Physics of Stars

Problem Set 4
Due Mon, October 28, 2002

1. In this problem we apply the Eddington approximation with boundary conditions from
the two-stream approximation to determine what happens when an incident radiative
flux $F_I$ falls on a planetary atmosphere that only scatters radiation (no absorption or
emission) that lies above a ground that absorbs all radiation. Let $F_R$ be the reflected
flux. Take the atmosphere to have optical depth $\tau_*$ and the ground to be completely
absorbing (i.e., neglect any energy emitted by the ground).
a. Calculate the mean intensity $J(\tau)$ as a function of optical depth $\tau$ in the atmosphere.
b. Solve for $F_R/F_I$.
Cc. Determine the limb darkening function $I(\mu)/I(0)$.

2.
   a. Calculate the ratio of $\text{H}^-$ to neutral hydrogen for $T = 6000$ K and an electron
      pressure of 30 dynes/cm$^2$. Assume all the atoms in a given ionization state are in
      the ground state of that ion. The statistical weight for the ground state of neutral
      hydrogen is 2 and that for $\text{H}^-$ is 1. The ionization potential of $\text{H}^-$ is 0.7 eV.
b. For a wavelength near 6000 Å, which levels of H can contribute to the bound-free
   opacity? What is the population of those levels relative to the ground state? What
   is the ratio of the $\text{H}^-$ bound-free opacity to that of H at that wavelength? What
   happens at a wavelength of 3000 Å? What has changed there?

3. Make a flow chart for a program that computes model stellar atmospheres. Your flow
chart should contain at least 5 and not more than 25 subroutines. Provide a few-sentence
description of the function of each of the subroutines in your program.

4. Imagine that for the stellar atmosphere for the Sun, the only source of opacity was hydro-
gen absorption; i.e., neglect $\text{H}^-$, metals, etc. Calculate the emergent energy distribution
in the continuum. For simplicity, use a grey atmosphere temperature distribution and
a depth-independent absorption coefficient; i.e., use $\kappa(H)$ for $T_{\text{eff}} = 5800$ K. Plot the
emergent flux $F_\lambda(0)$ for the surface. Describe qualitatively how inclusion of $\text{H}^-$ and
free-free emission would change your results.