Massachusetts Institute of Technology
Department of Physics

8.276 Nuclear and Particle Physics **April 5, 2007**

Reading Assignment for 4/10 and 4/12
Particles and Nuclei, Chapter 15 (omit Sect. 15.5)
Optional Reading: Coughlan and Dodd, Chapters 8-10
Cahn and Goldhaber, Chapter 5

Problem Set #7 (due 4/12)

1. The dominant decays of the η meson are

$$\eta \to 2\gamma \quad (39\%)$$
$$\eta \to 3\pi \quad (56\%)$$
$$\eta \to \pi\pi\gamma \quad (5\%)$$

and it is classified as a "stable" particle, so evidently none of these is a purely strong interaction. Offhand, this seems odd, since at 549 MeV/c^2 the η has plenty of mass to decay strongly into 2π or 3π.

a) Explain why the 2π mode is forbidden, for both strong and electromagnetic interactions.

b) Explain why the 3π mode is forbidden as a *strong* interaction, but allowed as an *electromagnetic* decay.

2. a) Explain how a comparison of the decays $\pi^+ \to \mu^+\nu_\mu$ and $K^+ \to \mu^+\nu_\mu$, could be used to determine the Cabibbo angle θ_C. The K^+ meson has strangeness $S = +1$.

b) Use the data in Table 14.3 to determine a value for θ_C. You will need to include a phase space factor $F = 18$, due to the different masses of the K^+ and π^+ and thus the different amounts of energy available in the decays.

3. With $\mathbf{s}_1$ and $\mathbf{s}_2$ being the spins of the constituent quarks having masses m_1 and m_2, meson masses in the quark model are predicted to be the sum of m_1 and m_2, plus a hyperfine interaction term:

$$m(q_1, q_2) = m_1 + m_2 + a\frac{\mathbf{s}_1 \cdot \mathbf{s}_2}{m_1 m_2},$$

Assuming $m_u = m_d = 0.310$ GeV/c^2, $m_s = 0.483$ GeV/c^2 and $a/m_u^2 = 0.64$ GeV/c^2,

obtain the masses of the pseudoscalar and vector mesons and compare them with the measured values.

4. a) How can one produce experimentally a beam of pure, monoenergetic K^0 particles?

b) When this beam interacts with matter, Λ and Σ particles, which have $S = -1$, can be produced, even though the K^0 has $S = +1$. Explain how this can happen.

5. a) Assume that K^0 and $\overline{K}^0$ beams of equal energy pass through a slab of matter. Will the beams be attenuated equally? Why or why not?

b) A pure K_2^0 beam passes through a slab of matter. Will the emerging beam still be a pure K_2^0 beam? Why or why not?

c) How could it be decided experimentally whether or not the K_2^0 beam is still pure after passage through the slab?

6. *P&N*, 13-4.