Homework Assignment 5
Physics 212

Handed out:	Thursday, March 4, 1999
Due in class on:	Thursday, March 11, 1999

Problem 1: Magnetic Moment of the Proton

1. The quark theory of baryons says that the proton $p = uud$ is composed of two up-quarks u and one down-quark d. Continuing our class discussion, express the wave function of a spin-up proton $|s = 1/2, s_z = 1/2\rangle$ in terms of the spin states of its quarks.

2. What values would you expect naively for the z-component of the magnetic moment of a spin-up proton if you added up the magnetic moments of its constituent quarks, treating them as isolated non-interacting particles?

3. Assuming that the up and down quarks each have a mass $m_q \approx m_p/3$ that is one-third the proton mass m_p and using your wave function for a spin-up proton in terms of the quark spin states, calculate the average value of the z-component of the proton magnetic moment and compare your value with the experimental value $\mu_z = 2.79\mu_B$.

4. Now assume that the up-quark mass m_u is *not* the same as the down-quark mass m_d. Derive new formulas for μ_n and μ_p (the z-components of the neutron and proton magnetic moments). Then deduce the values of m_u and m_d by comparing your two new formulas with the experimental values $\mu_n = -1.91\,\mu_B$ and $\mu_p = 2.79\,\mu_B$.

Problem 2: Problems in Griffiths

1. Problem 4.3 on page 128.

2. Problem 4.5 on page 128.

3. Problem 4.13 on page 142.

4. Problem 4.48 on page 172.

Problem 3: Decay of a Tritium Atom Into a Helium Ion

The tritium atom H^3 is an isotope of hydrogen that has a nucleus consisting of one proton and two neutrons. This nucleus is unstable with a half-life of 12.3 years and will beta decay, transforming the tritium atom into a positively charged He^3 ion whose nucleus has two protons and one neutron:

$$\mathrm{H}^3 \to \mathrm{He}^{3+} + e^- + \hat{\nu}. \tag{1}$$

(Recall that beta decay is the transformation of a neutron into a proton, electron, and antineutrino, $n \to pe^-\bar{\nu}$. The emitted electron typically has energies of order a few KeV which greatly exceeds the binding energy of a He atom, so it is unlikely for the emitted electron to be "captured" by the newly formed He^3 ion.) Assuming that the beta decay occurs instantly and that the tritium atom is in its ground state before decay, what is the probability:

1. that the newly formed He ion is in its ground state?

2. that the newly formed He ion is in a 2s-state?

3. that the newly formed He ion is in any bound state that is not an s-state?
4. Discuss whether the assumption of instantaneous decay is consistent with the time-energy uncertainty principle.

Extra credit: What is the approximate probability that the newly formed He ion will be completely ionized (have charge +2)?

Problem 4: Time for Completion

Please tell me the approximate time in hours that it took to finish this assignment.