6. Derive an expression to determine the energy eigen values for simple harmonic oscillator. What do you mean by zero point energy? Also write down the expression for any two normalized wave functions for simple harmonic oscillator. (15)

7. (a) Derive an expression to write down radial equation in spherical polar coordinates. What is role of centrifugal term in radial equation? (5)

(b) Derive an expression for recursion formula to determine coefficients of power series, used to evaluate energy eigen values and wave functions in case of Hydrogen atom. (10)

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321501

December 2023

B.Sc. (Physics) - V SEMESTER

Quantum Mechanics and Applications (BPH 501A)

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) Derive an expression for time independent Schrödinger equation. (1.5)

(b) Explain the conditions for physical acceptance of a wave function. (1.5)

(c) A dust particle of mass 10^{-15} kg is moving with a velocity 10^{-3} m/s. Calculate the wavelength associated with this dust particle. (Given Planck's constant $h = 6.6 \times 10^{-34}$ J-s). (1.5)

(d) What do you mean by stationary states? Why these are called so? (1,5)

(e) Why there is requirement of linearity and superposition for energy eigen functions of Schrödinger wave equation? (1.5)

(f) Illustrate the discreteness of energy levels with a suitable example. (1.5)

(g) Discuss the physical significance of boundary conditions. (1.5)

(h) Plot the graph of the eigen functions for $n = 0$ and $n = 1$ corresponding to a simple harmonic oscillator described by a particle moving along x-axis in range $0 \leq x \leq a$. (1.5)

(i) Explain the concept of spherical polar coordinates. Also, write down the range of each coordinate. (1.5)

(j) Describe the quantum numbers associated with s, p, d electronic shells. (1.5)

PART–B

2. (a) What do you mean by the dynamic evolution of a quantum state? What is time evolution operator. Discuss it's role in assessing future behaviour of a physical system. Discuss the dynamic evolution of system in terms of probabilistic interpretation. (5)

(b) Derive an expression for probability density and probability current densities in three dimensions. Also state the difference in these, with a suitable example. (5)

(c) Describe the operators for position, momentum and energy. Also, evaluate the various commutation relations between position and momentum operators. (5)

3. (a) A Particle is represented (at time $t = 0$) by the wave function

$$\Psi(x, 0) = \begin{cases} A(a^2 - x^2) & \text{if } -a \leq x \leq +a \\ 0 & \text{otherwise} \end{cases}$$

Find the expectation value of ρ^2. (5)

(b) Derive an expression to show the application of Schrodinger time dependent wave equation to spread of Gaussian wave-packet for a free particle in one dimension. (10)

4. (a) Explain Fourier transforms and its application in position space and momentum space wave functions. How, the probability densities in position space and momentum space may be regarded as equivalent? Explain. (10)

(b) State Heisenberg's uncertainty principle. How is it applicable to each and every phenomenon at minutes scales (atomic, molecular, nano, micro). Explain in your own words with proper argumentation. (5)

5. (a) Discuss the significance of type of potential in continuity of wave function. (5)

(b) Derive an expression to determine Reflection coefficient in case of a particle moving in positive x direction, strikes at a finite potential barrier of width "a". (10)