MANIPAL UNIVERSITY

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DEPARTMENT OF SCIENCES, M. Sc. (P/C/M/G)
I SEMESTER END SEMESTER EXAMINATIONS
NOVEMBER 2017
Subject: Quantum Mechanics I (PHY-4105)
(REVISED CREDIT SYSTEM)

Time: 3 Hours   Date: November 2017   MAX. MARKS: 50

Note: (i) Answer all the questions.
(ii) Answer the questions to the point.

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1. (i) Discuss Dirac's bra - ket notations. [5]
(ii) For a one-dimensional bound particle, show that
(a) $\frac{d}{dt}\int_{-\infty}^{\infty}\psi^*(x,t)\psi(x,t)\,dx = 0$, ψ need not be a stationary state.
(b) If the particle is in a stationary state at a given time, then it will always remain in a stationary state. [5]

2. (i) Obtain expressions of energy eigenvalues and eigenfunctions for a particle in an infinite deep potential well. [5]
(ii) An electron is in the ground state of a one-dimensional infinite square well with $a = 10^{-10}$ m. Compute the force that the electron exerts on the wall during an impact on either wall. [5]

3. (i) Establish the Schroedinger equation for a SHO and reduce it into the Hermite equation. [5]
(ii) Calculate the value of $< 1/r >$ for the hydrogen atom in the ground state. Use the result to calculate the average kinetic energy $< p^2/2m >$ in the ground state. [5]

4. Write the Schroedinger equation for spherically symmetric potentials. Break it into r, θ, ϕ dependent equations using separation of variables technique. [10]

5. (i) Describe how symmetric and antisymmetric wavefunctions are constructed for a system n identical particles? [5]
(ii) What is the ground state energy and wavefunction for two identical particles in an infinite deep potential of width a, if the two

particles are (a) bosons, and (b) fermions? **[5]**

Useful formulae:

$$\nabla^2 t = \frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial t}{\partial r}\right) + \frac{1}{r^2 sin\theta}\frac{\partial}{\partial\theta}\left(sin\theta\frac{\partial t}{\partial\theta}\right) + \frac{1}{r^2 sin^2\theta}\frac{\partial^2 t}{\partial\phi^2}$$

$$\int_0^\infty exp(-a^2x^2)cos(bx)\,dx = \frac{\sqrt{\pi}}{2a}exp\left(-\frac{b^2}{4a^2}\right)$$

$$\int_0^\infty x^n exp(-ax)\,dx = \frac{n!}{a^{n+1}}, \quad \textbf{where} \quad n \geq 0, \quad a > 0$$

For hydrogen atom

$$\psi_{100} = \sqrt{\frac{1}{\pi a_0^3}}e^{-r/a_0}$$

where a_0 **is the Bohr radius.**