Name:

Enrolment No:

UPES

End Semester Examination, December 2023

Course: Quantum Mechanics 1 **Semester: V**

Program: Int. B.Sc.-M.Sc Physics **Time : 03 hrs.**

Course Code: PHYS 3031 **Max. Marks: 100**

Instructions: Answers should be clearly marked by drawing a box around them.
There should be a clear separation between problems on the same page.
Use pictures/diagrams in solutions whenever you think is needed.

SECTION A
(5Qx4M=20Marks)

S. No.		Marks	CO
Q 1	An electron is trapped in a 1D infinitely deep potential well of width L = 10^{-9} m. Calculate the wavelength of photon emitted from the transition $E_4 \rightarrow E_3$.	**4**	**CO2**
Q 2	Derive 1D time-independent Schrodinger wave equation using a 1D free particle wave function.	**4**	**CO1**
Q 3	Show that x and $\frac{d}{dx}$ are liner operators.	**4**	**CO3**
Q 4	What are the possible z components of the vector $\vec{\boldsymbol{L}}$ that represents the orbital angular momentum of a state with l = 2? Compute the magnitude (length) of the angular momentum.	**4**	**CO4**
Q 5	An electron is bound to a region of space by a springlike force with an effective spring constant of k = 95.7 eV/nm^2. What is its ground-state energy?	**4**	**CO4**
	SECTION B **(4Qx10M= 40 Marks)**		
Q 6	Evidence for the electron spin was provided by the Sterrn–Gerlah experiment. Sketch and briefly describe the key features of the experiment. Explain what was observed and how this observation may be interpreted in terms of electron spin.	**10**	**CO3**
Q 7	Determine the degeneracy of the energy levels of a 3D isotropic harmonic oscillator.	**10**	**CO4**
Q 8	Given that $\boldsymbol{L} = \boldsymbol{r} \times \boldsymbol{p}$, show that $[L_x, L_y] = i\hbar L_z$	**10**	**CO3**
Q 9	A metallic surface, when illuminated with light of wavelength λ_1, emits electrons with energies up to a maximum value E_1, and when illuminated	**10**	**CO1**

	with light of wavelength λ_2 (where $\lambda_2 < \lambda_1$), it emits electrons with energies upto a maximum value E_2. Prove that Planck's constant h and the work function φ of the metal are given by $$h = \frac{(E_2 - E_1)\lambda_1\lambda_2}{C(\lambda_1 - \lambda_2)} \text{ and } \varphi = \frac{E_2\lambda_2 - E_1\lambda_1}{(\lambda_1 - \lambda_2)}$$ **Or** The work function for tungsten metal is 4.52 eV. (a) What is the cutoff wavelength λc for tungsten? (b) What is the maximum kinetic energy of the electrons when radiation of wavelength 198 nm is used? (c) What is the stopping potential in this case?		
SECTION-C (2Qx20M=40 Marks)			
Q 10	Show that the difference between the wavelength of the scattered photon and the incident photon in the Compton effect is given by $$\Delta\lambda = \frac{h}{m_o c}(1 - \cos\theta)$$ where the symbols have their usual meanings.	**20**	**CO1**
Q 11	State Ehrenfest's theorem. Show that $\frac{d\langle x\rangle}{dt} = \frac{\langle p_x\rangle}{m}$ where the symbols have their usual meanings. **Or** Prove that the operator L_x in the spherical polar coordinate system (r, θ, ϕ) is represented by $L_x = i\hbar\left(\sin\phi\frac{\partial}{\partial\theta} + \cot\theta\cos\phi\frac{\partial}{\partial\phi}\right)$.	**20**	**CO3**

Standard Physics Constants and their values:

Constants	Standard values
Planck's constant (h)	$6.626 \times 10^{-34}\ Js$
Speed of light (c)	$3 \times 10^{8}\ m/s$
Boltzmann constant (k_B)	$1.38 \times 10^{-23}\ J/K$
Rest mass of an electron (m_0)	$9.11 \times 10^{-31}\ kg$ or 511 keV/c^2
Charge on electron (e)	$1.6 \times 10^{-19}\ C$
Rest mass of a proton (m_P)	$1.67 \times 10^{-27}\ kg$