This text focuses on introducing students to the postulates and general principles of quantum mechanics. Application to harmonic oscillator, rigid rotor, one-electron and many-electron atoms, and homo- and hetero-nuclear diatomic molecules are discussed including variational method and time-independent perturbation theory approximations.

**1: The Dawn of the Quantum Theory**

- 1.1: Blackbody Radiation Cannot Be Explained Classically
- 1.2: Quantum Hypothesis used for Blackbody Radiation Law
- 1.3: Photoelectric Effect Explained with Quantum Hypothesis
- 1.4: The Hydrogen Atomic Spectrum
- 1.5: The Rydberg Formula and the Hydrogen Atomic Spectrum
- 1.6: Matter Has Wavelike Properties
- 1.7: de Broglie Waves can be Experimentally Observed
- 1.8: The Bohr Theory of the Hydrogen Atom
- 1.9: The Heisenberg Uncertainty Principle
- 1.E: The Dawn of the Quantum Theory (Exercises)

**2: The Classical Wave Equation**

- 2.1: The One-Dimensional Wave Equation
- 2.2: The Method of Separation of Variables
- 2.3: Oscillatory Solutions to Differential Equations
- 2.4: The General Solution is a Superposition of Normal Modes
- 2.5: A Vibrating Membrane
- 2.E: The Classical Wave Equation (Exercises)

**3: The Schrödinger Equation & a Particle in a Box**

The particle in a box model provides one of the very few problems in quantum mechanics which can be solved analytically, without approximations. This means that the observable properties of the particle (such as its energy and position) are related to the mass of the particle and the width of the well by simple mathematical expressions. Due to its simplicity, the model allows insight into quantum effects without the need for complicated mathematics.

- 3.1: The Schrödinger Equation
- 3.2: Linear Operators in Quantum Mechanics
- 3.3: The Schrödinger Equation is an Eigenvalue Problem
- 3.4: The Quantum Mechanical Free Particle
- 3.5: Wavefunctions Have a Probabilistic Interpretation
- 3.6: The Energy of a Particle in a Box is Quantized
- 3.7: Wavefunctions Must Be Normalized
• 3.8: The Average Momentum of a Particle in a Box is Zero
• 3.9B: Particle in a Finite Box and Tunneling (optional)
• 3.9: The Uncertainty Principle Redux - Estimating Uncertainties from Wavefunctions
• 3.10: A Particle in a Two-Dimensional Box
• 3.11: A Particle in a Three-Dimensional Box
• 3.E: The Schrödinger Equation and a Particle in a Box (Exercises)

4: Postulates and Principles of Quantum Mechanics
• 4.1: The Wavefunction Specifies the State of a System
• 4.2: Quantum Operators Represent Classical Variables
• 4.3: Observable Quantities Must Be Eigenvalues of Quantum Mechanical Operators
• 4.4: The Time-Dependent Schrödinger Equation
• 4.5: The Eigenfunctions of Operators are Orthogonal
• 4.6: Heisenberg Uncertainty Principle III - Commuting Operators
• 4.E: Postulates and Principles of Quantum Mechanics (Exercises)

5: The Harmonic Oscillator and the Rigid Rotor
• 5.1: A Harmonic Oscillator Obeys Hooke's Law
• 5.2: The Equation for a Harmonic-Oscillator Model of a Diatomic Molecule Contains the Reduced Mass of the Molecule
• 5.3: The Harmonic Oscillator is an Approximation
• 5.4: The Harmonic Oscillator Energy Levels
• 5.5: The Harmonic Oscillator and Infrared Spectra
• 5.6: The Harmonic-Oscillator Wavefunctions Involve Hermite Polynomials
• 5.7: Hermite Polynomials are either Even or Odd Functions
• 5.8: The Energy Levels of a Rigid Rotor
• 5.9: The Rigid Rotator is a Model for a Rotating Diatomic Molecule
• 5.E: The Harmonic Oscillator and the Rigid Rotor (Exercises)

6: The Hydrogen Atom
• 6.1: The Schrödinger Equation for the Hydrogen Atom Can Be Solved Exactly
• 6.2: The Wavefunctions of a Rigid Rotator are Called Spherical Harmonics
• 6.3: The Three Components of Angular Momentum Cannot be Measured Simultaneously with Arbitrary Precision
• 6.4: Hydrogen Atomic Orbitals Depend upon Three Quantum Numbers
• 6.5: s Orbitals are Spherically Symmetric
Electrons with more than one atom, such as Helium (He), and Nitrogen (N), are referred to as multi-electron atoms. Hydrogen is the only atom in the periodic table that has one electron in the orbitals under ground state. We will learn how additional electrons behave and affect a certain atom.

- **8.1**: Atomic and Molecular Calculations are Expressed in Atomic Units
- **8.2**: Perturbation Theory and the Variational Method for Helium
- **8.3**: Hartree-Fock Equations are Solved by the Self-Consistent Field Method
- **8.4**: An Electron Has An Intrinsic Spin Angular Momentum
- **8.5**: Wavefunctions must be Antisymmetric to Interchange of any Two Electrons
- **8.6**: Antisymmetric Wave Functions can be Represented by Slater Determinants
- **8.7**: Hartree-Fock Calculations Give Good Agreement with Experimental Data
- **8.8**: Term Symbols Gives Detailed Descriptions of an Electron Configuration
- **8.8B**: Multi-electron Considerations - A Closer Look at Helium
- **8.9**: The Allowed Values of J - the Total Angular Momentum Quantum Number
- **8.10**: Hund’s Rules Determine the Term Symbols of the Ground Electronic States
- **8.11**: Using Atomic Term Symbols to Describe Atomic Spectra
- **8.E**: Multielectron Atoms (Exercises)
• **9.4: Chemical Bond Stability**
• **9.5: Bonding and Antibonding Orbitals**
• **9.6: A Simple Molecular-Orbital Treatment of H$_2$ Places Both Electrons in a Bonding Orbital**
• **9.7: Molecular Orbitals Can Be Ordered According to Their Energies**
• **9.8: Molecular-Orbital Theory Does not Predict a Stable Diatomic Helium Molecule**
• **9.9: Electrons Populate Molecular Orbitals According to the Pauli Exclusion Principle**
• **9.10: Molecular Orbital Theory Predicts that Molecular Oxygen is Paramagnetic**
• **9.E: The Chemical Bond: Diatomic Molecules (Exercises)**

**MathChapters**

• **A: Complex Numbers**
• **B: Probability and Statistics**
• **C: Vectors**
• **D: Spherical Coordinates**
• **E: Determinants**
• **F: Matrices**
• **G: Numerical Methods**
• **H: Partial Differentiation**
• **I: Series and Limits**
• **J: The Binomial Distribution and Stirling's Approximation**