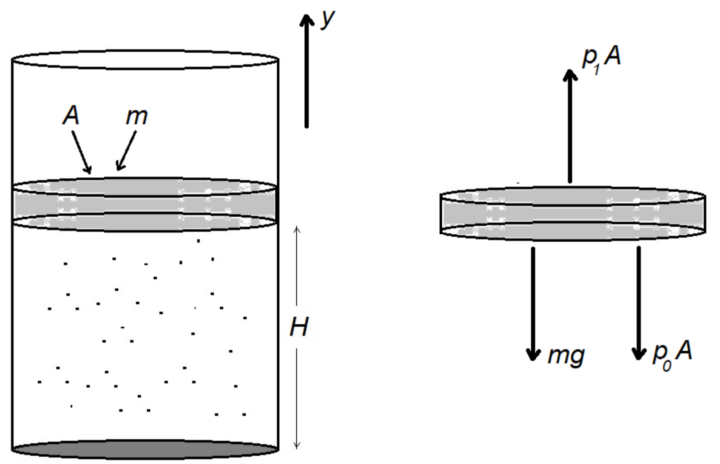
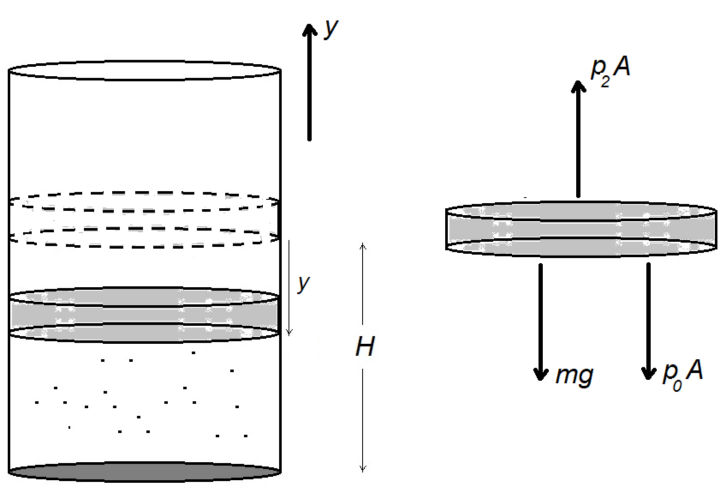
Physics 4C Lab 8: *Adiabatic Oscillations*

In this experiment, we will measure a value of gamma – the constant for an adiabatic process – for air.

We start with a cylinder of air, sealed with a movable piston (of area A and mass m) that is initially at rest. We can define this equilibrium state of the piston and consider the balanced forces acting on the piston.



We then displace the piston by a very small distance, and let it go.



The unbalanced forces now acting on the piston will push it back toward the equilibrium position… and the piston will oscillate! If we can measure the period of these oscillations, we can use the data to determine the constant *gamma*.

From the derivation provided in the supplemental file, we found that the period of oscillation for the piston is related to the equilibrium height of the cylinder by the expression:

$$T^2 = \alpha H \qquad \text{where} \qquad \alpha = \frac{4\pi^2}{\gamma\left(g + \frac{p_0 A}{m}\right)}$$

For this lab we will measure the period for a range of values of *H*, create a graph of our data – T^2 *vs H* – and use the slope of the best-fit line for this graph to calculate the value of *gamma*.

Setting up Equipment and Software

- Set up the cylinder with the pressure sensor attached to the black box.
- Open the Capstone software; use Hardware Setup to choose the proper sensor.
- Set the *sampling rate* to 4000 Hz (you will need to take a LOT of very fast measurements.)
- Open the Graph display.

Collecting Data

- Set the piston to the equilibrium position with *H* = 40 mm.
- Click *Record* on the software, then “flick” the piston gently.
- You should see a smooth curved “chevron”-like shape on the graph.
- Flick the piston several more times; you should have at least six good “chevrons”.
- Zoom in on one “chevron” to reveal the details of the oscillations.
- Use the cursor tool to find the *start time*, the time for the peak of one oscillation.
- Record the *start time*, then find the *end time* for a peak several oscillations away.
- Record the *end time* and the number of oscillations between the two times.
- Repeat these time measurements for three more “chevrons”.

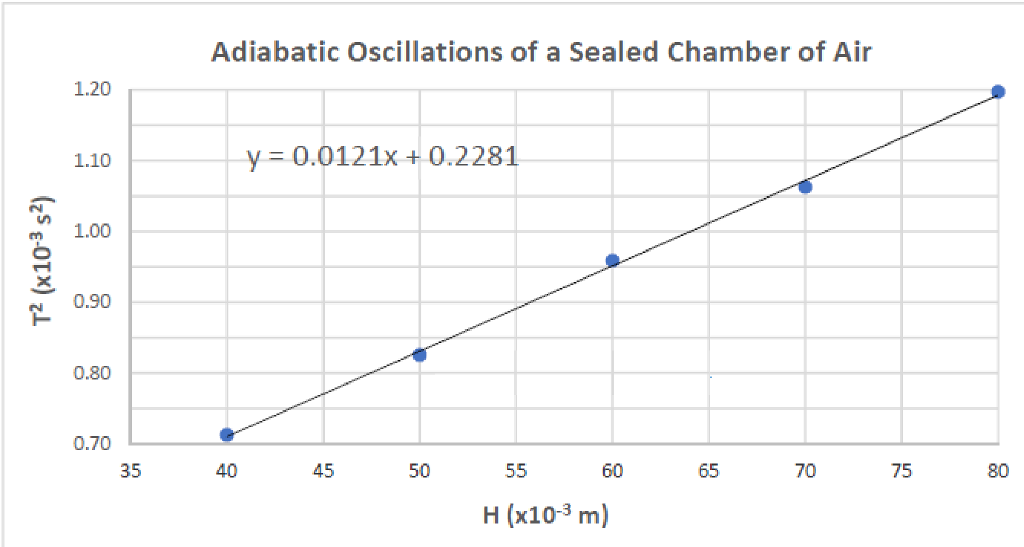
Calculate the period of oscillation for each pair of *start time* and *end time* measurements, then find the average of the four period calculations.

Repeat the process for *H = 50, 60, 70, and 80 mm*. You should now have a measurement for the period (i.e. the average of four individual measurements) for each value of *H*. Create a data table that looks like this (pay careful attention to how the units are presented):

Adiabatic Oscillations of a Sealed Chamber of Air

H (x10^{-3} m)	T (ms)	T^2 (x10^{-3} s^2)
40.0	26.6	0.713
50.0	28.8	0.826
60.0	31.0	0.959
70.0	32.5	1.063
80.0	34.6	1.197

- Create a graph of T^2 vs H. It should look like this:



Use the value of the slope from your graph to calculate the value of *gamma.* From the equation above, we can see that α should be the slope of your graph, and that:

$$\alpha = \frac{4\pi^2}{\gamma\left(g + \frac{p_0 A}{m}\right)}$$

If we rearrange this expression, multiplying both sides by *gamma* and dividing both sides by *alpha*, we get:

$$\gamma = \frac{4\pi^2}{\alpha\left(g + \frac{p_0 A}{m}\right)}$$

- Use this expression to calculate the value of *gamma*. Your calculation should look like this:

Calculations

Calculate measured value of gamma

$$\gamma = \frac{4\,\pi^2}{\alpha\left[g + \frac{p_o A}{m}\right]} = \frac{4\,\pi^2}{(0.0121\ s^2/m)\left[9.80\ m/s^2 + \frac{(101300\ Pa)\ (0.000830\ m^2)}{0.0350\ kg}\right]} = 1.35$$