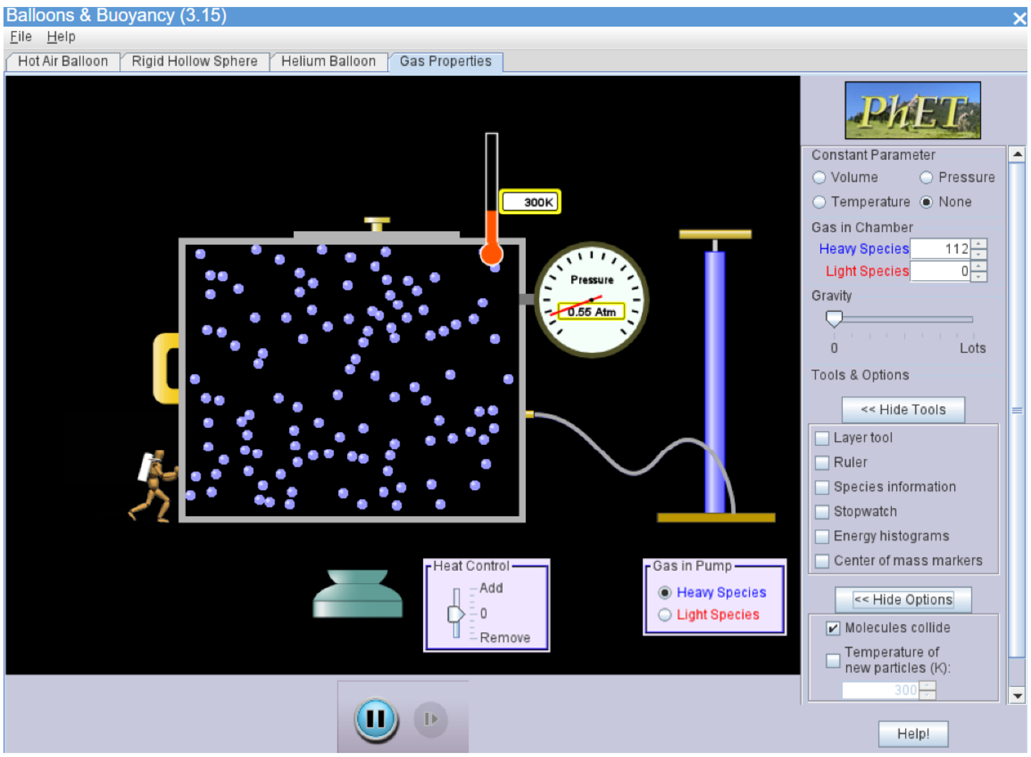
Fluids Module Student Guide

Activity 1: Numerical Simulation [20 Minutes]

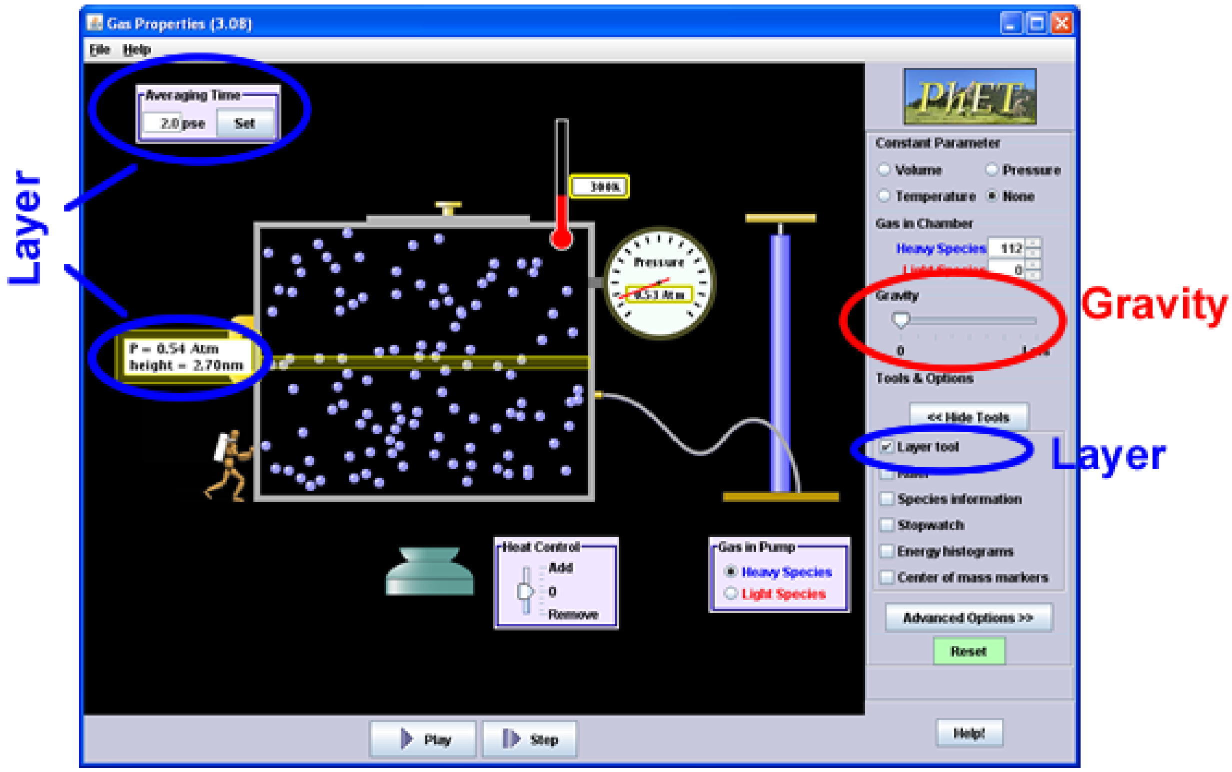
Open the Balloons & Buoyancy PhET animation which is located at https://phet.colorado.edu/en/simulation/balloons-and-buoyancy (this must be opened on a computer, not a phone or iPad). There are many useful ways to use this animation, and we will only draw you attention to a couple of things that you may wish to do; you are encouraged to explore further. For today's Activity 1, click "Browser Compatible Version". We will not be using the balloon today, so on the tab at the top click on "Gas Properties".

Here is a screen shot of the Ideal animation after some *Heavy Species* particles have been pumped into the container. I have clicked on Measurement Tools and Advanced Options:



A. Look at the Pressure Gauge, which reports pressure in units of Atm, where 1 Atm = 101,325 Pa. What causes the pressure, and why is it not exactly constant in this simulation? What would be necessary for the pressure reading to be more constant? Report the pressure you see, in Atm, as *value* ± *uncertainty*, which expresses your observed variations.

There are many options for controlling the animation. We shall describe two of them.



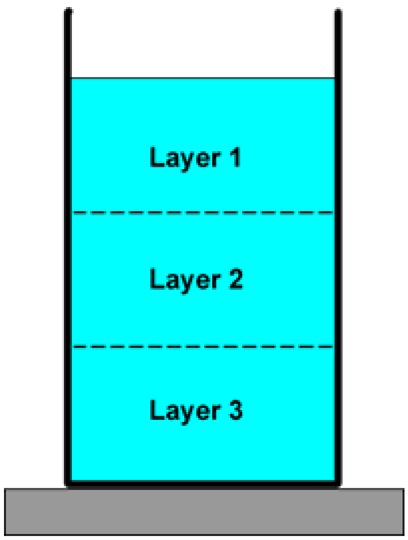
i. By default the acceleration due to gravity *g* is zero. You may introduce a non-zero value of *g* with the **Gravity** slider.

ii. By clicking on the **Measurement Tools** button you may turn on the **Layer tool**. This tool measures the pressure in the gas at a specified height; you may drag the position of the measurement up and down with the mouse. You can adjust the averaging time to get a more precise measurement, but less often.

B. With **Gravity** set to 0, use the Layer tool to take a measurement of the Pressure at 4 or 5 different values of the height. Make a quick plot of Pressure vs height for these measurements and include it in your slides. Does pressure vary with height?

C. With **Gravity** set to Lots, use the Layer tool to take a measurement of the Pressure at 4 or 5 different values of the height. Make a quick plot of Pressure vs height for these measurements and include it in your slides. You may want to increase the averaging time to reduce scatter. Does pressure vary with height?

Activity 2: Pencil and Paper [20 Minutes]

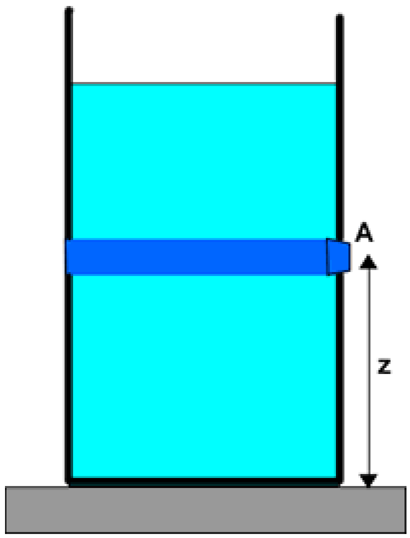


A rigid rectangular container filled with water is at rest on a table as shown. Two imaginary boundaries divide the water into three layers of equal volume. No material barrier separates the layers.

A. Draw a free body diagram for each layer. The label for each force should include:

- A description of the force, and
- The object on which the force is exerted, and
- The object exerting the force.

B. Rank the magnitude all the *vertical* forces you have drawn for Part A, from the smallest to the largest. Explain how you determined the ranking.
C. Rank the magnitude of all the *horizontal* forces you have drawn for Part A, from the smallest to the largest.

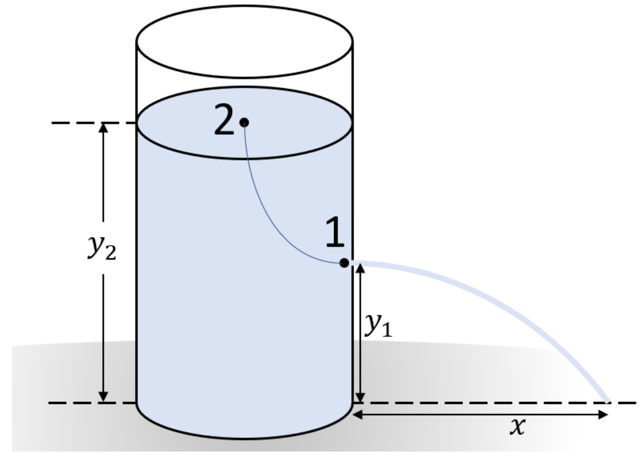


A small square hole of area **A** is cut in the side of the container. The centre of the hole is a height **z** above the tabletop. Consider the rectangular section of water of area **A** aligned with the hole, as shown.

D. Draw a free body diagram of all the forces acting on the rectangular section of water.
E. What will happen to the water just inside the hole?

Activity 3: Experiment   [25 Minutes]

A cylinder with water of height y_2 has a small hole cut in the side at height y_1. The water strikes the ground at x. The figure shows the streamline from the top of the water at **1** to just inside the hole **2**. Bernoulli's equation tells us that the quantity $p + \frac{1}{2}\rho v^2 + \rho g y$ is conserved along the streamline, and so has the same value at points **2** and **1.**



If the hole is small, it is reasonable to approximate that the speed of the water at **2** is zero. Since points **2** and **1** are in contact with the outside air, it is reasonable to approximate that the pressure is the same at point **2** and **1**, that of atmospheric pressure in the room. Using these simplifications, and also neglecting air resistance for the stream of water, it was shown in the Pre-Practical Video that:

$$x = \sqrt{4y_1(y_2 - y_1)}$$

A. Construct a cylinder with a hole inside your home and fill it with water. Take a photo of the setup as water squirts out of the hole and include it in the presentation. What are your measurements for x, y_1 and y_2. Please include estimated uncertainties.

B. From your measured values of y_1 and y_2, what is the predicted value of x based on the above equation? How does this compare to your measured value of x? If there is a discrepancy, can you think of any physical reasons to cause the difference between predicted and measured values of x?

C. [If you have time] The height of the hole, y_1, must be between 0 and y_2. If $y_1 = 0$, then $x = 0$. If $y_1 = y_2$, then $x = 0$ as well. So, there must be some intermediate value for which x is a maximum. What is this value, in terms of y_2?