PHYSICS 474: Introduction to Particle Physics

Homework 1 **Due: 11.30 Wednesday, 1/22/2020**

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?

   (c) *Optional:* Why don't we see that many? (You can find the list of all mesons and baryons seen so far in the *Particle Data Book*.)

2. **Nuclear β-decay:**

   (a) [10 points] In the early 1900s, 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) [5 points] Soon after Pauli's proposal in 1930 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 (of typical size 1 fm). Compare this with the typical neutrino energy in β-decay (a few keV) to verify whether the neutrino could have come from inside the nucleus.

3. **Pion decay:**

   A charged pion traveling at speed $0.9c$ decays into a muon and an antineutrino: $\pi^{-} \rightarrow \mu^{-} + \bar{\nu}_{\mu}$. If the neutrino emerges at 90° to the original pion direction,

   (a) [10 points] At what angle does the muon come off?

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