

What causes pressure?

A laboratory experiment from the
Little Shop of Physics at
Colorado State University

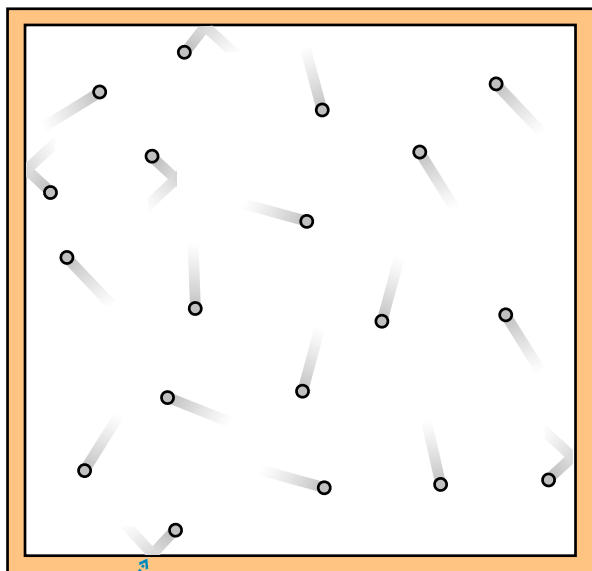


Overview

In our everyday lives, we are exposed to many references to pressure: atmospheric conditions such as high pressure or low pressure, psychological conditions such as feeling under pressure, and medical conditions such as sinus pressure. All of these interpretations of pressure have a common element: a weight, a pushing, a force. But physicists have a very particular meaning for the word pressure. When you pump air into your bike tires, the air makes an outward force that keeps the tires firm. This force is due to the pressure of the air. But what causes this pressure?

Theory

We can develop a pretty good understanding of pressure by thinking about an atomic-scale picture of what is going on in a gas. The molecules of a gas like air behave in a very simple manner: they move (at quite high speeds) in a straight line until they bump into something, then they bounce off and move in another direction. That's it!



The collisions of the particles with the walls of the container cause a force on the walls.

Necessary materials:

- one long rope
- a large open area in the classroom or outside

We call this experiment “Molecules in a Box.” The students are the molecules, and the box is an area defined by the rope.

You can also do this experiment without a rope by defining a certain location as your box. Perhaps you have a tiled area that would work or a corner of your classroom. You can even define an imaginary box.

If the gas is in a container—a box—the molecules hit the sides of the box from time to time. These collisions with the walls make a force on the walls of the container; we call this the pressure of the gas. The pressure is defined as the total force on one wall divided by the area of the wall. But you can get a qualitative understanding of the pressure by thinking about the collisions: Lots of collisions means lots of pressure.

The pressure in a container of a gas depends on the number of molecules in the container, the volume, and the temperature. Physicists use the formula:

$$p = NkT/V$$

where p stands for pressure, N for the number of atoms, T for temperature (in Kelvin), and V for vol-

ume. k is a constant known as Boltzmann's constant.

What the equation really says is this:

- More molecules means more pressure.
- Higher temperature (meaning faster molecules!) means more pressure.
- A smaller container means more pressure.

All of these make sense given our atomic-scale picture of a gas. More molecules means more collisions; higher temperature means faster molecules that hit the walls more often (and harder!) and a smaller container means the molecules hit the sides more often as well.

Rather than diving right into the equation, do a conceptual warmup first: Show students what the equation means. And you can do this in a very kinesthetic manner by having them be the molecules...

Doing the Experiment

Explain to your class that they will be taking part in a kinesthetic activity to demonstrate pressure, and some of them will be acting as air molecules in a container. Depending on the age and knowledge of the group, ask for a volunteer to answer the question: What is a molecule? If the student has difficulty with this, give an explanation that is appropriate for your group.

Call up four volunteers to hold the rope taut to make a square. Explain to the group that you are going to pretend that the rope forms the walls of a box. Have other students step inside the box and spread out facing any direction they choose. Tell them that they are going to act out the part of air molecules. Demonstrate or direct them to walk forward in the box. If they bump into each other or a wall of the box, they should bounce away and walk in their new straight path until they bump into something again. Explain that when they bump into the walls of the box and are forced to bounce back into the box, this is pressure.

Try several scenarios. Tell them that you are adding heat to the box and ask them how they should move. (Faster!) Have them act this out. Now suppose that heat is removed from the box and they've become cold molecules. How do they move now? (Slower!) Add or subtract molecules from the box. Reduce the volume of the box by shortening the rope and have the molecules continue to move around in the area. On each case, keep track of the frequency of collisions.

How do you "measure" the pressure? The quick way is to have students "beep" with gusto every time they bump into the rope. This will allow them to hear the difference between low pressure and high pressure: Lots of beeps means high pressure. But you can also get numbers: Run each situation for only 15 seconds. Have each person holding a corner of the box be in charge of one of the four walls of the box, keeping track of how many times the wall was bumped by individual molecules. Add the four sides up each time and compare the results of cold versus hot, smaller versus larger volume, and less versus more molecules. You can clearly show all of the variations noted above.

Summing Up

This is a great way to introduce the concept of air pressure and illustrate how it varies with density and temperature. Once students have done this, they will be able to visualize more readily what is happening both vertically and horizontally in the atmosphere due to changes in pressure.

For More Information

CMMAP, the Center for Multi-Scale Modeling of Atmospheric Processes: <http://cmmmap.colostate.edu>

Little Shop of Physics: <http://littleshop.physics.colostate.edu>