Physics 404
Second Homework Assignment
Due Monday April 16th

Choose any 5 of the following 7 problems. The students from Fresno who are going to CERN in the summer need to do the Relativistic Kinematics and the Root programming problems.

Problem 1 (4.35).
Quarks carry spin 1/2. Three quarks bind together to form a baryon (such as a neutron or proton); two quarks (or more precisely a quark and anti-quark) bind together to make a meson (such as the pion or the kaon). Assume that the quarks are in the ground state (so the orbital angular momentum is zero).

a) What spins are possible for baryons?

b) What spins are possible for mesons?

Problem 2 (4.36).
a) A particle of spin 1 and a particle of spin 2 are at rest in a configuration such that the total spin is 3 and its z-component is $\hbar$. If you measured the z-component of the angular momentum of the spin-2 particle, what values might you get and what is the probability of each one?

b) An electron with spin down is in the orbital angular momentum state with $l = 1$ and $m = 0$. If you could measure the total angular momentum squared of the electron alone, what values might you get, and what is the probability of each?

Problem 3 (4.55)
The electron in the hydrogen atom occupies the combined spin and position state:

$$R_{21}(r)(\sqrt{\frac{1}{3}}Y_{10}|\frac{1}{2}\frac{1}{2} > +\sqrt{\frac{2}{3}}Y_{11}|\frac{1}{2} - \frac{1}{2} >) \quad (1)$$

a) If you measured the orbital angular momentum squared (L^2), what values would you obtain, and what is the probability of each?

b) Same for the z-component of orbital angular momentum (L_z).

c) Same for the spin angular momentum squared (S^2).

d) Same for the z-component of the spin angular momentum (S_z).
Let $\vec{\hat{J}} = \vec{\hat{L}} + \vec{\hat{S}}$

e) If you measured J^2, what values might you get, and what is the probability of each?

f) Same for J_z.

Problem 4. (6.14)
Find the (lowest order) relativistic correction to the energy levels of the one dimensional harmonic oscillator.

Problem 5.
Use the Clebsch-Gordon table to find the inner products below. The notation is $< jm_j|lm_lsm_s >$.

$$< 11|2011 >, < 10|1010 >, < \tfrac{3}{2} - \tfrac{1}{2}|20\tfrac{1}{2} - \tfrac{1}{2} >, < 2 - 1|\tfrac{3}{2} - \tfrac{1}{2}\tfrac{1}{2} - \tfrac{1}{2} >$$

Problem 6: Root Programming. Write a computer program that will produce and plot simulated data. The data you are to simulate is a "Lorentian Peak" on a flat background. Your program will print out counts $C(i)$ versus channel number i, where the channel number i will go from 0 to 100. Your peak is to be centered at channel number 50, and be of the form:

$$C(i) = 16 + \frac{200 * 100}{(n-50)^2 + 100} \tag{2}$$

For each channel i, the simulated data should have a Gaussian probability distribution with a width equal to the square root of the counts. Have your root program plot the simulated data with error bars.

Problem 7: Relativistic Kinematics Problem. A positron is traveling with a kinetic energy of 215 KeV when it collides with an electron at rest in the lab reference frame. The two annilate and two photons are produced. One photon travels off in the same direction that the positron was moving. What are the energies of the two photons (in the lab frame) that are produced?