

Total No. of Questions : 8]

SEAT No. :

**P1934**

[Total No. of Pages : 3

**[4922]-204**

**M.Sc.**

**PHYSICS**

**PHY UT-604 : Quantum Mechanics-I  
(2013 Pattern) (5-Credits) (Semester-II)**

*Time : 3 Hours]*

*[Max. Marks : 50*

*Instructions to the candidates:*

- 1) *Attempt any five questions from eight questions.*
- 2) *Draw neat diagrams wherever necessary.*
- 3) *Figures to the right indicate full marks.*
- 4) *Use of calculators allowed.*

**Q1)** a) Using expansion postulate, show that eigen functions belonging to discrete eigen values are normalizable. **[4]**

b) Define adjoint of an operator A. Show that  $\langle A^+ A \rangle$  is always positive. **[3]**

c) What is harmonic perturbation? How is it differs from constant perturbation? **[3]**

**Q2)** a) Using ladder operators  $a$  and  $a^+$ , obtain the energy eigen values of linear harmonic oscillator. **[4]**

b) Show that  $[L_x, L_y] = i \hbar L_z$  and  $[L^2, L_x] = 0$ . **[3]**

c) Explain condition of validity of WKB approximation. **[3]**

**Q3)** a) What is unitary operator? Show that the norm of any state  $|\psi\rangle$  does not change under unitary transformation. **[4]**

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- b) Show that Pauli spin matrices  $\sigma_x$ ,  $\sigma_y$  and  $\sigma_z$  are unitary. [3]
- c) Obtain the matrix of Clebsch-Gordon co-efficients for a system having  $j_1 = 1/2$ ,  $j_2 = 1/2$ . [3]
- Q4)** a) Use variational method to estimate the ground state energy of harmonic oscillator with the help of trial wave function  $\psi(x) = Ae^{-\alpha x^2}$ . [4]
- b) State fundamental postulates of quantum mechanics. [3]
- c) For anti-Hermitian operator  $\hat{A}$ , show that  $e^{i\alpha\hat{A}}$  is unitary, where  $\alpha$  is real number. [3]
- Q5)** a) Define projection operator. Show that  $\sum |\psi_n\rangle\langle\psi_n| = I$ . [4]
- b) Show that for associated with any degenerate eigen value, there are always an infinite number of eigen functions. [3]
- c) Normalize the eigen function  $\psi_n(x) = A \sin\left(\frac{n\pi}{a}x\right)$  in the range  $0 < x < a$ . [3]
- Q6)** a) State and prove Fermi Golden rule. [4]
- b) Using WKB approximation obtain Bohr - Sommerfeld quantization condition for the bound state. [3]
- c) Obtain eigen value spectrum of  $J^2$  and  $J_z$  operators. [3]

- Q7)** a) Calculate the first order correction to ground state energy of an anharmonic oscillator of mass  $m$  and angular frequency  $w$  subjected to potential

$$V(x) = \frac{1}{2}mw^2x^2 + \lambda x^4. \quad [5]$$

- b) When a set of functions  $\{\phi_a\}$  will be orthonormal and complete? Hence obtain closure relation  $\sum_a \phi_a(x)\phi_a^*(x') = \delta(x-x').$  [5]

- Q8)** a) Obtain the equation of first order correction in energy using time independent perturbation. [5]

- b) Explain in brief dependent perturbation theory and obtain expression for first order amplitude  $a_n(t).$  [5]

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