Ex/SC/PHY/UG/CORE/TH/11/2023

B. Sc. Physics (Honours) Examination, 2023

(3rd Year, 1st Semester)

Quantum Mechanics and Applications

Paper – UG/SC/CORE/PHY/TH/11

Time : Two hours Full Marks : 40

Group – A (20 marks)

Answer ***any Two*** questions. 2×10=20

1. Consider that a particle subjected to $V = 0$ is confined within a two dimensional xy-plane. Find out the degenerate states having the lowest energy eigen value. Derivation is required. 10

2. a) What do you mean by the quantum mechanical tunnelling of a particle?

   b) How can you calculate the probability of tunnelling of a particle using the time-independent Schrodinger equation? Schematic diagram and derivation are required. 3+7

3. a) Consider the Hamiltonian **H** corresponding to a central force problem. Calculate $[\boldsymbol{L_i}, \mathbf{H}]$ inwhich $\boldsymbol{L_i}$ is the component of the usual orbital angular momentum operator.

   b) Starting from the $L = r \times p$ derive a generalized equation for $[L_i, L_j]$. 6+4

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4. Write down the Hamiltonian of a harmonic oscillator in one dimension. How many quantum numbers are required to express the energy eigenvalues of the same? Give the necessary derivation to justify it. How do you define raising and lowering operator? 1+7+2

Group – B (20 marks)

Answer ***any Two*** questions. 2×10=20

1. i) Suppose the Schrödinger equation for some potential is $H^0\psi_n^0 = E_n^0\psi_n^0$, where ψ_n^0 is a complete set of orthonormal and non-degerate eigenfunctions. If the potential is perturbed slightly, show that the first order correction to the n^{th} energy eigenvalue is $E_n^1 = \left\langle \psi_n^0 \middle| H' \middle| \psi_n^0 \right\rangle$, where H' is the perturbation.

   ii) The unperturbed wavefunction for the infinite square well is $\psi_n^0(x) = \sqrt{2/a}\sin(n\pi x/a)$. If the potential well is slightly raised by V_0, calculate the first order correction to the n^{th} energy state. 5+5

2. i) How does the spin-orbit coupling arise?

   ii) Calculate the contribution of the spin-orbit interaction to the total Hamiltonian in a Hydrogen atom.

   iii) Show the fine structure energy levels for the $n=3$ state of Hydrogen. Calculate the fine structure energy shifts (in eV). 2+3+5

3. i) Discuss differences between the weak and strong field anomalous Zeeman Effect.

   ii) Calculate Landé g-factor for the following states: $2S_{1/2}$, $2P_{1/2}$.

   iii) Calculate and show the splitting of the $n=2$ state in a weak magnetic B. Draw a diagram showing the states before and after the field is applied. 2+3+5