Roll No. : ....

Total No. of Questions : **16**] [Total No. of Printed Pages : **4**

PHYSSEM–115

M.Sc. (Ist Semester) Examination, Dec., 2022

PHYSICS

Paper – CC–103

(Quantum Mechanics-I)

*Time : **3** Hours*] [*Maximum Marks : **40***

The question paper contains three Sections.

Section–A **(Marks : 1 × 10 = 10)**

Note :– The candidate is required to answer all the *ten* questions carries **1** mark each. The answer should not exceed **50** words.

Section–B **(Marks : 3 × 5 = 15)**

Note :– The candidate is required to answer *five* questions by selecting at least *one* question from each Unit. Each question carries **3** marks. Answer should not exceed **200** words.

Section–C **(Marks : 5 × 3 = 15)**

Note :– The candidate is required to answer *three* questions by selecting at least *one* question from each Unit. Each question carries **5** marks. The answer should not exceed **500** words.

Section–A

1. (i) What are the physical significances of wave function ?

   (ii) Why we need Schrodinger Equation ?

   (iii) Define the unitary transformation.

   (iv) If any operator have real Eigen values, what is mean and what is significance of real Eigen values ?

   (v) What is the importance of the Ehrenfest theorem ?

   (vi) What do you understand by the commutation relations and what is their significance ?

   (vii) What is perturbation in regard to solve the Schrodinger equation ? Give example of time dependent and time independent perturbation.

   (viii) Why we are emphasizing on angular momentum in quantum mechanics and what are the suggestions from the Eigen values of J^2 ?

   (ix) What is the importance of CG coefficient ?

   (x) What is Stark effect and how does it differ from the Zeeman effect in regard of energy levels splitting ?

Section–B

Unit–I

2. What do you understand by a potential well ? Give its proper example. What will be the probability to find a particle having energy E inside the square shaped one dimensional potential (V_0) well of width a.

3. Calculate the probability of finding a simple harmonic oscillator within the classical limit if the oscillator is in its normal state and further show that if the oscillator is in its normal state, then the probability of finding the particle outside the classical limit is approximately 16%.

4. Find the expression for the continuity equation and discuss its physical significances.

Unit–II

5. Find the eigenvalues and eigenvectors of the following matrix :

$$M = \begin{pmatrix} 2 & 0 & -2 \\ -2i & i & 2i \\ 1 & 0 & -1 \end{pmatrix}$$

6. Let A and B two vector operators that commute with the Pauli matrices but do not commute between themselves. Prove that the Dirac identity :

$$(\hat{\sigma}.\hat{A})(\hat{\sigma}.\hat{B}) = (\hat{A}.\hat{B}) + i(\hat{A} \times \hat{B}).\hat{\sigma}$$

7. A quantum system can be described in terms of a complete set of three basis states $|a>, |b>, \text{and} |c>$. The state $|p>$ has following amplitudes in this representation :

$$\left\langle \frac{a}{p} \right\rangle = \frac{1}{3^{1/2}}, \left\langle \frac{b}{p} \right\rangle = 0 \text{ and } \left\langle \frac{c}{p} \right\rangle = i\left(\frac{2}{3}\right)^{1/2}$$

and a state $|q>$ has amplitude.

$$\left\langle \frac{a}{q} \right\rangle = \frac{(1+i)}{3^{1/2}}, \left\langle \frac{b}{q} \right\rangle = \frac{1}{6^{1/2}} \text{ and } \left\langle \frac{c}{q} \right\rangle = \frac{1}{6^{1/2}}$$

Find the amplitude $\left\langle \frac{p}{q} \right\rangle$ and the probability of finding the system in the state $<q|$ when it is initially in the state $|p>$.

Unit–III

8. Obtain the Schrodinger equation for a particle moving under a central force and carry out the separation for variables.

9. A particle moves in a potential field given by $\varphi x\rangle = \frac{1}{2}kx^2 + ax^4$. Treating the term ax^4 as a perturbation, calculate the ground state energy of the particle.

10. Apply the perturbation theory to derive the energy of the Helim atom in its normal state.

Section–C

Unit–I

11. Find the energy Eigen values and Eigen functions of Schrodinger equation of a harmonic oscillator by operator method and draw its Eigen functions.

12. Evaluate the semiclassical approximation the transmission coefficient for a parabolic potential barrier of the following form :

$$V(x) = \begin{cases} V_0\left(1 - \dfrac{x^2}{a^2}\right) \\ \text{for} - a \le x \le a \\ 0 \text{ for } |x| \ge 0 \end{cases}$$

Unit–II

13. What do you mean by the uncertainty [$\Delta A(\Psi)$] of an hermitian operator A, in any state $|\Psi>$? Define it.

14. Find the Clebsch-Gordan coefficients associated with the addition of two angular momenta $j_1 = 1$ and $j_2 = 1$.

Unit–III

15. What do you mean by the gross structure of line spectra in hydrogen atom ? Explain it. Write an expression for energy levels of hydrogen atom and calculate the energy of first excited state. Draw the probability distribution curve of radial function corresponding to $l = 2$ and 2 for hydrogen atom.

16. Derive the expression for the first and second order correction to the energy eigenvalues for a system under a time independent perturbation. Can the time independent perturbation theory applied to obtain perturbation corrections to degenerate eigenstates ? Explain.