Homework 3 for Physics 222/225b
Due Date: Tuesday, February 16th

1. Halzen & Martin 13.1
2. Halzen & Martin 13.2
3. Show explicitly that Equations 13.40 and 13.41 lead to 13.42. Then show that Table 13.2 follows from the quantum numbers listed in Table 13.1 given the decomposition of the neutral current into J^3 and j^{em}.
4. Using the results of the previous problems, compute the total widths and the branching fractions for Z and W decays into all possible final state fermions. Use $\sin^2 \Theta_W = 0.23$, $M_Z = 91$ GeV, $G = 1.17 \ 10^{-5}$ GeV^{-2} . Compare with experimental results.
5. Use comphep to plot the u ubar -> mu+mu- cross section as a function of invariant mass from 30-150GeV for the Tevatron. Then do the same for u ubar -> ν νbar . Form the ratio of the two cross sections as a function of invariant mass, and explain what you see. (You can dump the comphep spectra to a text file, then load the two text files into root, and divide to histograms. On the root web page there is an example of how to read in numbers form a file. You probably have to do a little bit of editing of the file that comphep spits out.)
6. This question is about ZZ production at a hadron collider. CDF presented the first measurement of this process at the FNAL w&c seminar Friday February 1st, 2008. The corresponding paper can be found at http://arxiv.org/abs/0801.4806 . This is work done by the UCSD CDF group, so let's take a closer look.
   a. Let's lump the possible final states of a single Z into l+l- (l=e or mu), MET (i.e. 2 neutrinos), and jets. What are the respective branching fractions into combinations of these 3 categories, given what you have learned in problem 3? (Treat tau+tau- as contributing to l+l- and jj only)
   b. Look at the paper, and explain why you think UCSD chose to restrict the analysis to only the 4-lepton and di-lepton di-neutrino final state.
   c. Revisit what you learned in problem 4 above. Estimate the cross section in the 4-lepton final state as well as in the di-lepton MET final state using comphep. (Make sure to check the invariant mass requirement in the paper for the two different final states!) How does the ratio of these two cross sections compare with a naïve expectation from the ratio of branching fractions of ZZ->4-leptons vs ZZ->llnunu as obtained from problem 3?
   d. In light of problem 6c., read the paper again and make sure you understand what the quoted cross section result actually means. What would a theorist have to calculate to compare with the measured 1.4 +0.7 - 0.6 pb cross section?