Fluids, Thermodynamics, Waves, & Optics
Fluids
Lab 5
The Clément-Desormes Experiment

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Overview

- Purpose

- Equipment & Setup

- Theory

- Procedure

Purpose of the Lab

To experimentally determine the ratio $\gamma = \frac{C_P}{C_V}$ for dry air.

You will measure pressure at two points in a series of thermodynamic processes on a sample of air.

From these two pressure readings, you will be able to determine γ by plotting a graph.

You will compare your value for gamma to the accepted value for a diatomic gas by calculating the percentage error.

Equipment
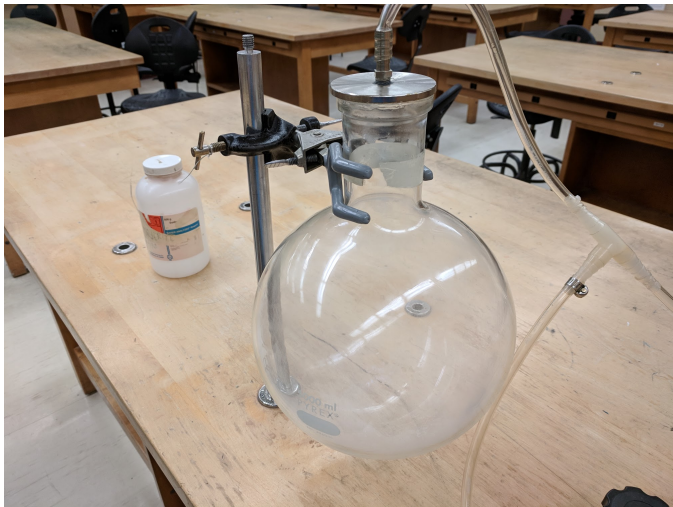
Connecting the Manometer
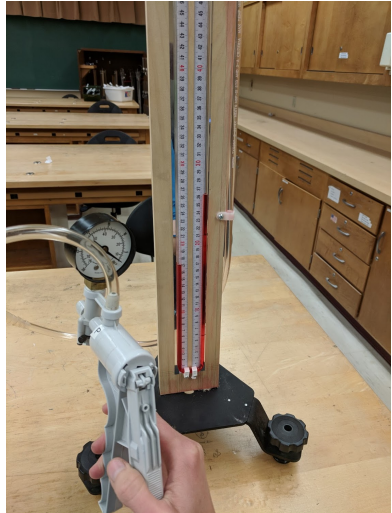
Connect the manometer to the pump tube.

Press the metal button to release the tube again at the end of the experiment.

Bulb Flask

Clamp the neck of the bulb flask to a vertical support in your lab bench. **This is a 2 person job!** Put some desiccant in the bulb flask.
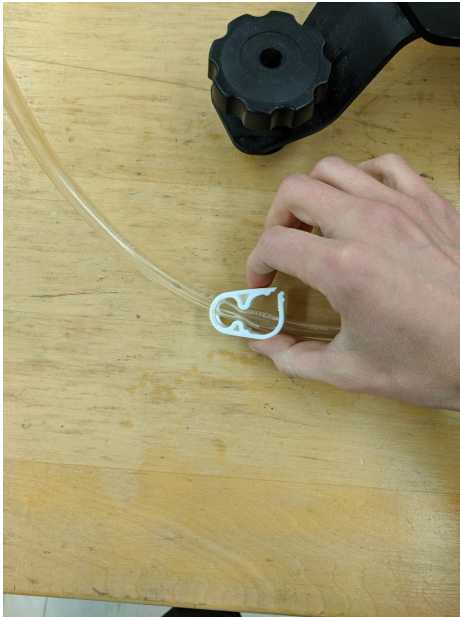
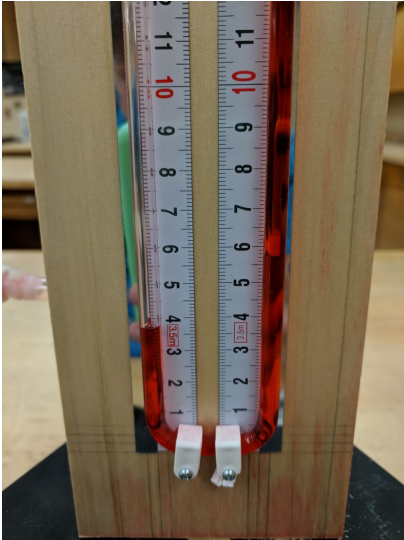# Pressurizing the Bulb Flask

The switch on the hand pump is set to "0".

Reading the Gauge Pressure

What Not to Do

Do not shoot red gauge fluid all over the lab!

If the gauge fluid on the left side goes down in to the base of the manometer U, the pressure difference will send it out of the tube, spraying everywhere.

Do not press down on the bulb flask lid.

If you see the fluid jetting upward, lift off the bulb flask lid.

Theory

We would like to experimentally investigate the molar heat capacities of a gas.

However, it is very difficult to measure C_V and C_P directly. (We would need a way to measure the heat transfer.)

It is much easier to measure pressure. From pressure measurements alone, we can determine

$$\gamma = \frac{C_P}{C_V}$$

Theory

We consider a three step process:

1. First air is compressed at constant (room) temperature.

2. Then it is allowed to expand adiabatically (fast). This cools the air.

3. The air is allowed to warm at constant volume, returning to room temperature.

Theory

Since the points lie on an isotherm:

$$P_1 V_1 = P_3 V_3$$

Since the points lie on an adiabat:

$$P_1 V_1^{\gamma} = P_2 V_2^{\gamma}$$

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Notice that $V_2 = V_3$ (constant volume process) and $P_0 = P_2$.
Therefore:

$$\frac{P_1}{P_0} = \left(\frac{V_3}{V_1}\right)^{\gamma}$$

Substituting in using the first equation gives:

$$\frac{P_1}{P_0} = \left(\frac{P_1}{P_3}\right)^{\gamma}$$

Theory

Taking the natural log of both sides:

$$\ln\left(\frac{P_1}{P_0}\right) = \gamma \ln\left(\frac{P_1}{P_3}\right)$$

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$$P = P_0 + \rho_{\text{oil}}gh$$

where

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Therefore,

$$\ln\left(1 + \frac{\rho_{\text{oil}}gh_1}{P_0}\right) = \gamma\left[\ln\left(1 + \frac{\rho_{\text{oil}}gh_1}{P_0}\right) - \ln\left(1 + \frac{\rho_{\text{oil}}gh_3}{P_0}\right)\right]$$

Since $\ln(1 + x) \approx x$ for $x \ll 1$,

$$h_1 \approx \gamma(h_1 - h_3)$$

Lab Activity

1. Set up the equipment.

2. Do 5 experimental runs, with varying values of h_1.

3. Calculate $\frac{\rho_{\text{oil}} g h_1}{P_0}$ (with correct units) for a typical value of h_1 and show that it is much less than 1.

4. Plot a graph of h_1 vs. $(h_1 - h_3)$ using Excel or similar spreadsheet software.

5. Determine γ from the graph.

6. Compare to the accepted value of γ for a diatomic gas using the percentage error.

Graphing with Excel

Input the data in the spreadsheet, and perform functions as needed.

Highlight the columns to plot.

Go to the **Insert** menu, choose **Scatter**, just points.

Right click on a point. Choose **Add Trendline**

Choose **Linear** and tick the **Display Equation** box.