

Contents

<i>Preface</i>	vii
1. Rutherford Scattering	1
1.1 Introductory Remarks	1
1.2 Rutherford Scattering	3
1.3 Scattering Cross Section	13
1.4 Measuring Cross Sections	17
1.5 Laboratory Frame and the Center-of-Mass Frame	19
1.6 Relativistic Variables	24
1.7 Quantum Treatment of Rutherford Scattering	29
2. Nuclear Phenomenology	33
2.1 Introductory Remarks	33
2.2 Properties of Nuclei	33
2.2.1 Labeling of Nuclei	33
2.2.2 Masses of Nuclei	34
2.2.3 Sizes of Nuclei	37
2.2.4 Nuclear Spins and Dipole Moments	40
2.2.5 Stability of Nuclei	42
2.2.6 Instability of Nuclei	43
2.3 Nature of the Nuclear Force	45
3. Nuclear Models	53
3.1 Introductory Remarks	53
3.2 Liquid Drop Model	53
3.3 The Fermi-Gas Model	56
3.4 Shell Model	59
3.4.1 Infinite Square Well	66
3.4.2 Harmonic Oscillator	67
3.4.3 Spin-Orbit Potential	70

3.4.4	Predictions of the Shell Model	73
3.5	Collective Model	75
3.6	Superdeformed Nuclei	78
4.	Nuclear Radiation	81
4.1	Introductory Remarks	81
4.2	Alpha Decay	81
4.3	Barrier Penetration	86
4.4	Beta Decay	91
4.4.1	Lepton Number	96
4.4.2	Neutrino Mass	96
4.4.3	The Weak Interaction	97
4.5	Gamma Decay	100
5.	Applications of Nuclear Physics	105
5.1	Introductory Remarks	105
5.2	Nuclear Fission	105
5.2.1	Basic Theory of Fission	106
5.2.2	Chain Reaction	113
5.3	Nuclear Fusion	116
5.4	Radioactive Decay	119
5.4.1	Radioactive Equilibrium	124
5.4.2	Natural Radioactivity and Radioactive Dating	126
6.	Energy Deposition in Media	133
6.1	Introductory Remarks	133
6.2	Charged Particles	134
6.2.1	Units of Energy Loss and Range	138
6.2.2	Straggling, Multiple Scattering, and Statistical Processes	139
6.2.3	Energy Loss Through Bremsstrahlung	142
6.3	Interactions of Photons with Matter	145
6.3.1	Photoelectric Effect	147
6.3.2	Compton Scattering	148
6.3.3	Pair Production	149
6.4	Interactions of Neutrons	153
6.5	Interaction of Hadrons at High Energies	154
7.	Particle Detection	157
7.1	Introductory Remarks	157

7.2	Ionization Detectors	157
7.2.1	Ionization Counters	159
7.2.2	Proportional Counters	162
7.2.3	Geiger-Müller Counters	165
7.3	Scintillation Detectors	165
7.4	Time of Flight	169
7.5	Cherenkov Detectors	173
7.6	Semiconductor Detectors	174
7.7	Calorimeters	175
7.8	Layered Detection	177
8.	Accelerators	183
8.1	Introductory Remarks	183
8.2	Electrostatic Accelerators	184
8.2.1	Cockcroft-Walton Machines	184
8.2.2	Van de Graaff Accelerator	185
8.3	Resonance Accelerators	187
8.3.1	Cyclotron	187
8.3.2	Linac or Linear Accelerator	190
8.4	Synchronous Accelerators	191
8.5	Phase Stability	194
8.6	Strong Focusing	197
8.7	Colliding Beams	199
9.	Properties and Interactions of Elementary Particles	207
9.1	Introductory Remarks	207
9.2	Forces	208
9.3	Elementary Particles	211
9.4	Quantum Numbers	214
9.4.1	Baryon Number	215
9.4.2	Lepton Number	215
9.4.3	Strangeness	217
9.4.4	Isospin	219
9.5	Gell-Mann-Nishijima Relation	223
9.6	Production and Decay of Resonances	225
9.7	Determining Spins	228
9.8	Violation of Quantum Numbers	232
9.8.1	Weak Interactions	232
9.8.1.1	Hadronic Weak Decays:	232

9.8.1.2	Semileptonic Processes:	233
9.8.2	Electromagnetic Processes	235
10.	Symmetries	239
10.1	Introductory Remarks	239
10.2	Symmetries in the Lagrangian Formalism	239
10.3	Symmetries in the Hamiltonian Formalism	244
10.3.1	Infinitesimal Translations	246
10.3.2	Infinitesimal Rotations	249
10.4	Symmetries in Quantum Mechanics	252
10.5	Continuous Symmetries	255
10.5.1	Isotopic Spin	260
10.6	Local Symmetries	263
11.	Discrete Transformations	267
11.1	Introductory Remarks	267
11.2	Parity	267
11.2.1	Conservation of Parity	271
11.2.2	Violation of Parity	274
11.3	Time Reversal	277
11.4	Charge Conjugation	281
11.5	<i>CPT</i> Theorem	283
12.	Neutral Kaons, Oscillations, and <i>CP</i> Violation	287
12.1	Introductory Remarks	287
12.2	Neutral Kaons	287
12.3	<i>CP</i> Eigenstates of Neutral Kaons	291
12.4	Strangeness Oscillation	293
12.5	K_1^0 Regeneration	294
12.6	Violation of <i>CP</i> Invariance	295
12.7	Time Development and Analysis of the K^0 - \bar{K}^0 System	300
12.8	Semileptonic K^0 Decays	309
13.	Formulation of the Standard Model	313
13.1	Introductory Remarks	313
13.2	Quarks and Leptons	314
13.3	Quark Content of Mesons	315
13.4	Quark Content of Baryons	318
13.5	Need for Color	319
13.6	Quark Model for Mesons	321

13.7	Valence and Sea Quarks in Hadrons	324
13.8	Weak Isospin and Color Symmetry	325
13.9	Gauge Bosons	326
13.10	Dynamics of the Gauge Particles	328
13.11	Symmetry Breaking	332
13.12	Chromodynamics (QCD) and Confinement	338
13.13	Quark-Gluon Plasma	342
14.	Standard Model and Confrontation with Data	345
14.1	Introductory Remarks	345
14.2	Comparisons with Data	345
14.3	Cabibbo Angle and the “GIM” Mechanism	348
14.4	CKM Matrix	352
14.5	Higgs Boson and $\sin^2 \theta_W$	353
15.	Beyond the Standard Model	359
15.1	Introductory Remarks	359
15.2	Grand Unification	361
15.3	Supersymmetry (SUSY)	366
15.4	Gravity, Supergravity and Superstrings	370
Appendix A	Special Relativity	377
Appendix B	Spherical Harmonics	383
Appendix C	Spherical Bessel Functions	385
Appendix D	Basics of Group Theory	387
Appendix E	Table of Physical Constants	393
<i>Index</i>		395