Phy 556: Problem Set 1
(Due: January 31, 2017)

1) Griffiths, Problem 2.2. Also sketch the lowest order Feynman diagrams for Bhabha scattering, $e^- + e^+ \to e^- + e^+$.

2) Griffiths, Problem 2.5 (part a) only).

3) Griffiths, Problem 2.7 (parts a)-l) only).

4) In this problem we revisit the introduction of a new particle, the *neutrino*, from the appearance of an electron energy *distribution* in neutron beta decay. (For the numerical aspects of this problem, refer to the data of the Particle Data Group compiliation, http:pdg.lbl.gov, for the particle masses.)

a) Use relativistic kinematics to determine the energy of the emitted electron in the presumed process $n \to p + e^-$. You may assume the neutron is initially at rest.

b) Now consider the process $n \to p + e^- + \bar{\nu}_e$ under the conditions of part a); you may also set the $\bar{\nu}_e$ mass to zero. Check the direct limit on this quantity from the PDG and argue why this is an excellent approximation. Use relativistic kinematics to determine the largest possible value of the electron energy. (What is its smallest possible value?) If the neutrino (rest) mass were slightly nonzero, how would the maximum energy electron change?

5) In this problem we use relativistic kinematics to analyze Compton scattering, $\gamma + e \to \gamma + e$ for an electron that is initially at rest. You should assume that the photon is massless. You may analyze this problem in two spatial dimensions without loss of generality. Introducing the scattering angle ϕ for the angle between the final-state and initial-state photons, show that the two photon energies are related in the following way:

$$E_f = \frac{E_i}{1 + \frac{E_i}{m}(1 - \cos\phi)} \tag{1}$$

Compton derived this formula and found it was bourne out experimentally. Under the replacement $E = h\nu$, where h is Planck's constant, we see that the energy shift is nonzero only if $h \neq 0$. (Note A. H. Compton, Phys. Rev. **22**, 409 (1923). Compton won a Nobel prize for this work in 1927.)

6) Griffiths, Problem 3.4.

7) Griffiths, Problem 3.18.