2023-24

Time - 3 hours

Full Marks - 60

*Answer **all groups** as per instructions.*
Figures in the right hand margin indicate marks.
Candidates are required to answer
in their own words as far as practicable.

GROUP - A

1. Fill in the blanks. (all) [1 × 8

(a) Dimensions of 3-dimensional wave function is _____.

(b) If $\int_{-\infty}^{+\infty} \psi^* \psi \, dx = N$, where N is a number, then norm of wavefunction ψ = _____.

(c) The commutation $[\hat{P}_j, \hat{P}_k]$ = _____ for all the components of $\vec{P}$.

(d) _____ operators always give real eigenvalues.

(e) For stationary states, probability density at each point is _____ of time.

(f) Solution of Schrodinger equation in 1-D potential box gives a series of stationary _____ waves.

(g) The magnetic moment of spinning electron is always equal to one _____.

(h) Quantum mechanical operator of K.E. is _____ in 3-dimensional motion.

GROUP - B

2. Answer any eight of the following within two or three sentences each. [1½ × 8

(a) Write the equation of continuity in quantum mechanics and explain each term.

(b) State the limitations for wave function ψ.

(c) Write orthogonality condition for two wave functions.

(d) What is the value of zero-point energy of 1-D harmonic oscillator having angular frequency w ?

(e) What is confirmed by Stern-Gerlach experiment ?

(f) Define orbital gyromagnetic ratio (g) and write its expression.

(g) State two Ehrenfest's theorems in mathematical form.

(h) Find the commutation $[L_x^2, L_x]$ where L_x represents x-component of angular momentum.

(i) If $\psi = A e^{i\vec{k}.\vec{r}}$ represents a wave function ψ, then find the probability density of finding the particle.

(j) Explain anomalous Zeeman effect.

GROUP - C

3. Answer any eight of the following within 75 words each. [2 × 8

(a) Give Born's interpretation of wave function.

(b) State the principle of superposition in quantum mechanics.

(c) Find the commutation $[\hat{H}, \hat{P}_x]$, where H = Hamiltonian and P = momentum.

(d) Normalise the wavefunction $\psi(x)$, where

$\psi(x) = A e^{-\alpha x}$ for $x > 0$

and $\psi(x) = A e^{+\alpha x}$ for $x < 0$ and α is some constant.

(e) State Larmor's theorem.

(f) Distinguish between Stark effect and Zeeman effect.

(g) Write a short note on quantum dot.

(h) The ground state energy of a particle in 1-D potential box is 2 eV. Find its energy in 2nd excited state.

(i) Explain briefly barrier penetration in potential problems.

(j) Distinguish between L-S coupling and J-J coupling.

GROUP - D

4. Answer any four of the following within 500 words each. [6 × 4

(a) Obtain equation of continuity from Schrodinger equation and explain probability current.

(b) Using Fourier transformation, find the momentum space wave function from co-ordinate space wave function.

(c) Find the commutator relation between Hamiltonian operator $(\hat{H})$ and x-component of linear momentum operator $(\hat{P}_x)$.

(d) Prove that :

(i) Eigenvalues of hermitian operator are real. [3

(ii) Any two eigenfunctions of a Hermitian operator belonging to different eigenvalues are real. [3

(e) A particle is trapped inside a finite square well potential. Solve Schrodinger equation to obtain the even and odd solutions for wave functions and transcendental equations. Briefly mention the graphical solutions.

(f) A particle having energy E faces a 1-D potential step of height V_0, such that $E > V_0$. Solve Schrodinger equation to obtain Transmission and Reflection coefficients.

(g) Explain normal Zeeman effect by using vector atom model.