C. U. SHAH UNIVERSITY
Summer Examination-2022

Subject Name: Quantum Mechanics - I

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

Semester: 1   **Date: 25/04/2022**   **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.	Write the general expression for time independent Schrodinger equation in terms of potential energy and total energy of a system.	01
	b.	What do you mean by perturbation?	01
	c.	Give the Rodrigue's formula for Associated Legendre polynomials.	01
	d.	What do you mean by removal of degeneracy?	01
	e.	What is meant by spherical harmonics?	01
	f.	Justify why hydrogen atom has been preferred to determine the wave function.	01
	g.	The presence of which quantity in physics confirms the use of quantum mechanics?	01

Q-2		**Attempt all questions**	**(14)**
	a.	Explain: Legendre's polynomial in brief.	07
	b.	For an equation $(H^0 - E^0)\, \Psi n^2 = (En^2 - H^2)\Psi n^0 + (En^1 - H^1)\, \Psi n^1$; determine the second order correction to energy.	07

OR

Q-2		**Attempt all questions**	**(14)**
	a.	Write a note on Perturbation theory for degenerate states.	07
	b.	Explain: Stark effect in hydrogen atom.	07

Q-3		**Attempt all questions**	**(14)**
	a.	Derive the expression for first order correction to i) energy and ii) wave function.	07
	b.	Find the first order correction to the energy for the ground state of particle in 1-D box (0 to L) due to perturbed part λx.	07

OR

Q-3	a.	Separate the Schrodinger equation of hydrogen atom in terms of spherical polar coordinates (Radial, angular and Azimuthal equations).	07
	b.	Derive an expression for Laguerre polynomials.	07

SECTION – II

Q-4		**Attempt the Following questions.**	**(07)**
	a.	What are classical turning points?	01
	b.	Define tunneling.	01
	c.	For what purpose WKB approximation method is used?	01
	d.	Define the characteristics of Delta function.	01
	e.	Variational Method is said to have errors in the calculation. Why?	01
	f.	Why are spherical polar coordinates introduced to solve the Schrodinger equation of hydrogen atom?	01
	g.	If the ground state energy of a hydrogen atom is given by E_0, what will be the energy of the excited states (having principle quantum number n)?	01

Q-5		**Attempt all questions**	**(14)**
	a.	Determine the normalized first order solution to Airy's equation by identifying the expression for Fx.	07
	b.	Prove that ground state energy is always less than the expectation value of Hamiltonian.	07

OR

Q-5	a.	Prove that the WKB method follows a semi classical treatment.	07
	b.	For $H = -\hbar^2/2m \ d^2/dx^2 - \alpha \ \delta(x)$, find the ground state energy of the delta function.	07

Q-6		**Attempt all questions**	**(14)**
	a.	Explain the importance of connection formulae taking the example of a linear harmonic oscillator.	09
	b.	Take Gamow's theory of alpha decay to explain the process of tunneling using WKB approximation.	05

OR

Q-6		**Attempt all Questions**	
	a.	If $\Psi(x) = Ax \quad\quad 0 \le x \le a/2$ $A(a-x) \quad\quad a/2 \le x \le a \ 0$ otherwise, Find the value of A.	07
	b.	Determine the WKB solutions for a second order differential equation $d^2\psi/dx^2 + k^2\psi(x) = 0$; where k could be any continuous function. Explain the exponentially amplifying and decaying solutions.	07