Experiment 10

Adiabatic Compression

In this experiment you investigate a **thermodynamic cycle** by systematically squeezing and releasing air in a sealed container. You will likely find that it takes work to use it, so it would be considered a heat pump rather than a heat engine. You will apply a simple **ideal gas** model to your measurements to determine the **ratio of specific heats** of air.

Preliminaries.

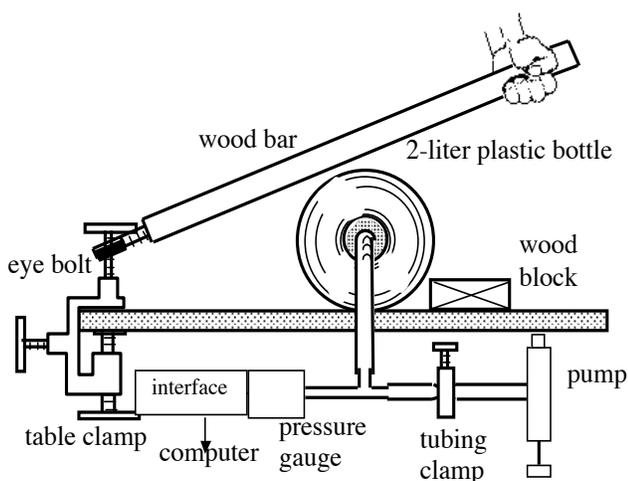You can use the apparatus below to compress gas and allow it to expand again.

Figure 1. Schematic of experiment

The gas pressure gauge allows you to measure and record pressure as a function of time throughout the experiment. The pressure gauge should be connected to the interface and then to the computer.

The thermodynamic cycle consists of the following steps:

Starting with an inflated (pressurized) bottle of air,

You can compress the gas, wait, and then allow the gas to expand again.

Steps 1 and 3 are *modeled* as **adiabatic** processes. Should you do this fast or slowly?

Steps 2 and 4 are *modeled* as isometric (or isochoric) processes, where heat is added to or removed at constant volume.
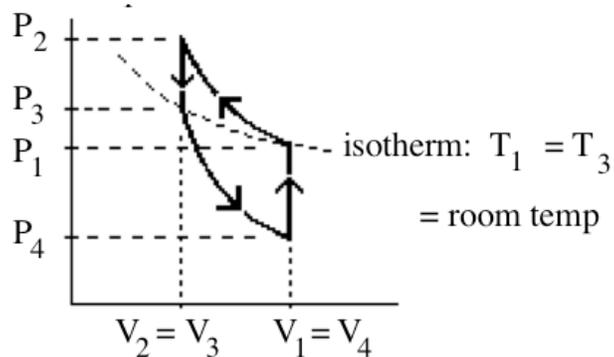

Figure 2. PV diagram for the cycle

Please identify the adiabatic curves. These curves are described by the equations

$$p_1 V_1{}^\gamma = p_2 V_2{}^\gamma$$

$$p_3 V_3{}^\gamma = p_4 V_4{}^\gamma \qquad \text{(eqs.1)}$$

where

$$\gamma = C_p/C_V$$

where C_p (C_V) is the **specific heat** of the gas at constant pressure (volume). Can you express this in terms of degrees of freedom of the gas. What is the number of degrees of freedom of air? Consider air is mostly N_2 and O_2 where the rotational modes are active, but the vibrational modes are *frozen out*.

Please show how γ can be expressed as:

$$\gamma = \frac{\log\left(\dfrac{p_1}{p_2}\right)}{\log\left(\dfrac{p_1}{p_3}\right)} \qquad \gamma = \frac{\log\left(\dfrac{p_3}{p_4}\right)}{\log\left(\dfrac{p_3}{p_1}\right)} \qquad \text{(eq. 2)}$$

Procedure

• Double-click on the icon labeled **pressure** on the computer desktop. This will load the experiment file. If asked about loading a calibration click **Yes**. You should now see a graph of pressure vs. time displayed on the computer screen. The pressure scale should be 0-2 atm and the time should be 0-30 s. If not, adjust it. (To change the axes scale click on the minimum or maximum value shown. It will turn into a little text entry box, you can enter a new

number.)   The current pressure is indicated on the left in the lower portion of the graph window.

• Check your system for leaks. If you leak air, then the measurements won't work.

• Click the "Start" button to begin taking data. A horizontal line at p_1 starts to appear.

• Once you have a good data set you can save it using **File/Save As…** or print out your graph using the **File/Print Graph** menu choice. Select **Examine** from the **Analyze** menu. Move the cursor to each of the points on the graph and record accurate values for the pressures p_1 through p_4.

• Graph your PV cycle as accurately as possible and calculate γ by both equations given above.

Questions (Answer clearly and completely).

1. What is your experimental value for γ and how close is it to your theoretical value of what air should be? What is the % disagreement and is this within your expected uncertainty?

2. Given that you start with a 2 liter bottle, can you use your data and the ideal gas law to determine the volume of your squeezed bottle?

3. Use your data to calculate your highest and lowest temperature during your experiment. What temperature units should you use?