

# Does air weigh anything?

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



## Overview

Air is usually invisible, so most of us don't give it much thought at all. In fact, when students are asked about the mass or weight of air, many are perplexed. Air seems like it doesn't have mass, but it does. Since this is where atmospheric pressure comes from, it's an important concept to address.

## Theory

When you dive under the water, pressure increases; you can feel the increased pressure in your ears. The pressure comes from the weight of the water above you. Just as sea creatures travel through the water bodies of the world, land dwellers navigate through a sea of air. You are, right now, about 100 kilometers deep in this sea called the atmosphere. All of the air above you has a significant weight! Imagine tracing out a square meter on the floor. If you measure the mass of the air above this area, up to the top of the atmosphere (more or less 100 kilometers up) you get a total mass of about 10,000 kg—about 10 tons! Even if you



*If you are careful, you can actually feel the difference between the weight of a “pumped” bottle and an “unpumped” one.*

## Necessary materials:

- One clean & dry 2-liter bottle
- One Fizzkeeper pump cap
- One triple beam balance

If you don't have a triple beam balance, you can use an equal arm balance and gram weights.

The Fizzkeeper pump cap is crucial to this experiment. These caps are designed to add air molecules to soda bottles to keep the carbonation under pressure so your soda stays fresh longer. You can obtain these pump caps at home stores such as Bed, Bath, & Beyond or you can order them directly from [www.jokari.com](http://www.jokari.com).

explain this to your students, some may still not believe that air has mass and weighs something. The experiment below will be quite surprising to those students, as they will experience putting extra air molecules into a bottle and measuring it directly!

We have seen experiments published in which students measure the mass of balloons before and after inflation. This doesn't work very well: the balloon changes size, and so the buoyant force on it changes. As the balloon displaces more air, it feels an upward force that negates the increased mass in the balloon. The experiment below uses a bottle, so the volume stays constant; the bottle expands very slightly when air is pumped in.

## Doing the Experiment

**SAFETY NOTE: A lot of pressure can build up in these bottles and the caps can become projectiles. When it's time for a student to release air from the bottle, be sure to have the student lay it on its side where it's not aimed at anyone, and slowly unscrew the cap.**

The experiment goes like this:

- Attach a Fizzkeeper cap to a 2-liter bottle but don't pump any extra air into the bottle. Have students feel the bottle, checking for weight and pressure.
- Weigh the bottle on a triple beam balance and record your findings.
- Ask your class to predict what will happen if you pump extra air molecules into the bottle and then measure its mass.
- Have students use the Fizzkeeper to pump more air molecules into the bottle. They can keep a count of the number of pumps if they like. In fact, if you have an accurate balance, students can measure the mass of the bottle as a function of the number of pumps. There is a clear trend, but at some point, the mass will stop increasing, as the pump caps won't pump any more air into the bottle.
- When the pumped bottle is pumped full as it can be, have the students feel the bottle, checking again for weight and pressure. What do they notice?
- Weigh the bottle on the triple balance beam and compare and discuss your two findings. If there are more molecules in the bottle, there's more pressure and more mass!

## Summing Up

This exercise is quick proof of the fact that air has mass. When you use the pump cap, more air molecules are pumped into the bottle. This increases the pressure, but it also increases the mass. You can easily increase the mass of the bottle by a few grams—a measurable amount!

## 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>