Name: **Enrolment No:**	UPES

UNIVERSITY OF PETROLEUM AND ENERGY STUDIES
End Semester Examination, November/December 2021

Course: Quantum Mechanics and Applications **Semester: V**
Course Code: PHYS3001
Programme: BSc Physics (H) **Max. Marks: 100**
Total pages: 2 **Time: 03 hrs.**

Instructions:

- All questions are compulsory (**Q9** and **Q11** have internal choice)
- Use blank paper as rough work to solve the questions in section-A and write only the correct options (type answers, no upload)

SECTION-A

S. No.		**Marks**	**CO**
Q1.	What wavelength (λ) of photons can eject electron from target metal surface if work function energy of the target plate is 3.22 eV? (a) $\lambda \geq 390$ nm, (b) $\lambda > 425$ nm, (c) $\lambda \leq 385$ nm, (d) any λ	**4**	**CO1**
Q2.	The number of anti-nodes for n = 5 state for a particle in a potential box of length L (between 0 to L) is (a) 3, (b) 4, (c) 2, (d) 5	**4**	**CO1**
Q3.	For a given wavefunction, $\psi(x) = \frac{1}{\sqrt{2}}\left(\psi_0(x) + \psi_1(x)\right)$, the average energy of the 1D harmonic oscillator is (a) $\frac{1}{2}\hbar\omega$, (b) $\frac{3}{2}\hbar\omega$, (c) $\hbar\omega$, (d) $\frac{5}{2}\hbar\omega$	**4**	**CO2**
Q4.	L_z operator is a function of (a) r, θ, ϕ, (b) θ, ϕ, (c) r, ϕ, (d) ϕ only.	**4**	**CO3**
Q5.	Choose the correct option. The value of $\boldsymbol{g m_j}$ for the state $^2P_{3/2}$ = (a) 2/3, 1/3, -1/3, -2/3, (b) 2, 2/3, -2/3, -2, (c) 2/3, -2/3, (d) 1/3, -1/3.	**4**	**CO4**

SECTION-B

Q6.	An electron is moving with non-relativistic speed v = 0.005c. What de Broglie wavelength is associated with this particle?	**10**	**CO1**

Q7.	Covert $\hat{L}_z = xp_y - yp_x$ in spherical polar coordinates.	**10**	**CO2**
Q8.	Normalize the wavefunction $\Psi_N(x)$. Assume, $\Psi_N(x)$ is normalizable between x = 0 to L (wavefunction is associated with a particle in a quantum mechanical box of length L). $$\Psi_N(x) = N\sin\left(\frac{n\pi x}{L}\right), \qquad n = \text{integers}$$	**10**	**CO2**
Q9.	Solve differential equation for radial part to obtain radial wavefunction of spherically symmetric potential OR Derive the expression for energy for nth state by solving radial wavefunction of hydrogen like atom.	**10**	**CO3**
	SECTION-C		
Q10.	(a) Using dimensional analysis prove that $[a_0] = [4\pi\varepsilon_0\hbar^2/me^2] = [L]$. (b) Prove that most probable distance of the electron in hydrogen atom appears to be, $r = a_0$, where a_0 is Bohr radius.	**10** **10**	**CO3** **CO3**
Q11.	(a) What is spin-orbit coupling? Analyse spin-orbit interaction and detailed transition with energy levels (say, $2p \longrightarrow 1s$). (b) Calculate Lande 'g' factor for the state: $3\,^2\boldsymbol{D}_{3/2}$ **OR** (a) State Zeeman effect. Analyse energy level splitting and transitions with level diagram (say, transition occurs between 2p→1s) (b) Apply space quantization concept to draw diagrams for space quantization of **J** (total angular momentum) about z-axis for $l = 1$ state.	**10** **10** **10** **10**	**CO4** **CO4** **CO4** **CO4**
	Physical constants: $h = 6.63 \times 10^{-34}\,J-s,\ c = 3\times 10^8\,m/s,\ k_B = 1.38\times 10^{-23}\,J/K, \mu_0 = 4\pi\times 10^{-7}H/m$ $\varepsilon_0 = 8.854\times 10^{-12}F/m$, mass of proton= 1.6726×10^{-27} Kg, mass of electron= 9.1×10^{-31} Kg		