Fluids Part 3: Temperature and Density

Last week, we asked the following question:

In our homes, we put heating registers on the floor rather than up by the ceiling because (in common language) "Hot air rises." Scientifically, though, this isn't exactly correct and may cause confusion for students. What's the real story?

Although it is true that hot air is higher than cold air within a given space, an important point is, *why*? There's nothing magical about hot air that makes it rise over all. First, let's do a "thought experiment" that looks at what happens when a **fluid** is heated. Then we'll look at the combination of hot and cold **fluids**.

Heating water experiment

You'll need:

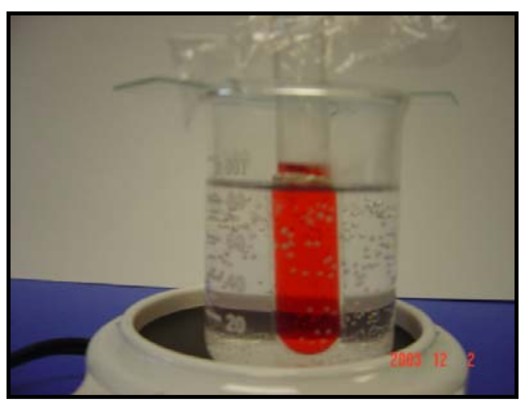
- Glass test tube
- Water
- Hot plate
- Container of water to hold and heat the test tube
- Rubber band
- Plastic wrap

Procedure:

1. Fill the test tube half-full with cold water.
2. Mark the water level in the test tube with the rubber band.
3. Cover the test tube with plastic wrap (reduce influence of evaporation)
4. Place test tube in the water-filled container, and slowly heat it on the hot plate.
5. What do you predict will happen to the water level in the test tube?

So what happened?

You will notice that the water level within the test tube rises. That means that the volume of water within the tube increased, even though no water was added. How is this possible?



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Let's go back to the idea we proposed last week: imagining **solids** and **fluids** composed of tiny balls.

We know that the balls are in constant motion. When a **fluid** is heated, the tiny balls move faster, and the space between them increases. The number of balls has not changed, but they take up more space. The evidence of this is the increased water level in the test tube.

So what happens if we mix hot and cold **fluids**, as when we heat our houses?

Hot and cold experiment

You'll need:

- Beaker of cold water
- Beaker of hot water
- Large transparent container (needs to hold both hot and cold water)
- Food coloring

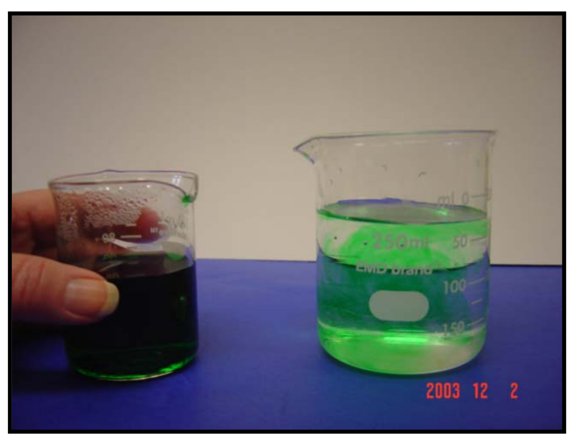
Procedure:

1. Add food coloring to hot water.
2. Put cold water in transparent container.
3. Predict what will happen when you tip the container containing cold water and pour hot water down the inside edge of the transparent container.

So what happens?

You will see the hot colored water move to the top of the container. But why is this?

We know from the previous experiment that when you heat water, its volume increases. How does that affect its density?



The number of tiny balls has not changed, but they've spread out and take up more room. Therefore, the hot water's density is less than cold water's density. The tiny balls in the cold water are closer together; cold water is therefore more dense.

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As the hot water is placed into the cold water, the less dense hot liquid is pushed up and out of the way by the denser cold water. Essentially, then, the hot water is not rising; it is being nudged out of the way. This connects to a principle we discussed in **Fluids 1**: two objects or substances cannot occupy the same space at the same time.

The same process occurs with gases, although it is more difficult to see evidence. Colored gases (bromine, chlorine, iodine) are not ordinarily ones we use in classes. However, most of us are familiar with dry ice, which is frozen CO_2:

"At normal atmospheric pressure on *this* planet, frozen CO_2 doesn't melt into a liquid, but rather evaporates directly into its gaseous form. Hence the name *dry* ice. This process is called *sublimation*."[1]

You've probably seen the effect that occurs when dry ice changes from a solid to a gas: there's an eerie white fog that makes great special effects for theatre and concerts. However, "This white fog is not the CO_2 gas, but rather it is condensed water vapor, mixed in with the invisible CO_2. The extreme cold causes the water vapor to condense into clouds. The fog is heavy, being carried by the CO_2, and will settle to the bottom of a container, and can be poured."[1] Thus we have evidence that cold CO_2 gas is denser than the warmer air.

Upcoming

Next week we'll look at one last important property of a fluid: pressure.

In the meantime, consider these questions:

1. How can we use the ideas of temperature and density to explain how wind occurs?
2. Where does pressure fit into this?

What do the standards say?

In the Elementary Core Curricula, Standard 4, The Physical Setting,

Major Understandings state:

- 3.1b *Matter has properties (color, hardness, odor, sound, taste, etc.) that can be observed through the senses.*
- 3.1c *Objects have properties that can be observed, described, and/or measured: length, width, volume, size, shape, mass or weight, temperature, texture, flexibility, reflectiveness of light.*

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- 3.2a *Matter exists in three states: solid, liquid, gas.*
  - *solids have a definite shape and volume*
  - *liquids do not have a definite shape but have a definite volume*
  - *gases do not hold their shape or volume*
- 3.2b *Temperature can affect the state of matter of a substance*
- 32.c *Changes in the properties or materials of objects can be observed and described.*

In the Intermediate Core Curricula, Standard 4, The Physical Setting,

Major Understandings state:

- 3.1a *Substances have characteristic properties. Some of these properties include color, odor, phase at room temperature, density, solubility, heat and electrical conductivity, hardness, and boiling and freezing points.*
- 3.1c *The motion of particles helps to explain the phases (states) of matter as well as changes from one phase to another. The phase in which matter exists depends on the attractive forces among its particles.*
- 3.1h *Density can be described as the amount of matter that is in a given amount of space. If two objects have equal volume, but one has more mass, the one with more mass is denser.*

[1]http://www.west.net/~science/co2.htm

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