Astronomy 223
Planetary Physics
Winter 2011
Problem Set #1
January 26, 2011
Due: Friday, Feb. 4th

1) Derive the average equilibrium temperature, $T_{eq}$, for a planet with Bond albedo $A_B$, stellar luminosity $L$, semimajor axis $a$, and planetary orbital eccentricity $e$.

2) For an $n$-layer leaky greenhouse model, show that the surface temperature $T_s=(n+1)^{1/4}T_e$, where $T_e$ is the emission temperature in the highest atmospheric layer.

3) Over a region where the temperature changes linearly with height and where $g(r)$ is a constant, show that the pressure, density, scale height, and radius are related by:

$$\frac{p}{p_o} = \left(\frac{H}{H_o}\right)^{-1/\beta} \quad \text{and} \quad \frac{n}{n_o} = \left(\frac{H}{H_o}\right)^{-(1+\beta)/\beta}$$

where $\beta = dH/dr$ and $p_o$, $n_o$, and $H_o$ are the values at a starting distance $r_o$.

4) Assume that solar radiation is absorbed only at the Earth's surface, where the albedo is 0.40. The re-radiated energy is absorbed mainly by water vapor, which we approximate as a gray absorber with a density scale height of 2 km and a total tau=2. Plot the temperature distribution with height for radiative equilibrium. What is the temperature discontinuity at the ground? What is the gradient in the air temperature just above the ground?