Sr. No. 752103

December 2023

M.Sc. (Physics) - I SEMESTER

Quantum Mechanics - I (MPH 103)

Time: 3 Hours **Max. Marks:75**

Instructions:
1. *It is compulsory to answer all the questions (1.5 marks each) of Part -A in short.*
2. *Answer any four questions from Part -B in detail.*
3. *Different sub-parts of a question are to be attempted adjacent to each other.*

PART -A

Q1 (a) Describe an electron on the basis of dual nature of matter. Is it a wave, or a particle, or partly both or nothing. Append your answer with appropriate explanation. (1.5)

(b) Calculate the kinetic energy of an electron having a de-Broglie wavelength of 1 Å. (Given mass of electron = 9.1×10^{-31} kg) (1.5)

(c) If the uncertainty in the position of proton is 6×10^{-8}m, Calculate the minimum uncertainty in its speed. (Given mass of proton = 1.66×10^{-27} kg) (1.5)

(d) Provide a brief overview of linear vector space. (1.5)

(e) How a matrix element in old basis can be transformed in terms of new basis. Illustrate with example. (1.5)

(f) Express the orbital angular momentum operator in terms of spherical polar coordinates. (1.5)

(g) Write down matrix representation of J^2 and J_z with $j = 1$. (1.5)

(h) Explain the physical significance of representing a spin state as spinor. (1.5)

(i) What is perturbed state of a physical system. Illustrate with suitable example. (1.5)

(j) Discuss transition probability for harmonic perturbations for time dependent perturbed systems. (1.5)

PART -B

Q2 (a) State and prove Ehrenfest theorem for velocity and force analogue in classical physics. (7)

(b) Discuss analytical treatment for energy eigen values in case of harmonic oscillator. (8)

Q3 (a) Discuss the application of quantum mechanics in order to derive ground state radial wave function of Hydrogen atom. Also plot the graphs for first two excited states wave functions. (10)

(b) Explain the significance of inner product in accessing information about a quantum state. (5)

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Q4 (a) Describe any five applications of completeness relation. (5)

(b) Derive an expression for matrix representation of annihilation and creation operators. (5)

(c) Discuss the time development of quantum system in Schrödinger, Heisenberg and Interaction pictures. (5)

Q5 (a) Define orbital angular momentum quantum number. Express components of **L** in cartesian and spherical polar coordinates. (5)

(b) Describe ladder operator for orbital angular momentum operator. Discuss the application of ladder operator in determination of eigen values of $\mathbf{L}^2$ and $\mathbf{L}_z$. (5)

(c) Explain the general angular momentum operator. Derive matrices for J_+ and J_-. (5)

Q6 (a) Analyse outcomes of Stern Gerlach experiment for the origination of spin. (5)

(b) Explain perturbation theory for non-degenerate for first order correction in eigen values and eigen functions. (10)

Q7 Describe perturbation theory for degenerate systems. Discuss first order correction for Stark effect in Hydrogen atom. (15)

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