QFT

Chapter 58: Spinor Electrodynamics
Overview

• Quantum Electrodynamics: theory of photons
  • Spinor electrodynamics: photons interacting with fermions
  • Scalar electrodynamics: photons interacting with scalars

• Recall that in chapter 36, we found that the U(1) symmetry of the Dirac field has a conserved Noether current. We now take this to be by definition the electromagnetic current.
  • Note that this is the fundamental relation; the more familiar aspects of E&M (like electric deflection and magnets) are consequences of this.

• We define the conserved (electric) current to be

\[ j^\mu(x) = e \overline{\Psi}(x) \gamma^\mu \Psi(x) \]

• The Noether charge, defined in the usual way, becomes our electric charge operator.
• e is our proportionality constant. We have to measure it in a lab – determine the cross-section (for example) and find the corresponding charge.
  • Of course, this should match our “classical” value for the electron charge, for example, the Millikan Oil Drop Experiment.
  • But, this is highly dependent on our renormalization scheme, more on that later
  
  \[ e = -0.302 \text{ 822} \]
Gauge Transformations

• Note:
  • A Noether current is conserved only when the action is stationary
  • In the previous chapters, we assumed that the current is always conserved

• To resolve this, we require gauge transformations to shift both the EM field (A) and the fermion fields.
  • This way, the Lagrangian is invariant under the transformation, and the Noether current will always be conserved, resolving the inconsistency.

• Gauge Covariant Derivative:
  • Our “regular” derivative knows nothing about a gauge transformation.
  • This is a problem, because terms in the Lagrangian need to be gauge-invariant.
  • We define a gauge covariant derivative to account for this. This usually takes the form: $D_\mu = \partial_\mu - ieA_\mu$
Feynman Rules

• Now we’re done: we have our gauge-invariant interacting Lagrangian and our Path integral.
  • We now use the usual procedure:
    • Expand the path integral into infinite sums
    • Impose normalization
    • Represent the infinite sums as diagrams, the value of each is given by the Feynman rules, given in Srednicki.