PHYSICS 489Y - Problem Set #4

Due 20th November

Do problems 11.4, 11.6, 11.9, 12.2, 12.6 from the textbook.

Then do the two simple, practical questions below.

1) The cross section for the absorption of antineutrinos with the typical energies emitted from a reactor is about $10^{-43} cm^2$.

(a) Compute the thickness of water absorber needed to reduce the intensity of an antineutrino beam by a factor of 2.

(b) Since neutrinos are very penetrating particles, they are difficult to detect. A liquid scintillator is an organic liquid which emits small flashes of light when traversed by a charged particle. Typically liquid scintillators are some mixture of Hydrogen and Carbon, with an atomic ratio of *H/C = 1.10*. The density of a typical scintillator might be about $0.95\, g/cm^3$. Consider an experiment where a tank containing 10^3 litres of liquid scintillator intercepts a beam of antineutrinos from a reactor. The flux of antineutrinos is $10^{13}\ \bar{\nu}/cm^2$ sec. How many events of the type $\bar{\nu}_e p \to e^+ n$ will occur per day, if the cross section is about $10^{-43} cm^2$?

This is typically how experiments are made to detect neutrinos from reactors. These experiments are designed to measure the mixing between different species of neutrino, and hence determine the pattern of neutrino masses.

(c) What property of the final state particles would one have to observe in order to be sure that the initial particle was a neutrino and not an antineutrino? Write down the analogous reaction which contains an initial state neutrino. Also write down which additive quantum numbers are being conserved.

2) In the standard model the partial width for the decay of the Z^0 to a fermion-antifermion pair is

$$\Gamma\left(Z^0 \to f\bar{f}\right) = 2\left[\left(c_V^f\right)^2 + \left(c_A^f\right)^2\right]\frac{GM_Z^3}{12\pi\sqrt{2}}$$

where c_V^f and c_A^f are the fermion couplings to the Z^0 given in Table 15.1 in the textbook. Assuming three generations of fermions calculate the total width of the Z^0 if $G = 1.17\times10^{-5} GeV^{-2}$, $M_Z = 91.2 GeV$, and $\sin^2\theta_W = 0.23$. Because each quark comes in three colours, the decays can occur in three times as many ways as those for the uncoloured leptons. Allow for this.