



Does air have mass?



COLLEGE OF
NATURAL SCIENCES
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, so it would be impossible to weigh anything, but it does! Since this is where atmospheric pressure comes from, it is an important concept to address.

Theory

When you dive underwater, the pressure increases; you can feel this 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 explain this to your students, some may still not believe that air has mass, as they don't sense its weight in their daily lives. This experiment will be quite surprising to those students, as they will gather data which directly demonstrates that air has mass!

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, so the buoyant force on it changes. As the balloon displaces more air, it experiences an upward force from the surrounding air that negates the increased mass in the balloon. This experiment uses a bottle, so the volume stays constant (the bottle expands very slightly when air is pumped in, but not enough to significantly affect the results).

Doing the activity

Show students a Fizzkeeper cap and demonstrate that you can pull up on the cap and push it down. Tell them that when you do this, it pushes air through two openings on the bottom of the cap. Some students might not understand or believe this, so attach a balloon to the Fizzkeeper cap and then blow up the balloon with the cap. Explain that the Fizzkeeper cap puts extra air molecules into the balloon; this is why the balloon expands.

Attach a Fizzkeeper cap to a 2-liter bottle, but don't pump any extra air into the bottle yet. Let students feel the bottle, checking for weight and pressure. Weigh the bottle on the digital scale and record your findings, then ask your class to predict what will happen if you pump extra air molecules into the bottle and then measure its mass. Record their prediction(s) on a whiteboard or large piece of paper.

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.

Necessary materials:

- Fizzkeeper pump cap*
- balloon
- 1-liter bottle**
- digital scale

*The Fizzkeeper pump cap is crucial to this experiment. These caps are designed to add air molecules to soda bottles to keep the liquid under pressure, retaining carbonation so soda stays fresh longer.

**Make sure to use a bottle with a reinforced bottom — one with a “footprint” that looks a bit like a 5-pointed asterisk. These bottles hold up better under pressure.

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, 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 pressure will be so high that the pump caps won't be able to add any more air to 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 digital scale (you can easily increase the mass of the bottle by a few tenths of a gram) and compare and discuss your findings. Do they support or refute the predictions from earlier? Why? The big idea here: 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 amount of mass inside the bottle, and therefore the reading on the scale.

For more information

Little Shop of Physics: <https://www.lsop.colostate.edu>

Colorado State University College of Natural Sciences: <https://www.natsci.colostate.edu>