(i) Printed Pages : 4] Roll No. .....

(ii) Questions : 9] **Sub. Code : 3704**

Exam. Code : 0472

M.Sc. 1st Semester Examination

1127

PHYSICS

(Quantum Mechanics–I)

Paper : PHY–6003

Time : 3 Hours] **[Max. Marks : 60**

Note :– (i) Attempt *five* questions in all, taking *one* question each from Units I to IV.

(ii) Unit V is compulsory.

Unit–I

1. (a) How does a quantum mechanical system evolve under (i) Schrödinger representation (ii) Heisenberg representation ?

(b) Show that for operators A, B, C satisfying $[A, B] = iC$, the following relation holds. $\Delta A \, \Delta B \geq \frac{1}{2}\langle C \rangle$, where symbols have their usual meanings. 6,6

2. (a) For harmonic oscillator having Hamiltonian H, if the operators are :

$$a = \sqrt{\frac{m\omega}{2\hbar}}\left(q + \frac{ip}{m\omega}\right),\ a^{+} = \sqrt{\frac{m\omega}{2\hbar}}\left(q\frac{-ip}{m\omega}\right)$$

show that $a^{+}a = \frac{H}{\hbar\omega} - \frac{1}{2}$ and $[a, a^{+}] = 1$. Also find eigen values of a and a^{+}.

(b) State and prove Schwarz inequality. 6,6

Unit–II

3. (a) Calculate C.G. coefficients for $j_1 = 1$ and $j_2 = \frac{1}{2}$.

(b) Obtain the eigen values of L^2 and L_z. 6,6

4. (a) Show that J_+ and J_- are ladder operators.

(b) Obtain eigen values of J^2 and J_z. 6,6

Unit–III

5. (a) Use variational method to estimate the energies of ground state for one dimensional harmonic oscillator.

(b) State and explain Stark effect. Show that there is no first order Stark effect for the ground state of an atom. 6,6

(a) Calculate the first order energy correction for one dimensional harmonic oscillator whose Hamiltonian is :

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

and the ground state wave function is :

$$\psi_0 = \left(\frac{k}{\pi\hbar\omega}\right)^{1/4} \exp\left(\frac{-kx^2}{2\hbar\omega}\right)$$

Further show that value of ground state energy can be written as :

$$E = \frac{\hbar\omega}{2}\left(1 + \frac{3a}{2}\frac{\hbar\omega}{k^2}\right)$$

(b) Discuss the advantages of the variational method over other perturbation methods. Use the variational method to estimate the upper limit for the ground state energy of the helium atom.

Unit–IV 6,6

(a) Discuss briefly the time dependent perturbation theory and derive an expression for the transition probability from one state to another under constant harmonic time dependent perturbation.

(b) Give the selection rules regarding the emission

and absorption of light that allow electric dipole transitions between two states of atoms.

8. (a) Explain Fermi Golden rule and apply it to explain radiative transitions in atoms. 8,4

(b) Discuss the concept of absorption of radiation, induced emission and spontaneous emission using Einstein coefficients. 6,6

Unit–V

9. (a) Give the postulates of quantum mechanics.

(b) Find the value of $\frac{1}{2}(L_- L_+ + L_- L_+)$.

(c) Show that momentum operator is Hermitian.

(d) What is Zeeman effect ?

(e) Find the expectation value of position of a particle whose normalised wave function is :

$$\psi(x) = Ne^{-(x^2/2a^2)+ikx}$$

(f) Discuss the relevance of Hermitian operation and unitary operator in Physics.

6×2=12