

BIRLA INSTITUTE OF TECHNOLOGY, MESRA, RANCHI
(END SEMESTER EXAMINATION)

CLASS: I MSc
BRANCH: MATHEMATICS AND COMPUTING

SEMESTER : V
SESSION : MO/2025

SUBJECT: PH301 QUANTUM MECHANICS AND APPLICATIONS

TIME: 3 Hours

FULL MARKS: 50

INSTRUCTIONS:

1. The question paper contains 5 questions each of 10 marks and total 50 marks.
2. Attempt all questions.
3. The missing data, if any, may be assumed suitably.
4. Before attempting the question paper, be sure that you have got the correct question paper.
5. Tables/Data hand book/Graph paper etc. to be supplied to the candidates in the examination hall.

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|--|---|----|----|
| Q.1(a) A wave function $\psi(x) = A_n \sin \frac{2n\pi x}{L}$ in the region $0 \leq x \leq L$. Find the value of A_n using normalization condition? [5] | 1 | 3 | 3 |
| Q.1(b) Derive time independent Schrodinger equation? [5] | 1 | | 2 |
| Q.2(a) Calculate the expectation value of momentum of a particle whose wave function is given by $\psi(x) = N e^{\frac{-x^2}{2a^2} + ikx}$ [5] | 2 | | 3 |
| Q.2(b) Calculate the momentum wave function in the ground state of hydrogen atom? [5] | 2 | | 3 |
| Ground state of the hydrogen atom is given by $\psi(x) = \frac{1}{\sqrt{\pi}} \left(\frac{1}{a_0} \right)^{3/2} e^{-r/a_0}$ | | | |
| Q.3(a) Explain how you obtain the time-independent Schrodinger equation from using separation of variables, for a quantum harmonic oscillator. [5] | 3 | | 2 |
| Q.3(b) The Hermite differential equation is given by $u''(\xi) - 2\xi u'(\xi) + (\Lambda - 1)u(\xi) = 0$, where Λ is a constant. Using Frobenius series, find the indicial equation. [5] | 3 | | 3 |
| Q.4(a) Using the commutation relations $[x, p_x] = [y, p_y] = [z, p_z] = i\hbar$, show that $[L_x, L_y] = i\hbar L_z$. [5] | 4 | | 3 |
| Q.4(b) Given that for $n=1$ and $l=0$, the radial wavefunction for hydrogen atom is given by $R_{10}(r) = (2/a_0^{3/2}) \exp(-r/a_0)$. Show that $r^2 R_{10}^2(r)$ is maximized at $r = a_0$. [5] | 4 | | 3 |
| Q.5(a) Explain the Stern-Gerlach experiment and how it led to the concept of quantum spin. [5] | 5 | | 2 |
| Q.5(b) Find all possible values of the total angular momentum quantum number J, under LS coupling scheme, for two electrons having quantum numbers $l_1 = 1$ and $l_2 = 2$. [5] | 5 | | 3 |

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