Massachusetts Institute of Technology
Department of Physics

8.276 Nuclear and Particle Physics **April 24, 2007**

Reading Assignment for 4/26, 5/1 and 5/3

Particles and Nuclei Sects. 2.3, 6.2, 17.1, 17.3, 17.4 (Nuclear structure)
Sects. 3.1, 15.5, 17.6 (β-decay)

Problem Set #9 (due 5/3)

1. The reaction $\pi^- + d \rightarrow 2n + \pi^0$ is a strong interaction and thus must conserve parity as well as, of course, energy, momentum, and angular momentum. Although there is sufficient energy in the $\pi^- d$ system to allow this process for a π^- at rest, it does not occur. Why not? Can the reaction occur for a π^- with appreciable kinetic energy? Why or why not?

2. a) Use the continuity and normalization conditions to evaluate the coefficients A and C in the bound-state nucleon-nucleon wave functions $u_I(r)$ and $u_{II}(r)$ in Eq. (16.11). Hint: Use the following trigonometric identities to simplify your result for A, which will consist of a single term containing κ, a, and numerical factors:

$$\sin 2x = \frac{2\cot x}{1+\cot^2 x} \quad \sin^2 x = \frac{1}{1+\cot^2 x}$$

b) Use the results of part a) to find an expression for the fraction of the time, f, that the neutron and proton in the deuteron spend outside the range of the potential. Evaluate f for $a = 1.7$ fm and $V = 35$ MeV.

3. a) Show that the continuity condition in Problem 2 may be written in the form $x = -\tan bx$.

b) Evaluate b for $a = 2$ fm, and solve the equation either graphically or numerically to find a value for V.

4. The so-called tensor term in the nucleon-nucleon potential [see Eq. (16.8)] depends on the relative orientation of the spins and the spatial separation of the particles. The separation vector, $\mathbf{x}$, could be oriented either parallel or perpendicular to the spin vectors $\mathbf{s}_1$ and $\mathbf{s}_2$.

a) Calculate the difference in energy between the two orientations. Take $V_T(r) = 20$ MeV.

b) Which orientation corresponds to the ground state of the deuteron? Explain your choice.

c) Is your answer to part b) consistent with the sign of the electric quadrupole moment of the deuteron? Explain why or why not.