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 <u>by definition</u> 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 = -0.302 822

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.