

CONTENTS

Preface vii

Introduction

1

- Elementary Particle Physics 1
- How Do You *Produce* Elementary Particles? 4
- How Do You Detect Elementary Particles? 7
- Units 8
- References and Notes 10

1 Historical Introduction to the Elementary Particles 11

- 1.1 The Classical Era (1697-1 932) 11
- 1.2 The Photon (1900-1 924) 14
- 1.3 Mesons (1934-1 947) 17
- 1.4 Antiparticles (1930-1 956) 18
- 1.5 Neutrinos (1930-1 962) 22
- 1.6 Strange Particles (1947-1 960) 28
- 1.7 The Eightfold Way (1961-1964) 33
- 1.8 The Quark Model (1964) 37
- 1.9 The November Revolution and Its Aftermath (1974-1983) 41
- 1.10 Intermediate Vector Bosons (1983) 44
- 1.11 The Standard Model (1978-?) 46
- References and Notes 49
- Problems 51

2 Elementary Particle Dynamics 55

55

- 2.1 The Four Forces 55
- 2.2 Quantum Electrodynamics (QED) 56
- 2.3 Quantum Chromodynamics (QCD) 60
- 2.4 Weak Interactions 65
- 2.5 Decays and Conservation Laws 72
- 2.6 Unification Scheme 76
- References and Notes 78
- Problems 78

3	Relativistic Kinematics	81
	3.1 Lorentz Transformations	81
	3.2 Four-Vectors	84
	3.3 Energy and Momentum	87
	3.4 Collisions	91
	3.5 Examples and Applications	93
	References and Notes	99
	Problems	99
4	Symmetries	103
	4.1 Symmetries, Groups, and Conservation Laws	103
	4.2 Spin and Orbital Angular Momentum	107
	4.3 Addition of Angular Momenta	109
	4.4 Spin $\frac{1}{2}$	113
	4.5 Flavor Symmetries	116
	4.6 Parity	122
	4.7 Charge Conjugation	128
	4.8 <i>CP</i> Violation	130
	4.9 Time Reversal and the <i>TCP</i> Theorem	134
	References and Notes	135
	Problems	137
5	Bound States	143
	5.1 The Schrödinger Equation for a Central Potential	143
	5.2 The Hydrogen Atom	148
	5.3 Fine Structure	151
	5.4 The Lamb Shift	154
	5.5 Hyperfine Structure	156
	5.6 Positronium	159
	5.7 Quarkonium	164
	5.8 Light Quark Mesons	168
	5.9 Baryons	172
	5.10 Baryon Masses and Magnetic Moments	180
	References and Notes	184
	Problems	186
6	The Feynman Calculus	189
	6.1 Lifetimes and Cross Sections	189
	6.2 The Golden Rule	194
	6.3 The Feynman Rules for a Toy Theory	201
	6.4 Lifetime of the <i>A</i>	204
	6.5 Scattering	204

81

- 6.6 Higher-Order Diagrams 206
- References and Notes 210
- Problems 211

7 Quantum Electrodynamics

21

103

- 7.1 The Dirac Equation 213
- 7.2 Solutions to the Dirac Equation 216
- 7.3 Bilinear Covariants 222
- 7.4 The Photon 225
- 7.5 The Feynman Rules for Quantum Electrodynamics 228
- 7.6 Examples 231
- 7.7 Casimir's Trick and the Trace Theorems 236
- 7.8 Cross Sections and Lifetimes 240
- 7.9 Renormalization 246
- References and Notes 250
- Problems 251

8 Electrodynamics of Quarks and Hadrons

257

143

- 8.1 Electron-Quark Interactions 257
- 8.2 Hadron Production in e^+e^- Scattering 258
- 8.3 Elastic Electron-Proton Scattering 262
- 8.4 Inelastic Electron-Proton Scattering 266
- 8.5 The Parton Model and Bjorken Scaling 269
- 8.6 Quark Distribution Functions 273
- References and Notes 277
- Problems 277

9 Quantum Chromodynamics

279

- 9.1 Feynman Rules for Chromodynamics 279
- 9.2 The Quark-Quark Interaction 284
- 9.3 Pair Annihilation in QCD 289
- 9.4 Asymptotic Freedom 292
- 9.5 Applications of QCD 295
- References and Notes 296
- Problems 296

189

10 Weak Interactions

301

- 10.1 Charged Leptonic Weak Interactions 301
- 10.2 Decay of the Muon 304
- 10.3 Decay of the Neutron 309
- 10.4 Decay of the Pion 314

- 10.5 Charged Weak Interactions of Quarks 317
- 10.6 Neutral Weak Interactions 322
- 10.7 Electroweak Unification 330
- References and Notes 338
- Problems 339

11 Gauge Theories 343

- 11.1 Lagrangian Formulation of Classical Particle Mechanics 343
- 11.2 Lagrangians in Relativistic Field Theory 344
- 11.3 Local Gauge Invariance 348
- 11.4 Yang-Mills Theory 350
- 11.5 Chromodynamics 355
- 11.6 Feynman Rules 357
- 11.7 The Mass Term 360
- 11.8 Spontaneous Symmetry-Breaking 362
- 11.9 The Higgs Mechanism 365
- References and Notes 368
- Problems 368

APPENDIX A. The Dirac Delta Function 372

APPENDIX B. Decay Rates and Cross Sections 376

APPENDIX C. Pauli and Dirac Matrices 378

APPENDIX D. Feynman Rules 380

Index 384