PHY 201 Homework 12

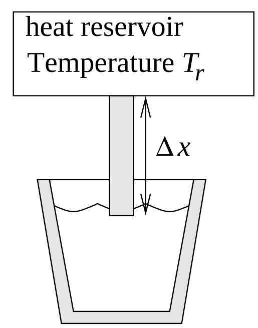
Due at noon Friday, December 13 at SE 316.

1. I have a one liter container which is filled with air. I lower the temperature of the air in the container to 0° C and close up the container. What is the pressure of the air in the container at this point? Now, I heat up the air in the container to 100° C, keeping the volume constant. After I do this, I measure the pressure in the container to be 1.365 ± 0.005 atmospheres. Assuming that air is well approximated by the ideal gas law, find the temperature for absolute zero, along with its error.

2. In Experiment 12, we assume that the temperature of the water in the cup is an exponential function of time. In this exercise, we will derive this result.

   (a) Consider a cup of water, mass m. Find a relation between the heat Q and temperature T_w of the water.

   (b) Imagine that this cup of water is connected to a thermal reservoir, temperature T_r, via an Aluminum rod. (A thermal resevoir is a large body that is assumed to have constant temperature.) The rod has length Δx and cross sectional area A. Look up the definition of thermal conductivity in your textbook and derive an expression for dQ/dt in terms of the temperatures, *et cetera*.

   (c) Use your answer to find a first order differential equation for T_w.

   (d) Show that the *Ansatz*

   $$T_w(t) = T_r + Be^{-\gamma t}$$

   is a solution of this equation. Find an expression for γ.

   (e) Choose values for the parameters and find a numerical value for γ.

   Note that the constant B is not fixed by this analysis. This "boundary condition" is fixed by demanding that the initial temperature has a certain value.

3. Use the Gibbs distribution to show that the average velocity $\langle \mathbf{v} \rangle$ in an ideal gas is equal to zero.

4. Use the Gibbs distribution to find the root-mean-square (RMS) velocity of molecules in an ideal gas. First, calculate $\langle \mathbf{v}^2 \rangle$ and then take the square root $\sqrt{\langle \mathbf{v}^2 \rangle}$. What is the RMS velocity, in meters per second, of the following gases at room temperature and pressure: H_2, He, and N_2?

5. Look up the density of liquid Nitrogen. Using the ideal gas model, what pressure would I need in order to achieve the same density at 20° C? At this pressure, the ideal gas model is no longer valid for Nitrogen.