Stellar Structure & Evolution, Fall 2003
Problem Set 1

Due date: Monday, 8 September 2003 at 17:00

Note: To get full credit, each response must have a proper explanation, meaning for example that variables are defined, all relevant assumptions are stated clearly, and the answer is generally understandable to a reader who does not necessarily have the text of the question at hand. If you have any questions about this requirement, please send an e-mail to Michelle and/or ask to have this be discussed in class.

1. Terminology check

(a) What is the *H–R diagram*? How does it help us to understand more about stars?

(b) What is the *main sequence*? Note the principal characteristic of stars on the main sequence and mention some of the consequences of this fact, e.g., in terms of observable quantities or stellar properties.

(c) What is meant by *equation of state*? Give the equation(s) of state necessary for calculations of stellar structure.

(d) What is an *adiabatic* process? What is the corresponding equation of state and how does it relate to your previous answer?

2. Characteristic numbers

What is the range in mass, radius, effective temperature and luminosity for stars on the main sequence? Discuss what determines the lower and upper limits.

What are the corresponding values in the surface gravity $\log g$? What are the corresponding dynamical, thermal and nuclear timescales?

3. Observations

Chapter 1.4 of the book begins with the following sentence: "As we have seen, the two most fundamental properties of a star that can be inferred from observation are the luminosity L and the effective temperature $T_{\rm eff}$."

Suppose an astronomer has measured the flux at Earth from a star at two particular wavelengths. Explain how to obtain L and $T_{\rm eff}$ from this and discuss some of the difficulties or uncertainties involved.

4. Gas degeneracy

(a) Explain what is meant by a *degenerate gas* (and full or partial degeneracy). Discuss and plot the speed distribution. Why is the degenerate gas pressure higher than what you would expect from the ideal gas law?

(b) Under what kinds of physical conditions do you expect degeneracy, and how can it be lifted?

5. Radiative temperature gradient

Derive the temperature equation

$$\frac{dT}{dr} = -\frac{3}{4ac}\frac{\rho\kappa}{T^3}\frac{L(r)}{4\pi r^2} \tag{1}$$

directly from the radiative transfer equation

$$-\frac{\mu}{\rho\kappa_\nu}\frac{dI_\nu}{dr} = I_\nu - S_\nu\,, \tag{2}$$

where $\mu = \cos\theta$ and θ is the angle between the light ray and the outward radial direction.

Hint: Introduce the Rosseland mean opacity κ, which is defined via the relation

$$\frac{1}{\kappa}\int_0^\infty \frac{\partial B_\nu}{\partial T}\,d\nu \equiv \int_0^\infty \frac{1}{\kappa_\nu}\frac{\partial B_\nu}{\partial T}\,d\nu \tag{3}$$

6. Student feedback

Yes, you do get credit for answering these annoying questions!

(a) What point(s) in the book or lecture were not very clear?

(b) What topic(s) would you like to hear/talk more about in the tutorial?

(c) If you were the teacher, what question(s) would you ask about the material covered so far?

And finally, a note from your friendly local advertiser:
Looking for a less boring problem to sink your teeth into? Want a real-life example (well, okay, as real as we're gonna get around here) to let you practice thinking like an astrophysicist? Check out the course Web page later this afternoon!