# PHYS 4134, Fall 2016, Homework #9

**Due Monday, November 14**

## 1. Fusion reactions

If the reaction occurs at a very low initial energy, calculate the energies of each outgoing product in: a) $d(d,\ ^3He)n$ and b) $d(d,\ ^4He)\gamma$. [Hint: part b will require using the quadratic equation. See 11.1 and 11.2 for examples.]

## 2. Tokamak design

If the average magnetic field strength in a tokamak is 5.6T, calculate the radii of curvature for: a) 50 keV deuterons and b) 40 keV tritons and c) 40 keV electrons moving in closed orbits. d) What would be the strength of an electric field E, applied at 90° to the 5.6T magnetic field, which would allow 15 keV tritons to move undeflected in a direction orthogonal to to both E and B? e) What would be the energy of an undeflected deuteron? [Hint: See 11.9 and 11.10.]

## 3. The Early Universe

Approximately 3 seconds after the Big Bang, the ratio of protons:neutrons "froze" when the temperature was $10^{10}$ K.

a) find the energy in MeV at that temperature.

b) Use equation 11.11 to calculate the ratio of neutrons to protons at $t = 0$. [Hint: you need $kT$ for this part, not $\frac{3}{2}kT$.]

c) The neutron has a half-life of 10.24 minutes. About 250 seconds after, fusion reactions converted neutrons and protons into $^4$He nuclei. Calculate the fraction of neutrons still left at 250 seconds after the big bang. The others converted into protons, neutrinos and electrons.

d) What is the ratio of neutrons to protons at t=250 seconds? e) Calculate the ratio of masses of hydrogen to helium (hint: it should be about 3).