Assignment #8 **PHYSICS 8.284**

11:04am Wednesday 19 April 2006

- Shu *The Physics of Astrophysics, Volume II: Gas Dynamics* Chapter 15 pps. 214-217; Chapter 17 (but don't bog down on equations 17.6-17.19, for which you will not be held responsible).

1. The reaction p + n $\leftrightarrow$ d + Q, where Q = 2.2MeV, is an important one in the history of the universe, occuring when its temperature and density were much higher than at present. As time goes by the universe gets cooler and less dense and a larger fraction of the available protons and neutrons combine. Suppose that when the number densities of neutrons and deuterons are equal, $n_n = n_d$, the temperature is $T = 8.62 \times 10^8$K. Find the number density of protons at this time. The deuteron has $g_d = 3$.

(2) In class we derived the jump conditions for adiabatic shocks,

$$\rho_1 v_1 = \rho_2 v_2,$$

$$P_1 + \rho_1 v_1^2 = P_2 + \rho_2 v_2^2, \quad \text{and}$$

$$\frac{1}{2}v_1^2 + \frac{\gamma}{\gamma - 1}P_1/\rho_1 = \frac{1}{2}v_2^2 + \frac{\gamma}{\gamma - 1}P_2/\rho_2.$$

Derive the expressions for ρ_2/ρ_1, P_2/P_1 and T_2/T_1 (in terms of adiabatic index and Mach number) presented without proof in class.

(3) Consider a point explosion with total energy E_{tot} at the center of an infinite star whose density is given by $\rho = \rho_0(r_0/r)^n$.

a) Suppose that explosion generates a stong, self-similar, Sedov-type shock, such that the *temperature* immediately behind the shock varyies inversely as the first power of the time since the explosion. *Find* the numerical value of the exponent n.

b) Consider a point explosion with total energy E_{tot} at the center of an infinite star whose density is given by $\rho = \rho_0(r_0/r)^{32/11}$. This isn't a bad approximation for the envelope of a red giant. Use dimensional arguments to determine the power law dependence of radius and velocity with time.

(4) Consider a *cylindrically* symmetric explosion which releases an energy per unit length λ along the z-axis of a cylindrical coordinate system into a medium of uniform density ρ. Using dimensional arguments, determine the power law dependence of radius and velocity with time.