? Draw a fully labelled energy level diagram showing the levels for 4s3d configuration. 6
