

Contents

1. Review of Quantum Mechanics	1
1.1 Wave Functions and Equations of Motion	1
1.1.1 States and Wave Functions	1
1.1.2 Linear Operators and Observables	3
1.1.3 The Hamiltonian and Equations of Motion	7
1.2 Symmetries	9
1.2.1 Constants of Motion and Symmetries	9
1.2.2 The Radial Schrödinger Equation	12
1.2.3 Example: The Radially Symmetric Harmonic Oscillator	14
1.3 Bound States and Unbound States	16
1.3.1 Bound States	16
1.3.2 Unbound States	19
1.3.3 Examples	22
1.3.4 Normalization of Unbound States	28
1.4 Resonances and Channels	30
1.4.1 Channels	30
1.4.2 Feshbach Resonances	32
1.4.3 Potential Resonances	37
1.5 Methods of Approximation	39
1.5.1 Time-independent Perturbation Theory	39
1.5.2 Ritz's Variational Method	42
1.5.3 Semiclassical Approximation	45
1.6 Angular Momentum and Spin	49
1.6.1 Addition of Angular Momenta	50
1.6.2 Spin	51
1.6.3 Spin-Orbit Coupling	53
Problems	55
References	58
2. Atoms and Ions	59
2.1 One-Electron Systems	59
2.1.1 The Hydrogen Atom	59
2.1.2 Hydrogenic Ions	61
2.1.3 The Dirac Equation	62
2.1.4 Relativistic Corrections to the Schrödinger Equation	66
2.2 Many-Electron Systems	68

2.2.1	The Hamiltonian	68
2.2.2	Pauli Principle and Slater Determinants	70
2.2.3	The Shell Structure of Atoms	74
2.2.4	Classification of Atomic Levels	76
2.3	The N -Electron Problem	81
2.3.1	The Hartree-Fock Method	81
2.3.2	Correlations and Configuration Interaction	85
2.3.3	The Thomas-Fermi Model	88
2.3.4	Density Functional Methods	92
2.4	Electromagnetic Transitions	93
2.4.1	Transitions in General, "Golden Rule"	94
2.4.2	The Electromagnetic Field	98
2.4.3	Interaction Between Atom and Field	102
2.4.4	Emission and Absorption of Photons	103
2.4.5	Selection Rules	108
2.4.6	Oscillator Strengths, Sum Rules	111
	Problems	112
	References	115
3.	Atomic Spectra	117
3.1	One Electron in a Modified Coulomb Potential	117
3.1.1	Rydberg Series, Quantum Defects	117
3.1.2	Seaton's Theorem, One-Channel Quantum Defect Theory	123
3.1.3	Photoabsorption and Photoionization	125
3.2	Coupled Channels	129
3.2.1	Close-Coupling Equations	129
3.2.2	Autoionizing Resonances	134
3.2.3	Configuration Interaction, Interference of Resonances ..	138
3.2.4	Perturbed Rydberg Series	143
3.3	Multichannel Quantum Defect Theory (MQDT)	146
3.3.1	Two Coupled Coulomb Channels	146
3.3.2	The Lu-Fano Plot	153
3.3.3	More Than Two Channels	155
3.4	Atoms in External Fields	163
3.4.1	Atoms in a Static, Homogeneous Electric Field	164
3.4.2	Atoms in a Static, Homogeneous Magnetic Field	171
3.4.3	Atoms in an Oscillating Electric Field	181
	Problems	185
	References	189
4.	Simple Reactions	191
4.1	Elastic Scattering	191
4.1.1	Elastic Scattering by a Short Ranged Potential	191
4.1.2	Elastic Scattering by a Pure Coulomb Potential	200

4.1.3	Elastic Scattering by a Modified Coulomb Potential, DWBA	201
4.1.4	Feshbach Projection. Optical Potential	205
4.2	Spin and Polarization	207
4.2.1	Consequences of Spin-Orbit Coupling	207
4.2.2	Application to General Pure Spin States	210
4.2.3	Application to Mixed Spin States	213
4.3	Inelastic Scattering	215
4.3.1	General Formulation	215
4.3.2	Coupled Radial Equations	221
4.3.3	Threshold Effects	226
4.3.4	An Example	228
4.4	Exit Channels with Two Unbound Electrons	230
4.4.1	General Formulation	231
4.4.2	Application to Electrons	238
4.4.3	Example	241
	Problems	243
	References	247
5.	Special Topics	249
5.1	Multiphoton Absorption	249
5.1.1	Experimental Observations on Multiphoton Ionization ..	249
5.1.2	Calculating Ionization Probabilities via Volkov States ..	252
5.1.3	Calculating Ionization Probabilities via Floquet States ..	257
5.2	Classical Mechanics and Quantum Mechanics	258
5.2.1	Phase Space Densities	259
5.2.2	Coherent States	264
5.2.3	Coherent Wave Packets in Real Systems	270
5.3	Chaos	273
5.3.1	Chaos in Classical Mechanics	273
5.3.2	Traces of Chaos in Quantum Mechanics	279
5.3.3	Ionization of the Hydrogen Atom in a Microwave Field ..	285
5.3.4	The Hydrogen Atom in a Uniform Magnetic Field	287
	Problems	294
	References	297
	Appendix: Special Mathematical Functions	301
A.1	Legendre Polynomials, Spherical Harmonics	301
A.2	Laguerre Polynomials	302
A.3	Bessel Functions	303
A.4	Whittaker Functions, Coulomb Functions	306
	References	307
	Subject Index	309