2023

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) If ψ_1 and ψ_2 are two solutions of the Schrödinger equation, show that a linear combination $\psi = c_1\psi_1 + c_2\psi_2$, where c_1 and c_2 are constants is also a solution. 3

(b) Find the expectation value of momentum and position for a particle described by the wave function

$$\psi = \begin{cases} \sqrt{\frac{2}{a}} \sin \frac{n\pi x}{a}, & 0 < x < L \\ 0, & elsewhere \end{cases}$$ 5

(c) State the fundamental postulates of quantum mechanics and hence derive the Schrödinger time-dependent equation. 6

2. (a) What is a Gaussian wave packet? Obtain the expression for the normalized wave function associated with a Gaussian wave packet. 6

(b) What are momentum-space wave functions? Show that these wave functions can be obtained as Fourier transform of position-space wave functions. 6

(c) Calculate the uncertainty in momentum of an electron, if the uncertainty in position is 2Å. 2

UNIT –II

3. (a) What are bound state? Show that for bound states of a one-dimensional system, the energy states are non-degenerate. Plot the first three eigen functions. 5

   (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. 3

   (c) Show that there is always some probability of transmission for a quantum mechanical particle with energy $E < V_0$. 6

4. (a) Derive the energy eigen values and eigen functions for a linear harmonic oscillator. 8

   (b) What is the zero point energy of a pendulum of length 1 m and a bob of mass 0.1 kg? 2

   (c) For a linear harmonic oscillator in the ground state, show that the probability of finding the particle outside the classical limits is approximately 0.16. 4

UNIT–III

5. (a) How much energy is released, when a 3d electron in the hydrogen atom makes a transition to 2p state? 2

   (b) Why are spherical polar coordinates convenient in the Schrödinger equation? Solve the zenith component of the Schrödinger equation and find the normalized eigen functions. 8

   (c) Define radial probability density. Find the radial probability density for the first excited state in hydrogen atom. 4

6. (a) The ground state wave function for the hydrogen atom is

   $\psi_{100} = \frac{1}{\sqrt{\pi a_0^{\frac{3}{2}}}} e^{\frac{-r}{a_0}}$. Show that the average radius is $1.5a_0$. 3

   (b) What is degeneracy? Show that the hydrogen atom has n^2 fold degeneracy for n^{th} state. 7

   (b) Explain the physical significance of the quantum numbers n, l and m. 4

UNIT–IV

7. (a) What is Larmor precession? Obtain an expression for Larmor frequency. 5
   (b) What is Zeeman effect? Explain the normal Zeeman effect using classical theory and also obtain the expression for Zeeman shift. 6
   (c) Calculate the Lande's g-factor for p-electron and d-electron. 3

8. (a) Discuss the quantum mechanical theory of anomalous Zeeman effect, with special reference to Zeeman pattern for D_1 and D_2 lines of sodium. Draw a neat diagram to illustrate Zeeman splitting of D_1 and D_2 lines of sodium. 7
   (b) Explain Paschen-Back effect. What is strong field quantum number? 5
   (c) What was the necessity of introducing the concept of electron spin? 2

UNIT–V

9. (a) Show that the magnetic field observed by the electron depends on its own orbital angular momentum. 7
   (b) Prove that the total wave function for fermions is anti-symmetric and for bosons it is symmetric. 4
   (c) The series limit of Balmer series is 3646 Å. Find the wavelength of first spectral line of this series. 3

10. (a) What is *JJ* coupling? Explain *JJ* coupling in the case of two electron system. 7
    (b) Discuss how Bohr model was able to explain the line spectrum that the Rutherford model could not. 7
