Roll No. | | | | | | | | | | | | | **Total No. of Pages : 03**

Total No. of Questions : 11

M.Sc.(Physics) (2018 Batch) (Sem.–1)

QUANTUM MECHANICS-I

Subject Code : MSPH-413-18

M.Code : 75124

Date of Examination : 12-01-2023

Time : 3 Hrs. **Max. Marks : 70**

INSTRUCTIONS TO CANDIDATES :

1. **SECTION-A is COMPULSORY consisting of TEN questions carrying TWO marks each.**
2. **SECTION-B contains SEVEN questions carrying FIVE marks each and students have to attempt any SIX questions.**
3. **SECTION-C contains THREE questions carrying TEN marks each and students have to attempt any TWO questions.**

SECTION-A

1. Answer briefly :

a) Differentiate between Hermitian operator and Anti-Hermitian operator.

b) Show that the expectation values of anti-Hermitian operator are always imaginary;

c) Distinguish between the Schrodinger picture and Heisenberg picture of a dynamical quantum system.

d) Evaluate the commutator $[\hat{H}, \hat{a}\dagger]$ where $\hat{H}$ is the Hamiltonian operator and $\hat{a}\dagger$ is the creation operator.

e) Show that $[\hat{L}_+, \hat{L}_-] = 2\hbar\hat{L}_z$.

f) What do you understand by the stationary state approximate methods?

g) What is optical theorem in scattering?

h) Evaluate the commutator $[\hat{L}_z, \hat{r}^2]$,

i) When you will prefer to use the perturbation theory as compared to variational method for solving quantum mechanics problem?

j) What do you understand by the scattering amplitude and scattering length.

SECTION-B

2. a) Show that eigen values of a Hermitian operator are real.

   b) Show that eigen vectors belonging to two different eigen values of a Hermitian operators are orthogonal.

3. Calculate the expectation value of momentum $(\hat{p}_x)$ for the ground state wavefunction of a 1-D harmonic oscillator $\psi(x) = N \exp[-\beta x^2]$, where N is the normalization constant and β is a parameter.

4. Using matrix mechanics, show that the ground state of a linear harmonic oscillator has non-zero, real and positive energy.

5. Using the angular momentum algebra, discuss the orbital angular momentum theory and derive the relations

$$\hat{L}_{\pm} \mid l, m) = \hbar\sqrt{l(1+1) - m(m \pm 1)}\,|l, m \pm 1\rangle$$

   In above relation $\hat{L}_+$ and $\hat{L}_-$ and are the raising and lowering operators, respectively and $| l, m)$ is the joint eigenstate of $\hat{L}^2$ and $\hat{L}_z$ operators.

6. Using the time-independent perturbation theory for the non-degenerate case, derive the expression for first order correction to energy and wavefunction.

7. Estimate the ground state energy of a 1-D harmonic oscillator using a trial wavefunction $\psi(x) = C \exp[-\alpha x]$,

8. Using the time dependent perturbation theory, derive the expression for transition probability in harmonic perturbation.

SECTION-C

9. What is difference between Sehrodinger, Heisenberg and Interaction representation? Show that the time evolution of state in interaction picture is governed by the interaction term $\hat{V}_I(l)$.

10. What is 'degeneracy' in quantum mechanics? Explain how two fold 'degeneracy' can be resolved and how are the splittted energy components calculated?

11. What do you understand by the 'Born Approximation' in the scattering theory. Explain the first, second, and third terms in the Born Approximation with the help of diagrams. What is n^{th} order Born approximation.

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