Ay 7A - Fall 2009
Review Sheet 2
Given the constants and equations sheet, you should feel fairly comfortable solving these problems.

Radiation and Radiative Transfer

1. The flux transmitted through a slab of material can be written:

$$F = F_0 e^{-\rho\kappa x}$$

   (a) What does F_0 represent?
   (b) Why is there a negative sign in the exponent?
   (c) Why should F be proportional to $e^{-\rho}$?
   (d) What is the mean molecular weight, μ?
   (e) How is ρ related to n and μ?
   (f) Why should F be proportional to $e^{-\kappa}$?
   (g) How is κ related to σ and μ?

2. Optical depth can be defined as:

$$\tau = \int \rho\kappa dx$$

   (a) What is optical depth?
   (b) What do the terms “optically thin” and “optically thick” mean?
   (c) Use a Taylor expansion to rewrite the equation for $F(\tau)$ in the optically thin regime.
   (d) Why do astronomers often say we “see down to optical depth of 1”?

3. At visible wavelengths the extinction (absorption + scattering) cross-section of the average interstellar dust grain is $\sigma_d = 6 \times 10^{-10}$ cm^2. Also, the ratio of the number densities of dust and gas in the ISM is $\left\langle \frac{n_d}{n_g} \right\rangle = 8 \times 10^{-13}$. The density of gas in the ISM (atomic hydrogen mostly) is 50 cm^{-3}.

   (a) Write out the expression for the optical depth of dust in the ISM at visible wavelengths given this information and a path length l.
   (b) What is l for $\tau = 1$?
   (c) The number density of gas in this room is about $n_g = 2 \times 10^{19}$ cm^{-3}. If the dust-to-gas ratio in this room were the same as in the ISM, what would l be for $\tau = 1$?

4. A cylinder of ionized hydrogen gas is placed 0.5 AU from the Sun. The slab has a length $l = 1$ km and has a circular cross-sectional area (facing the Sun) of radius $b = 100$ km. Assume the opacity, κ, is due to Compton scattering of electrons which we can approximate using the Thomson cross-section (i.e., $\kappa \approx \kappa_{\text{Thomson}} = 1$ cm^2/g).

   (a) How much energy per second does the cylinder of gas receive from the Sun?
   (b) What is the electron density if the flux of scattered light is 7.3×10^4 erg/cm^2/s?
   (c) What is the total mass of the slab?

Stellar Atmospheres

1. Under what conditions would a star have no limb brightening?
2. Why do we usually get absorption lines at visible wavelengths in the solar spectrum?
3. Why is opacity important for stellar structure? In other words, what would happen to a star if $\kappa = 0$ throughout its interior?
4. Using optical depth arguments, explain why the Ring Nebula looks like a ring (recall that it's actually an optically thin spherical shell of gas).
5. Consider the star at the center of the Ring Nebula and assume the shell isn't moving.
   (a) Do you see absorption or emission lines at the center?
   (b) What about towards the edges (or limb)?
   (c) Draw a spectrum for each case.
6. Repeat the above problem but now assume that the shell is expanding radially outward with velocity v. How do the spectra for the above cases change?

Stellar Structure

1. Pressure vs. Gravity
   (a) What is hydrostatic equilibrium and what is the equation for it?
   (b) What is pressure?
   (c) What kinds of pressure are there?
   (d) When is each kind of pressure important in stellar interiors?
2. What are the other equations of stellar structure?
3. Explain the equations of stellar structure in words.
4. Estimate the central temperature of the Sun.
5. Why doesn't helium fusion take place in main sequence stars?
6. In Ay 10 we teach the students that $L \propto M^5$ for solar-like main sequence stars and they have to take it on faith. You're not gonna take it, no, you ain't gonna take it, so derive this proportionality.
7. Consider main sequence lifetimes of stars.
   (a) How does the main sequence lifetime of a Sun-like star scale with mass?
   (b) How does the main sequence lifetime of a 0.5 solar mass star compare to the Sun?
   (c) How does the main sequence lifetime of a 5 solar mass star compare to the Sun?
   (d) Qualitatively, explain why more massive stars die quicker (i.e., have shorter main sequence lifetimes).
8. Astronomers sometimes say that main sequence stars are "perfect thermostats".
   (a) What do we mean by this?
   (b) What happens if a main sequence star gets too hot in its core?
   (c) What if it gets too cold?
9. What would happen to a star's physical characteristics if you somehow compressed it to half its original radius?
10. Why is there a well-defined line of stars on an H-R diagram (i.e., the main sequence)?
11. At a fixed temperature, which has a higher gas pressure: a gas of neutral hydrogen or a gas of ionized hydrogen?