ATM 320 Homework # 2
Due Tuesday 20 September

Answer the following questions on a separate sheet of paper. SHOW ALL WORK!

1) This problem makes use of the form of the equation of state expressed in terms of the universal gas constant: \( pV = nR^*T \).
   
a) Calculate the molar volume (cm\(^3\) mol\(^{-1}\)) of an ideal gas at a temperature of 0\(^\circ\)C and a pressure of 1013.25 hPa.
   
b) What is the diameter (cm) of a sphere occupying the volume calculated in part (a)? (For comparison purposes, the diameters of a soccer ball and a basketball are 22 cm and 24 cm, respectively.)
   
c) Recalling that \( n = M/m \), where \( M \) is the mass of a sample of an ideal gas and \( m \) is its molecular weight, show that the ideal gas law may be expressed equivalently as \( pV = MR^*T \), where \( R \) is the gas constant (\( R = R^*/m \)).
   
d) Use the form of the ideal gas law derived in part (c) to calculate the mass of dry air in units of kg for a room with dimensions 3 m high by 4 m wide by 5 m deep, a pressure of 1013.25 hPa, and a temperature of 71\(^\circ\)F.

2) The atmosphere of Mars is composed of 95.32\% CO\(_2\), 2.7\% of N\(_2\), 1.6\% Ar, 0.13\% of O\(_2\) and 0.18\% of CO.
   
a) Compute the mean molar mass of the Martian atmosphere
   
b) What is the gas constant for Mars? How does this compare to the dry-air gas constant?
   
c) The average surface pressure and temperature on Mars is 0.6 kPa and -55\(^\circ\)C. What is the typical surface density?
   
d) The surface temperature on Mars can vary from a high of 20\(^\circ\)C near the equator during the day and -153\(^\circ\)C at night at the poles. Given the density computed for c), what is the difference in surface pressure between these two locations?

3) On 11 August 2017, weather conditions at Montauk, NY (KMTP), at 11:54 a.m. EDT were as follows:
The weather observed at MONTAUK, NY (KMTP) at 11:54 AM EDT was: Temperature: 77°F (25°C) Dewpoint: 59°F (15°C) Relative humidity: 54% Winds variable in direction at 3 mph. Sea level pressure: 1021.9 millibars. Altimeter setting: 30.18 inches of mercury. The saturation vapor pressure, e_s, at KMTP, based on the air temperature of 25.0°C, is 31.6874 hPa.

The elevation of KMTP (2 m, refer to http://weather.rap.ucar.edu/surface/stations.txt) is close enough to sea level to approximate the station pressure by the sea level pressure. Given this information, calculate the following quantities for the KMTP observation reproduced above. Perform the calculations in the requested order and use “exact” formulas for each calculation. Show your work, including the formulas selected for each calculation, and be very careful with units.

a) saturation mixing ratio (g kg$^{-1}$).

b) mixing ratio (g kg$^{-1}$).

c) specific humidity (g kg$^{-1}$).

d) vapor pressure (hPa).

e) volume fraction of water vapor (%).

f) virtual temperature (°C).

g) moist air density (kg m$^{-3}$).

h) water vapor density (kg m$^{-3}$).

4) One can show that the buoyant force per unit mass (i.e., acceleration) can be written as:

$$F_b = \frac{\rho - \rho_p}{\rho_p}g,$$

where $\rho_p$ is the density of an air parcel, $\rho$ is the density of the environment and $g$ is the acceleration due to gravity.

a) Assuming that the parcel has a temperature of 20°C and the environment has a temperature of 18°C, what is the buoyant acceleration?

b) If the parcel has a mixing ratio of 2 g kg$^{-1}$, how does this change the buoyant force? How about if the mixing ratio is 10 g kg$^{-1}$?