Contents

Preface v

PART I. FREE FIELDS

CHAPTER 1. INTRODUCTION 3

1.1 Relation of Quantum and Classical Field Theory 3
1.2 Vibrating Line of Atoms 4
1.3 Continuous Vibrating Line 6

CHAPTER 2. THE HARMONIC OSCILLATOR 9

2.1 Eigenvalues of H 9
2.2 Properties of the Eigenstates of H 11
2.3 Time Dependence of Motion 12

CHAPTER 3. COUPLED OSCILLATORS 18

3.1 Eigenvalues of the Hamiltonian 18
3.2 Quantum Features 20
3.3 Dynamical Aspects 21

CHAPTER 4. FIELDS 23

4.1 Continuously Coupled Oscillators 23
4.2 Derivation of Field Equations from a Lagrangian 29

CHAPTER 5. OBSERVABLES 34

5.1 Energy, Momentum, and Angular Momentum. 34
5.2 Parity 40
5.3 Number of Particles and Particle Density 41
5.4 Local Observables 43

CHAPTER 6. STATES 47

6.1 Vacuum and One-particle States 47
6.2 Two-particle States 52
6.3 Many-particle States 55

CHAPTER 7. INTERNAL DEGREES OF FREEDOM 58
7.1 Fields with Two Internal Degrees of Freedom 58
7.2 Three and More Degrees of Freedom 63

PART II. SOLUBLE INTERACTIONS

CHAPTER 8. GENERAL ORIENTATION 71
8.1 Field Equations 71
8.2 Quantization 75
8.3 Scattering and Wave Matrix 78

CHAPTER 9. STATIC SOURCE 82
9.1 Interpretation of "Static" Source 82
9.2 Energy of the Coupled System 84
9.3 Connection between Bare and Physical States 86
9.4 Fluctuations of the Field 89
9.5 Several Sources 90

CHAPTER 10. PRODUCTION OF PARTICLES 93
10.1 General Remarks 93
10.2 Specific Examples 96

CHAPTER 11. PAIR THEORY, CLASSICAL 100
11.1 General Remarks 100
11.2 Bound States 104
11.3 Behavior of the Wave Matrix Ω 106
11.4 Scattering 109

CHAPTER 12. PAIR THEORY, QUANTUM-MECHANICAL 112
12.1 Quantization and Commutation Relations in the Presence of a Bound State 112
12.2 Scattering 113
12.3 Energy Expressions in Terms of the Asymptotic Fields 119
12.4 Virtual Particles 122

CHAPTER 13. THE LEE MODEL: STATES WITH $Q = \pm\frac{1}{2}$ 126
13.1 Introduction 126
13.2 Commutation Relations and Equations of Motion 127
13.3 Physical Nucleons. 130
13.4 Scattering States 131
13.5 Completeness 132
13.6 The Phase Shift 135

CHAPTER 14. LEE MODEL: STATES WITH $Q = -\frac{3}{2}$ 139
14.1 Scattering: Low Equation 139
14.2 $\pi^- + n$ Scattering 141
14.3 Low- and High-energy Behavior of $T(k)$ 145

PART III. PION PHYSICS

CHAPTER 15. INTRODUCTION 153
15.1 The Static Model 153
15.2 Commutation Relations and Equations of Motion 158
15.3 Comparison with Other Models 162

CHAPTER 16. GENERAL FEATURES OF THE STATIC MODEL . . 166

16.1 Classical Treatment of Stationary Motion 166
16.2 Classical Treatment of Scattering 172
16.3 Quantum Aspects of the Static Model 175

CHAPTER 17. THE GROUND STATE 179

17.1 Exact Results 179
17.2 Perturbation Theory 183
17.3 Tamm-Dancoff Approximation 184
17.4 Tomonaga Intermediate-coupling Approximation 186
17.5 Strong-coupling Approximation 192
17.6 Numerical Methods 196

CHAPTER 18. PION SCATTERING 198

18.1 Introduction 198
18.2 The Scattering Matrix 199
18.3 Properties of the Scattering Matrices 201
18.4 Low- and High-energy Limits of Elastic Scattering 203
18.5 Diagonalization of the T Matrix 204
18.6 Relation of Low Equations to Experiment 208
18.7 Approximate Solution of the Low Equation 210
18.8 Summary 214

CHAPTER 19. PROPERTIES OF THE NUCLEON 219

19.1 Expectation Value of the Field 219
19.2 Ground-state Expectation Value of Observables 220
19.3 Renormalization Constants and Other Parameters of the Static Model 222
19.4 Nucleon Self-energy 224
19.5 Charge and Current Distribution of Physical Nucleon. Magnetic Moment 225

CHAPTER 20. ELECTROMAGNETIC PHENOMENA 232

20.1 Contributions to Charge and Current Operators 232
20.2 The Production Amplitude 235
20.3 General Features of the Cross Section 242
20.4 Comparison with Experiment 244
20.5 Compton Scattering 247

CHAPTER 21. NUCLEAR FORCES 249

21.1 Introduction: Classical Calculation of Nuclear Interaction Energy . 249
21.2 Static Potential, Quantum-mechanical 252
21.3 Comparison with Experiment 255
21.4 Concluding Remarks 256

Appendix 259

List of Symbols 263

Index 269