Quantum Field Theory I, PHY6648

SYLLABUS

I. Introduction
   1. Problems with Relativistic quantum mechanics (MS 1)
   2. Lorentz invariance (MS 2)
   3. Free scalar field (MS 3)
   4. A first look at interacting scalar fields

II. Dirac Equation
   1. Dirac equation for the free electron (MS, 1: pp 7-10)
      (a) Lorentz Invariance (MS, 2,33)
      (b) Energy-momentum and Spin
      (c) Particles and Holes
   2. Second Quantization
      (a) General formalism (MS, 1: pp 11-13)
      (b) Application to Dirac equation
   3. Weyl fermions: Left and right handed fermions (MS, 34,35)
   4. Charge Conjugation and Majorana Fermions (MS,36)
   5. Parity, and Time Reversal.

III. Time Dependent Perturbation Theory
   1. General formalism (Dyson Formula)
   2. Scattering in an external field: Born approximation
   3. Perturbation theory for time ordered products.
   4. Propagators

IV. External Electromagnetic Fields
   1. Time Dependent Quantum Theory
   2. Green Functions, Feynman Rules
   3. Scattering in an External Field
      (a) Reduction Formalism (MS 5, 41, 56)
      (b) Calculation of cross sections —Mott Scattering
   4. Vacuum polarization
   5. Charge renormalization

6. Vacuum energy in a weak static field; Pair creation in a weak external field.
7. Constant fields of arbitrary strength (Optional)

V. Path History Quantization

1. General formalism (MS 6, 7)
2. Classical limit
3. Time ordered products
4. Gaussian path integrals (MS 8)
5. Anticommuting fields
6. Interacting Scalar fields (MS 9)

VT. Feynman rules for scalar field theory (MS 10, 11, 12)

VII. Quantization of the Free Electromagnetic Field

1. Canonical Operator Quantization (MS 54, 55, 56)
2. Path Integral Quantization (MS 57)
3. Dirac field and Path Integrals (MS 43 44)
4. Gauge-fixing—Fadeev-Popov prescription

VIII. Quantum Electrodynamics

1. Derivation of Feynman rules (MS 58)
2. Compton, Moller, and Bhaba Scattering (MS 59)
3. Pair production
4. Higher order Processes (MS 62)
   (a) Ultraviolet divergences
   (b) Ward identities (MS 67, 68)
5. Mass and Charge Renormalization
6. Anomalous Magnetic Moment; Lamb shift; $\pi_0 \to 2\gamma$
7. Positronium and Quarkonium
8. Infrared Divergences; Soft Photon Bremstrahlung; Gauge Invariance
9. Renormalization Group and Callan-Symanzik Equation

IX. Representations of the Poincarè Group for General Spin (MS 33)

1. Little group constructions
2. Finite dimensional (non-unitary) representations of the Lorentz Group.
3. Two component spinor formalism. (MS, 34,35)

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