Exam. Code : 209003
Subject Code : 4881

M.Sc. Physics 3rd Semester (Batch 2020-22)

QUANTUM MECHANICS—II

Paper—PHY-501

Time Allowed—3 Hours] [Maximum Marks—100

Note :—Attempt **FIVE** questions in all, selecting at least **ONE** question from each section. The **fifth** question may be attempted from any section. All questions carry equal marks.

SECTION—A

1. (a) Discuss time independent perturbation theory and obtain expressions 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

2. (a) 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 $\pm\hbar\omega$). 15

(b) What do you mean by anhormanic oscillator ? Write down its total Hamiltonian. 5

SECTION—B

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

4. 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—C

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

6. Prove that a Dirac electron has a magnetic moment

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

SECTION—D

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

(b) State Fermi-Dirac statistics and explain its significance. 10

8. (a) 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. 10

(b) Prove that :

$$\bar{\sigma} \times \bar{\sigma} = 2i\bar{\sigma}.$$ 10