Meteorology 3510
Exercise #1
Due Thursday, January 17, 2008

These exercises accompany sections 1 and 2 of the thermodynamics notes. In these exercises, you will apply the equation of state of an ideal gas and Dalton's Law.

1. (a) A sample of hydrogen gas is at a pressure of 1000 mb and a temperature of $+10°$ C. Calculate its specific volume and its density.
   (b) A sample of dry air is at a pressure of 850 mb and a temperature of $+20°$ C. Calculate its specific volume and its density.
   (c) A sample of dry air at a pressure of 500 mb has a density of 0.8 kg m^{-3}. What is its temperature?
   (d) A sample of dry air at a temperature of 300 K has a density of 0.5 kg m^{-3}. What is its pressure?

2. From the data given in Table 1 of the notes for the four most abundant constituents of dry air, calculate the mean molecular weight of air to four significant figures. Compare your result with the value given in section 2 of the notes.

3. Determine the mean molecular weight of the Venusian atmosphere, assuming that it consists of 95% $C0_2$ and 5% N_2 by volume. What is the specific gas constant for such an atmosphere?

4. Write a program using MATLAB to calculate the isotherms of an $\alpha, -p$ diagram for dry air for temperatures of 200 K, 300 K, and 400 K. **IMPORTANT:** Let the pressure vary from 1000 mb (100 kPa) to 200 mb (20 kPa) and let α range from 1 m^3 kg^{-1} to 2.5 m^3 kg^{-1}. Use MATLAB to plot the isotherms on a single graph similar to Figure 1 of the notes. *Include a title and axis labels, and label the isotherms.* Print and submit your program and your plot.

Problems 5, 6, and 7 are on the reverse side.

5. (a) Pressure is force per unit area. Weight is force (mass times acceleration). Atmospheric pressure is the weight of the overlying atmospheric column divided by the column's area. At sea level, the atmospheric pressure is about 14.7 pounds per square inch (psi). A *pound* used in this context is a unit of force equivalent to 4.448 newtons (nt). An inch equals 2.54 cm. Convert 14.7 psi to Pascals (nt/m^2).
(b) Because pressure is so often measured with mercury barometers, the height of the mercury column has often been used as a unit of pressure. The conversion between the column's height and other pressure units can be calculated using the density of mercury (13.60 g/cm^3) and the acceleration of gravity (9.806 m/s^2). One atmosphere (atm) is defined as 1013.25 mb (hPa); this is approximately the mean sea level pressure. Calculate the height of the mercury column in inches and in millimeters that corresponds to one atmosphere?

6. (a) Suppose that you wake up one morning to discover that the tire on your bicycle is completely flat. You have a pressure gauge, with which you can verify that the tire pressure is indeed zero. Do you then deduce that a flat tire contains a perfect vacuum?
(b) During a 3-day drive from Texas to Iowa during December, the temperatures ranged from 80 to 20°F. If the tires on the car did not leak during this trip, how much variation in tire pressure might have been expected? Tire pressure is measured after the car has been sitting idle for several hours. Assume that a tire gauge indicated 40 psi (pounds per square inch) for all tires at the beginning of the trip (when the temperature was 80°F). *Hint:* Don't do this part of the problem before you understand part (a).

7. One way that pressure is regulated in a pressure cooker is to put a weight over a small opening in the lid of the cooker. As the cooker is heated, the internal pressure increases until the weight is lifted slightly and gases exit the cooker, thereby decreasing the internal pressure until the weight again prevents gases from exiting the cooker. If the mass of the weight is 0.1 kg and the diameter of the opening is 2.5 mm, at what *internal* pressure will gases begin to escape from the cooker? Assume an *external* (atmospheric) pressure of 1000 mb (10^5 Pa). When you obtain your answer, ask yourself if it makes sense on the basis of what you know (or can learn) about pressure cookers.