# Ph 406: Elementary Particle Physics
# Problem Set 11

K.T. McDonald
kirkmcd@princeton.edu
*Princeton University*
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1. Estimate the decay rate $\Gamma_{t \to bW^+}$ of the top quark, and give the order-of-magnitude of the lifetime in seconds.

   If you wish to pursue a more detailed calculation (not required), note that a top quark in a given spin state can decay to a $W^+$ in two different spin (helicity) states, so the total rate is the sum of that to these two $W$-states. A good approximation is that $m_b \ll m_W$, but $m_W$ is comparable to $m_t$. It seems favorable to evaluate the matrix elements directly using the appropriate Dirac spinors, rather than resorting to Feynman's trace tricks.

2. In Set 8, Prob. 5 you considered the cross section for the reaction $e^+e^- \to \nu\bar{\nu}$ in the V−A Fermi theory of the weak interaction, which theory is significantly modified at high energy by the existence of the $Z^0$ boson. Compare the amplitudes for the inverse reaction, $\nu\bar{\nu} \to e^+e^-$, near threshold in the Weinberg-Salam model to those in the Fermi theory to deduce the ratio of the cross sections in these two models. Also, give an expression for the cross section as a function of center-of-mass energy $\sqrt{s} \approx m_Z$ supposing that the reaction is only $\nu\bar{\nu} \to Z^0 \to e^+e^-$.

   *You may ignore lepton masses, and consider only lefthanded neutrinos (righthanded antineutrinos). The discussion in the Notes on p. 399, Lecture 22 has some unfortunate typos, which you can correct by noting that the result on p. 216, Lecture 12 should agree with that on p. 210, Lecture 9 when $\sqrt{s} = E_R = m_c$.*

3. Now that the Higgs boson, $h$, has been discovered we optimistically contemplate measurement of the reaction $e + h \to e + Z^0$. Estimate the cross section for this reaction in the center-of-mass frame, and the form of its angular dependence assuming unpolarized initial electrons.

   *Since the Higgs particle couples to mass, hee vertices are negligible here, although you might wish to draw the simplest diagrams that include them.*