PHYSICS 474: Introduction to Particle Physics

Homework 1 Due: noon Friday, Jan 26, 2018

1. **Mesons and Baryons:**

   (a) [10 points] How many different meson ($q\bar{q}$) and baryon (qqq) combinations can be made with n quark flavors?

   (b) [5 points] The Standard Model has 6 flavors of quarks (u, d, c, s, t, b). From your answer to part (a), how many varieties of mesons and baryons would you expect in Nature?

   Bonus: [2 points] Do we really see that many? (You can find the list of all mesons and baryons seen so far in the *Particle Data Book*.) Why not?

2. **Nuclear β-decay:**

   (a) [10 points] Before the discovery of neutrino, the β-decay of an unstable nucleus was thought to be a two-body decay: ${}^{A}_{Z}X \rightarrow {}^{A}_{Z+1}Y + e^{-}$. Find the energy and momentum of the outgoing electron in this case.

   (b) [10 points] Soon after Pauli's proposal that a (anti)neutrino must accompany the electron to conserve energy in the β-decay process, there was some confusion whether the neutrino could be coming from *inside* the nucleus. Use Heisenberg's uncertainty relation to estimate the minimum momentum and energy of a neutrino confined to the nucleus (typical size 1 fm). Compare this with the typical neutrino energy in β-decay (a few keV) to show that the neutrino could *not* have come from inside the nucleus, but must have been produced in the decay process itself.

3. **Pion decay:**

   A charged pion at rest decays into a muon and a muon neutrino: $\pi^{-} \rightarrow \mu^{-} + \bar{\nu}_{\mu}$.

   (a) [10 points] Find the energy and momentum of the muon.

   (b) [5 points] How far the muon could travel in vacuum before disintegrating itself? (Muon decays into electron (and neutrinos), with a decay lifetime of 2.2 μs in its rest frame).