Name: **Enrolment No:**	UPES UNIVERSITY OF TOMORROW

UPES

End Semester Examination, December 2024

Course: Quantum Mechanics I **Semester: I**
Program: MSc Physics **Time : 03 hrs.**
Course Code: PHYS 7003 **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 it is needed.
Scientific calculators are allowed.

SECTION A
(5Qx4M=20Marks)

S. No.		Marks	CO
Q 1	Show that the following operator is Hermitian. $$A = \begin{bmatrix} 3/2 & 0 & -i/2 \\ 0 & 2 & 0 \\ i/2 & 0 & 3/2 \end{bmatrix}$$	**4**	**CO1**
Q 2	Given that the complete wave function of a hydrogen-like atom in a particular state is $\psi(r, \theta, \phi) = N\, r^2 \exp(-Zr/3a_0)\ \sin^2\theta\ e^{2i\phi}$ determine the eigen value of L_z.	**4**	**CO3**
Q 3	Calculate the shortest wavelength of the Lyman series lines in hydrogen. In what region of the electromagnetic spectrum does each lie?	**4**	**CO1**
Q 4	Write down the expressions for position operator (x_{op}) in real (x) and momentum (p) space (use free particle wave-function).	**4**	**CO2**
Q 5	Explain how de-Broglie proposed his relation (λ=h/p) i.e., a moving materialistic particle have a wave-like behavior. The symbols have their usual meanings.	**4**	**CO1**

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**	**CO1**

Q 7	Using the uncertainty principle, estimate the ground state energy of a 1-D simple harmonic oscillator (quantum mechanical system).	**10**	**CO2**
Q 8	Determine the degeneracy of the energy levels of a 3D isotropic harmonic oscillator.	**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 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 $h = \frac{(E_2 - E_1)\lambda_1\lambda_2}{C(\lambda_1 - \lambda_2)}$ 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?	**10**	**CO1**
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. **Or** Derive a relation $\left(\frac{K}{E} = \frac{\frac{2hv}{m_o c^2} \sin^2\theta/2}{1 + \frac{2hv}{m_o c^2} \sin^2\theta/2}\right)$ between the kinetic energy K of the recoil electron and the energy E of the incident photon in the Compton effect.	**20**	**CO1**
Q 11	Using virial theorem, show that expectation kinetic energy of hydrogen atom is equal to its expectation total energy.	**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)	$1.67 \times 10^{-27}\ kg$