

ASTRO 342 – FALL 2006

**Problem Set #3 - DUE Mon., Oct. 16**

**For reference, the values for the solar radius, mass and luminosity are:**

**$M = 2 \times 10^{30}$  kg.,  $R = 7.0 \times 10^8$  m,  $L = 3.9 \times 10^{26}$  W. The radiation constant is:  
 $\sigma = 5.67 \times 10^{-8}$  W m<sup>-2</sup> K<sup>-4</sup>.**

*Problems from De Pater and Lissauer:*

1. (4.1) Calculate the approximate pressure scale height near the surfaces of Earth, Venus, Mars, Pluto, and Titan, and at the 1 bar levels of Jupiter, and Neptune. Comment on similarities and differences.
2. (4.2) Although in some respects the Earth and Venus are 'twin planets,' they have very different atmospheres. For example, the surface pressures on Earth and Venus are 1 bar and 95 bars, respectively. Calculate the mass of each atmosphere both in grams and as a fraction of each planet's total mass. Recalculate these values for Earth including Earth's oceans as part of its 'atmosphere.' (If all of the water above Earth's crust were spread evenly over the planet, this global ocean would be about 3 km deep.) Compare the calculations for the two planets and comment on the results.
3. (4.12) Consider a parcel of dry air in the Earth's atmosphere. Show that if you replace some portion of the air molecules (80% N<sub>2</sub>, 20% O<sub>2</sub>) by an equivalent number of water molecules, the parcel of air becomes lighter and rises.

*Note: the next 4 problems have been taken (and modified) from the text of Zeilik, Gregory and Smith (Saunders College Pub.).*

4. a) Suppose that the inner solar system was very dusty (at a young age), and 50% of the sunlight in the optical (e.g., wavelength = 500 nm) is absorbed and re-emitted in the infrared. Using the solution of the radiative transfer equation without sources, find the optical depth at this wavelength?  
  
b) Suppose that the mean orbital radius of this dust is about equal to Mercury's mean orbital radius, and that this absorption is the primary heat source of the dust. Assuming that heating is balanced by thermal radiation, estimate the thermal temperature of the dust.
5. Use the blackbody radiation law to estimate the wavelength of maximum intensity for the light from the photosphere (5800 K) and corona ( $\approx 3,000,000$  K).

6. A sunspot's umbra has a temperature of only 4000 K. At an equal optical depth of  $\tau = 1.0$ , the umbra is about 1800 K cooler than the photosphere. Calculate the umbral intensity contrast,  $I_U/I_{ph}$ , at wavelengths of 550 nm and 1.0 micron (micrometer). Compare to the observed values of 0.1 at 550 nm and 0.23 at 1.0 micron.
7. Using the Stefan-Boltzmann Law with reasonable values for the temperature and radius, estimate the energy output of the Sun's photosphere and corona in watts. Compare your results for these layers to the value of the total solar luminosity. Comment on the validity of the blackbody (thermal radiator) approximation for the corona.
8. **Heating the Planet** a) Suppose that Earth's atmosphere absorbs 100% of the solar radiation it receives, distributes it uniformly around the planet, and reradiates it like a perfect thermal radiator. (Actually these are better approximations for Venus.) Estimate the Earth's surface temperature in this situation.
- b) Now suppose instead that while the Earth's surface is again a uniform perfect absorber and emitter on the light side, that none of the heat is communicated to the dark side. (This is more like the Moon.) What is the surface temperature of the bright side?
9. **Solar Activity** A large solar flare has an energy of order  $10^{25}$  J, which is released over about an hour. Suppose that roughly 50% of the flare energy is radiated as 1.0 KeV (kilo electron volt) X-rays.
- a) What is the X-ray luminosity of the flare, and how does it compare to the total average luminosity of the Sun?
- b) Assume that the cross section of a human is about  $1.0 \text{ m}^2$ , and assume that the flare X-rays are emitted isotropically into a hemisphere of the sky around the flare site. What is the total dose (net flux) of X-rays received by an astronaut working on the space station in orbit around the Earth? What dose would be received by an astronaut on the light side of Mercury?
- c) A dose of about  $1.0 \times 10^{12}$  X-ray photons per  $\text{cm}^2$  is needed to liberate 1 rad in carbon (which equals 1 rem in carbon, assuming a "quality factor" of unity). An exposure of more than 0.2 rems is dangerous. (Radiation data from the Handbook of Space Astronomy and Astrophysics, Zombeck.) Are the astronauts at Earth and Mercury in any danger?