

Introduction to Quantum Mechanics

Introduction to Quantum Mechanics – Study Notes

1. What Is Quantum Mechanics?

- **Definition:** The branch of physics that describes the behavior of matter and energy at atomic scale ($\sim 10^{-10}$ m) and subatomic ($\sim 10^{-15}$ m) dimensions.
 - **Why It Matters:** Explains phenomena that classical physics cannot (e.g., atomic spectra, chemical bonding, semiconductor behavior, lasers, superconductivity).
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2. Historical Milestones

Year	Event	Key Contributor(s)	Significance
1900	Blackbody radiation ? Planck's quantization of energy	Max Planck	First hint that energy comes in discrete "quanta".
1905	Photoelectric effect ? Light as particles (photons)	Albert Einstein	Demonstrated particle nature of light.
1913	Bohr model of the hydrogen atom	Niels Bohr	Introduced quantized electron orbits.
1924–1925	Waveparticle duality (de Broglie) & matrix mechanics	Louis de Broglie; Werner Heisenberg	Showed matter waves; first formal quantum theory.
1926	Schrödinger equation (wave mechanics)	Erwin Schrödinger	Provided a differential equation description of quantum states.
1927	Uncertainty principle	Werner Heisenberg	Limits simultaneous knowledge of complementary variables.
1928	Dirac equation (relativistic quantum mechanics)	Paul Dirac	Merged quantum mechanics with special relativity; predicted antimatter.

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Year	Event	Key Contributor(s)	Significance
1935	EPR paradox & Schrödinger's cat	Einstein, Podolsky, Rosen; Erwin Schrödinger	Highlighted non-locality and measurement problems.
1947–1950s	Quantum electrodynamics (QED)	Richard Feynman, Julian Schwinger, Sin-Itiro Tomonaga	First successful quantum field theory.

3. Core Concepts & Postulates

Postulate	Statement	Practical Implication
1. State Vector	The physical state of a system is represented by a normalized vector	(Eigenvalues = possible
2. Observables	Every measurable quantity corresponds to a Hermitian operator ($\hat{A}$)	measurement results; eigenvectors = states after measurement.
3. Measurement	Upon measurement, the system collapses to an eigenstate of the observable; probability = $\lvert \langle a_i \rvert \psi \rangle \rvert^2$	(
4. Time Evolution	The state evolves according to the Schrödinger equation: $i\hbar \frac{\partial}{\partial t} \psi = \hat{H} \psi$	$\lvert \psi(t) \rangle = e^{-i\hat{H}t/\hbar} \lvert \psi(0) \rangle$
5. Composite Systems	The state space of a combined system is the tensor product of the subsystems' spaces	Enables description of entanglement and many-body physics.

4. Mathematical Toolkit

Tool	Description	Typical Use
Complex Numbers	$a + bi$	Representing quantum states and operators.