

PREFACE	xiii
INTRODUCTION	xvii

CHAPTER 1 The Wave-Particle Duality	1
1.1 The Particle Model of Light	1
1.1.1 The Photoelectric Effect	1
1.1.2 The Absorption and Emission of Light by Atoms	5
1.1.3 The Compton Effect	13
1.2 The Wave Model of Radiation and Matter	14
1.2.1 X-Ray Scattering	14
1.2.2 Electron Waves	15
Suggestions for Further Reading	18
Basic Equations	18
Summary	19
Questions	19
Problems	20

CHAPTER 2 The Schrödinger Wave Equation	23
2.1 The Wave Equation	23
2.2 Probabilities and Average Values	28
2.3 The Finite Potential Well	32
2.4 The Simple Harmonic Oscillator	35
2.4.1 The Schrödinger Equation for the Oscillator	36
2.5 Time Evolution of the Wave Function	38
Suggestion for Further Reading	41
Basic Equations	41
Summary	42
Questions	43
Problems	44

CHAPTER 3 Operators and Waves	47
3.1 Observables, Operators, and Eigenvalues	48
3.2 *Algebraic Solution of the Oscillator	52
3.3 Electron Scattering	57
3.3.1 Scattering from a Potential Step	57
3.3.2 Barrier Penetration and Tunneling	61
3.4 The Heisenberg Uncertainty Principle	64
3.4.1 The Simultaneous Measurement of Two Variables	64
3.4.2 Wave Packets and the Uncertainty Principle	67
3.4.3 Average Value of the Momentum and the Energy	69

Suggestion for Further Reading	71
Basic Equations	71
Summary	72
Questions	73
Problems	73
CHAPTER 4 Hydrogen Atom	75
4.1 The Gross Structure of Hydrogen	75
4.1.1 The Schrödinger Equation in Three Dimensions	75
4.1.2 The Energy Levels of Hydrogen	76
4.1.3 The Wave Functions of Hydrogen	78
4.1.4 Probabilities and Average Values in Three Dimensions	81
4.1.5 The Intrinsic Spin of the Electron	83
4.2 Radiative Transitions	84
4.2.1 The Einstein <i>A</i> and <i>B</i> Coefficients	84
4.2.2 Transition Probabilities	85
4.2.3 Selection Rules	90
4.3 The Fine Structure of Hydrogen	91
4.3.1 The Magnetic Moment of the Electron	91
4.3.2 The Stern-Gerlach Experiment	94
4.3.3 The Spin of the Electron	95
4.3.4 The Addition of Angular Momentum	96
4.3.5 Rule for Addition of Angular Momenta	97
4.3.6 *The Fine Structure	98
4.3.7 *The Zeeman Effect	99
Suggestion for Further Reading	101
Basic Equations	102
Summary	103
Questions	104
Problems	105
CHAPTER 5 Many-Electron Atoms	109
5.1 The Independent-Particle Model	109
5.1.1 Antisymmetric Wave Functions and the Pauli Exclusion Principle	110
5.1.2 The Central-Field Approximation	111
5.2 Shell Structure and the Periodic Table	113
5.3 The <i>LS</i> Term Energies	114
5.4 Configurations of Two Electrons	115
5.4.1 Configurations of Equivalent Electrons	116
5.4.2 Configurations of Two Nonequivalent Electrons	118
5.5 The Hartree-Fock Method	118
5.5.1 A Hartree-Fock Applet	121
5.5.2 The Size of Atoms and the Strength of Their Interactions	123
Suggestion for Further Reading	126
Basic Equations	126
Summary	127
Questions	127
Problems	128

CHAPTER 6	The Emergence of Masers and Lasers	131
6.1	Radiative Transitions	131
6.2	Laser Amplification	132
6.3	Laser Cooling	136
6.4	*Magneto-Optical Traps	137
	Suggestions for Further Reading	141
	Basic Equations	141
	Summary	142
	Questions	142
	Problems	143
CHAPTER 7	Statistical Physics	145
7.1	The Nature of Statistical Laws	145
7.2	An Ideal Gas	148
7.3	Applications of Maxwell-Boltzmann Statistics	151
7.3.1	Maxwell Distribution of the Speeds of Gas Particles	151
7.3.2	Black-Body Radiation	158
7.4	Entropy and the Laws of Thermodynamics	163
7.4.1	The Four Laws of Thermodynamics	166
7.5	A Perfect Quantum Gas	168
7.6	Bose-Einstein Condensation	173
7.7	Free-Electron Theory of Metals	176
	Suggestions for Further Reading	180
	Basic Equations	180
	Summary	182
	Questions	183
	Problems	184
CHAPTER 8	Electronic Structure of Solids	187
8.1	Introduction	187
8.2	The Bravais Lattice	188
8.3	Additional Crystal Structures	192
8.3.1	The Diamond Structure	192
8.3.2	The Hexagonal Close-Packed Structure	193
8.3.3	The Sodium Chloride Structure	194
8.4	The Reciprocal Lattice	194
8.5	Lattice Planes	198
8.6	Bloch's Theorem	203
8.7	Diffraction of Electrons by an Ideal Crystal	208
8.8	The Band Gap	210
8.9	Classification of Solids	212
8.9.1	The Band Picture	212
8.9.2	The Bond Picture	213
	Suggestions for Further Reading	216
	Basic Equations	216
	Summary	218
	Questions	218
	Problems	219

CHAPTER 9

Charge Carriers in Semiconductors

223

9.1

Density of Charge Carriers in Semiconductors

223

9.2

Doped Crystals

227

9.3

A Few Simple Devices

228

9.3.1

The p - n Junction

228

9.3.2

Bipolar Transistors

230

9.3.3

Junction Field-Effect Transistors (JFET)

231

9.3.4

MOSFETs

232

Suggestions for Further Reading

233

Summary

233

Questions

233

CHAPTER 10

Semiconductor Lasers

235

10.1

Motion of Electrons in a Crystal

235

10.2

Band Structure of Semiconductors

237

10.2.1

Conduction Bands

237

10.2.2

Valence Bands

238

10.2.3

Optical Transitions

239

10.3

Heterostructures

240

10.3.1

Properties of Heterostructures

240

10.3.2

Experimental Methods

242

10.3.3

Theoretical Methods

243

10.3.4

Band Engineering

244

10.4

Quantum Wells

245

10.4.1

The Finite Well

246

10.4.2

Two-Dimensional Systems

246

10.4.3

*Quantum Wells in Heterostructures

248

10.5

Quantum Barriers

250

10.5.1

Scattering from a Potential Step

250

10.5.2

T -Matrices

252

10.6

Reflection and Transmission of Light

255

10.6.1

Reflection and Transmission by an Interface

256

10.6.2

The Fabry-Perot Laser

258

10.7

Phenomenological Description of Diode Lasers

259

10.7.1

The Rate Equation

260

10.7.2

Well Below Threshold

262

10.7.3

The Laser Threshold

263

10.7.4

Above Threshold

264

Suggestions for Further Reading

265

Basic Equations

265

Summary

267

Questions

267

Problems

268

CHAPTER 11

Relativity I

271

11.1

Introduction

271

11.2

Galilean Transformations

271

11.3

The Relative Nature of Simultaneity

274

11.4	Lorentz Transformation	277
11.4.1	The Transformation Equations	277
11.4.2	Lorentz Contraction	280
11.4.3	Time Dilation	281
11.4.4	The Invariant Space-Time Interval	285
11.4.5	Addition of Velocities	286
11.4.6	The Doppler Effect	287
11.5	Space-Time Diagrams	289
11.5.1	Particle Motion	290
11.5.2	Lorentz Transformations	293
11.5.3	The Light Cone	294
11.6	Four-Vectors	295
	Suggestions for Further Reading	301
	Basic Equations	301
	Summary	303
	Questions	303
	Problems	304

CHAPTER 12 Relativity II 307

12.1	Momentum and Energy	307
12.2	Conservation of Energy and Momentum	311
12.3	*The Dirac Theory of the Electron	315
12.3.1	Review of the Schrödinger Theory	315
12.3.2	The Klein-Gordon Equation	317
12.3.3	The Dirac Equation	318
12.3.4	Plane Wave Solutions of the Dirac Equation	322
12.4	*Field Quantization	326
	Suggestions for Further Reading	327
	Basic Equations	328
	Summary	330
	Questions	330
	Problems	331

CHAPTER 13 Particle Physics 333

13.1	Leptons and Quarks	333
13.2	Conservation Laws	341
13.2.1	Energy, Momentum, and Charge	341
13.2.2	Lepton Number	342
13.2.3	Baryon Number	344
13.2.4	Strangeness	346
13.2.5	Charm, Beauty, and Truth	348
13.3	Spatial Symmetries	349
13.3.1	Angular Momentum of Composite Systems	349
13.3.2	Parity	351
13.3.3	Charge Conjugation	353
13.4	Isospin and Color	355
13.4.1	Isospin	356
13.4.2	Color	361

13.5	Feynman Diagrams	364
13.5.1	Electromagnetic Interactions	366
13.5.2	Weak Interactions	367
13.5.3	Strong Interactions	369
13.6	*The Flavor and Color $SU(3)$ Symmetries	370
13.6.1	The $SU(3)$ Symmetry Group	371
13.6.2	The Representations of $SU(3)$	374
13.7	*Gauge Invariance and the Higgs Boson	379
	Suggestions for Further Reading	382
	Basic Equations	382
	Summary	384
	Questions	384
	Problems	385
CHAPTER 14	Nuclear Physics	389
14.1	Introduction	389
14.2	Properties of Nuclei	389
14.2.1	Nuclear Sizes	390
14.2.2	Binding Energies	393
14.2.3	The Semiempirical Mass Formula	395
14.3	Decay Processes	397
14.3.1	Alpha Decay	399
14.3.2	The β -Stability Valley	400
14.3.3	Gamma Decay	403
14.3.4	Natural Radioactivity	404
14.4	The Nuclear Shell Model	404
14.4.1	Nuclear Potential Wells	405
14.4.2	Nucleon States	405
14.4.3	Magic Numbers	408
14.4.4	The Spin-Orbit Interaction	408
14.5	Excited States of Nuclei	409
	Suggestions for Further Reading	413
	Basic Equations	414
	Summary	414
	Questions	414
	Problems	415
APPENDIX A	Natural Constants and Conversion Factors	419
APPENDIX B	Atomic Masses	421
APPENDIX C	Solution of the Oscillator Equation	427
APPENDIX D	The Average Value of the Momentum	433
APPENDIX E	The Hartree-Fock Applet	435
APPENDIX F	Integrals That Arise in Statistical Physics	437
APPENDIX G	The Abinit Applet	441
INDEX		443