Problem Set 1 — due Wed. Jan. 21

1. Suppose the electron emitted in beta decay had been trapped inside the nucleus before it was released. If the radius of the nucleus is 1 fm $= 10^{-13}$ cm, what does the uncertainty relation give for the minimum electron momentum in MeV? The minimum energy? Compare this with the maximum electron energies in beta decay, such as tritium, ~ 18 keV. This argument led some physicists in the 1920s to conclude that electrons could not be present in the nucleus (in order to try to get different charge-to-mass ratios for different isotopes), even before the neutron was detected directly.
2. Problem 1.4 of Bettini.
3. Problem 1.8 of Bettini.
4. Problem 1.10 of Bettini.
5. The B meson has two rare decay modes, $B^0 \to K^+\pi^-$ and $B^0 \to \pi^+\pi^-$, which are somewhat hard to distinguish experimentally. Here $m_B =$ 5280 MeV, $m_K = 493.7$ MeV, and $m_\pi = 139.6$ MeV. Assume the B^0 is at rest, and find the magnitudes of the outgoing momenta in the two cases. About how accurately (what percentage error) would you have to measure the momentum to distinguish the two possibilities? Now compute the velocity of the K^+ in the first case, and compare it to the velocity of the π^+ in the second case. Charged particles emit Čerenkov light when their velocity exceeds the velocity of light in a medium, c/n, where n is the index of refraction. What range of n might be used to distinguish the two decay modes, using the presence or absence of Čerenkov light as the criterion?
6. An experiment at SLAC (E158) measured parity violation in electron-electron scattering, $e^-e^- \to e^-e^-$. It scattered 45 GeV electrons off electrons at rest ($m_e = 0.511$ MeV). What is the center-of-mass energy of the collision? The most interesting scattering angle was 90° in the center-of-mass frame; at this angle the parity-violating effects are the largest. What is this scattering angle in the lab frame, or in other words, how many milliradians from the beamline should they put their detector?
Hint: Use the fact that the transverse momenta of the final electrons are invariant under a Lorentz boost along the beamline. Also, neglect the electron mass where it is negligible.