📘 Quantum Mechanics – Complete Notes (Sem VI Physics, B.Sc.)

1) Introduction & Historical Background

- Limitations of Classical Physics

- Black-body radiation, Photoelectric effect, Compton effect

- Matter waves and **De Broglie hypothesis**

- Wave–particle duality concept

- Davisson–Germer experiment (demonstration of matter waves)

2) Wave Function & Postulates

- Definition of **wave function** $\psi(x, t)$

- Physical meaning: Probability density $|\psi|^2$

- Normalization of wave function

- Continuous, single-valued functions

- Square-integrable conditions

- **Postulates of Quantum Mechanics**

  - State vector / wave function represents system

  - Operator corresponds to observable

  - Measurement yields eigenvalues

  - Collapse of wave function on measurement

3) Schrödinger Equation

Time-Dependent Schrödinger Equation

$$i\hbar \frac{\partial \psi}{\partial t} = \hat{H}\psi$$

$$\hat{H}\psi = E\psi$$

$$\hat{H} = -\frac{\hbar^2}{2m}\nabla^2 + V(x)$$

- Probability current density & continuity equation

4) Operators, Eigenvalues & Expectation Values

- Hermitian operators → real eigenvalues

- Position $\hat{x}$, momentum $\hat{p} = -i\hbar \frac{\partial}{\partial x}$

- Commutator:

$$[\hat{A}, \hat{B}] = \hat{A}\hat{B} - \hat{B}\hat{A}$$

- Expectation value:

$$\langle A \rangle = \int \psi^* \hat{A} \psi \, dx$$

(Covers link between classical & quantum mechanics) rkmmanr.org

5) Exactly Solvable Problems

Free Particle

- Plane-wave solutions

- Probability interpretation

Particle in a Box (Infinite Potential Well)

$$V(x) = 0 \quad 0 < x < a, \quad \infty \text{ outside}$$

$$E_n = \frac{n^2 \pi^2 \hbar^2}{2ma^2}$$

Potential Step & Barrier (Qualitative)

- Reflection & transmission

- Tunnelling (Quantum barrier penetration)

Harmonic Oscillator

- Ladder operators (creation & annihilation)

- Quantized energy

$$E_n = \hbar\omega \left(n + \tfrac{1}{2}\right)$$

Schrödinger Equation in Spherical Coordinates

- Separation of variables for central potentials

- Radial equation

6) Angular Momentum in Quantum Mechanics

- Operators: $\hat{L}_x, \hat{L}_y, \hat{L}_z$

- Commutation relations

$$[\hat{L}_i, \hat{L}_j] = i\hbar\varepsilon_{ijk}\hat{L}_k$$

- Spin and total angular momentum

7) Approximation Methods (Introductory)

(Typically Part of further sections but good to overview)

- Time-independent perturbation theory

- Variational method

- WKB approximation

8) Quantum Statistics & Identical Particles

- Bosons vs Fermions

- Pauli exclusion principle

- Symmetric & antisymmetric wave functions

📄 Useful Equations Summary

Topic	Key Equation
Schrödinger	$\hat{H}\psi = E\psi$
Momentum Operator	
Commutator	$[x, p] = i\hbar$
Expectation value	$\int \psi^* \hat{A}\psi, dx$
Uncertainty Principle	$\Delta x, \Delta p \geq \frac{\hbar}{2}$

📥 Optional (Free Online Courses & Notes)

Here are some **structured modules** and free resources you can use to supplement your study:

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