Physics 135a
Problem set number 5
Due Wednesday, February 11, 2004

Reading: Chapter 7, on Quantum Electrodynamics.

24. A simple exercise on flux: Suppose that we have a perfectly elastic rubber ball which bounces back and forth between two walls of a box. Let the ball's speed be v_b (a constant). Now suppose we shoot a projectile, with speed v_p into the box, colinear with the ball, so that it collides with the ball. Assume that we shoot the projectile at a random time, as far as the ball's motion is concerned. What is the probability that the projectile will collide with the ball when their relative velocity is $v_b + v_p$?

    Now consider a bubble chamber, filled with liquid deuterium. We shoot a beam of π^- mesons into the bubble chamber. Assume we are doing a "high energy" experiment, so that the deBroglie wavelength of the π^- is small compared to the typical $p - n$ separation in the deuteron. Thus, sometimes the π^- will hit the neutron in the deuteron and knock it out, without the proton being much involved. In such a reaction, we refer to the proton as a "spectator". A spectator proton, after such an interaction keeps moving however it was moving (according to the deuteron wave function) before the interaction, only now it is a free particle, and typically leaves a short visible track in the bubble chamber. Let θ be the angle between the spectator proton track and the π^- beam. Will $\cos\theta > 0$ or $\cos\theta < 0$ most of the time? (This is too easy ... don't get it wrong! – I find that many people do get it wrong, either out of carelessness, or from not determining what is important.)

25. Problem 7.8 in text. Note that we have actually already done a piece of this in class.

26. Problem 7.12 in text.

27. Some more isospin: Consider the p and n baryons. Let us regard them as two states of a single nucleon, distinguished by their 3rd component of isospin: $I_3(p) = +\frac{1}{2}$, $I_3(n) = -\frac{1}{2}$. Suppose we have a system consisting of two of these nucleons. Determine the allowed values of L+S+I,

where L is the relative orbital angular momentum, S is the total spin of the two quarks, and I is the total isospin of the two nucleons. Even though you use an "extended" Pauli principle, note that it is really a bookkeeping device – the number of states has not changed. Using your result, make an argument for the spin of the deuteron.

28. We tried the wave equation for a free particle of mass m of the form:

$$H\psi = (\boldsymbol{\alpha} \cdot \mathbf{p} + \alpha_0 m)\psi \tag{1}$$

Show that with the requirement that $H\psi = E\psi$, the alpha's must be traceless Hermitian matrices of even dimension, with lowest dimension equal to 4.

29. Prove the following assertions we made in class:

    (a) $\gamma^{\mu\dagger} = \gamma^0 \gamma^\mu \gamma^0$.

    (b) The anticommutation relations for the gamma matrices:

$$\gamma^\mu \gamma^\nu + \gamma^\nu \gamma^\mu = 2g^{\mu\nu}$$