Exam. Code : 209003
Subject Code : 3763

M.Sc. Physics 3rd Semester

QUANTUM MECHANICS—II

Paper—PHY-501

Time Allowed—3 Hours] [Maximum Marks—100

Note :— Attempt **five** questions in all. Section A is compulsory. Attempt at least **one** question each from Sections B, C, D & E.

SECTION—A

1. (i) Define Scattering length. How is it related to zero energy cross-section ?

(ii) Show that Dirac's matrices are even dimensional and have zero trace.

(iii) Write short note on harmonic and sudden perturbations ?

(iv) Explain Fermi-Golden rule.

(v) Define differential cross-section. How the differential cross-section is related in CM and Lab frames.

(vi) Find out the equation of motion for the state vectors and operators in the interaction picture.

(vii) State optical theorem for scattering problem.

(viii) Why does Dirac theory more important than Klein-Gordan theory ?

(ix) What do you mean by negative energy state of an electron ?

(x) Explain the ramsauer townsend effect. 10×2=20

SECTION—B

2. (a) Discuss time independent perturbation theory and obtain expression for the first order correction to energy and Eigen wave function. 10

(b) Apply the first order perturbation result to calculate the energy of the helium atom in its ground state. 10

3. A two-level system is represented by the Hamiltonian

$\hat{H}_0 = \begin{bmatrix} E_1^{(0)} & 0 \\ 0 & E_2^{(0)} \end{bmatrix}$. Now a time dependent perturbation

$\hat{H}'(t) = \begin{bmatrix} 0 & \lambda\cos\omega t \\ \lambda\cos\omega t & 0 \end{bmatrix}$ is switched on. At t =0, the system is in the ground state $\begin{bmatrix} 1 \\ 0 \end{bmatrix}$. Using first-order time-dependent perturbation theory, find the probability that the system has made a transition to excited state $\begin{bmatrix} 0 \\ 1 \end{bmatrix}$ at time t. (Assuming $E_2^{(0)} - E_1^{(0)} = \hbar\omega_{21}$ is not close to $\pm\hbar\omega$). 20

SECTION—C

4. What is phase shift ? Deduce an expression for it. Explain the nature of phase shift in case of repulsive and attractive potentials. 20

5. Find out differential cross-section, under Born approximation, in case a particle is scattered by the potential V(r) given as $V(r) = -V_0 e^{-r^2/a^2}$. 20

SECTION—D

6. Derive the Klein-Gordon relativistic wave equation of a free particle. Explain how this equation leads to positive and negative probability density values. 20

7. Prove that a Dirac electron has a magnetic moment

$$\vec{\mu} = \frac{e\hbar}{2mc}\vec{\sigma}'.$$ 20

SECTION—E

8. (a) What is particle exchange operator ? Show that its eigenvalues are ±1 and it is a constant of motion. 10

   (b) Two identical Fermions with antisymmetric spin wave function are placed in a one-dimensional box of length L. Each particle has mass 'm'. The energy of the system is $5\hbar^2\pi^2/(2mL^2)$. Write the space part of the wave function. 10

9. What are symmetric and antisymmetric wave-functions ? Show that the antisymmetric wave function for two electrons would vanish if both occupy the same position with identical spin. 20