CONTENTS

I. BASIC CONCEPTS 1

A. THE EVOLUTION OF THE PARTICLE CONCEPT BEFORE THE ADVENT OF QUANTUM MECHANICS 3

B. NONRELATIVISTIC QUANTUM MECHANICS AND ATOMIC PHYSICS 9

1. The Principles of quantum mechanics 9
   (a) State vectors. Observables 9
   (b) The equations of motion 10
   (c) Unitary operators and symmetries 11
   (d) Stationary states 11
   (e) The natural system of units 13
2. Resolution of the Boltzmann paradox 13
3. Rotations and angular momentum 15
   (a) The rotation operators 16
   (b) Angular momentum eigenstates 17
   (c) Angular momentum $j = 1$: vectors 18
   (d) Angular momentum $j = \frac{1}{2}$: spinors 19
   (e) Two-level systems and the spin analogy 21
   (f) The addition of angular momenta 22
4. Space reflection and parity 24
5. Fermions and bosons 28
6. The electromagnetic nature of atomic phenomena 29
7. Free particle wave functions 32

C. RELATIVISTIC QUANTUM THEORY 34

1. Field operators 34
2. The quantum theory of the electromagnetic field 35
3. The Dirac theory of spin ½ particles 38
4. Interactions 39
5. Crossing and charge conjugation 43
6. Causality and its consequences 44

D. NUCLEAR PHENOMENA 46

1. The nuclear spectrum 46
2. Isotopic spin 48
3. Electromagnetic and weak transitions between nuclear states. Neutrinos 52
4. Lepton number conservation and parity violation 55
5. Summary 58

E. SUBNUCLEAR PHENOMENA 59

1. Introduction 59
2. The baryon spectrum 61
3. Mesons 65
   (a) Meson emission and absorption 65
   (b) π-, K-, D-, and F-mesons 66
   (c) The meson spectrum 69
4. Conservation of isospin, strangeness, charm, and baryon number 69
5. Quarks 74
   (a) General remarks 74
   (b) Basic assumptions 75
   (c) Quark charges and masses 77
   (d) Interactions 78
6. Hadronic spectroscopy 79
   (a) Baryon and meson types 79
   (b) Meson nonets 81
   (c) The necessity of color 86
   (d) Baryon octets and decuplets 88
   (e) Mesons composed of heavy quark–antiquark pairs 93
7. The strong interaction field: quantum chromodynamics 95
   (a) General considerations 95
   (b) Quantum chromodynamics 97
   (c) Hadronic processes in quantum chromodynamics 100
   (d) Quark and gluon jets 102
8. The electromagnetic interaction of hadrons 110
   (a) Conservation laws 110
   (b) Radiative transitions and magnetic moments 111
   (c) $e^+e^- \rightarrow$ hadrons 113
9. Charge-changing weak interactions 114
   (a) General remarks 114

(b) Other leptons 115
(c) Role of other quarks 118
(d) Weak interaction processes 120
(e) The intermediate vector bosons $W^{\pm}$ 125
(f) Space reflection and charge conjugation 130
(g) Universality 132
10. The relationship between weak and electromagnetic interactions; neutral current weak processes 137
(a) Weak isospin 137
(b) The electroweak connection and the charge-preserving weak interaction 138
(c) Symmetry breaking 142
(d) Determination of θ_W, m_W, and m_Z. Observation of W and Z 144
11. Neutral kaons and CP Violation 148
(a) $K^{\circ}-\bar{K}^{\circ}$ mixing 148
(b) CP Violation 152
12. Synopsis: the Standard Model 154
(a) The Quantum Ladder 155
(b) Fermions 155
(c) Vector bosons and gauge fields 158
13. Outlook 161
(a) Grand unification 162
(b) CP violation and the cosmological proton abundance 165
(c) Gravitation 167
(d) Lepton and quark substructure 168
Appendix I. Particle properties 170
Bibliography 182
Index 185