

PHY 556/714: Handout 3

Date: 10/16/2007

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RE: Topics, Reading & Assignment, lectures 10 thru 15, 10/04/07 thru 11/1/07

Last week, we began a discussion 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 lecture 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 11/6)

- 1) Griffiths problem 7.6
- 2) Griffiths problem 7.3; derive this for just one spinor: $u^{(1)}$
- 3) Griffiths problem 7.22
- 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 first 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 eqn 6.42 (use $\hbar = c = 1$).
 - 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.

- e. By what factor would the cross-section change for the configuration in part d., if the incident electron energy is 1 GeV instead of 10 GeV?
- 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 eqn 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 spin-average matrix element, eqn 8.4 in Griffiths, in the high energy limit. Derive it starting with eqn 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 20 GeV and a luminosity of $10^{31} \text{ cm}^2 \text{ s}^{-1}$, 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 courses to tackle this problem).