Assignment 16

1. Some questions about air.
   a. Explain why warm air rises.
   b. Explain the afternoon sea breeze.
   c. Explain why an air bubble in water grows in volume as it rises.
   d. Show that the upward acceleration of an air bubble in water is not constant, but increases with time.

2. Iced tea is made in a thermos bottle (which effectively prevents heat flow) by putting 700 g of hot tea at 90° C and 160 g of ice at 0° C into the bottle.
   a. When thermal equilibrium is reached, what state variable for the system has remained unchanged?
   b. What is the final temperature?
   c. How much of the ice melted?
   d. If the ice started at −10° C, what would your answers to (b) and (c) be?
   [Use \( c = 1.00 \) for tea (essentially water), \( c = 0.530 \) for ice, both in cal/g-K; use \( L_f = 333 \) cal/g for ice.]

3. One mole of helium (\( c_V = 3R / 2 \)) at temperature 300 K occupies a volume of 20 L. The gas is expanded at constant pressure to a volume of 40 L, and then expanded adiabatically until the temperature returns to 300 K.
   [Take \( R = 0.08 \) L-atm/mol-K, and express all energies in L-atm.]
   a. Sketch the process on a \( P-V \) diagram.
   b. What is the heat input in the constant pressure step?
   c. What is the total work done in both steps? [What is the change in temperature in the adiabatic step?]
4. Questions about thermal processes for an ideal gas.
   a. Show that the work done in isothermal expansion at temperature $T$ from volume $V_i$ to $V_f$ is $W(i \rightarrow f) = nRT \cdot \ln(V_f / V_i)$.
   b. Show that the work done in an adiabatic expansion that takes the gas from volume $V_i$ to $V_f$, starting at pressure $P_i$, is
   
   $$W(i \rightarrow f) = \frac{P_i V_i}{\gamma - 1} \left[1 - \left(\frac{V_i}{V_f}\right)^{\gamma - 1}\right].$$
   c. Show that this work can be expressed more simply in terms of the temperatures as $W(i \rightarrow f) = \frac{nR}{\gamma - 1}(T_i - T_f)$.
   d. Show that this is the same as $-\Delta E_{\text{int}}$ for the process. [No surprise.]

5. Newton made a calculation of the speed of sound in air, assuming it was an ideal gas and that the changes in pressure as the wave went past a point occurred at constant temperature. This was one of the rare times when his calculations were wrong.
   a. What error did he make?
   b. The correct formula for an ideal gas is $v = \sqrt{\frac{\gamma RT}{M}}$. What was Newton’s formula?

6. An ideal gas starts at pressure $2P_0$ and volume $V_0$. It is expanded until the pressure drops to $P_0$. We consider three different processes: (1) the gas is expanded adiabatically; (2) it is expanded isothermally; (3) the expansion follows a straight line on a P-V diagram until the pressure is $P_0$ and the volume is $2V_0$.
   a. Draw the three processes on a P-V diagram.
   b. For (1) and (2) find the final volume.
   c. Find the work done by the gas in all three cases.
   d. For all three cases, find the change in internal energy.
   e. For all three cases, find the heat taken in.