C. U. SHAH UNIVERSITY
Winter Examination-2022

Subject Name : Quantum Mechanics - I

Subject Code : 5SC01QUM1   **Branch: M.Sc. (Physics)**

Semester: 1   **Date: 04/01/2023**   **Time: 11:00 To 02:00**   **Marks: 70**

Instructions:
 (1) Use of Programmable calculator and any other electronic instrument is prohibited.
 (2) Instructions written on main answer book are strictly to be obeyed.
 (3) Draw neat diagrams and figures (if necessary) at right places.
 (4) Assume suitable data if needed.

SECTION – I

Q-1	**Attempt the Following questions.**	**(07)**
a.	Give an example of perturbation.	**01**
b.	Why are spherical polar coordinates introduced to solve the Schrodinger equation of hydrogen atom?	**01**
c.	Give the Rodrigue's formula for Associated Legendre polynomials.	**01**
d.	Give the radial part equation for hydrogen atom.	**01**
e.	Which are the two sets of solutions for a spherical Bessel equation?	**01**
f.	What do you mean by removal of degeneracy?	**01**
g.	The problem of Helium atom is solved using the wave function of hydrogen atom. Why?	**01**

Q-2	**Attempt all questions.**	**(14)**
A	Resolve the Schrodinger equation of hydrogen atom in terms of spherical coordinates (r, θ, ø).	**07**
B	Prove that the Rodrigue's formula for Legendre polynomial leads to the same polynomial.	**07**

OR

Q-2	**Attempt all questions.**	**(14)**
A	Explain how solution for radial part solutions can be obtained using Bessel's and Neumann's functions.	**07**
B	Write a note on Perturbation theory for degenerate states	**07**

Q-3	**Attempt all questions.**	**(14)**
A	Using Perturbation theory, solve a system exhibiting Zeeman effect.	**07**
B	Give the azimuthal part of Hydrogen atom and also solve the expression.	**07**

OR

Q-3	**Attempt all questions.**	
A	Derive the expressions for the first order correction to Energy and Wave function using the concepts of Perturbation theory.	**07**
B	Explain the concept of Hydrogen Spectrum.	**07**

SECTION – II

Q-4   **Attempt the Following questions.**   **(07)**

     a. Give the condition for validity of WKB approximation method.   **01**

     b. Give the general expression for Airy's Equation?   **01**

     c. Define the characteristics of Delta function.   **01**

     d. Name the different methods used to determine the wave function and energy of a system quantum mechanically.   **01**

     e. Which quantity in physics confirms the use of quantum mechanics and helps in distinguishing quantum from classical mechanics?   **01**

     f. Write the statement for Variational Principle.   **01**

     g. Variational Method is said to have errors in the calculation. Why?   **01**

Q-5   **Attempt all questions.**   **(14)**

     A Give an account on WKB approximation and also prove the method follows a semi classical treatment.   **07**

     B Explain the exponentially amplifying and decaying solutions for a second order differential equation $d^2\psi/dx^2 + k^2\psi(x) = 0$; where k could be any continuous function.   **07**

OR

Q-5   **Attempt all questions.**

     A Find an upper bound for the ground state energy of a one dimensional harmonic oscillator, Hamiltonian is given by $H = -\hbar^2/2m \, d^2/dx^2 + \frac{1}{2} m\omega^2 x^2$ **07**

     B Prove that ground state energy is always less than the expectation value of Hamiltonian.   **07**

Q-6   **Attempt all questions.**   **(14)**

     A Determine the normalized first order solution to Airy's equation by identifying the expression for $F(x)$.   **07**

     B Find the $\langle H \rangle$, for $H = -\hbar^2/2m \, d^2/dx^2 - \alpha x$.   **07**

OR

Q-6   **Attempt all questions.**

     A Explain the importance of connection formulae while solving a linear harmonic oscillator problem using WKB approximation method.   **07**

     B Derive the formula for the second order correction to wave function based on perturbation theory.   **07**