Problem Set 12

Problem 1

Read Peskin and Schroeder Chapter 5 for Monday.

Problem 2

According to the Standard model of particle physics, there is a scalar particle called the Higgs boson, whose field H couples to each quark and lepton field ψ according to

$$\mathcal{L} = -g_a \bar{\psi}_a \psi_a H \tag{1}$$

where the constants g_a are different for the different types of particles (labeled by a). The H field has a potential $V(H)$ such that the minimum is at some nonzero value v, so the field H has a classical value v about which it fluctuates. We can then write $H = v + \phi$, so that the field ϕ is classically equal to zero. Then the Lagrangian density above becomes

$$\mathcal{L} = -g_a v \bar{\psi}\psi - g_a \phi \bar{\psi}\psi \ .$$

Since v is just a constant, the first term here acts as a mass term for the fermion. In fact, according to the Standard model, this is the *only* kind of mass term that appears (e.g. the $-m\bar{\psi}\psi$ term in QED is really coming from a coupling (1) to the Higgs, so that $m = g_a v$).

a) Calculate the rate for decay of a Higgs boson to a fermion with mass m and its antiparticle.

b) If $v \approx 250GeV$, and the Higgs mass is around $150GeV$ how does the likelihood to decay to an electron-positron pair compare with the likelihood to decay to a bottom-quark anti-bottom quark (mass $\approx 4.5GeV$)? If these were the only possible decays, what would the lifetime of the Higgs boson be (in seconds)?

Problem 3

Amos and Abigail decide one morning that they would like to make some antimatter. Each of them has a light source capable of producing 1 MeV photons in a uniform beam with cross-sectional area $1mm^2$. If the sources are placed 100m apart and turned on so that the beams are perfectly aligned (head on), how much total energy (in Joules) needs to be expended to produce 1,000,000 positrons?