

Contents

Preface	<i>page</i> ix
PART I. INTRODUCTORY	1
Chapter 1 The Need for a Non-Classical Description of Microscopic Phenomena	3
1.1 Photons	4
1.2 Quantization of Energy and Angular Momentum	12
1.3 The Wave Nature of Matter	19
<i>Exercises</i>	23
Chapter 2 Classical Concepts and Quantal Inequivalences	27
2.1 Particles	27
2.2 Coordinate Systems: Positions, Velocities, Momenta	28
2.3 Dynamical Equations, Generalized Coordinates and Conserved Quantities	30
2.4 Potentials and Limits of Motion	34
2.5 States of a System	35
2.6 Measurements and Uncertainty	37
<i>Exercises</i>	40
Chapter 3 Introducing Quantum Mechanics: A Comparison of the Classical Stretched String and the Quantal Box	46
3.1 The Uniform Stretched String	46
3.2 Quantum Dynamics	57
3.3 The Particle in a Quantal Box	63
3.4 *The Concept of Hermiticity	70
<i>Exercises</i>	77
Chapter 4 Mathematical Background	84
4.1 Vectors and Matrices in Three Dimensions	85
4.2 N Dimensions, Hilbert Space, and Dirac Notation	91
4.3 Operators	101
4.4 The Position Operator: Delta Functions and Locality	108
4.5 Functions of Operators	117
<i>Exercises</i>	122

PART II. THE CENTRAL CONCEPTS	127
Chapter 5 The Postulates of Quantum Mechanics	129
5.1 Observables	129
5.2 States, Wave Functions, and Probabilities	132
5.3 Measurements/Connection with Experimental Data	138
5.4 The Coordinate Representation for Observables	146
5.5 The Fundamental Dynamical Equation	156
5.6 Eigenstate Expansions	161
<i>Exercises</i>	165
Chapter 6 Applications of the Postulates: Bound States in One Dimension	174
6.1 The Quantum Box, Revisited	175
6.2 The Linear Harmonic Oscillator	184
6.3 General Remarks on Non-Confining Potentials	207
6.4 The Half-Space Square Well	213
6.5 The Square Well	218
6.6 The Delta-Function Potential	220
<i>Exercises</i>	222
Chapter 7 Applications of the Postulates: Continuum States in One Dimension	230
7.1 Wave-Packet Description of Scattering	230
7.2 The Equation of Continuity and the Plane-Wave Limit for Scattering	245
7.3 Plane-Wave Scattering: Attractive Potentials	255
7.4 Plane-Wave Scattering: Potential Barriers and Tunneling Phenomena	266
<i>Exercises</i>	275
Chapter 8 *Quantal/Classical Connections	281
8.1 Some Temporal Aspects of the Theory	281
8.2 Path-Integral Formulation of Quantum Mechanics	289
8.3 The Classical Limit	295
<i>Exercises</i>	303
Chapter 9 Commuting Operators, Quantum Numbers, Symmetry Properties	307
9.1 The Heisenberg Uncertainty Principle	308
9.2 Quantal Constants of the Motion	315
9.3 Complete Sets of Commuting Operators	317
9.4 General Remarks on Symmetries and Symmetry Operators	319
9.5 Reflections	321
9.6 Translations	332
9.7 Rotations	344
<i>Exercises</i>	356

PART III. SYSTEMS WITH FEW DEGREES OF FREEDOM	363
Chapter 10 Orbital Angular Momentum	365
10.1 The Orbital Angular Momentum Operator	365
10.2 The Orbital Angular Momentum Eigenvalue Problem	372
10.3 Spherical-Harmonics Expansion of Plane Waves	382
10.4 Orbital Angular Momentum Uncertainty Relations	387
<i>Exercises</i>	392
Chapter 11 Two-Particle Systems, Potential-Well Bound-State Problems	396
11.1 Some Features of the Two-Particle System	396
11.2 Reduction of the \hat{H}_{12} Two-Body Problem to an Effective One-Body Problem	400
11.3 Some Properties of the Solutions in Three Dimensions	409
11.4 Two Quantal Boxes	412
11.5 The Symmetric Three-Dimensional Square Well	421
11.6 The $1/r$ Potential	427
11.7 *The Symmetric Two-Dimensional Oscillator	440
<i>Exercises</i>	444
Chapter 12 Electromagnetic Fields	451
12.1 Charged Particle in External Electromagnetic Fields	452
12.2 Quantal Particle in a Uniform Magnetic Field	454
12.3 Quantal Particle in a Uniform Electric Field	462
12.4 Quantum-Theoretic Aspects of $\hat{H}^{(A)}(\mathbf{r}, t)$	465
12.5 Gauge Invariance	469
12.6 Gauge Transformations: The Spatially Uniform Electric Field	473
12.7 *The Aharonov–Bohm Effect	476
<i>Exercises</i>	481
Chapter 13 Intrinsic Spin, Two-State Systems	487
13.1 The Stern–Gerlach Experiment and its Interpretation	487
13.2 Spin $\frac{1}{2}$: Operators, States, Properties	491
13.3 Magnetic-Field Phenomena	499
13.4 Other Two-State Systems	510
<i>Exercises</i>	511
Chapter 14 Generalized Angular Momentum and the Coupling of Angular Momenta	517
14.1 Generalized Angular Momentum	517
14.2 Rotations and Spin $\frac{1}{2}$	525
14.3 The Coupling of Angular Momenta	529
14.4 $\hat{\mathbf{J}}_1 \cdot \hat{\mathbf{J}}_2$ Interactions	540
14.5 *Conceptual/Interpretational Controversies, Bell’s Inequality	544
<i>Exercises</i>	551

Chapter 15 Three-Dimensional Continuum States/Scattering	555
15.1 Wave-Packet Analysis	556
15.2 Angular Distributions and the Plane-Wave Limit	563
15.3 The Lippmann–Schwinger Equation and the Scattering Amplitude	566
15.4 Spherical Symmetry, Partial Waves, Phase Shifts	571
15.5 Some Phase-Shift Calculations	580
15.6 A Weak-Potential/High-Energy Approximation	584
15.7 *Spin- $\frac{1}{2}$ Projectiles	588
<i>Exercises</i>	592
 PART IV. COMPLEX SYSTEMS	 597
 Chapter 16 Time-Dependent Approximation Methods	 599
16.1 Time-Dependent Perturbation Theory	599
16.2 Electromagnetic Transitions Between Bound States	612
16.3 *Sudden and Adiabatic Approximations, Geometric Phases	625
16.4 *Exponential Decay and the Time–Energy Uncertainty Relation	632
<i>Exercises</i>	639
 Chapter 17 Time-Independent Approximation Methods	 644
17.1 Rayleigh–Schrödinger Perturbation Theory: The Non-Degenerate Case	644
17.2 Fine Structure and Hyperfine Structure in the Spectrum of Hydrogen	652
17.3 Rayleigh–Schrödinger Perturbation Theory: The Degenerate Case	659
17.4 The Variational Method for Bound States	669
17.5 *The WKB Approximation	680
<i>Exercises</i>	684
 Chapter 18 Many Degrees of Freedom: Atoms and Molecules	 689
18.1 Identical-Particle Symmetries	690
18.2 Two-Electron Atoms	700
18.3 The Hartree–Fock Approximation for Atoms	713
18.4 The Atomic Central-Field Approximation and the Periodic Table of the Elements	719
18.5 Elements of Molecular Structure	732
<i>Exercises</i>	750
 <i>Appendix A Elements of Probability Theory</i>	 756
<i>Appendix B Fourier Series and Integrals</i>	763
<i>Appendix C Solution of Legendre’s Equation</i>	771
<i>Appendix D Fundamental and Derived Quantities: Conversion Factors</i>	775
<i>References</i>	776
<i>Index</i>	783