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 its force against us. It may seem like it doesn't exist, but air is actually made of many particles that are as real as those that are in a chair or table. They have mass and they take up space.

Air is also affected 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 surface. 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 fly 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 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 particles 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. **Density** is the mass of an object divided by the object's volume. 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 expand. Which means, the same amount of air takes up more space than it did at a lower temperature. In other words, it has more volume. Remember we said that density is the mass of an object divided by its volume. When something expands, 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 expand and float? Although you can't see it, the metal will expand when heated. In fact, engineers who design bridges must account for the expansion and contraction of the metal at different temperatures or the bridge will fail. But it won't float. Even when the metal expands, it is still more dense than the air around it. So, the metal will not rise.

Here are some misconceptions about buoyancy.

1. Heat Rises: Not exactly. Heat is a form of energy, not a physical object that can rise or fall. Heating air causes it to spread out and become less dense. The warmer, less dense air rises because colder, denser air pushes it out of the way. Gravity continues to pull down on warm air, but the cold air pushes it up with more force than gravity pulls it down, causing it to rise.
2. 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 particles are pushing up with the same pressure they're pushing down, so we don't feel it.
3. Weight determines if an object will sink or float: No, an object's density and the density of the fluid surrounding it determine if it will sink or float. Have you ever been on a cruise ship? It is very heavy, but it is still buoyant.
4. All objects with air inside them always float: No, density determines if an object will sink or float.

Activity: (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 particles are pushing it upward.

Try the simulation:

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? Are there more or less molecules in the container? What happens to the temperature? Does it go up or down? Where are most of the molecules? Is gravity affecting the molecules?
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?

Put 50 heavy pieces into the container. Add heat to the balloon and watch it move up and down. What do you notice about what is happening in the balloon? What type of energy is present in the balloon? It is kinetic and thermal. Thermal energy be transferred by convection, conduction and radiation. What type of transfer happens in our balloon? In our hot air balloon, convection is happening. Convection occurs when thermal energy is transferred through the movement of particles from one location to another. Further, the air moving in and out of the balloon forms convection currents. The heated air expands and is replaced by the cooler air.

The cooler air is then heated and the process repeats again. Weather patterns are influenced by convection currents. Heating and cooling of homes is also an example of convection currents.

6. Would a hot air balloon work on the moon?
7. Explore different combinations.