ASTR 688R
Problem Set 2
Due Thursday, March 2

1. Your colleague Dr. I. M. N. Sane has written you an e-mail proposing a new model for how stellar luminosity is generated. In his model, neutrons in nuclei occasionally decay via the pathway $n \rightarrow p + e^- + \bar{\nu}_e + \gamma$, where the antineutrino has practically no energy and momentum, so the photon carries almost all the energy difference between the neutron and the proton+electron. The production of these photons is what generates all the required energy. He tells you that this decay is very rare, and the half-life for decay is about 10^{11} yr. Dr. Sane agrees with the standard picture that the original composition of the Sun by mass was roughly 75% hydrogen and 25% helium. Even supposing that Dr. Sane's particle physics is correct, and that the net energy generation rate per reaction is $m_n c^2 - m_p c^2 - m_e c^2$:

(a) Convince him that his mechanism cannot power the Sun.

(b) Convince him that *regardless* of the half-life for decay, his mechanism will contradict observations.

2. Show for an ideal gas ($\mu/kT \ll 0$) that $P = nkT$ is a general result independent of how relativistic the particles are (i.e., nonrelativistic, partially relativistic, ultrarelativistic, whatever). You may wish to use some of the discussion in section 3.1, plus integration by parts.

3. At the end of the movie "Star Trek: Generations", the nasty weapon employed by the bad guy was a rocket that, when it hit a star, stopped all fusion in the star. This resulted in a virtually instantaneous explosion of the star. Aside from the other physics-violating problems with this (the faster-than-light rocket, the faster-than-light light recording the explosion, and so on), the reaction wouldn't be nearly this fast. Assuming that photons

in the Sun travel by diffusion, that the Sun has a uniform density and is completely ionized, and that the photon cross section is always equal to the Thomson cross section, approximately how long would it take photons to diffuse from the center of the Sun to the surface? How long would it take if the density decreased linearly outwards to zero at the surface, assuming that the mass and radius of the Sun remained the same?

4. Problem 3 from chapter 6 of Hansen & Kawaler (helium core flash). I'll need from you (a) a plot of the temperature as a function of time, and (b) an e-mail copy of your code, which has to be able to compile and run on the astro machines! (i.e., no funky libraries allowed). I'll also need a short write-up of the equations you used.