ACTIVITY 2-Effects of Uneven Heating on Density

Standard 6.3.1 **Develop a model** to describe how the cycling of water through Earth’s systems is driven by energy from the Sun, gravitational forces, and density.

Scientific and Engineering Practices Utilized:

* Developing and using models
* Analyzing and interpreting data
* 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:**

The purpose of this activity is to teach students about how uneven heating affects density, which result in convection currents in water that can model patterns of atmospheric and oceanic circulation. When matter is cooler it is denser because the atoms are vibrating less and therefore closer together. As the temperature increases, the motion of the atoms increase so they move farther apart and the matter becomes less dense. This results from a transfer of energy into matter when it is contact with matter that has a greater temperature or it absorbs electromagnetic radiation.

When portions of a liquid or gas are heated or cooled by a transfer of energy into or out of the gas or liquid, the resulting changes in density will result in motion of the liquid or gas due to the forces of gravity and buoyancy. These motions are called convection currents. Gravity acting on the denser portions of the gas or liquid cause them to sink and the less dense parts to rise. Think about the old adage: heat rises. Heat rises because warmer air is less dense and thus rises above the cooler, denser air. You can see this in real life in hot air balloons. They rise because the hot air in the balloons is warmer and less dense than the cooler, denser air outside of it. The flame inside the balloons heats the air inside it up causing it to rise.

A circulating pattern of movement can form from adjacent columns of rising and falling gas or liquid. In the atmosphere, colder, denser air pulled down by gravity will produce a region of high pressure near Earth’s surface. This air will then move horizontally towards the region of low pressure created by the adjacent rising column of air. High in the atmosphere, this convection current of rising air can be drawn toward the column of sinking air to replace the air that is moving down. This creates a circulating flow of air which results from the uneven heating of Earth’s surface.

Materials

* Rectangular tank with a divider
* Food coloring
* Hot water
* Ice
* 2 Styrofoam cups
* Effects of Uneven Heating on Density Worksheet (1 per student)

Set up

Set up stations for groups of 3-4 students with all of the materials listed above. Print out one copy of Effects of Uneven Heating on Density Worksheet for each student.

**Student Performance Outline**

Phenomenon: Movement of water in a cyclical pattern caused by temperature differences and changing density

Group Discussion

Review material from the first density tank activity and the Matter is Made of Atoms worksheet.

Group Performance

Make a prediction about what the uneven heating of the water will cause in terms of movement of the water and patterns created and observe the experiment to see if what happens matches the predictions.

Individual Performance

Answer questions on Effects of Uneven Heating on Density worksheet to develop a written model of what occurred in the experiment

Group Discussion

Have students discuss their models first in small groups and later as a class to ensure that everyone has come to the correct conclusions and that their models are coherent.

**Procedure:**

Start the activity with a group discussion using the review questions below to remind students about what they saw and learned in the first density tank activity and what they learned from the Matter is Made of Atoms worksheet.

Review Questions:

What phase of matter is the densest? (Solid)

What can you do to make the volume that a material takes up increase? (Heat it up)

What does an increase in temperature do to density? (Decreases it)

What happens when two different density liquids are put in the same container? (The less dense one ends up on top)

Divide students up into groups of 3-4 and send one group to each station. Hand out copies of the worksheet to each student and go over the set up and instructions with them.

Instructions to the Students (also on student worksheet)

1. Remove the tank divider.

2. Fill the tank about 2/3 full with room temperature water.

3. Fill one Styrofoam cup with ice and the other with hot water.

4. Place the tank on top of both cups with each cup under the center of each compartment. Wait about 5 minutes.

With the uneven heating in different sides of the tank, what do you predict is happening to the water in the tank? Explain your reasoning.

5. Test your prediction by adding one drop of one food coloring to the water in the tank above the cup with the ice. The food coloring will make visible any motion in the water.

6. Carefully observe how the food coloring moves for several minutes.

***Note to teachers:*** After students have followed these instructions they will then move on to answering the following questions individually. These questions are designed to elicit from students a model of the phenomenon they are experiencing in this experiment.

Individual questions for students (on their worksheet):

Make a diagram of this experiment and draw the patterns in the motions you observe. Indicate in the diagram where heat energy is moving into or out of the tank. Describe what effect this movement of heat energy has on the density of the water near those locations in the tank.

Describe the flow of matter (water) in the tank. Explain how the flow of heat energy causes the water to move in this pattern. In your explanation, include the role of heat energy, gravity, and density.

Example model:

The heat energy from the warm water enters the tank and causes the water in the tank above it to heat up. This rise in temperature causes the density of this water to go down. The heat energy leaving the tank above the ice water and entering the cup of cold water causes the water immediately above the ice cup to go down. This decrease in temperature causes the density to go up. The water inside the tank that now has difference densities is acted upon by the force of gravity which causes the less dense, warmer water to rise to the top while the denser, colder water sinks to the bottom.

After students finish making their explanations, have them discuss their conclusions with their group and make any adjustments as necessary. (2-3 min)

When they have completed the small group discussion, come back as a class and discuss the models that the students created to ensure understanding.

Name:

Density Tank Activity 2: Effects of Uneven Heating on Density

Instructions:

1. Remove the tank divider.

2. Fill the tank about 2/3 full with room temperature water.

3. Fill one Styrofoam cup with ice and the other with hot water.

4. Place the tank on top of both cups with each cup under the center of each compartment. Wait about 5 minutes.

During the 5 minutes discuss the question below with your group and write your predictions below.

With the uneven heating in different sides of the tank, what do you predict will happen/is happening to the water in the tank? Explain your reasoning.

5. Test your prediction by adding one drop of one food coloring to the water in the tank above the cup with the ice. The food coloring will make visible any motion in the water.

6. Carefully observe how the food coloring moves for several minutes.

**Individual Questions:**

Label the diagram of this experiment and draw the patterns in the motions you observe. Indicate in the diagram where heat energy is moving into or out of the tank.

Describe what effect the movement of heat energy has on the density of the water near the locations where heat energy is moving into or out of the tank.

Describe the flow of matter (water) in the tank. Explain how the flow of heat energy causes the water to move in this pattern. In your explanation, include the role of *heat energy, gravity,* and *density*.

When you are done writing your explanation, wait for your group members to finish. Discuss your explanation with your group and compare what is the same and what is different between the group members. If necessary, revise your model and write your new explanation below:

**KEY** Density Tank Activity 2: Effects of Uneven Heating on Density

**Individual Questions:**

Label the diagram of this experiment and draw the patterns in the motions you observe. Indicate in the diagram where heat energy is moving into or out of the tank.

Heat energy in

Heat energy out

Heat energy out

Heat energy in

Ice

Hot Water

Describe what effect the movement of heat energy has on the density of the water near the locations where heat energy is moving into or out of the tank.

Where heat energy is moving into the tank, the density of the water is decreasing. Where heat energy is moving out of the tank, the density of the water is increasing.

Describe the flow of matter (water) in the tank. Explain how the flow of heat energy causes the water to move in this pattern. In your explanation, include the role of *heat energy, gravity,* and *density*.

Heat energy moving from the tank into the ice causes the temperature of the water immediately above the cup with ice to go down. This decrease in temperature increases the density of the water in that location. This increase in density causes it to weigh more than the surrounding water and gravity pulls it down.

Heat energy moving from the hot water into the tank causes the temperature of the water immediately above the cup to increase. This rise in temperature causes the density of this water to go down. Because it weighs less than the surrounding water, it will rise.

The colder, denser water pulled down by gravity pushes the water at the bottom of the tank to the side. As the hotter, less dense water rises, the water pushed to the side by the colder water moves along the bottom of the tank to replace the rising water. When that hotter water reaches the top, it moves towards the cold side of the tank to replace the colder water moving down. This creates a circulating flow of water.