Name_____ Date_____

Modeling Thermal Convection

Directions: Use the materials listed and the procedures provided to model thermal convection in a fluid system.

Materials

- One rectangular, plastic bin (approximately 13" long x 8" wide and 5" deep, such as a dish-washing bin)
- Four 5" x 5" squares of thick cardboard (1/4" thick)
- Five 12-ounce polystyrene or plastic cups
- Hot water
- Ice cubes
- Melting chocolate or wax
- Paper towels for spills
- Red and blue liquid food coloring, each with dropper or Beral pipette
- Very cold water

Procedure

As you construct the model, take care to clean up any liquid spills or dropped objects so that they do not become a slip/fall hazard.

Part 1: Convection

1. Fill the bin with very cold water (a little ice is preferable), up to a depth of 4 inches.
2. On a flat table or desk, place four of the polystyrene (or plastic) cups upside down on top of the four squares of cardboard. These cups will support the bin of water so that a fifth cup of hot water can slide underneath. Place the bin on top of the four inverted cups so that the bin is steady.
3. Draw some of the red food coloring up into the pipette and then insert the pipette into the center of the cold-water bin to deposit the dye just above the bottom of the bin. Expel the food coloring slowly so that it stays (mostly) in a dense, circular area.
4. Using the blue food coloring, place two more circles of dye on either side of the red dye, about two inches to the left and to the right. Remember to expel the dye slowly so that it stays in dense circles near the bottom of the water bin.

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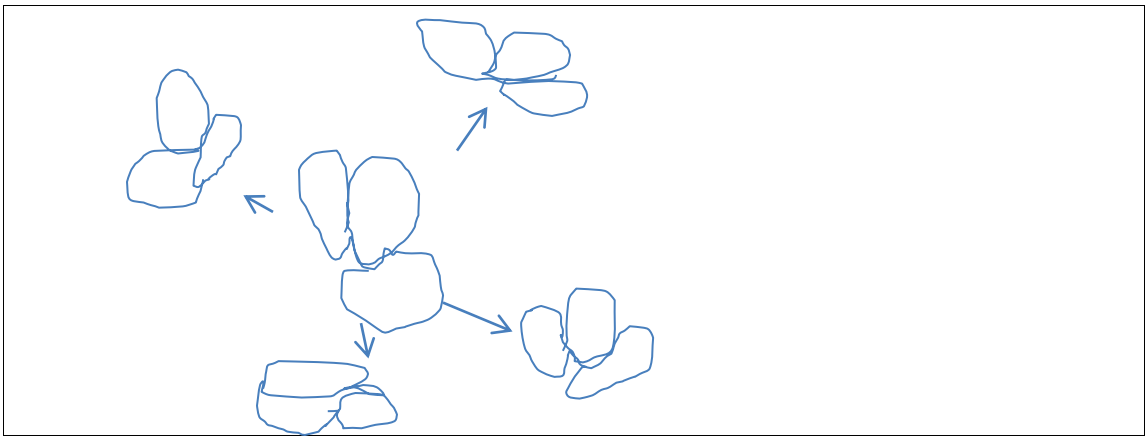
5. Fill the last polystyrene cup with very hot tap water. Carefully slide it under the cold-water bin so that it is under the circle of red dye.
6. Observe how the dyes move within the bin as thermal energy travels through the system. It may take a few minutes to see the changes.

Part 2: Surface Forces

7. Empty the plastic bin and refill with fresh cold water to a depth of 4 inches.
8. Repeat steps 3 and 4 to add food coloring to the bin.
9. To model tectonic plates floating atop the asthenosphere, melt some chocolate or wax. Using a spoon, add the melted substance to the cold water in two or three locations. You may need to place an ice cube atop each floater to help it solidify, or to model a more massive plate.
10. Repeat steps 5 and 6, and record your observations. In which direction do the floating pieces move?
11. Repeat steps 7–10 two times to try new locations for the floating chocolate or wax, or to be certain that the behaviors you observe are consistent.

Analyze

1. Describe the motion of the red and blue dyes in the bin. Draw a simple, labeled diagram to show the movement of matter and energy. Use arrows to show how the dyes spread out, come together, or change direction. Then, provide a brief written explanation to supplement your drawing. **4 points**



Explanation:

Since the red and blue dye is liquid, and they were put in the water, their molecules will spread in water in all directions. Therefore, when heat is applied underneath the bin, the molecules move in all directions and at higher speeds.

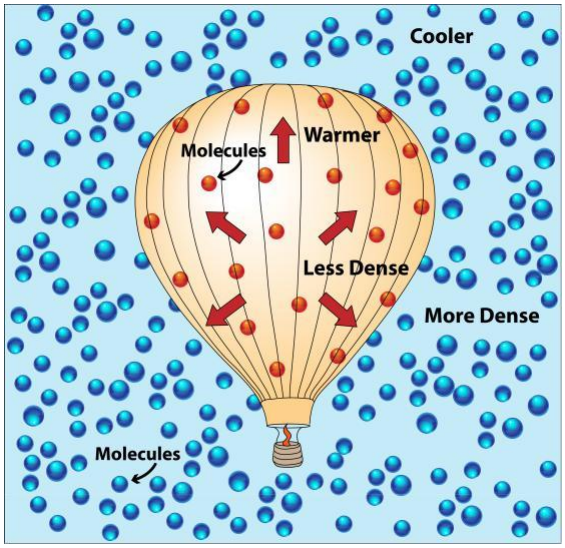
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2. What is the role of density changes in a convection cycle? **2 points**

Convection can be defined as the heat transfer process due to the fluid's density difference. How hot or cold the substance determines the density of an object. When you heat the importance, the molecules speed up hence spreading apart, occupying large volumes that cause the density to decrease.

3. Compare what happens with the red dye in the water bin with what happens to a hot air balloon surrounded by cool air. **2 points**

Since the heat is being applied to the red dye in the water bin, it will cause it to move outward. Therefore, hot air balloons fly when the air inside is more desirable than the balloon. When the cool air is surrounding the hot air balloon, there is no need for hot air inside the balloon to lift it; rather, the balloon will move so long as there is cool air outside.



4. Recall that matter cannot move without energy. What is the energy source that moves the red dye? What is the energy source that moves the blue dye? **2 points**

Both the water heater under the cup moved the red and blue dye. This is the energy source that moves red and blue dye.

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5. Why is the motion of the water in the bin considered a cycle? What could stop the cycle? What could accelerate it? **3 points**

   The motion of the water is considered a circle because the circular motion occurs when the warm liquid rises, causing the cooler liquid to drop down hence forming a convection cycle. This motion can be stopped by the density of the substances being applied to it. When the thickness is high, the cycle will be first, and when the density is low, there will be a slow cycle. Since the warmer water started the cycle, it can be, therefore, being accelerated by the hot water applied to it. At the same time, the cycle can be decelerated by using cold water on it.

6. Describe the forces that moved the floating pieces of chocolate (or wax) during Part 2 of the activity. How did the forces relate to the direction of water flow in the bin? **2 points**

   During part 2 of the activity, the melted chocolate was moved by the cold water. When the melted objects become in contact with the cool substances, that object will harden up. Therefore, the movement of the chocolate will be inward since it started to cool again. This can be explained by the cooler a liquid is the closer the molecules.

7. Water has a low viscosity (thickness). How might the movement of the dyes change if a fluid with a higher viscosity is used? **1 point**

   Since the water has a low viscosity, the movement of dye would be higher, but as long as the fluid with a higher density is used, the direction of the dye would be slower since the substance is thicker

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8. Evaluate the food coloring and water bin model. What are its strengths and limitations in modeling thermal convection? **4 points**

Food coloring and water bin model illustrates diffusion in water. But the molecule in the cold water has low kinetic energy as compared to the warm water. However, food coloring can show movement like agitation by convection. When there is hard water in a friendly environment, the water bin will conduct heat to the periphery of the water; hence the cool and denser water sinks. Therefore, when the food coloring is added to this column which is sinking will speed up the convection flow to the bottom of the bin and in all directions of the container, speeding up the diffusion rate.

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