M.Sc. Semester—I (C.B.C.S. Scheme) Examination

PHYSICS

1-PHY-3 : Quantum Mechanics—I

Time : Three Hours] [Maximum Marks : 80

Credit : 4

EITHER

1. (a) What is Photoelectric effect ? Deduce Einstein's photoelectric equation. 5

(b) Obtain energy eigen values and eigen functions for a particle in the infinite potential well. 8

(c) An electron and a proton have the same velocity. Compare the wavelengths and phase and group velocities of their DeBroglie waves. 3

OR

(p) Give the explanation of Compton effect with the help of quantum theory and find an expression for Compton shift. 6

(q) Obtain energy eigen values and eigen functions for a linear harmonic oscillator. 8

(r) The average period that elapses between the excitation of an atom and the time it radiates is 1.0×10^{-8} sec. Find the inherent uncertainty in the frequency of the photon. 2

EITHER

2. (a) Outline Dirac's Bra and Ket notations. 4

(b) Show that Hermitian matrix can be expressed as diagonal matrix. 4

(c) Show that the operators having common set of eigen functions commute to each other. 4

(d) Prove that the fundamental commutation relation $[x, p_x] = ih$ remains unchanged under unitary transformation. 4

OR

(p) Show that, if operator A is Hermitian then :

$$\int u^* \hat{A} v \, d\tau = \int \hat{A}^* u^* \, v \, d\tau .$$ 4

(q) What is unitary transformation ? In a unitary transformation show that the operator equation remains unchanged in form. 4

(r) Obtain the Schrödinger equation in matrix form. 4

(s) Show that operator $\left(-i\frac{d}{dx}\right)$ is Hermitian. 4

EITHER

3. (a) Write down the Schrödinger equation for H-atom in spherical polar coordinates and separate it in to radial, polar and azimutal wave equations. Obtain solution of polar wave equation. 8

(b) Obtain the operators L_x, L_y, L_z, L_+ and L_- in spherical polar coordinates. 8

OR

(p) Write down radial wave equation for H-atom, obtain its solution and energy eigen values. 8

(q) A ground state wave function of a linear harmonic oscillator is :

$$\psi_0(x) = A \exp\left(-\frac{m\omega x^2}{2\hbar}\right)$$

where A is a constant. Using the raising and lowering operators, obtain the wave function of the excited states of the harmonic oscillator. 8

EITHER

4. (a) What are Pauli's spin matrices ? Show that they anticommute in pairs. 4

(b) Determine the total angular momentum that may arise when the following angular momenta are added :

(i) $j_1 = 1, j_2 = 1$

(ii) $j_1 = 3, j_2 = 4$. 4

(c) Obtain eigen values of J^2 and J_z operators. 8

OR

(p) Evaluate the following commutation relations :

(i) $[L_x, [L_y, L_z]]$

(ii) $[L_x^2, L_y^2]$. 4

(q) Obtain the matrix for J_+, for $j = 1/2$. 4

(r) Evaluate Clebsh-Gordan coefficients for a system having $j_1 = 1/2$ and $j_2 = 1/2$. 8

EITHER

5. (a) Explain the Heisenberg picture. Obtain the equation of motion for an operator in it. 8

(b) If the Hamiltonian $H(t) = H^0 + H'(t)$, show that the state vectors change in accordance with H'(t) while dynamical variables change in accordance with H^0 in the interaction picture. 8

OR

(p) Use variation method to obtain the ground state energy of hydrogen atom assuming trial function $\psi(r) = Ae^{-\lambda r}$, where λ is a variational parameter and A is normalization constant. 8

(q) Describe WKB approximation method for a one dimensional case and derive the connection formulae. 8