1. Postulates of Quantum Mechanics

❖ Definition:

❖ Postulates are the **basic foundational principles** upon which the entire structure of quantum mechanics is built.
They cannot be derived from other theories; instead, they are **assumptions verified by experiments** and used to describe microscopic systems such as electrons, atoms, and photons.

❖ 1.State Postulate (Wavefunction Postulate)

❖ The **state** of a quantum system is completely specified by a **wavefunction ψ(x,t).**

❖ ψ(x,t) contains **all measurable information** about the system.
❖ The probability of finding the particle like electron in a region between x and x+dx is : $\mathbf{P(x)dx=|\psi(x,t)|^2dx}$
❖ The wavefunction must satisfy the **normalization condition**: $\int_{-\infty}^{\infty} |\psi(x,t)|^2 dx=1$
❖ **Example:** The wave function describes how likely it is to find an electron at a certain distance from the nucleus at a given time.

❖ 2.Observable Postulate

❖ Each **measurable (observable) physical quantity** (like position, momentum, energy) is represented by a **linear Hermitian operator** $\hat{A}$.
❖ The **expectation value** (average measurement) of the observable is $\langle A\rangle=\int \psi^*(x)\hat{A}\psi(x)dx$

❖ Hermitian property ensures **real eigenvalues**, which correspond to measurable results.

❖ **Example:**

- Position(x) → $\hat{x}$
- Momentum(p) → $\hat{p}$ $=-i\hbar\, d/dx$
- Energy(E) (Hamiltonian) → $\hat{H} = \hat{T} + \hat{V} = -\hbar^2/2m + V(x)$

❖ 3. Measurement Postulate

- ❖ When we measure an observable (quantity), the system will only be found in one of the operator's eigenvalues.
- ❖ This means the measurement outcome is quantized (discrete values).
  Mathematically: $\hat{A}\psi = a\psi$
- ❖ **Where:** Â = operator
  - ➢ ψ= wave function
  - ➢ a= eigenvalue (measured value)
- ❖ [The probability of getting a particular eigenvalue 'ai' is given by $|\ c_i\ |^2$

  Where c_i is the coefficient in $\psi = \sum i c_i \psi_i$, c_i is the coefficient]

- ❖ **Example:** For momentum measurement: $\hat{p}\psi = \hbar k\psi$
- ❖ The measured momentum can only be one of the allowed eigenvalues ħk.

❖ 4.Time Evolution Postulate

- ❖ The **time evolution** of a quantum state is determined by the **time-independent Schrödinger wave equation**
- ❖ The wave function changes with time according to the time-independent Schrödinger wave equation: $\hat{H}\psi(x,t) = i\hbar\partial\psi/\partial t$
- ❖ This wave equation describes how the wave function evolves or moves over time and The Hamiltonian $\hat{H}$ represents the total energy operator.

- ❖ **Example:** It predicts how an electron's position probability changes with time.

❖ 5.Expectation value postulate

- ❖ The average expected value of a measurable quantity : $\langle A\rangle = \int \psi * \hat{A}\psi dx$
- ❖ **Example:** Average position is the average outcome if we measured position for many identical systems.

❖ 6: Identical particles & antisymmetry

- ❖ If two or more particles are *identical* (e.g. electrons), the total wave function must change sign when we swap any two particles.
  - ➢ $\psi(1,2) = -\psi(2,1)$

- It leads to the Pauli exclusion principle which states that no two electrons can have the same set of 4 quantum numbers.
- **Example:** In atoms, electrons fill up different energy levels because of this rule.

7.Superposition Principle

- If ψ_1 and ψ_2 are possible states of a system, any linear combination
- $\psi = c_1 \psi_1 + c_2 \psi_2$ is also a possible state.
- This principle leads to **interference** and **quantum coherence** phenomena.

- **Example:**
  In a double-slit experiment, the final wavefunction is the **superposition** of waves from both slits.

8.Probability Conservation

- The total probability of finding a particle anywhere in space is always **1**, and this remains **constant in time**: $\int |\psi(x,t)|^2 dx = 1$
- This ensures that **probability density is conserved** during evolution.

NOTE: LAST 2 POSTULATES ARE NOT COMPULSERY