Physics 222 – Test 3 – Spring 2011

One-page reminder sheet allowed. Constants: speed of light 3×10^8 m s^{-1}; Planck's constant 1.06×10^{-34} J s; mass of proton 1.67×10^{-27} kg; mass of electron 9.11×10^{-31} kg; mass of moon 7.36×10^{22} kg; fine structure constant $\alpha = 1/137$; quark charges $u = c = t = 2/3$, $d = s = b = -1/3$. Also, 1 eV $= 1.60 \times 10^{-19}$ J. *Show all work – no credit given if work not shown!*

1. What does the existence of "high momentum transfer" scattering events tell you about

   (a) photons scattered by atmospheric water droplets,

   (b) the Geiger-Marsden experiment (scattering of alpha particles off of gold atoms), and

   (c) high energy proton-antiproton collisions?

2. Protonium:

   (a) Calculate the "Bohr radius" and the binding energy (in electron volts) for an "atom" consisting of an anti-proton orbiting around a proton. Hint: The Bohr radius and binding energy for a normal hydrogen atom are 5.29×10^{-11} m and 13.6 eV. (Since the two particles have equal mass, they actually orbit around a common center of mass half way between them, but ignore this detail here.)

   (b) Are the two particles close enough for strong forces to act? Recall that the inter-nucleon strong force becomes small for separations exceeding about 10^{-14} m.

3. A common decay mode of the Λ^0 particle (quarks: uds) is to a proton (uud) and a negative pion ($\overline{u}d$).

   (a) Does this decay occur by the strong, weak, or electromagnetic interaction? Explain.

   (b) Draw a diagram showing the details of this decay at the quark level.

4. The easiest fusion reaction to induce is between deuterium ($Z = 1$, $A = 2$) and tritium ($Z = 1$, $A = 3$) nuclei, resulting in a helium-4 nucleus and a neutron.

   (a) Are any leptons produced by weak processes in this interaction? Explain.

   (b) Compute the energy released in this reaction. (The binding energy of deuterium is 2.22 MeV, tritium is 8.48 MeV, and helium-4 is 28.30 MeV.)