HEI-003-020103 Seat No. ______

M. Sc. (Physics) (Sem. I) (CBCS) Examination

December – 2017

CT-3 : Quantum Mechanics - I

Faculty Code : 003
Subject Code : 020103

Time : $2\frac{1}{2}$ Hours] [Total Marks : **70**

Instructions : (1) Attempt all questions.
(2) All questions carry equal marks.
(3) Assigned marks are given on R.H.S.
(4) Mathematical symbols have usual meanings.

1 Answer in brief any **seven** :

(a) In the solution of one dimensional harmonic oscillator in quantum mechanics why $u(\xi) = h(\xi)\exp\left(\frac{\xi^2}{2}\right)$ is not used ? **2**

(b) Draw the eigen functions for H_0 and H_1, where $n = 0$ and $n = 1$, respectively. **2**

(c) Draw the polar diagram for $\ell = 0, m = 0$ and $\ell = 1, m = 0$. **2**

(d) Define Hilbert space. **2**

(e) What is trial wave function ? How it is selected ? **2**

(f) Name the phenomena experiencing the time independent perturbation. **2**

(g) Draw the highly peaked function $\sin^2\left[\left(w_{mi} \pm w\right)t/2\right] \big/ \left[\left(w_{mi} \pm w\right)/2\right]^2$ and prove time-energy uncertainty principle. **2**

(h) Why WKB approximation is known as semi-classical approximation ? **2**

(i) In the separable variable method to solve Schrödinger equation in polar coordinates which variables are separated ? Explain in brief without derivation. **2**

2 Answer any **two** :

(a) Solve the one-dimensional harmonic oscillator problem **7**

using $\frac{d^2h}{d\xi^2} - 2\xi\frac{dh}{d\xi} + h(\in -1) = 0$

(b) Using suitable form of a and a^+ prove that **7**

$H = \hbar w\left(a^+ a + \frac{1}{2}\right)$

(c) Compare quantum harmonic oscillator with classical oscillator using necessary plots. **7**

3 (a) In spherical polar coordinates, if **7**

$\nabla = e_r \frac{\partial}{\partial r} + e_\theta \frac{1}{r}\frac{\partial}{\partial \theta} + e_\phi \frac{1}{r \sin\theta}\frac{\partial}{\partial \phi}$ and

$e_z = e_r \cos\theta - e_\theta \sin\theta$ then obtain the relations for

$\vec{L}, L_z,$ and $\vec{L}^2$.

(b) Prove the following relations of angular momentum operators : **7**

(i) $[J_z, J_+] = \hbar J_+$

(ii) $[J_+, J_-] = 2\hbar J_z$

(iii) $J_- J_+ = J^2 - J_z^2 - \hbar J_z$.

OR

3 (a) From the angular part of Schrödinger equation in polar coordinates of the given form **7**

$\frac{1}{\sin\theta}\frac{\partial}{\partial\theta}\left(\sin\theta\frac{\partial y}{\partial\theta}\right) + \frac{1}{\sin^2\theta}\frac{\partial^2 y}{\partial\phi^2} + \lambda y = 0$. Obtain separate

equations for θ and ϕ.

(b) Solve the attractive Coulomb potential case using radial equation. **7**

4 Answer any **two** :

(a) Discuss WKB approximation in detail. **7**

(b) Explain the first order time independent perturbation theory and obtain the criterion for the smallness of perturbation. **7**

(c) In the time independent perturbation theory using an anharmonic oscillator having Hamiltonian **7**

$$H = \frac{p^2}{2m} + \frac{1}{2}kx^2 + ax^3 + bx^4$$

Show that the perturbation shifts the ground state to higher level by the amount of $\frac{3}{4}b\left(\frac{\hbar w}{k}\right)^2$.

5 Write notes on any **two** :

(a) Fermi's golden rule **7**

(b) Spherical harmonics **7**

(c) Variation method **7**

(d) Raising, lowering and number operators. **7**