Integrating Chemistry & Earth Science

URBAN HEAT ISLAND MODULE

LESSON 2:

Convection

THE GEORGE WASHINGTON UNIVERSITY WASHINGTON, DC

BALTIMORE CITY PUBLIC SCHOOLS

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Cary Institute of Ecosystem Studies

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The following lesson and associated materials are part of the Integrating Chemistry and Earth science (ICE) Urban Heat Island Module. The Module brings together important concepts from Earth science and chemistry to help students build an understanding of why urban areas have higher temperatures both during the day and at night, than their rural counterparts.

ICE Partners

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WASHINGTON, DC

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Lesson 2: Convection

Driving Question: *How is heat transferred within fluids, such as water bodies or the Earth's interior?*

Summary: Students will explore the process of convection with the goal of understanding: 1) the general behavior of fluids, 2) the outer core, mantle, bodies of water, and the atmosphere all regularly behave like fluids, 3) heat energy is transferred in fluids by diffusion, conduction, and convection/advection, and 4) where gravity is at work, cooled/more dense materials move downwards into the fluid forming convection cells.

Activity Description:

- **Opening Activity:** Engage student's prior knowledge/real world experience with the idea of convection by discussing a convection oven.
  - Show students a picture of a convection/toaster oven and ask students how they work.
  - If necessary, explain that convection ovens use fans to move hot air from the heating elements to evenly cook the food.
    - Optional video explanation: What is a convection oven? How it works?(YouTube 1:10)
- **Vocabulary Development:** Student's build vocabulary by defining key terms.
  - Ask students to use their own words to write definitions for what they think a fluid is.
  - Fluid: a substance that has no fixed shape and yields easily to external pressure; a gas or a liquid
- **Convection Experiment:** Students will investigate the behavior of water when it is heated from a single point, observing motion and the development of convection patterns.
  - *Convection Lab Student Sheet*
  - Materials needed:
    - Styrofoam cups
    - Clear plastic boxes
    - Food coloring
    - Ice cubes with food coloring
    - Hot water
    - Sawdust (or other granular floating material—black pepper would work as well.)
  - Discussion Prompt: What caused the patterns you observed? How do you know that the hot water and ice caused the water motion observed? How could you test it?
  - Optional Videos:
    - Convection Currents (You Tube-3:04) (a bit over-hyped, but it relates the motion of ocean water and tectonic plates). Discuss how the rising and falling of fluids are caused by density differences, and how it makes a complete cycle.
    - Convection Experiment (You Tube-2:41). Discussion here relates to movement of air; emphasize this happens in various Earth systems.

- **Homework:** Ask students to use the UHI Modeling Template to draw a model of the Earth's internal structure with layers and convection processes included.
    - Students should be able to show that convection moves heat around in the mantle (Note: the layers of the Earth are not included in the Urban Heat Island Module here, but are included in the Thermochemistry Unit as part of a fuller curriculum on heat energy).
- Student models should all be different.

Convection Lab

Objective: Students will model the motion of convection in water and relate it to motion in the Mantle.

Introduction: In this activity you will investigate how convection currents are created and how they move through a liquid or in the case of plate movement, the mantle of Earth. The mantle is a solid that is able to move slowly, often described as flexible like plastic. To understand how energy moves in the Earth system, it is important to understand convection. Convection currents affect many of Earth's systems including weather and climate, the movement of the ocean, and plate tectonics. The Theory of Plate Tectonics was not complete until scientists understood convection in the mantle. You will model how scientists explain how something as large as a continent can move.

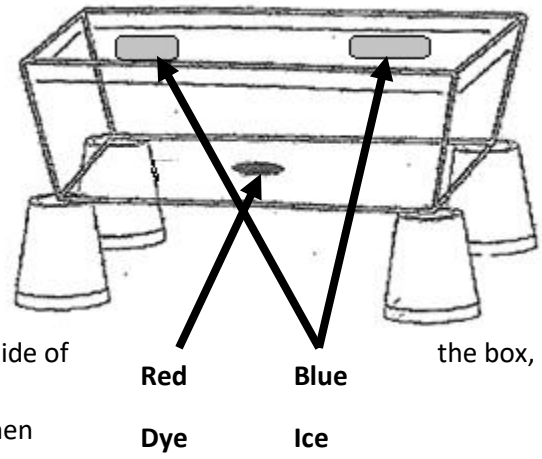
Materials:

- 5- Styrofoam cups
- 1- clear plastic rectangular pan
- 2- Pipettes
- 1- food coloring
- Water
- Paper towels
- Heat Source / Hot water
- Saw dust
- 2-Colored Ice cubes (blue dye)

Procedures:

Trial A

1. Set the clear plastic box onto the four Styrofoam cups as shown in the diagram. Carefully fill the box with cold tap water to within 3-4 cm from the top. Let the water calm before proceeding.
2. Using the pipette, carefully place 1 spot of red food coloring on the center bottom of the box. Insert the pipette all the way down to the bottom of the box before squeezing out the dye. Each spot should be about 2-4 cm in diameter. Try to minimize disturbing the water as you insert and remove the pipette.

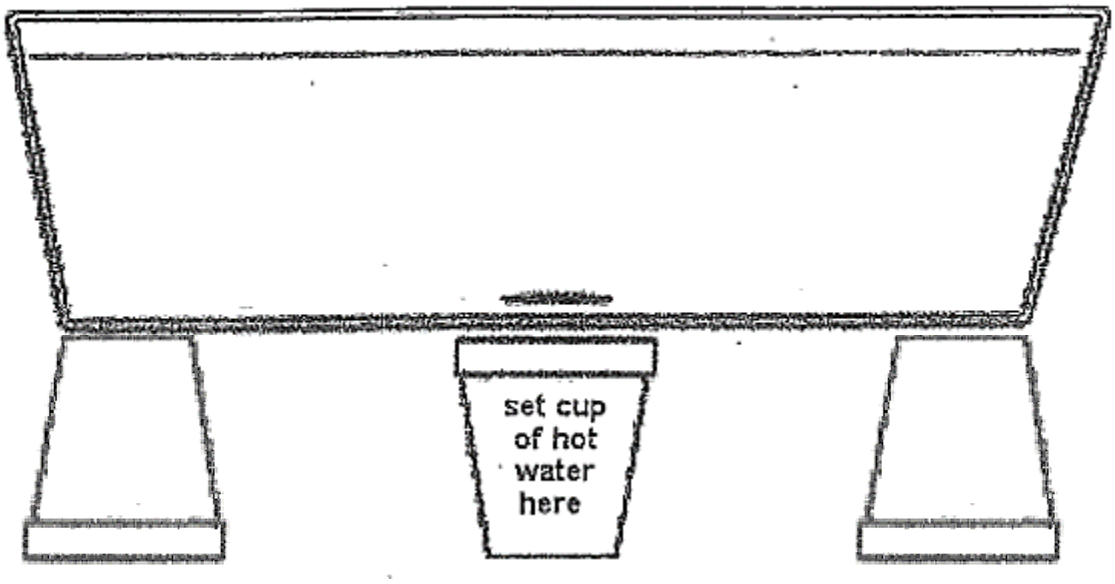


3. Float 2 ice cubes with blue food coloring on either side of the box, as shown in the diagram.
4. Fill one empty Styrofoam cup with hot water and then carefully position it beneath the center red dye spot.
5. Observe the system and record your observations below.

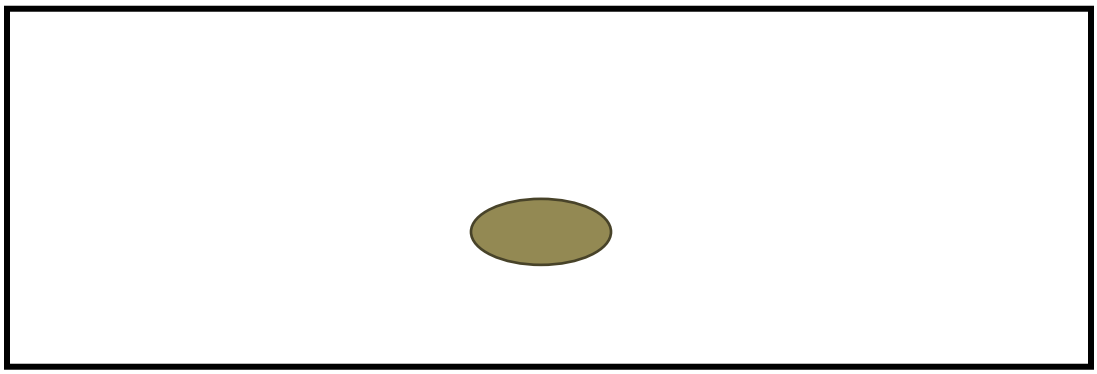
Observations:

Sketch your observations. Use colors and arrows to indicate motion.

Side View:



Top View



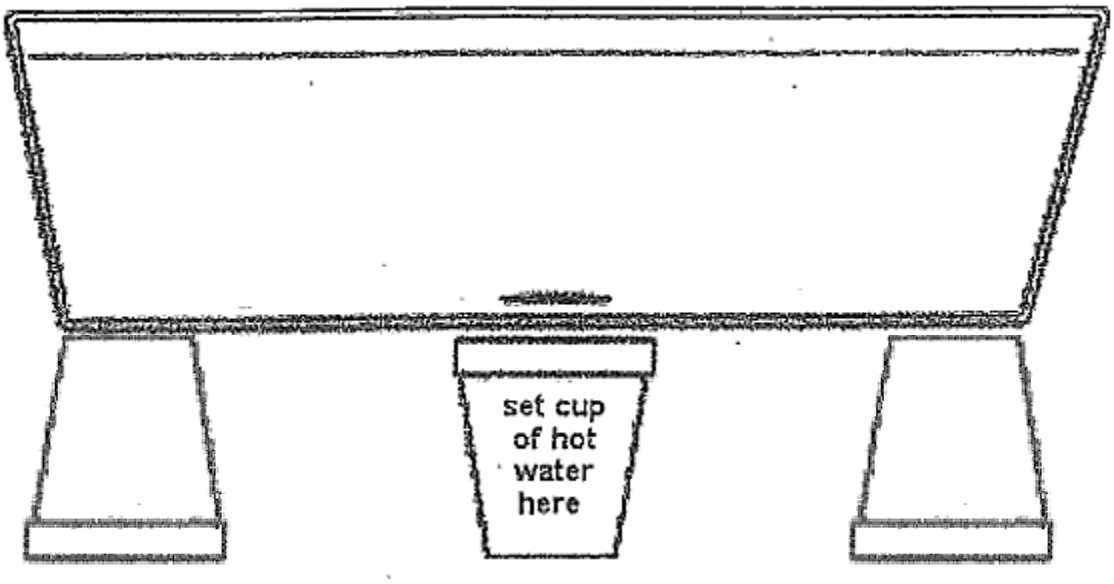
Trial B:

1. Empty your box as directed by your instructor.
2. Place your box back on the 4 cups.
3. Place 1 red drop of food coloring in the center of the box.
4. Sprinkle sawdust on the top. Place a cup under the center of the box with very hot water. The top of the hot water should touch the bottom of the box.
5. Record your observations below.

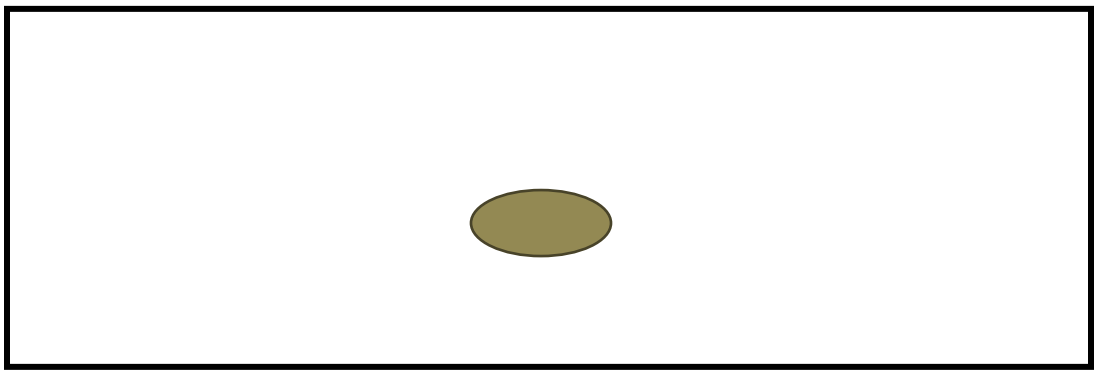
Observations:

Sketch your observations. Use colors and arrows to indicate motion.

Side View:



Top View



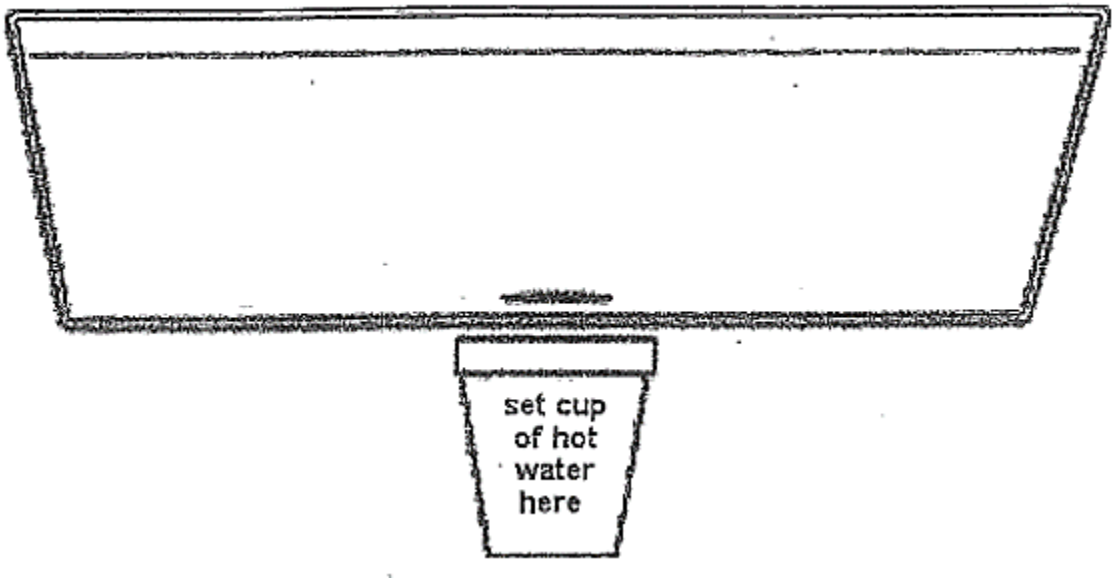
Analysis Questions:

1. A. Why does colder water sink?

   B. Why does warmer water rise?

   C. During the lab, what effect did the cups of hot water have on the density of the water directly above them?

2. You may have noticed convection cells in the box of water. Put arrows on the dashed lines in the diagram to show the direction of the flow in the box.



3. What happens to the sawdust on the surface of the water as the cup of hot water is under the box?

Conclusion: Using CER format explain how a convection current works (Claim, evidence, reasoning)