Y/K/TY

Reg. No:

VIT

Vellore Institute of Technology

Final Assessment Test – November 2025

Course: **BAPHY106 - Foundations of Quantum Mechanics** Slot: **D1+TD1**

Class NBR(s): **5303 / 5309 / 5314** Max. Marks: **100**

Time: **Three Hours**

- **KEEPING MOBILE PHONE/ANY ELECTRONIC GADGETS, EVEN IN 'OFF' POSITION IS TREATED AS EXAM MALPRACTICE**
- **DON'T WRITE ANYTHING ON THE QUESTION PAPER**

COs	CO Statements
CO1	Identify limitations of classical physics through experimental observations
CO2	Apply matrix algebra and Dirac notation for the understanding of quantum mechanical problems involving linear operators, eigenvalues and eigenvectors.
CO3	Solve the particle in 1-D and 3-D potential box problem using the principles of quantum mechanics
CO4	Apply fundamental concepts of quantum states and operators to understand the principles of quantum computing.

BL – Blooms Taxonomy Level (1 – Remember, 2 – Understand, 3 – Apply, 4 – Analyse, 5 – Evaluate, 6 – Create)

Answer ALL Questions

(10 X 10 = 100 Marks)

1. Explain with a neat diagram of the Stern-Gerlach experimental setup. List down the observations and interpret the results. CO1 BL2

2. a) Find the de Broglie wavelength of (i) a 46 g golf ball with a velocity of 30 m/s, and (ii) an electron with velocity of 10^7 m/s. CO1 BL3

   b) X-rays of wavelength 10 pm are scattered from target. Find the maximum wavelength of the scattered X-rays and the maximum kinetic energy of the recoil electrons.

3. Find the results of the following commutators and interpret the results. CO2 BL3

   a) $[\hat{x}, \hat{p}_x]$

   b) $[\hat{x}, \hat{p}_y]$

   c) $\left[\hat{p}_x, \frac{\hat{p}_x}{2m}^2\right]$

   d) $\left[\hat{x}, \frac{\hat{p}_x}{2m}^2 + \hat{V}(x)\right]$

4. From the time-dependent Schrödinger equation, derive the time-independent Schrödinger equation. CO2 BL3
   Is $\psi(x,t) = sin(x)e^{-i\omega_1 t} + sin(2x)e^{-i\omega_2 t}$ a stationary state? Interpret the result.

5. Find the square of the expectation value of the position operator $(\langle\hat{x}\rangle^2)$ and the expectation value of square of position operator $(\langle\hat{x}^2\rangle)$ for the given wavefunction $\Psi(x,t) = \frac{1}{\sqrt{2L}} exp\left(\frac{ipx - iEt}{\hbar}\right)$ where $-L \leq x \leq L$. Therefrom, find the difference between the two. CO2 BL3

6. For a particle confined in an infinite potential well of length L, derive the energy eigenfunction and eigenvalue starting from the time-independent Schrödinger equation. CO3 BL2

7. a) Write down the energy of the second excited state for a particle in a 3D box of dimensions $L \times L \times L$. Comment on the degeneracy for the second excited level. CO3 BL3

b) Explain quantum tunneling using a neat diagram.

8. Write down the four forms of Bell states. Construct quantum circuits to generate the Bell states. CO4 BL2

9.a) Show that the Pauli matrices $\sigma_x, \sigma_y, \sigma_z$ have eigenvalues of unit modulus. Also show that their trace is equal to sum of eigenvalues and their determinant is equal to the product of the eigenvalues. CO2 BL3

[OR]

9.b) Check if the following matrix $\begin{pmatrix} 2 & 2-i & 1+2i \\ 2+i & 1 & i \\ 1-2i & -i & 2 \end{pmatrix}$ is Hermitian, unitary and idempotent. Find their eigenvalues.

10.a) Discuss Bloch sphere representation of a single qubit. Explain the action of Pauli operators on the state $|1\rangle$ in the Bloch sphere representation. CO4 BL3

[OR]

10.b) Discuss the actions of Pauli and Hadamard gates. Prove that single qubit gates cannot produce entanglement.

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