Reg. No.										

MANIPAL
ACADEMY of HIGHER EDUCATION
(Deemed to be University under Section 3 of the UGC Act, 1956)

DEPARTMENT OF SCIENCES, II SEMESTER M.SC. (PHYSICS)
END SEMESTER EXAMINATIONS, JUNE/JULY 2022

QUANTUM MECHANICS - II [PHY 5253]

(Choice Based Credit System (CBCS) - 2020)

Time: 3 Hours MAX. MARKS: 50

Note: Answer all questions

1.

a) Calculate the expectation value of the square of the separation distance $\langle (x_1 - x_2)^2 \rangle$ between two particles by assuming both of them to be i) distinguishable, ii) identical Bosons and iii) identical Fermions. Using your obtained results, describe exchange force.

b) Consider the following density matrix:

$$\rho = \begin{bmatrix} \frac{1}{2} & \frac{\sqrt{3}}{20} + \frac{2}{5} \\ \frac{\sqrt{3}}{20} + \frac{2}{5} & \frac{1}{2} \end{bmatrix}$$

Does ρ describe a pure or a mixed state? Justify. Evaluate $\langle S_y \rangle$ in this state.

c) Apply the variational principle to estimate the ground state energy of a particle moving in the potential

$$V(x) = a\, x^4$$

(Use the Gaussian trial wave function, $\psi(x) = (2b/\pi)^{1/4} \exp(-bx^2)$)

(4 + 3 + 3 = 10 Marks)

2.

a) Starting from the spin-orbit interaction Hamiltonian, derive the first order corrections to the energy levels of hydrogen atom due to spin-orbit coupling.

b) Using the WKB approximation, evaluate the allowed energies of the harmonic oscillator.

c) Describe Fermi's golden rule.

(5 + 3 + 2 = 10 Marks)

3.

a) Analyse a two-level system subjected to time-dependent sinusoidal (harmonic) perturbation.

b) Derive the selection rules for the magnetic quantum number m in electromagnetic transitions.

c) Calculate the ratio of rates of stimulated emission to spontaneous emission at T = 300 K (assume thermal radiations as a source for stimulated emissions). At what range of frequencies would spontaneous emission dominate?

(5 + 3 + 2 = 10 Marks)

4.

a) Derive and explain the optical theorem in scattering theory.

b) Convert the Schrodinger equation into the integral form. What is Born approximation?

c) Using the Born approximation, calculate the scattering amplitude and total cross-section for scattering from Yukawa potential.

(3 + 3 + 4 = 10 Marks)

5.

a) Derive the Klein-Gordon wave equation. Discuss the problems associated with the Klein-Gordon equation.

b) Obtain the continuity equation from the Dirac equation. Comment on the probability density in Dirac theory.

c) Write the explicit form of Dirac matrices and obtain the identities satisfied by these matrices.

(3 + 3 + 4 = 10 Marks)

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