Density and the Buoyant Force – Hot Air Balloon

What is air? We breathe it, we need it every minute of our lives, but what is it? We can't see it, smell it, or taste it. We don't even feel it like we can feel an object. Instead we only feel it pushing against us. It may seem like it's not there, but air is actually made of many pieces that are as real as those that are in a chair or table. They have mass, or weight, and they take up space.

Air is also pulled on by gravity just like a chair or a table. You may not know it, but air is pulled toward the earth and stays close to the ground. The higher you fly into the sky, the less air you will pass through because gravity is pulling it down toward the ground.

So how do things fly? How can a hot air balloon float upward when gravity is pulling it down? Something must be stronger than gravity. Something must be lifting the balloon into the air with more force than gravity is pulling down on it. This force is called the **buoyant force**.

Now when we think of floating or buoyancy, we think of a boat. An object that is buoyant, floats. But the air is exactly like water in that it is made up of pieces that are pulled down by gravity. The same way a boat floats is also how a hot air balloon rises. Have you ever noticed that you can blow bubbles underwater and they always go upward towards the surface? This is because an air bubble is less dense than the water around it. This means the water pushes the air bubble upward. In the same way, the air in a hot air balloon is less dense than the air outside of it causing the balloon to rise.

So how do we make the air in a balloon less dense? One way is to heat the air. We know that anything that is heated will get bigger. Which means, the same amount of air takes up more space than it did at a colder temperature. In other words, it has more volume. When something gets bigger, it has more volume which means it is less dense.

So does this work with all objects? What if I want to heat metal, will it get bigger and float? Although you can't see it, the metal will get bigger when heated. In fact, engineers who design bridges must plan for the metal to get bigger or smaller at different temperatures or the bridge will fall. But it won't float. Even when the metal gets bigger, it is still more dense than the air around it. So, the metal will not rise.

Here are some wrong ideas about floating or buoyancy.

1. Air doesn't have mass (or weight): Not true. We don't feel the weight of the air on top of us because the air pieces are pushing up with the same pressure they're pushing down, so we don't feel it.
2. Weight tells us if an object will sink or float: No, an object's density and the density of what is around it tells us if it will sink or float. Have you ever been on a cruise ship? It is very heavy, but it still floats.
3. All objects with air inside them always float: No, density tells us if an object will sink or float.

Activity: Ask your parents to help you. (You may need java installed on your computer. To install Java, go to https://www.java.com/en/download/manual.jsp.)

Take a hair dryer, face it up toward the ceiling and turn it on low. Now place a ping pong ball on top of the air going upward. What happens? The ping pong ball floats because air is pushing it upward.

Try the experiment:

1. Click on Balloons-and-Buoyancy_en.jar.
2. You will notice there is a pump on the right side. What happens when you pump the handle? Is there more or less air in the container? What happens to the temperature? Does it go up or down? Where are most of the molecules/air? Is gravity pulling the air down?
3. Drag the scuba diver to the left to make the container bigger. Now that we are increasing the volume of the air outside of the balloon, what happens?
4. Add heat to the balloon. (The control is on the right side) What happens?
5. Now see if you can make changes that will blow the lid off the container. What changes worked? Can you separate heat from pressure?
6. Try different combinations.