720/820 Nuclear Physics - Homework #1. Due: Friday, 2/12/10

I. ISOSPIN

1. There are many other hadrons besides the nucleons and pions, and all carry definite isospin. In particular, there are hadrons that contain strange quarks in addition to up and down quarks. The hyperons Σ^*, Σ, and Λ are hadrons that carry strangeness. Both Σ^* and Σ carry $I = 1$, while Λ has $I = 0$.

   (a) Find the two-index tensor S_{ab} that contains the Σ fields using the techniques developed in lecture.

   (b) Assuming exact isospin symmetry, find the relations between the decay rates for $\Sigma^{+*} \to \Sigma^0\pi^\pm$ and $\Sigma^{-*} \to \Sigma^-\pi^0$.

   (c) Can these rates be related to that for $\Sigma^* \to \Lambda\pi$ by isospin? If so, what are the relations?

2. Consider the isospin decomposition of the six possible πN states. Which states are pure isospin states and which are mixtures? What are the implications of isospin for πN scattering?

II. KINEMATICS

3. The relativistic dispersion relation (relation between energy E and momentum p) of a particle with rest mass m is given by

$$E = \sqrt{p^2c^2 + m^2c^4} . \tag{1}$$

   Show that in the non-relativistic limit, $pc \ll mc^2$, this relation reduces to the expected form in non-relativistic classical mechanics.

4. A beam of π^+'s is incident upon a hydrogen target at rest in the laboratory. Find the minimum beam energy required to produce a Δ resonance. Use $M_\pi = 140$ MeV, $M_p = 940$ MeV and $M_\Delta = 1230$ MeV. Find the minimum energy required to produce a J/ψ (use $M_{J/psi} = 3096.9$ MeV).