

Contents

PART I. INTRODUCTION

Chapter 1 The Scalar Field 5

Plane wave solutions of the Klein-Gordon equation. Canonical quantization. Lorentz invariance. The energy-momentum operators. The commutation relations for unequal times. Creation and annihilation operators. The spin of a scalar particle. The charge operator. Gauge invariance of the first kind and the general form of the charge operator. The parity operator. Time reversal and anti-unitary operators.

Chapter 2 The Dirac Field 30

The Dirac equation and plane wave solutions. Energy and spin projection operators. Lorentz transformations of $\psi(x)$. Quantization with anti-commutators. The Exclusion Principle. The charge operator and charge conjugation. The spin of the Dirac field quantum. Parity and superselection rules. Time reversal.

Chapter 3 Vector Mesons and Photons 51

The field equations. Quantization of the vector field. Proof that the spin of a vector particle is 1. The electromagnetic field equations. Connection of gauge invariance with the existence of only two polarization states. Quantization and the subsidiary condition. The indefinite metric for the scalar and longitudinal photons.

Chapter 4 Lorentz Invariance and Spin 65

The commutation relations of the ten operators of the inhomogeneous Lorentz group. The little group. The spin operator. The case of zero

mass. The transformation properties of one-particle state vectors (canonical representation). The spinor basis and free field creation and annihilation operators. The helicity basis and its connection with other bases. Two-particle states in the helicity representation and the center of mass frame. The relation between helicity eigenstates and total angular momentum eigenstates. The normalization of the two-particle states. The reduction of the scattering matrix in the helicity representation. An appendix on finite dimensional representations of the homogeneous Lorentz group.

Chapter 5 Fields in Interaction 86

Conditions which must be satisfied by Lagrangians. Gauge invariance of the second kind and "minimal" electromagnetic coupling. Non-uniqueness of the prescription.

Chapter 6 The Scattering Matrix 93

Definition of scattering matrix. "In" and "out" Heisenberg state vectors, as two bases for the vector space of physical states. Asymptotic "in" and "out" fields. The LSZ asymptotic conditions. Weak and strong convergence. Reduction of the S -matrix.

Chapter 7 Reduction Formulas 102

The expression of scattering matrix elements in terms of T -products or retarded commutators of field operators. Time-reversal invariance of the S -matrix. Decomposition into irreducible parts. The reduction formulas in terms of unrenormalized fields.

Chapter 8 Perturbation Theory 113

Connection between unrenormalized operators and free field operators. The U -operator. The Gell-Mann—Low theorem. Expression of T -product of unrenormalized fields in terms of free field operators. Functional method for the calculation of vacuum expectation values of T -products of free field operators. Illustration of graphical representation.

Chapter 9 The Feynman Graph Rules 134

The Feynman rules for the interaction of spin $\frac{1}{2}$ particles with photons. Rules in x -space. Rules in momentum space. Furry's theorem. Interaction of spin 0 bosons with photons. Rules for the calculation of transition rates and cross sections. Proof of relativistic invariance of cross section.

PART II. INTRODUCTION

Chapter 10 The Compton Effect and Related Processes 147

The Compton process matrix element. Gauge invariance. Calculation of square of matrix element using traces. The polarization sum. The invariant form of Klein-Nishina formula. The backward peak in the angular distribution. Scattering of polarized photons by polarized electrons. The scattering of photons by spin 0 bosons at threshold. Pair annihilation in flight. The transfer of positron helicity.

Chapter 11 The Scattering of Electrons and Positrons 165

The Møller amplitude. Nonrelativistic limit. Suppression of spin flip in scattering. Feynman rules for scattering by external field. The Coulomb cross section. Higher order scattering in a Coulomb field and the validity of the Rutherford cross section formula.

Chapter 12 Bremsstrahlung and Related Processes 175

The soft photon limit of the bremsstrahlung cross section. Radiation of photon by a classical current. Infrared divergence of bremsstrahlung cross section. The Weizsacker-Williams method. Calculation of radiation length. Pair production by photons in a Coulomb field. Polarization of hard bremsstrahlung by polarized electrons.

Chapter 13 Higher Order Terms in Perturbation Theory 186

The need for renormalization. Mass renormalization by asymptotic condition. General form for mass shift. Radiative corrections to Coulomb scattering. Radiative corrections on external lines. Radiative correction on vertex. Subtraction of infinity at vertex. Ward's identity. Vacuum polarization and the renormalization of the charge. The anomalous moment of the electron. The cancellation of the infrared divergence.

PART III. INTRODUCTION

Chapter 14 The Baryons 211

The nucleon. The Λ^0 particle. The determination of the Λ^0 -spin from its decay characteristics. Hypernuclei. The Σ hyperons. The Σ - Λ parity. The Ξ particle.

Chapter 15	The Pseudoscalar Mesons	225
<p>The determination of the pion spin. The two-photon decay of the π^0. The parity of the pion and the capture of slow π^- by protons. The K-mesons. The Dalitz plot. The spin of the K. Hyperfragments and the parity of the K. The η^0-meson.</p>		
Chapter 16	Charge Independence and Strangeness	243
<p>Charge independence of nuclear forces. I-spin. The addition of i-spins. The i-spin of antiparticles. The i-spin of the pion. Tests for i-spin conservation. The new particles and the introduction of strangeness. Consequences of the Gell-Mann—Nishijima scheme. G-parity.</p>		
Chapter 17	Unitary Symmetry	257
<p>Review of $SU(2)$. The commutation relations for $SU(3)$. Graphical representation of shift operators. Representations of $SU(3)$ in graphical form. The labeling of states. U-spin. The reduction of the product of two representations. Irreducible tensors.</p>		
Chapter 18	The Eightfold Way	276
<p>The classification of the mesons and baryons in the octet representation. Quarks. The two Yukawa couplings, F and D. The matrix representation of octets. $SU(3)$ currents. Methods for calculating branching ratios. The Gell-Mann—Okubo mass formula.</p>		
Chapter 19	Baryon Resonances	289
<p>The detection of resonances. The $N_{\frac{3}{2}}^*(1238)$, its i-spin and spin. Some other $Y = 1$ resonances. The $Y_1^*(1385)$ resonance. The spin determination. The $Y_0^*(1405)$. The angular distribution of K^-p scattering at the resonance. Other $Y = 0$ resonances. The $Y = -1$ resonances. The Ω^- and $SU(3)$. The decuplet and predicted widths. Higher representations.</p>		
Chapter 20	Boson Resonances	313
<p>The ρ-meson and its quantum numbers. The forward-backward asymmetry in the angular distribution. I-spin evidence for peripheral production. The ω-meson. Spin and parity determination from the Dalitz plot. The i-spin violating 2π decay of the ω. The ϕ meson. ω-ϕ mixing. The K^*-meson. The nonet representation and the prediction of the ω-ϕ mixing angle. The ninth pseudoscalar meson. A nonet of 2^+-mesons. Other resonances: the A_1 peak, the ϵ-meson and the B-meson.</p>		

Chapter 21 Properties of S -Matrix Elements I. Unitarity **335**

Unitarity of S . The optical theorem. Generalized unitarity and the crossed processes. The one-particle contributions.

Chapter 22 Properties of S -Matrix Elements II. Analyticity **348**

The forward scattering amplitude for photons on protons. The dispersion relation. Need for subtraction. Analyticity from Feynman graph for vertex. Anomalous thresholds and loosely bound systems. The Mandelstam Representation.

Chapter 23 Pion-Nucleon Scattering and the Forward Scattering Dispersion Relations **363**

The general form of the amplitude. I -spin decomposition. The pole terms. Crossing. The partial wave decomposition. The forward scattering dispersion relations. Comparison with experiment. A threshold theorem. The real part of the scattering amplitude at high energies.

Chapter 24 Properties of Partial Wave Amplitudes **386**

Analyticity properties of partial wave amplitudes from Mandelstam representation. Threshold behavior. The effective range approximation. Resonances. Solution with a given left hand cut. Bound states. CDD ambiguity. Inelastic N/D method. Multichannel unitarity and threshold behavior. A two channel model in the zero range approximation.

Chapter 25 The Dynamical Origin of Resonances **411**

Left-hand cut as potential. Static limit of pion-nucleon scattering and the $T = J = \frac{3}{2}$ resonance. The crossing matrix in the static limit. The reciprocal bootstrap. Results of partial wave calculations for pion-nucleon scattering. The octet-octet scattering crossing matrix. The octet-decuplet reciprocal bootstrap and the D/F ratio. The treatment of the decuplet as a spin $\frac{3}{2}$ particle.

Chapter 26 Form Factors **433**

The general form of the current matrix element. The values of $F_1(0)$ and $F_2(0)$. The data on the form factors. Dispersion approach to the form factors. The vector meson dominance. $SU(3)$ properties of the electric current. The electromagnetic mass formula. The magnetic moments of the Λ and the Σ^+ . An outline of a calculation of the isovector magnetic moment.

Chapter 27 One-Particle Exchange Mechanism 453

The one-pion exchange model. The density matrix of the peripherally produced ρ -meson. Helicity decomposition of amplitudes. Absorption corrections. Comparison with experiment.

Chapter 28 Elastic Scattering at High Energies 472

The black sphere model. The Pomeranchuk-Okun theorems. Dominance of exchange with vacuum quantum numbers. Impact parameter representation and the elastic scattering for low momentum transfers. Digression on Regge poles. Regge poles in nonrelativistic potential scattering. Diffraction shrinkage. The van Hove model for diffraction scattering. Large-angle scattering and the Wu-Yang conjecture.

PART IV. INTRODUCTION

Chapter 29 "Classical Theory" of Beta Decay 499

The Fermi theory. Nonrelativistic electron spectrum. Fierz terms and the electron-neutrino correlation. Universality and the decay modes of the pion.

Chapter 30 Parity, Charge Conjugation and Time Reversal, and Tests for their Validity 508

Evidence for parity conservation in the strong interactions. The Lee-Yang paper. The CPT theorem. The equality of masses and lifetimes of particles and antiparticles. Tests for P , C , and T with and without final state interactions.

Chapter 31 The Form of the Beta Interaction 520

The Co^{60} Experiment. The two-component neutrino conjecture. Data on the electron helicities. The measurement of the neutrino helicity. Lepton conservation and the decay of the muon. The values of C_V and C_A . The intermediate vector boson. Two neutrinos.

Chapter 32 Weak Interactions of Strange Particles I. Selection Rules and Symmetries, and the Properties of Neutral K -Mesons in Decay 540

The currents for strange particle decays. The $|\Delta S| = 1$ rule. The $\Delta S = \Delta Q$ rule. The $\Delta T = \frac{1}{2}$ rule. Spurions. Tests in Λ^0 decay and the Σ triangle. Two lifetimes for neutral K 's. The K_S and the K_L . The determination of

their mass difference. The violation of CP. The $T = \frac{1}{2}$ transformation properties of the strangeness-changing current.

**Chapter 33 Weak Interactions of Strange Particles II.
Nonleptonic and Leptonic Decays** **558**

The nonleptonic decay of the Λ^0 . Asymmetry parameters. The role of $SU(3)$ in the nonleptonic weak interactions. Suppression of Λ^0 beta decay. The leptonic decays of the K -mesons.

Chapter 34 Conserved and Partially Conserved Currents **573**

The weak current as an i -spin current. The conserved vector current. The beta decay of the pion. Weak magnetism. High-energy neutrino physics. The partially conserved axial current. The Goldberger-Treiman relation. The Cabibbo hypothesis. Determination of Cabibbo angle. Prediction of leptonic decays of hyperons. The connection between the "weak" and "strong" D/F ratios. Commutation relations among the currents and the magnitude of C_A/C_V .

References to Problems **597**

Bibliography **599**

Index **605**