Bago University

Department of Physics

Second Semester Examination, September 2019

Fourth Year (BSc) **Phys 4106**

(Physics Specialization) **Quantum Mechanics**

Time Allowed: (3) Hours

Answer any Six questions.

1 (a) Why is the quantum number $n = 0$ not allowed for the particle confined to move in a one - dimensional box?

(b) Consider a particle with quantum number 'n' moving in a one - dimensional box of length 'L'.

(i) Find the probability of finding the particle in the region between $x = 0$ and $x = \frac{L}{4}$.

(ii) For what value of n is this probability maximum?

(iii) What is the limit of this probability for $n \to \infty$?

2 (a) Derive the energy of harmonic oscillator from Schroedinger equation.

(b) A beam of particle of energy E is incident on a potential step of height V_0 .What are the reflection and transmission coefficients for the following incident energy $E = \frac{4V_0}{3}$.

3 (a) What do you understand by the terms of the degeneracy of the state?

(b) Find (i) $\langle x \rangle$ and (ii) $\langle x^2 \rangle$ for the first excited state of the harmonic oscillator.

4 (a) Give the names and the allowed values of the quantum numbers for the electron in the hydrogen and hydrogen - like atoms.

(b) Find the energy and the magnitude of the orbital angular momentum for each of the following electrons in the Li^{++} ion. (i) 2p electron (ii) 4d electron (iii) 5f electron.

5 (a) Write out the r-equation from the quantum mechanical treatment of the hydrogen atom.

(b) The ground state wave function of the hydrogen atom is given by $\psi_{100}(r, \theta, \phi) = \frac{1}{\sqrt{\pi} a_0^{\frac{3}{2}}} e^{-\frac{r}{a_0}}$.

Show that it is normalized wave function.

6 (a) Draw a vector diagram to show the orientation of the orbital angular momentum $\vec{L}$ of the electron in the 3f state of hydrogen atom.

(b) Find $\langle V \rangle$ and $\langle T \rangle$ for the ground state of the hydrogen atom. Then, show that $E = \langle T \rangle + \langle V \rangle$.

7 (a) What is perturbation? Distinguish between the perturbed and unperturbed systems.

(b) The radial function of the state with $n = 2$, $l = 1$ of the hydrogen atom is given by $R_{21}(r) = \frac{1}{2\sqrt{6}\,(^1/_{a_0})^{5/2}} r\, e^{-r/2a_0}$. Show that it is a normalized function.

8 (a) Derive the time independent Schroedinger equation for unperturbed system.

(b) Evaluate the change in the ground state energy of a 1-D harmonic oscillator whose Hamiltonian ($\hat{H}$) and the ground state wave function, $\psi_0(x)$, are given by

$\psi_0(x) = \left(\frac{\alpha}{\pi}\right)^{1/4} \exp(-\alpha x^2/2)$, $\alpha = m\omega_0/\hbar$.

The Unperturbed Hamiltonian, $\hat{H} = \frac{\hbar^2}{2m} \frac{d^2}{dx^2} + \frac{1}{2} kx^2 + \frac{b}{10} x^4$.