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Total Pages : 4

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December, 2019

M.Sc. (Physics)-III SEMESTER

Advanced Quantum Mechanics (PHL-301)

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

1. (a) Deduce degeneracy of three-dimensional harmonic oscillator, with eigen function characterized by the Quantum numbers n and l. (1.5)

(b) What is spherical harmonics? Give example. (1.5)

(c) Show that symmetry of identical particles remain unaffected under any transposition. (1.5)

(d) What is Ehrenfest theorem? (1.5)

(e) What is condition for a set of n wave function to be orthonormal? (1.5)

(f) Why Hartee's method is called self consistent field method? (1.5)

(g) What do you mean by second quantization? (1.5)

(h) Calculate the de-Broglie wavelength associated with a proton moving with a velocity equal to 1/20th of the velocity of light. (1.5)

(i) Explain non-uniqueness of Electromagnetic Potentials and concept of Gauge. (1.5)

(j) What do you mean by second quantization? (1.5)

PART - B

2. (a) What is central field approximation method for a system consisting of many elrctron atoms? (7)

(b) Give an account of second quantization for a harmonic oscillator and interpret the creation and annihilation operator. (8)

3. (a) Construct symmetric and antisymmetric wave function for any three spinless identical particles. Show that antisymmetric wave function obeys Pauli's exclusion principle. (7)

(b) Discuss the properties of the electronic states and optical spectrum of Helium, considering electron as identical particles. (8)

2. Solve the Schroedinger equation for three-dimensional Harmonic Oscillator to find normalized eigen function and eigen value (in Cartesian co-ordinates). (15)

5. (a) If $\vec{\alpha}$ represnts three Dirac matrices α_x, α_y, α_z and B and C are usual three-dimensional vectors, then show that

$$(\vec{\alpha}.B)\,(\vec{\alpha}.C) = B.C + i\vec{\sigma}'.B \times C$$

Where $\vec{\sigma}' = \begin{bmatrix} \vec{\sigma} & 0 \\ 0 & \vec{\sigma} \end{bmatrix}$ is a 4 × 4 matrix. $\vec{\sigma}$ being 2 × 2 pauli spin matrices. (7)

(b) Drive Klein-Gordan equation for a free particle. Discuss the difficulties associated with the interpretation of this equation. Determine the current density and probability density. (8)

6. (a) Show that the indistinguishability of similar particles implies that admissible wave-functions must obey symmetry restrictions with respect to interchange of particles. (7)

(b) Derive an expression for relativistic Lagrangian and Hamiltonian of a charged particle in an electromagnetic field. (8)

7. Show that classical field equations in terms of functional derivatives of Lagrangian $L = L[\psi(r, t); \dot{\psi}(r, t)]$ given by

$$\frac{\partial L}{\partial \psi} - \frac{d}{dt}\left[\frac{\partial L}{\partial \dot{\psi}}\right] = 0. \qquad (15)$$
