Last week, we began a discussion of the theoretical basis for some of our understanding of the interactions among elementary particles. We began with an introduction to Lagrangian Field Theory, which helps introduce the notation. We now discuss the Dirac equation and the notion of local gauge invariance, which leads us to the Lagrangian of electrons, photons and the interactions between them. Next week, we will motivate and elucidate the Feynman rules for Quantum Electrodynamics, which will allow us to perform calculations of electromagnetic scattering processes. Following that, we will discuss electromagnetic scattering processes in colliders and fixed-target experiments. Towards the end of the lectures 15, we will begin discussion of weak interactions.

Main Reading:
Griffiths: Sections 7.1 thru 7.8, 6.2, 11.1 thru 11.3, 11.6 and Chapter 8.

Supplementary Reading:
Kane, Sections 2.1 thru 2.7, Chapter 3, Sections 5.1 thru 5.7

Homework Assignment 3 (due 11/8)

1) Griffiths problem 7.6
2) Griffiths problem 7.7; do this for just one spinor: \( \psi_1 \)
3) Griffiths problem 7.12
4) This problem deals with the fundamental QED process of electron-electron scattering.
   a. Draw the two Feynman diagrams, labeling all external fermions according to the conventions laid out in the Feynman rules.
   b. 714 students should do Griffiths problem 7.34. 556 students can assume this result and proceed, but you will get extra credit for doing it.
   c. Griffiths problem 7.36. You will need eq. 8.42 (see hint), bar \( v + c = 1 \).
   d. Relativistic kinematics exercise: Suppose an electron of energy 10 GeV scatters off an electron at rest in the laboratory frame. Find the center-of-mass and laboratory scattering angles for the case where the two scattered electrons have the same laboratory scattering angle.

5) This problem deals with the QED process of electron-positron annihilation to quark-antiquark pairs.
   a. Draw the Feynman diagram, labeling all external momenta.
   b. 714 students should work out eq. 8.3 in Griffiths, starting with the Feynman rules. 556 students can assume this and proceed. Again, extra credit for 556 students if you do it.
   c. Rewrite the spinors in eq. 8.4 in Griffiths, in the high energy limit. Do this starting with eq. 8.3.
   d. Armed with the expressions for the differential cross-section for the process in the center-of-mass frame, obtain the total cross-section. If an electron-positron collider is operating at a center-of-mass energy of 200 GeV and a luminosity of 10^{34} cm^{-2} s^{-1}, how many quark-antiquark pairs are observed in 1 day of running?

6) Griffiths problem 6.7 (both parts).

Following for 714 students only:

7) Griffiths problem 7.8 (you will need some basic commutation relations from your quantum mechanics course to tackle this problem).