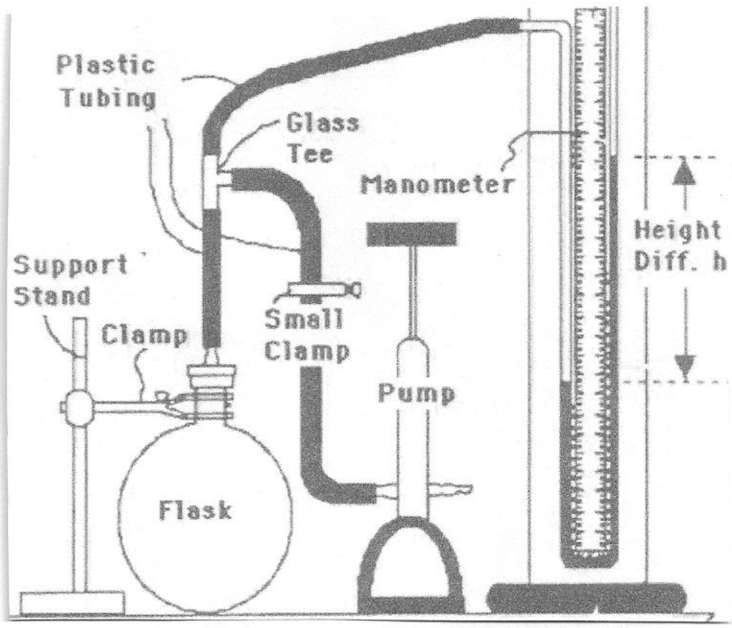
4C Lab – The Clément-Desormes Experiment

Goal: To determine gamma, $\gamma = C_p/C_v$, for air

Equipment:

- Manometer
- Flask with drying agent
- Rod and clamps
- Hand pump and tubing with hose clamp
- Vacuum grease

Diagram of setup:



Pre-lab exercise: Derive equations (6) and (7)

Background: A method to determine gamma, the ratio of heat capacity at constant pressure to the heat capacity at constant volume for an ideal gas, was proposed by Clément and Desormes. The method consists of allowing an ideal gas to undergo a quasi-static adiabatic expansion followed by a constant volume process.

When the flask is closed, a mass of dry air of volume V_o at atmospheric pressure P_o is partly inside the flask and partly outside the flask. When the air from outside the flask is slowly pumped into the flask the volume is reduced to the volume of the flask, V_1, and the pressure is increased to P_1. A U-tube manometer indicates a height difference recording the pressure change:

(1) $$P_1 = P_o + \rho_{oil} g h_1$$

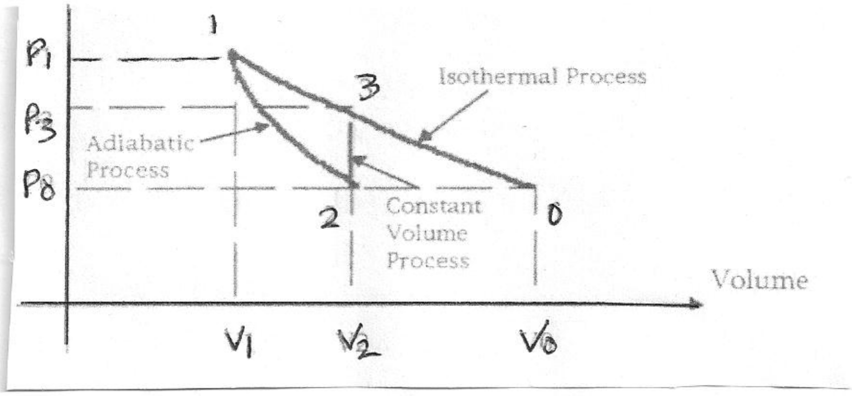
When the lid of the flask is quickly opened and closed, the extra air is allowed to escape the flask and the pressure returns momentarily to atmospheric. The sample expands adiabatically ($P_2 = P_o$, $T_2 < T_o$) and the temperature of the gas falls below ambient. Since PV^{γ}= *constant* along an adiabatic process:

(2) $$P_1 V_1^{\gamma} = P_2 V_2^{\gamma}$$

Finally, the sample is allowed to warm up slowly at constant volume. $T_3 = T_o$, $V_3 = V_2$ (although we don't know the exact volume since V_2 represents some of the gas outside and some inside the flask)

(3) $$P_3 = P_o + \rho_{oil} g h_3$$

The P-V diagram for this process is:



Since the product PV is constant along an isotherm:

(4) $$P_oV_o = P_1V_1 = P_3V_3$$

Combining equations (2) and (4) and taking the natural log of both sides we obtain:

(5) $$ln(P_1/P_o) = \gamma\, ln(P_1/P_3)$$

In terms of variables measured in lab:

(6) $$ln\left[1+\left(\rho_{oil}gh_1/P_o\right)\right] = \gamma\left\{ln\left[1+\left(\rho_{oil}gh_1/P_o\right)\right] - ln\left[1+\left(\rho_{oil}gh_3/P_o\right)\right]\right\}$$

If $\rho_{oil}gh/P_o$ is small when compared to one (1), we can approximate using $x << 1$, $ln(1+x) \sim x$
Then, equation (6) becomes:

(7) $$h_1 \cong \gamma(h_1 - h_3)$$

Procedure:

1. Set up the equipment as shown in the diagram. Remember, the flask has a round bottom and needs support. Place a small amount of blue drying agent in the flask. (Pink agent no longer absorbs moisture well.)
2. Record the values for atmospheric pressure and density of oil. (the specific gravity of the oil is 0.841 at 20°C) Your value for the pressure must be in pascals.
3. Leak test the system by pumping on the system with the hose clamp open, closing the clamp and observing the manometer oil level.
4. CAREFULLY add air to the system by pumping on it. Close the clamp. ****Measure h_1*****
5. Quickly remove the lid and replace it. Allow the system to warm up. ****Measure h_3*****
6. Repeat for a total of 5 sets of manometer readings. The data should be spread out, so pump to varying initial heights.

Analysis: Using excel, graph both equation (6) and equation (7) to determine gamma.
Conclusion: Compare your values for γ with the accepted value for dry air (a diatomic gas).