Physics 222 – Test 3 – Spring 2012

One-page reminder sheet allowed. Constants: $c = 3 \times 10^8$ m s^{-1}; $\hbar = 1.06 \times 10^{-34}$ J s; $e = 1.6 \times 10^{-19}$ C; $m_{electron} = 9.11 \times 10^{-31}$ kg = 0.511 MeV; $m_{muon} = 106$ MeV; $m_{\pm pion} = 140$ MeV; $m_{proton} = 1.672648 \times 10^{-27}$ kg = 938.280 MeV; $m_{neutron} = 1.674954 \times 10^{-27}$ kg = 939.573 MeV. *Show all work – no credit given if work not shown!*

1. If the electron had spin 3/2, determine what the atomic numbers Z of the first two elements with closed electron shells would be. Explain how you got your result.

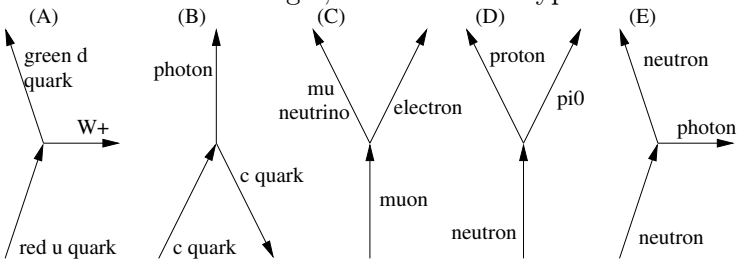
2. Determine the Bohr radius and binding energy of muonic hydrogen, where the electron is replaced by a muon, in terms of the Bohr radius and binding energy for ordinary hydrogen, $a_0 = 5.29 \times 10^{-11}$ m and $E_B = 13.6$ eV. Hint: You may wish to solve this by proportions.

3. The Δ^- particle is made up of three d quarks and has a rest energy of 1232 MeV. A potential decay process is into a neutron (udd) and a π^- ($\overline{u}d$).

   (a) Determine whether this reaction is energetically possible, and if so, determine how much kinetic energy is released.

   (b) Draw a Feynman diagram showing the detailed the processes involving quarks in this decay. Is this a strong, weak, or electromagnetic decay?

4. Determine which of the vertices below is legal, taking into account the quark composition of hadrons as needed. Particles may be virtual, so energy and momentum conservation aren't issues. If a vertex is legal, determine the type of force acting. If it is illegal, state why.



5. Natural uranium at the present day has abundances of 99.28% for U-238 and 0.72% for U-235. Both isotopes are unstable; the half life of U-238 is 4.54×10^9 yr and that of U-235 is 7.04×10^8 yr. The best scientific estimate of the age of the earth is 4.54×10^9 yr.

   (a) Suppose you currently have 6 kg of natural uranium. Compute how much U-235 and U-238 you have.

   (b) Compute how much U-235 and U-238 there was in this sample of uranium at the time the earth was formed, according to the above estimate for the age of the earth.

   (c) Compute the percentage abundances of U-235 and U-238 at this earlier time.

6. Tritium, consisting of one proton and two neutrons, has a binding energy of 8.38 Mev and decays into helium-3, consisting of two protons and one neutron, and two other particles. The binding energy of helium-3 is 7.72 MeV.

   (a) Determine the other two particles released in the decay.

   (b) Determine the kinetic energy (in MeV) released by the decay.