Note Since the hose has a cylindrical shape, you can calculate the volume of air contained in it by noting that the equation for the volume of a cylindrical shape of length L and inner diameter d is given by $V=\pi(d/2)^2L$. (17.2)

17.8.1. Activity: Volume vs. Temperature

a. How do you predict that the volume of the air trapped in the flask, hose, and syringe will change if it is heated (or cooled) at constant pressure? Sketch a graph and explain your prediction.

b. Explain why the pressure of the air remains constant even if the volume of the air in the system changes.

c. You will start measurements of V vs. T with the plunger bottomed at the 0 or 1cc mark when the flask is sitting in the cold water. Determine the initial volume of the system including the hose, flask, and syringe. Show your basic measurements and calculations. **Hint:** You can use an electric balance to determine how many grams of water it takes to fill the flask up to the stopper. The number of grams is the same as the number of cubic centimeters of available flask volume.

Volume of hose: ____________ cm^3

Volume of flask: ____________ cm^3

d. Stir the water vigorously as you take and record the data needed to determine the total volume of the trapped air as a function of the temperature of the water surrounding the gas inside the flask. **Note:** Strictly speaking, you should measure the temperature of the air in the flask, but it's much faster to measure the surrounding water temperature, which is roughly proportional to that of the air.

T (°C)	T (K)	V flask (cm^3)	V syringe (cm^3)	V total (cm^3)

e. Use the Kelvin temperature scale and affix a graph of your *V* vs. *T* data (or the graph from another group). How are *V* and *T* related mathematically?

PROJECT B: *P* vs. *T* for a Gas (Charles Law II (or Gay-Lussac's or Amontons'))

What happens to the pressure, *P*, of a gas if its volume is kept constant while its temperature, *T*, changes? For this project you will need:

- 1 computer data acquisition system
- 1 data logger software (C170802)
- 1 immersion heater
- 1 Erlenmeyer flask, approx. 125 ml
- 1 #5 one-hole rubber stopper
- 1 plastic in-line coupler (for connecting tubing to pressure sensor)
- 1 length of Tygon® tubing, 50 cm (1/8" inner diameter)
- 1 beaker (500 ml)
- 1 temperature sensor (or thermometer, 0–50°C)
- 1 pressure sensor (to measure small pressure changes)

Recommended Group Size:	4	Interactive Demo OK?:	N

We want you to measure how gas pressure depends on its temperature. In other words, you should determine the shape of a *P* vs. *T* curve at constant volume and display your results using a computer graphing routine.

The flask contains your test volume of a gas (air). You can begin the experiment by immersing the flask in the beaker filled with cold water. Then, as you transfer thermal energy to the water with the immersion heater you can measure the pressure of the air in the flask as a function of its temperature.

17.9. THE IDEAL GAS LAW

We have seen how pressure depends on temperature at constant volume, and how volume depends on temperature at constant pressure, and how pressure and volume are related at a constant temperature. Let's summarize these relationships using simple mathematics.

17.9.1. Activity: Summarizing Boyle's and Charles' Laws

a. Write down an equation that describes the relationship (as explored in Activity 17.8.1) between volume and temperature when the pressure is held constant. Express this in terms of V, T, and C_1, where C_1 is a constant. Then solve the equation for C_1.

b. Write down an equation that describes the Charles' law II relationship you discovered in Activity 17.8.2 in terms of P, T, and another constant, C_2. Then solve the equation for C_2.

c. Write down an equation that describes the Boyle's Law relationship you discovered in Activity 17.8.3 in terms of P, V, and another constant, C_3. Then solve the equation for C_3.

d. Multiply the three relationships from parts a., b., and c. together to get the product $C_1C_2C_3$ on one side and a combination of P, V, and T on the other side.

e. Now take the square root of both sides and summarize the results in terms of a new constant C_4. Solve your equation so the product PV is on the left and C_4 and T are on the right.

The Ideal Gas Law describes all three relationships mathematically in an idealized fashion. If you did the same experiments with different amounts of gas, you would find that the factor C_4 turns out to be nR. So the Ideal Gas Law is given by:

$$PV = nRT \tag{17.3}$$

where n = the number of moles of gas
R = the Universal Gas Constant given by 8.31 J/mol•K

An alternative statement of the Ideal Gas Law is:

$$PV = Nk_BT \tag{17.4}$$

where N = the number of gas molecules
k_B = Boltzmann's Constant given by 1.38×10^{-23} J/K