Astro 112 – Physics of Stars
Problem Set #2, Spring 2017
Due on Wednesday, April 19, 2017

1) The Sun's mass is $2 \cdot 10^{30}$ kg, its radius is $7 \cdot 10^{8}$ m, and its surface T_{eff} is 5,800 K. The energy being radiated away comes entirely the conversion of mass to energy in the Sun's core, via $E=mc^2$. Find the mass loss for the Sun in one second. How many years are needed for the Sun to lose 1% of its mass by radiation?

2) A simple star: given a spherical equilibrium configuration of mass M and radius R, assume that the density distribution is given by $\rho(r)=\rho_c(1-r/R)$. Express all results below in terms of M and R, not ρ_c.

a) Write ρ_c in terms of M and R.
b) Calculate the mass distribution $m(r)$.
c) Calculate the pressure distribution $P(r)$. It is fine to assume $P(R)=0$.
d) Using the M and R values for the Sun (see problem 1), what is the Sun's central pressure? Compare to the real value of 2.48×10^{16} pascals.
e) Assume the ideal gas law, and assume a solar composition mix ($\mu=0.61$), to find the central temperature. Compare to the real inferred value of 1.57×10^{7} K.

3) Two stars are measured to have the same effective temperature of 30,000 K and luminosities of 10^5 L_Sun and 0.1 L_Sun. One of the stars has a radius of 15 R_Sun. What is the radius of the other, in units of R_Sun?

4) Let us assume, for simplicity, that the temperature stratification inside a region of a star is isothermal, with temperature T, and with a constant gravitational acceleration, g. The gas is ideal. Show that the pressure stratification follows the expression:

$$P(r) = P(r_o) \exp(-\mu\, m_H\, g\, r / (k_B\, T)),$$

where r is the distance from a reference radius r_o, μ is the unitless mean molecular weight, m_H is the mass of the hydrogen atom, k_B is Boltzmann's constant, and $P(r_o)$ is the pressure at our reference radius, r_o.