Assignment #3

Elementary Particle Physics: Phys-4602/5602

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Due January 30$^{\text{th}}$, 2012

Students registered in 4602 do only problems 1, 2, and 3. Students registered in 5602 do ALL problems.

1. Sketch the lowest-order QED Feynman diagram representing neutral pion decay $\pi^0 \to \gamma + \gamma$.

2. Consider $\pi^0 \to \gamma\gamma$:

   (a) Deduce an expression for the energy of a photon from the decay of a neutral pion in term of the mass m_π, energy E_π, and velocity $\beta\, c$ of the pion; and of the angle of emission θ in the centre-of-mass frame.

   (b) Find an expression for the ratio of energies of the two photons from π^0 decay.

   (c) Show that for ultra relativistic neutral pions $\pi^0 \to \gamma_1\gamma_2$ the ratio R of energies of the two photons is given by $R = \frac{E_1}{E_2} = \frac{1+\cos\theta}{1-\cos\theta}$.

3. Particle A, at rest, decays into three or more particles:
   $A \to B + C + D + \cdots$

   (a) Determine the maximum and minimum energies that B can have in such a decay, in terms of the various masses.

   (b) Find the maximum and minimum electron energies in muon decay: $\mu^- \to e^- \nu_\mu\, \bar{\nu}_e$.

   Additional question for 5602

4. (a) The CKM matrix implies various relations among its elements. Provide a full list of these relations.

   (b) Prove that there is never a FCNC in the Standard Model. In other words show that: $d'\bar{d}'Z + s'\bar{s}'Z + b'\bar{b}'Z = d\bar{d}Z + s\bar{s}Z + b\bar{b}Z$.