Physics 400/506
Problem Set 5
Due Tuesday, March 7, 2006 by the end of class

1. The (approximate) total cross-section for the charged current interaction of a ν_μ on a nucleon is given as a function of the neutrino energy by

$$\sigma_{tot} = 0.7 \times 10^{-38} \text{ cm}^2 \times \frac{E_\nu}{1 \text{ GeV}}$$

Consider a neutrino beam with a mean energy of 10 GeV. The beam is incident on an infinitely thick slab of lead. Calculate the mean distance that a neutrino in this beam will travel before interacting.

2. Griffiths Problem 6.6

3. The Zappa particle (to be discovered in 2012) has three decay modes. In the first mode, it decays into a yellow shark, in the second, it decays into dental floss, and in the third, it decays into plastic people. A collection of Zappa decays is observed, and the mean time between particle creation and each kind of decay is found to be:

Mode	Mean lifetime
yellow shark	5 μsec
dental floss	50 msec
plastic people	20 μsec

What is the mean lifetime of the Zappa particle, and what are the branching ratios for each of the three modes?

4. Griffiths 6.12

5. The Dirac equation (with $\hbar = c = 1$) is

$$(i\gamma^\mu \partial_\mu - m)\psi = 0$$

Operate on the Dirac equation with $\gamma^\nu \partial_\nu$ and show that each of the four components ψ_i satisfies the Klein-Gordon equation. (Hint: use the γ matrix commutation relations.)

6. *Graduate students only:* When working with the Dirac equation, an *adjoint spinor* is defined by $\bar{\psi} \equiv \psi^\dagger \gamma^0$. Prove that the adjoint spinor satisfies a form of the Dirac equation given by

$$i\partial_\mu \bar{\psi} \gamma^\mu + m\bar{\psi} = 0.$$