MANIPAL ACADEMY of HIGHER EDUCATION
(Institution of Eminence Deemed to be University)

| Reg.No. | | | | | | | | | |
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**DEPARTMENT OF SCIENCES, II SEMESTER M.Sc. (PHYSICS)**
**END SEMESTER (MAKE UP) EXAMINATIONS, JULY/AUGUST 2023**
**Quantum Mechanics - II [PHY 5253]**
(CHOICE BASED CREDIT SYSTEM - 2020)

Time: 3 Hours Date: 02/08/2023 MAX. MARKS: 50

Note (i) Answer ALL questions

(ii) Draw diagrams, and write equations wherever necessary

| Q No | Question | Marks | CO | BL |
|---|---|---|---|---|
| 1A | Explain the properties of density matrix for mixed states. | 3 | 1 | 2 |
| 1B | Evaluate the first order correction to the energy eigenvalues in the non-degenerate perturbation theory.<br>Given: $H^0\psi_n^1 + H'\psi_n^0 = E_n^0\psi_n^1 + E_n^1\psi_n^0$ | 3 | 2 | 5 |
| 1C | Evaluate the ground state energy for the one-dimensional harmonic oscillator using the variational method. | 4 | 2 | 5 |
| 2A | The general wave function for a two-level system with a time-dependent Hamiltonian $H(t) = H^0 + H'(t)$ is given by $\psi(t) = c_a(t)\psi_a e^{-iE_a t} + c_b(t)\psi_b e^{-iE_b t}$, where $\psi_a$ and $\psi_b$ are eigenfunctions of $H^0$. Prove that $\dot{c_a} = -\frac{i}{\hbar}H'_{ab}e^{-i\omega_0 t}c_b \quad ; \quad \dot{c_b} = -\frac{i}{\hbar}H'_{ba}e^{i\omega_0 t}c_a$ . | 5 | 3 | 3 |
| 2B | Describe the interaction of electromagnetic waves with an atom using time-dependent perturbation theory. | 5 | 3 | 3 |
| 3A | Define lifetime and half-life of an excited state. Derive the expression for lifetime in terms of Einstein's $A$ coefficient. | 4 | 3 | 3 |
| 3B | Explain differential scattering cross-section and scattering amplitude. Express differential cross-section in terms of scattering amplitude. | 3 | 4 | 3 |
| 3C | Derive the integral form of the Schrödinger equation. | 3 | 4 | 3 |
| 4A | Prove that $\sigma = \frac{4\pi}{k}\, Im\, f(\theta = 0)$ | 5 | 4 | 5 |
| 4B | Arrive at the Klein-Gordon equation for a free particle. What is the discrepancy associated with the probability density in the Klein-Gordon theory? | 5 | 5 | 3 |
| 5A | Calculate the differential scattering cross-section for scattering from a Coulomb potential. | 4 | 4 | 3 |
| 5B | Discuss the significance of Dirac equation. | 2 | 5 | 2 |
| 5C | Arrive at the free particle Dirac equation. Explain the concept of antiparticle. | 4 | 5 | 4 |

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