

# CONTENTS

<b>1</b>	<b>THERMAL RADIATION AND PLANCK'S POSTULATE</b>	<b>1</b>
1-1	Introduction	2
1-2	Thermal Radiation	2
1-3	Classical Theory of Cavity Radiation	6
1-4	Planck's Theory of Cavity Radiation	13
1-5	The Use of Planck's Radiation Law in Thermometry	19
1-6	Planck's Postulate and Its Implications	20
1-7	A Bit of Quantum History	21
<b>2</b>	<b>PHOTONS—PARTICLELIKE PROPERTIES OF RADIATION</b>	<b>26</b>
2-1	Introduction	27
2-2	The Photoelectric Effect	27
2-3	Einstein's Quantum Theory of the Photoelectric Effect	29
2-4	The Compton Effect	34
2-5	The Dual Nature of Electromagnetic Radiation	40
2-6	Photons and X-Ray Production	40
2-7	Pair Production and Pair Annihilation	43
2-8	Cross Sections for Photon Absorption and Scattering	48
<b>3</b>	<b>DE BROGLIE'S POSTULATE—WAVELIKE PROPERTIES OF PARTICLES</b>	<b>55</b>
3-1	Matter Waves	56
3-2	The Wave-Particle Duality	62
3-3	The Uncertainty Principle	65
3-4	Properties of Matter Waves	69
3-5	Some Consequences of the Uncertainty Principle	77
3-6	The Philosophy of Quantum Theory	79
<b>4</b>	<b>BOHR'S MODEL OF THE ATOM</b>	<b>85</b>
4-1	Thomson's Model	86
4-2	Rutherford's Model	90
4-3	The Stability of the Nuclear Atom	95
4-4	Atomic Spectra	96
4-5	Bohr's Postulates	98
4-6	Bohr's Model	100
4-7	Correction for Finite Nuclear Mass	105
4-8	Atomic Energy States	107
4-9	Interpretation of the Quantization Rules	110
4-10	Sommerfeld's Model	114
4-11	The Correspondence Principle	117
4-12	A Critique of the Old Quantum Theory	118

<b>5</b>	<b>SCHROEDINGER'S THEORY OF QUANTUM MECHANICS</b>	<b>124</b>
5-1	Introduction	125
5-2	Plausibility Argument Leading to Schrodinger's Equation	128
5-3	Born's Interpretation of Wave Functions	134
5-4	Expectation Values	141
5-5	The Time-Independent Schrodinger Equation	150
5-6	Required Properties of Eigenfunctions	155
5-7	Energy Quantization in the Schrodinger Theory	157
5-8	Summary	165
<b>6</b>	<b>SOLUTIONS OF TIME-INDEPENDENT SCHROEDINGER EQUATIONS</b>	<b>176</b>
6-1	Introduction	177
6-2	The Zero Potential	178
6-3	The Step Potential (Energy Less Than Step Height)	184
6-4	The Step Potential (Energy Greater Than Step Height)	193
6-5	The Barrier Potential	199
6-6	Examples of Barrier Penetration by Particles	205
6-7	The Square Well Potential	209
6-8	The Infinite Square Well Potential	214
6-9	The Simple Harmonic Oscillator Potential	221
6-10	Summary	225
<b>7</b>	<b>ONE-ELECTRON ATOMS</b>	<b>232</b>
7-1	Introduction	233
7-2	Development of the Schrodinger Equation	234
7-3	Separation of the Time-Independent Equation	235
7-4	Solution of the Equations	237
7-5	Eigenvalues, Quantum Numbers, and Degeneracy	239
7-6	Eigenfunctions	242
7-7	Probability Densities	244
7-8	Orbital Angular Momentum	254
7-9	Eigenvalue Equations	259
<b>8</b>	<b>MAGNETIC DIPOLE MOMENTS, SPIN, AND TRANSITION RATES</b>	<b>266</b>
8-1	Introduction	267
8-2	Orbital Magnetic Dipole Moments	267
8-3	The Stern-Gerlach Experiment and Electron Spin	272
8-4	The Spin-Orbit Interaction	278
8-5	Total Angular Momentum	281
8-6	Spin-Orbit Interaction Energy and the Hydrogen Energy Levels	284
8-7	Transition Rates and Selection Rules	288
8-8	A Comparison of the Modern and Old Quantum Theories	295
<b>9</b>	<b>MULTIELECTRON ATOMS—GROUND STATES AND X-RAY EXCITATIONS</b>	<b>300</b>
9-1	Introduction	301
9-2	Identical Particles	302
9-3	The Exclusion Principle	308
9-4	Exchange Forces and the Helium Atom	310
9-5	The Hartree Theory	319

9-6	Results of the Hartree Theory	322
9-7	Ground States of Multielectron Atoms and the Periodic Table	331
9-8	X-Ray Line Spectra	337
<b>10</b>	<b>MULTIELECTRON ATOMS—OPTICAL EXCITATIONS</b>	<b>347</b>
10-1	Introduction	348
10-2	Alkali Atoms	349
10-3	Atoms with Several Optically Active Electrons	352
10-4	<i>LS</i> Coupling	356
10-5	Energy Levels of the Carbon Atom	361
10-6	The Zeeman Effect	364
10-7	Summary	370
<b>11</b>	<b>QUANTUM STATISTICS</b>	<b>375</b>
11-1	Introduction	376
11-2	Indistinguishability and Quantum Statistics	377
11-3	The Quantum Distribution Functions	380
11-4	Comparison of the Distribution Functions	384
11-5	The Specific Heat of a Crystalline Solid	388
11-6	The Boltzmann Distributions as an Approximation to Quantum Distributions	391
11-7	The Laser	392
11-8	The Photon Gas	398
11-9	The Phonon Gas	399
11-10	Bose Condensation and Liquid Helium	399
11-11	The Free Electron Gas	404
11-12	Contact Potential and Thermionic Emission	407
11-13	Classical and Quantum Descriptions of the State of a System	409
<b>12</b>	<b>MOLECULES</b>	<b>415</b>
12-1	Introduction	416
12-2	Ionic Bonds	416
12-3	Covalent Bonds	418
12-4	Molecular Spectra	422
12-5	Rotational Spectra	423
12-6	Vibration-Rotation Spectra	426
12-7	Electronic Spectra	429
12-8	The Raman Effect	432
12-9	Determination of Nuclear Spin and Symmetry Character	434
<b>13</b>	<b>SOLIDS—CONDUCTORS AND SEMICONDUCTORS</b>	<b>442</b>
13-1	Introduction	443
13-2	Types of Solids	443
13-3	Band Theory of Solids	445
13-4	Electrical Conduction in Metals	450
13-5	The Quantum Free-Electron Model	452
13-6	The Motion of Electrons in a Periodic Lattice	456
13-7	Effective Mass	460
13-8	Electron-Positron Annihilation in Solids	464
13-9	Semiconductors	467
13-10	Semiconductor Devices	472

<b>14</b>	<b>SOLIDS—SUPERCONDUCTORS AND MAGNETIC PROPERTIES</b>	<b>483</b>
14-1	Superconductivity	484
14-2	Magnetic Properties of Solids	492
14-3	Paramagnetism	493
14-4	Ferromagnetism	497
14-5	Antiferromagnetism and Ferrimagnetism	503
<b>15</b>	<b>NUCLEAR MODELS</b>	<b>508</b>
15-1	Introduction	509
15-2	A Survey of Some Nuclear Properties	510
15-3	Nuclear Sizes and Densities	515
15-4	Nuclear Masses and Abundances	519
15-5	The Liquid Drop Model	526
15-6	Magic Numbers	530
15-7	The Fermi Gas Model	531
15-8	The Shell Model	534
15-9	Predictions of the Shell Model	540
15-10	The Collective Model	545
15-11	Summary	549
<b>16</b>	<b>NUCLEAR DECAY AND NUCLEAR REACTIONS</b>	<b>554</b>
16-1	Introduction	555
16-2	Alpha Decay	555
16-3	Beta Decay	562
16-4	The Beta-Decay Interaction	572
16-5	Gamma Decay	578
16-6	The Mössbauer Effect	584
16-7	Nuclear Reactions	588
16-8	Excited States of Nuclei	598
16-9	Fission and Reactors	602
16-10	Fusion and the Origin of the Elements	607
<b>17</b>	<b>INTRODUCTION TO ELEMENTARY PARTICLES</b>	<b>617</b>
17-1	Introduction	618
17-2	Nucleon Forces	618
17-3	Isospin	631
17-4	Pions	634
17-5	Leptons	641
17-6	Strangeness	643
17-7	Families of Elementary Particles	649
17-8	Observed Interactions and Conservation Laws	653
<b>18</b>	<b>MORE ELEMENTARY PARTICLES</b>	<b>666</b>
18-1	Introduction	667
18-2	Evidence for Partons	667
18-3	Unitary Symmetry and Quarks	673
18-4	Extensions of SU(3)—More Quarks	678
18-5	Color and the Color Interaction	683
18-6	Introduction to Gauge Theories	688
18-7	Quantum Chromodynamics	691
18-8	Electroweak Theory	699
18-9	Grand Unification and the Fundamental Interactions	706

Appendix A	The Special Theory of Relativity
Appendix B	Radiation from an Accelerated Charge
Appendix C	The Boltzmann Distribution
Appendix D	Fourier Integral Description of a Wave Group
Appendix E	Rutherford Scattering Trajectories
Appendix F	Complex Quantities
Appendix G	Numerical Solution of the Time-Independent Schroedinger Equation for a Square Well Potential
Appendix H	Analytical Solution of the Time-Independent Schroedinger Equation for a Square Well Potential
Appendix I	Series Solution of the Time-Independent Schroedinger Equation for a Simple Harmonic Oscillator Potential
Appendix J	Time-Independent Perturbation Theory
Appendix K	Time-Dependent Perturbation Theory
Appendix L	The Born Approximation
Appendix M	The Laplacian and Angular Momentum Operators in Spherical Polar Coordinates
Appendix N	Series Solutions of the Angular and Radial Equations for a One-Electron Atom
Appendix O	The Thomas Precession
Appendix P	The Exclusion Principle in $LS$ Coupling
Appendix Q	Crystallography
Appendix R	Gauge Invariance in Classical and Quantum Mechanical Electromagnetism
Appendix S	Answers to Selected Problems
Index	