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Reg. No.

I Semester M.Sc. Degree Examination, August - 2021

PHYSICS

Quantum Mechanics - I

(CBCS Scheme 2018-19 Repeaters)

Paper : P103

Time : 3 Hours **Maximum Marks : 70**

Instructions to Candidates:

*All parts are **compulsory.***

PART - A

Answer any **Four** of the following questions. **(4×5=20)**

1. Explain how the idea of wave packet led to the Heisenberg uncertainty principle. State the three uncertainty relations.
2. Discuss the density of energy levels of a particle confined in a cubical box.
3. What is Hermitian operator? Show that two eigenvectors of a Hermitian operator belonging to two distinct eigenvalues are orthogonal.
4. Explain the features Heisenberg picture. Obtain the equation of motion in Heisenberg picture.
5. What are ladder operators? Show that $\left[\hat{J}_+,\hat{J}_-\right]=2\hbar\hat{j}_z$ *and* $[\hat{J}^2,\hat{J}_\pm]=0$.
6. What are Pauli spin matrices? Explain their properties.

PART - B

Answer any **Four** of the following questions. **(4×10=40)**

7. Bring out the reasoning which led Louis de Broglie to propose the concept of matter waves. Obtain expressions for the wavelength of matter waves associated with a photon, non - relativistic and relativistic matter particle.
8. State Ehrenfest theorem. Prove the Ehrenfest theorem deriving the following relations:

   i. $m\frac{d}{dt}\langle x\rangle=\langle p_x\rangle$ and

   ii. $\frac{d}{dt}\langle p_x\rangle=\left\langle\frac{dV}{dx}\right\rangle$.

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9. Setup Schrödinger wave equation for a one - dimensional harmonic oscillator and write down the expressions for energy and wavefunctions. What do you mean by zero - point energy? Schematically represent the energy levels, wavefunction, and probability density for first three states of the oscillator.

10. Derive reflection and transmission coefficients for a beam of particles of energy E incident on a finite width potential barrier of height V_0 such that $E < V_0$.

11. Obtain the generalized uncertainty relationship for two observables A and B of a state of a physical system, satisfying $[\hat{A}, \hat{B}] = i\hat{C}$.

12. For given angular momentum state $|j, m\rangle$, show that

$$\hat{J}_{\pm}|j,m\rangle = \sqrt{j(j+1) - m(m\pm1)}\hbar|j, m\pm1\rangle$$

PART - C

Answer any **Two** of the following questions. **(2×5=10)**

13. Determine the expectation of x-position of a particle trapped in one - dimensional box of width L for the state n=2 state. Given the normalized wavefunction, $\psi_n(x) = \sqrt{\frac{2}{L}}\sin\left(\frac{n\pi x}{L}\right)$.

14. Calculate the normalization constant for the wavefunction $\psi(\theta,\phi) = A\sin(\theta)\cos(\phi)$ in the regions $-\frac{\pi}{2} \le \theta \le \frac{\pi}{2}$ and $0 \le \phi \le 2\pi$.

15. Show that exp $(i\vec{k}, \vec{r})$ is simultaneously an eigenfunction of the operators $-i\hbar\hat{\nabla}$ and $-\hbar^2\hat{\nabla}^2$.

16. If $\hat{L}_x, \hat{L}_y$ and $\hat{L}_z$ are components of angular momentum operator $\hat{L}$, show that $\left[\hat{L}_x, \hat{L}_y\right] = i\hbar\hat{L}_z$.