Ay 101 - The Physics of Stars – fall 2015 - J. Cohen

Homework 3, due Friday Oct 23 at class (2 pm)

1. (5 points) Consider a gas of pure neutral hydrogen with number density $n_H = 10^{17}$ cm^{-3}. Let us assume that the cross section for the absorption of light by nuetral hydrogen atoms is independent of frequency and is 100 times the area of the nucleus of a H atom. What is the absorption coefficient per gram of this gas ? If a tube 1 m long is filled with this H gas, maintaining the value of n_H given above, what is the optical depth of the tube ?

2. (10 points) (a) The amount of energy we receive from the Sun per cm^2 per second just above the atmosphere of the Earth is the solar constant. It has a value of $S = \pi f_\odot = 1.38 \times 10^6$ erg cm^{-2} s^{-1}. Using the distance from the Earth to the Sun, what is the surface flus πF on the Sun. What effective temperature does this imply for the Sun ?

(b) The mean T of the Earth is about 300°K. What fraction of the incident solar energy goes to heat the Earth and what fraction is reflected back into space ? (What approximations have you made, if any, to derive an answer ?)

(c) What fractional change in T_{eff} for the Sun would change the mean temperature of the Earth by 10°K ?

3. (10 points) Assume the specific intensity of the radiation field is $I = I_0 + \mu\ I_1$, where $\mu = \cos(\theta)$. Solve for the radiation pressure P_{rad} and the energy flux carried by radiation in terms of I_0 and I_1. Show that in the solar interior, where all the luminosity is generated at $r < 3 \times 10^{10}$ cm and $T > 3 \times 10^6$K, in that region, I_1 is much less than I_0.

4. (15 points) Evaluate the possibility that conduction transfers the solar luminosity from the center of the star to the surface. We assume a pure hydrogen fully ionized gas. We assume the free electrons are carrying the energy. They move at a speed v_e and travel

a distance l before colliding with the nucleus of an H nucleus and transferring most of their kinetic energy to the H nucleus. The energy flux carried by conduction is given by

$$F(\text{ergs/cm}^2) = -n_e \; l \; v_e \; (dT/dz),$$

where the last term is the temperature gradient. The mean distance between collisions l can be represented as $1/(n_H \; \sigma)$, where σ is the cross section (units cm^2) of the nucleus of a H atom.

a) Evaluate (approximately) the conductive flux between the center of the Sun and its surface.

b) Calculate the flux of energy of radiation per unit area at the surface of the Sun.

c) Is conduction capable of carrying the necessary energy flux from the center of the Sun to its surface ?

d) In what kind of stars would you expect conduction to play an important role in energy transfer ?

5. (5 points) LeBlanc problem 3.4

Optical Depth and Thomson Scattering

Assume that at a given frequency the opacity of the stellar plasma at the surface of a star is dominated by Thomson scattering. Estimate the depth of the atmosphere that is visible to an ouside observer at that frequency, while assuming that the electron density in this region is constant at $n = 10^{16} \, cm^{-3}$. What percentage of the solar radius is this value?