PHYSICS 474: Introduction to Particle Physics

Midterm Exam **March 4, 2020 11.30-12.50**

1. [5 points] For each of the following reactions, indicate what kind of interaction (Strong, Electromagnetic, Weak, or None) is responsible and why: (a) $\pi^0 \to \gamma + \gamma$, (b) $\pi^- \to \mu^- + \bar{\nu}_\mu$, (c) $\Lambda \to p + \pi^-$, (d) $\Delta^0 \to p + \pi^-$, (e) $p \to e^+ + \gamma$.

2. [5 points] What is the probability of a muon (with rest mean lifetime of 2.2×10^{-6}s) lasting more than 1 second in its rest frame?

3. (a) [10 points] Using the meson mass formula

$$M_{\text{meson}} = m_1 + m_2 + A\frac{\mathbf{S}_1 \cdot \mathbf{S}_2}{m_1 m_2}\,, \tag{1}$$

calculate the mass splitting between the π and ρ mesons. Use $m_u = m_d = 308$ MeV$/c^2$ for the constituent quark masses and $A = (2m_u/\hbar)^2 \times 159$ MeV$/c^2$ for the constant in Eq. (1).

(b) [10 points] Using the baryon mass formula

$$M_{\text{baryon}} = m_1 + m_2 + m_3 + A'\left[\frac{\mathbf{S}_1 \cdot \mathbf{S}_2}{m_1 m_2} + \frac{\mathbf{S}_2 \cdot \mathbf{S}_3}{m_2 m_3} + \frac{\mathbf{S}_1 \cdot \mathbf{S}_3}{m_1 m_3}\right]\,, \tag{2}$$

calculate the mass splitting between the Δ-baryons and nucleons (proton/neutron). Use $m_u = m_d = 363$ MeV$/c^2$ for the constituent quark masses and $A' = (2m_u/\hbar)^2 \times 50$ MeV$/c^2$ for the constant in Eq. (2).

4. [10 points] A Uranium-238 nucleus at rest undergoes alpha-decay (by emission of an alpha-particle, i.e. Helium-4) to Thorium-234. Find the energy and momentum of the alpha particle in terms of its mass and the masses of the Uranium and Thorium nuclei.

5. [10 points] Using isospin conservation, find the ratio of the rates for the strong decays $\Sigma^0 \to K^- p$ and $\Sigma^0 \to \overline{K}^0 n$.