

Effects of Temperature on Density

Density Tanks

Standard 6.2.2 Develop a model to predict the effect of heat energy on states of matter and density. Emphasize the arrangement of particles in states of matter (solid, liquid, or gas) and during phase changes (melting, freezing, condensing, and evaporating).

Scientific and Engineering Practices:

- Developing and using models
- Analyzing and interpreting data
- Using mathematics and computational thinking
- Constructing explanations and designing solutions
- Obtaining, evaluating, and communicating information

Crosscutting Concepts:

- Cause and effect: mechanism and explanation
- Systems and system models
- Stability and change

Teacher Background:

Familiarize yourself with the material on the Matter is Made of Atoms student worksheet as it contains helpful background information for understanding and developing an intuition for what density and temperature are and how they are related to the states of matter.

This lesson is the start of a series of three lessons that are designed to teach students about the relationship between temperature and density and how this relationship impacts the real world. Ultimately, students will apply their knowledge from activities 1 and 2 in activity 3 to understand the cycling of matter in the water cycle and how energy flows to create this cycling. To begin it is vital to understand what exactly density is. Density is a measure of mass per **unit** volume. Think of it similarly to how you think of miles per **one** gallon or ounces per **one** dollar. These are all quantities that are measured as something per unit something. In your classroom the unit volume that density will likely be measured in is one cubic centimeter. So the measure of density is how much mass is within one cubic centimeter.

When matter is in solid form it is denser (with the notable exception of water, due to the empty space between molecules. Ice floats instead of sinking which is the only reason why fish and other river and lake critters don't freeze to death during the winter). When matter is in a gas form it is least dense. This should be intuitive to think about. You walk through gas every day; it is the air that you breathe. It is easy to walk normally through the air, but it is harder to wade through liquid and impossible to walk through a solid. This is because gases are less dense than liquids which are less dense than solids.

Beyond there being differences in density between the states of matter, there can be differences in density within a state of matter based on differing temperatures. Raising the temperature is how matter is moved from solid, to liquid, to gas. Within each of these states of matter an

increase or decrease in temperature will decrease or increase the density. For example, warmer water is less dense than cooler water. Denser liquids (or gases) sink below less dense liquids (or gases) when acted upon by gravity. If you have ever been swimming in a lake or reservoir think about the layers that can form in the water on a hot day. This partly has to do with the sun hitting the top with more intensity, but the reason that the heated water stays on the top instead of mixing in with the rest of the water (in the absence of wind) is because it is less dense. This process and these layers are called stratification.

In this experiment students are going to see this process occur as they watch hot water become layered on top of cooler water. When the divider is removed, the denser water (cold) sinks to the bottom of the container and the less-dense water (hot) floats above, forming two layers. As the water is moving, an internal wave forms for a short time in the tank. This wave is called a gravity wave.

Materials

- Rectangular tank with a divider
- Cold water and hot water in separate containers
- Food coloring (two different colors)
- 2 stir sticks or straws
- Effects of Temperature on Density Worksheet (1 per person)

Set up

For this activity students will be divided into small groups. We recommend groups of 3-4 as this will allow everyone to participate and view the experiment closely. Each group will need the materials listed above. When setting up the stations we recommend that you put ice cubes in water and then let the ice cubes melt to make water that will be quite cold. Hot water from the tap will work in combination with ice cold water. **If you choose to produce hot water by heating it, use caution so that it does not become hot enough to cause burns to the skin.** The key is to ensure a large enough temperature difference so that the stratification occurs quickly. This may be difficult if the range of temperatures from the faucet is limited.

Student Performance Outline

Phenomenon:

When hot and cold water are allowed to interact, they do not initially mix but instead separate into two distinct layers with the warmer water above the cooler water.

Individual Performance

Read and answer questions about states of matter and the relation of density to the different states of matter on the Matter is Made of Atoms Worksheet

Group Discussion

Brief discussion of student answers to ensure that everyone understands the relationship between temperature, volume and density.

Group Performance

Predict how water of different temperatures will combine and observe to see if predictions were correct

Individual Performance

Develop a written model to explain the effect of temperature on density.

Group Discussion

Brief discussion of student written models to ensure correct understanding and to address any misconceptions

Procedure

Prior to the Density Tank activity, the students should read and answer questions on the Matter is Made of Atoms Worksheet. Either as a class or in small groups have students discuss the answers to the questions. The goal here is to give students the necessary background information to develop a written model of the effect of temperature on density. It is important that they understand that mass doesn't change with increasing temperature. Instead, volume increases. If students understand this concept they will have a much easier time making the connection between higher temperature and lower density.

Divide the students into small groups and give each student the Effect of Temperature on Density Worksheet.

Go over the instructions with the students. Things to impress upon them:

- Pour the hot and cold water into the density tank simultaneously to avoid the water mixing before it should. We suggest having one student pour the hot water, one student pour the cold water, and one count down so that they start pouring at the same time.
- Tell them to carefully watch what happens as they pull out the divider. The water moving and settling is not only really interesting to watch, but they may have an easier time making their model at the end if they watch the whole process.

Students should follow the instructions on the worksheet.

After students have completed the activity with the water ask them to answer the questions on the bottom of the worksheet. The goal of these questions is for students to develop a written model to explain the effects of temperature on density.

Example model: When a liquid or gas is heated, their molecules begin to move faster, bounce off each other with more force, and move farther apart. This increases the volume but not the mass. Increasing the volume of a substance without changing mass will lower its density. When the density of a liquid or gas is less than that of its surroundings, the heated portion of the liquid or gas will rise.

If students are having trouble developing a model have them look back over the Matter is Made of Atoms Worksheet and try to use the information there combined with their observations to develop their written model.

Finally, hold a class discussion and have a few students share their observations and their written models. Make sure that everyone understands the relationship between temperature and density.

Name:

Density Tank Activity 1: Effects of Temperature on Density

Materials:

Density Tank (tank with two compartments)

Hot water

Cold water

Food coloring (two different colors)

Stir stick

Instructions:

1. Obtain a tank and a container with hot water and another container with cold water.
2. Place the hot water in one tank compartment and the cold water in the other (in order to keep water from one chamber leaking into the opposite chamber it is important to pour the hot and cold water into their separate chambers at the same time).
3. Add 1-2 drops of one food coloring to one compartment and 1-2 drops of the other food coloring to the other compartment (different color in each), then stir the water in each compartment until the food coloring is evenly distributed.

What do you predict will happen when you remove the divider between the compartments? Explain your reasoning.

4. Test your prediction by removing the tank divider.
5. Once all of the motion of the water has appeared to stop, make a diagram of the final arrangement of the water. Was your prediction correct?

Analysis:

Place your fingertips on top of the fluid surface and slowly move your hand down toward the bottom of the tank. Can you feel the temperature change?

Where is the cooler water? Where is the warmer water?

If you have two liquids, A and B, and liquid A is denser than liquid B which one would be on the bottom if they were both placed in a cup and allowed to settle?

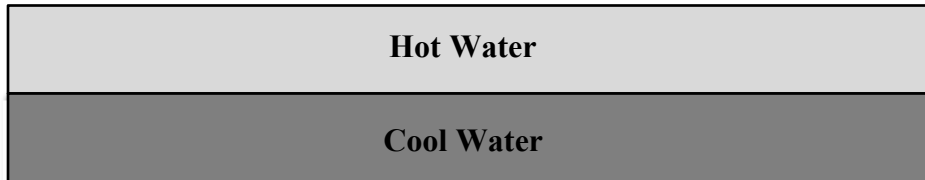
What temperature of water is most dense?

Using your answers to the above questions and what you observed in the tank, try to explain why you saw the results you did. If it would be helpful, use a picture in your explanation.

KEY

Density Tank Activity 1: Student Worksheet

5. Once all of the motion of the water has appeared to stop, make a diagram of the final arrangement of the water. Was your prediction correct?



Analysis:

Place your fingertips on top of the fluid surface and slowly move your hand down toward the bottom of the tank. Can you feel the temperature change?

Yes

Where is the cooler water? Where is the warmer water?

Cooler at the bottom, warmer at the top

If you have two liquids, A and B, and liquid A is denser than liquid B which one would be on the bottom if they were both placed in a cup and allowed to settle?

Liquid A

What temperature of water is most dense?

Colder water

Using your answers to the above questions and what you observed in the tank, try to explain why you saw the results you did. If it would be helpful, use a picture in your explanation.

In the hot water, the molecules move faster, bounce off each other with more force, and move farther apart. This increases the volume but not the mass. So the hot water has a lower density than the cold water. When the divider is removed, the more dense cold water moves to the bottom of the tank and the hot, less dense water moves to the top of the tank.