

Lab Activity on Density, Buoyancy and Convection

© 2006 Ann Bykerk-Kauffman, Dept. of Geological and Environmental Sciences, California State University, Chico*

Introduction

One of the four themes for this course is “Density, Buoyancy, and Convection.” These three important concepts help explain why the crust floats on the mantle, the tectonic plates move about, magma--which forms at great depths-- rises to the surface, the ocean has currents, the wind blows, and clouds form. The knowledge you gain in today's lab will serve as a foundation for much of the rest of the course.

Objectives

When you have completed this lab, you should be able to...

1. define *density*, *buoyancy* and *convection*.
2. describe how density affects buoyancy.
3. describe how and why temperature affects density.
4. explain how, why and under what conditions convection happens.
5. relate how convection serves as an effective mechanism for transporting heat energy.

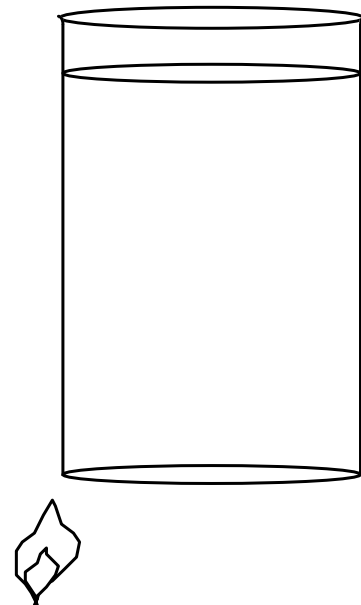
Activity #1: A Look at Convection

Materials: large (1000 ml) pyrex beaker
powdered miso cup soup
stirring stick
ring stand
wire screen
insulated gloves
Bunsen burner, hooked up to a gas valve
matches or a lighter

Activity

1. Pour about 800 ml of hot tap water into the beaker.
2. Sprinkle about 1 tsp. of soup powder into the water; stir.
3. Place the wire screen on the ring stand and place the beaker on the screen.
4. Place the Bunsen burner under the beaker, but **not in the center; place it under one edge of the beaker**. Turn on the gas and light the Bunsen burner with a match. Adjust the flame as needed, using the lever at the base of the burner, to make the flame quite hot.

Observation Question: Write a written description of the currents you see in the soup (the pattern of fluid motion formed by these currents is called **convection**). Also draw the currents on the adjacent diagram.



*Supported by NSF Grant #9455371. Permission is granted to reproduce this material for classroom use, provided no profit is made. If you use these materials in your class, please write me at abykerk-kauffman@csuchico.edu.

Lab Activity #2: Comparison of Motor Oil and Corn Syrup

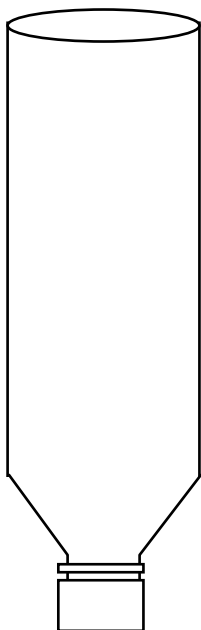
Introduction: In the first activity, you observed the phenomenon of convection. The rest of this lab will consist of a series of activities that will help you construct an understanding of how and why convection occurs. The concepts you encounter in the various activities will build on each other to form a coherent package.

Materials: 1 clear plastic bottle containing corn syrup (light colored) and SAE 50 Motor Oil (dark), turned upside down.

Activity: Turn over the bottle so that it is right side up. Observe what happens. When the fluids have stopped moving, turn over the bottle again so that it is upside down. Observe what happens this time. Repeat as often as needed.

Observation Question

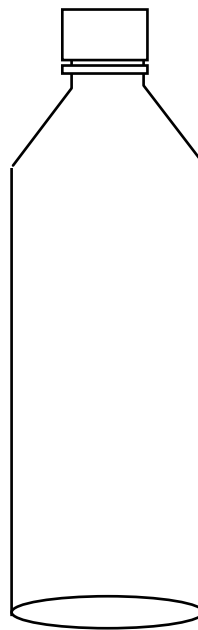
1. Complete the three diagrams below, showing the two fluids in the bottle at the times given.



a. Before you turn over the bottle



b. A few seconds after you turn the bottle right side up



c. After the two fluids have stopped moving

Thought/Interpretation Questions

2. Which fluid is more buoyant, motor oil or corn syrup? How do you know?

- Motor oil and corn syrup have different physical properties such as color, clarity, odor, density, mass, volume. Which of these properties determines the buoyancy of the fluid? Explain.
- Combining your answers to questions 2 and 3, explain which of the two fluids is more buoyant and why.
- If we took this bottle of corn syrup and motor oil up in space where there is essentially no gravity, how would the results be different? Why?

Lab Activity #3: Volume Change Caused by Temperature Change*

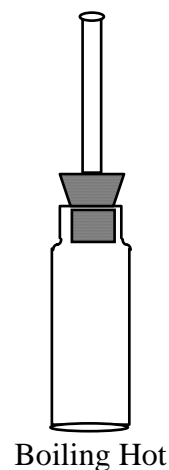
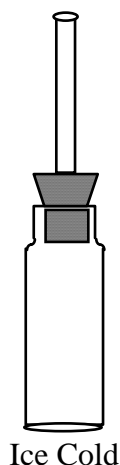
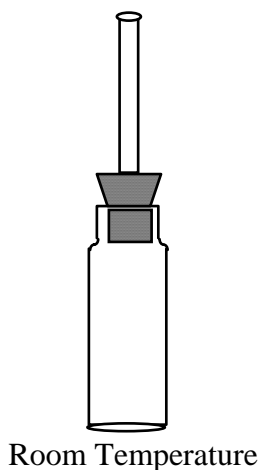
Materials: small clear glass bottle filled with green-colored water, capped with a rubber stopper that has a glass eye dropper inserted into the hole**
overhead transparency pen (water-soluble)
2 large (1000 ml) pyrex beakers
hot plate
crushed ice (from the styrofoam cooler near the sink, front left corner of the room)

Activity

1. On the eye dropper, use the pen to mark the level of the green water.
2. Pour about 400 ml of hot tap water into one of the pyrex beakers; place it on the hot plate and turn the hot plate on “high.”
3. Put about 400 ml of crushed ice into a large beaker. Add enough water to just cover the ice.
4. Place the bottle of green water in the ice water. Watch the level of the green water in the eye dropper. When the green water has settled to a constant level, mark that level with the overhead transparency pen.
5. Remove the beaker of hot water from the hot plate. Place the bottle of green water into the hot water. Watch the level of the green water in the eye dropper. When the green water has settled to a constant level, mark that level with the overhead transparency pen.

Observation Question

1. Complete the diagrams below, showing the various levels of the green water. The levels do not have to be perfectly accurate; they just have to convey the general idea.



*Activities 3 and 4 were adapted from the “Hot Water, Cold Water” activity in the Full Option Science System (FOSS) Water Module for Grades 3-4. The FOSS curriculum materials were developed under the guidance of Dr. Lawrence F. Lowerey by the Lawrence Hall of Science at UC Berkeley; they are distributed by Encyclopaedia Educational Corporation. The FOSS Water Module is in our library.

**If this set-up has not been completed for you, follow the procedure below:

1. Mix a small amount of water and a few drops of green food coloring in a beaker
2. Pour the green water into the clear glass bottle until it is almost completely full.
3. Push the end of the eye dropper into the hole on the large end of the rubber stopper.
4. Place the rubber stopper on the glass bottle; press down to seal tightly. Some green water should rise up into the eye dropper.
5. If there is any excess green water in the large beaker, discard it.

2. Did the volume of the green water change over the course of the experiment? Explain.

3. Was any green water added or taken away as you conducted the experiment? _____
4. Do you suppose the mass of the green water changed over the course of the experiment? Explain.

5. Did the density of the green water change over the course of the experiment? Explain.

6. Complete the sentence below by circling the appropriate words.

Any substance will expand / contract when it is heated and expand / contract when it is cooled (circle the correct answers).

You have just formulated a general scientific law!

7. (Extra question--answer if you have extra time at the end of lab or are assigned to present this activity) Design a thermometer, using what you learned from this activity.

Lab Activity #4: Sinking and Floating Water

Materials: hot plate

2 pyrex beakers, one large (1000 ml) and one smaller

piece of white paper

large paper clip (used to hold the pill bottle down on the bottom of the beaker)

2 clear cylindrical “pill bottles,” each with two holes in the cap

red and blue food coloring in plastic squeeze bottles, diluted to half strength

stirring stick

crushed ice (from the styrofoam cooler near the sink, front left corner of the room)

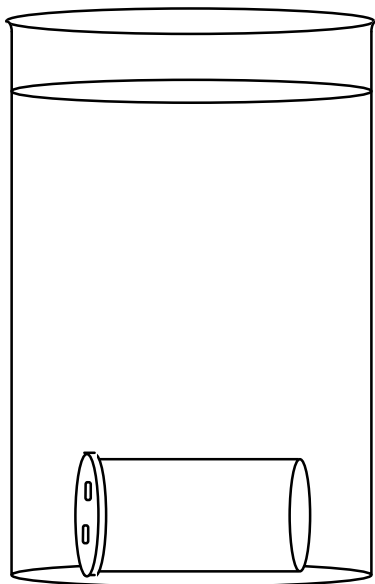
red and blue colored pencils

First Part of Activity

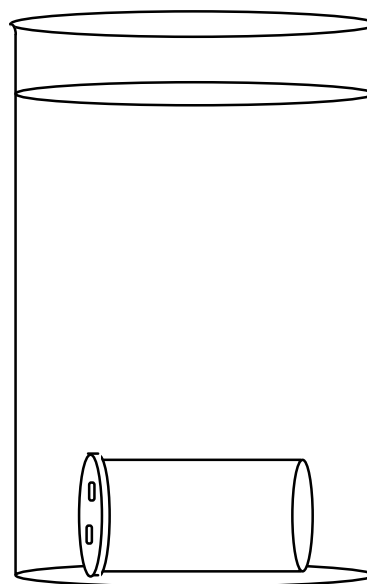
1. Using the hot plate and the small beaker, heat a small amount of water to boiling. Turn off the hot plate (the next activity requires an initially cool hot plate).
2. Fill the large beaker (to about 900 ml) with cold tap water and place it on the white paper. Let it rest undisturbed for a few minutes.
3. Place the paper clip in one of the pill bottles. Add about 10 drops of red food coloring. Then fill the pill bottle to the brim with boiling hot water. Place a cap on the pill bottle.
4. Holding the hot pill bottle upright by its cap (to avoid burning your fingers), gently place it in the beaker of water. Hold on to the pill bottle until it is completely submerged. Then let go and let it sink to the bottom. Using the stirring stick, gently tip the pill bottle on its side.

Observation Question

1. Observe the movement of the red (hot) water (Note: the red food coloring is simply a tracer to show the motion of the hot water--it does not move independently; it stays with the hot water). Record your observations by completing the two drawings below. Use a red colored pencil to show the red (hot) water.



A few seconds after placing the pill bottle in the beaker (while the water is still flowing rapidly)



Several minutes after placing the pill bottle in the beaker (after the water has mostly stopped flowing)

Thought/Interpretation Questions

2. Using the knowledge that you gained from Activities #2 and #3, explain why the red (hot) water behaved the way it did.

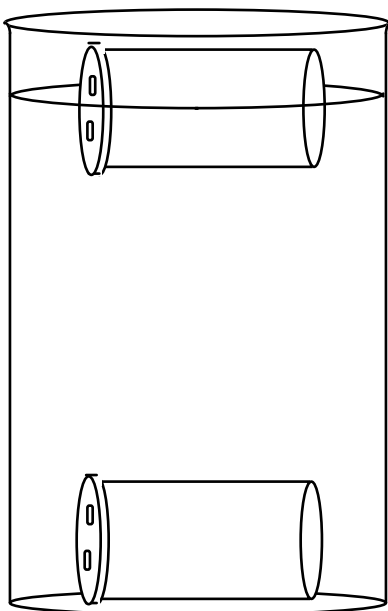
3. What do you think would happen if you placed a pill bottle full of ice cold water into the beaker?

Second Part of the Activity

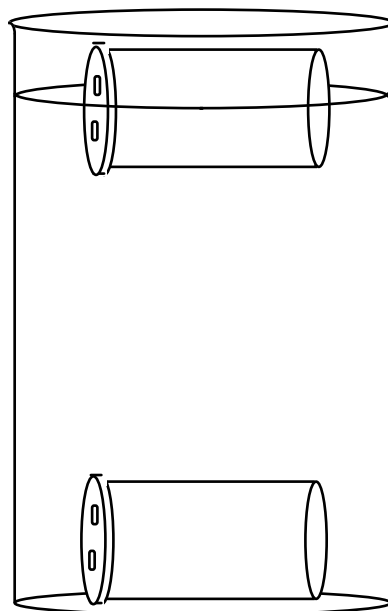
5. Completely fill the second pill bottle with crushed ice. Add a little cold water and about 5 drops of blue food coloring. Place a cap on the pill bottle.
6. Gently place the blue (cold) pill bottle sideways in the beaker; it should float.

Observation Question

4. Observe the movement of the blue (cold) water. Record your observations by completing the two drawings below. Use colored pencils to show the red (hot) and blue (cold) water.



A few seconds after placing the blue pill bottle in the beaker (while the water is still flowing rapidly)



Several minutes after placing the blue pill bottle in the beaker (after the water has been flowing for awhile)

Thought/Interpretation Questions

5. Which is more buoyant, hot water or cold water? How do you know?
6. A change in temperature must cause some other properties of the water to change, causing the difference in buoyancy that you observed. Complete the two sentences below by filling in the blanks and circling the appropriate options.
- a. When the temperature of water **increases**, its **volume** decreases / increases, causing its _____ to decrease / increase, which causes its **buoyancy** to decrease / increase.
- b. When the temperature of water **decreases**, its **volume** decreases / increases, causing its _____ to decrease / increase, which causes its **buoyancy** to decrease / increase.
7. Does the buoyancy of water go up or down when it freezes? Why?
8. How is the freezing of a substance different from a simple change in temperature? (i.e. what extra phenomenon occurs?)

Lab Activity #5: Comparison of Two Ways to Heat a Fluid (Heating from Above vs. Heating From Below)

Materials: 2 large (1000 ml) pyrex beakers

thermometer

red and blue food coloring in plastic squeeze bottles (diluted to about half strength)

2 eye droppers

electric immersion heater

hot plate that has cooled to room temperature

matches

insulated gloves

Caution: **DO NOT** plug in the immersion heater until you have placed it in water. **DO NOT** remove the immersion heater from the water until you have unplugged it. If the heater is left plugged in without being immersed in water, it will heat to red hot, blow a fuse and cease to function.

1st Part of the Activity (Beaker #1):

1. Fill one large beaker with 1000 ml of cold tap water.
2. Measure the temperature of the water at the top and bottom of the beaker. Record these temperatures in the appropriate boxes of the tables on the next page.
3. Carefully place a dropper full of blue food coloring in the bottom of the beaker, disturbing the water as little as possible. The food coloring should form a dark pool at the bottom of the beaker; there should be no food coloring in the rest of the water.

Suggested procedure:

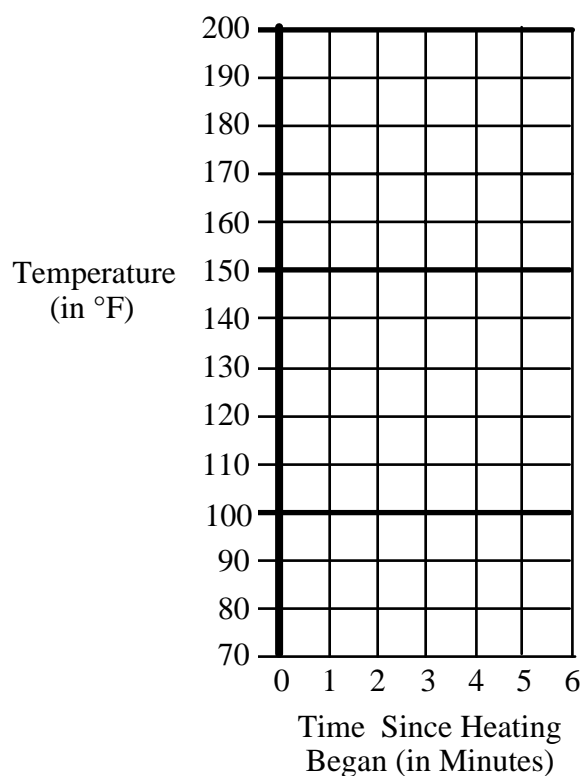
- a. Unscrew the cap on the bottle of food coloring.
 - b. Squeeze the bulb on the end of the eye dropper. Place the eye dropper in the bottle of food coloring and let go of the bulb; the eye dropper will fill with food coloring.
 - c. Very gently and slowly (so as not to disturb the water) lower the eye dropper into the beaker. When the tip of the eye dropper is in the desired location, gradually squeeze the bulb to release the food coloring. **Do not** release the bulb.
 - d. Slowly lift the eye dropper out of the water, holding the bulb in a squeezed position until the eye dropper is out of the water.
4. Immerse the metal part of the immersion heater (NOT the plastic handle or the cord) into the water. To keep the immersion heater in place, hold onto the plastic handle of the heater or drape the heater cord over the ring stand. **Once the heater is immersed in the water, plug it in. Keep the heater immersed in the water as long as it is plugged in!**
 5. Note the time (in seconds).

6. As the water gradually heats, do the five things listed (a–e) below:
 - a. Continue to hold onto the plastic handle of the heater and keep the metal part of the heater immersed in the water.
 - b. Measure the temperature near the top and bottom of the beaker every 60 seconds, completing the table below.
 - c. Carefully watch what happens to the blue food coloring.
 - d. **Important!** To get a more “hands-on” experience of the temperature changes, occasionally feel the temperature of the top and bottom of the beaker with your hands (Be careful! Don't burn yourself).
 - e. After 2–3 minutes of heating, gently and slowly, place a dropper full of red food coloring in the water near the **top** of the beaker as close to the heater as possible. Watch what happens to the red food coloring in the beaker.
7. Unplug the immersion heater before removing the heater from the water. **Leave the beaker undisturbed** until the end of the lab period.
8. Graph the change of temperature over time on the next page, using the data recorded in the table below. Connect the corresponding data points with a smooth line. Plot the temperatures for the water near the top and bottom of the beaker on the same graph, using blue pen or pencil for the temperatures near the bottom of the beaker and red pen or pencil for the temperatures near the top of the beaker.

Tables Recording the Changes in Temperature Over Time for the Two Beakers

Beaker #1 (Heated from Above)		
Time Since Heating Began	Temperature near the top of the Beaker	Temperature near the bottom of the Beaker
0		
1 min		
2 min		
3 min		
4 min		
5 min		
6 min		

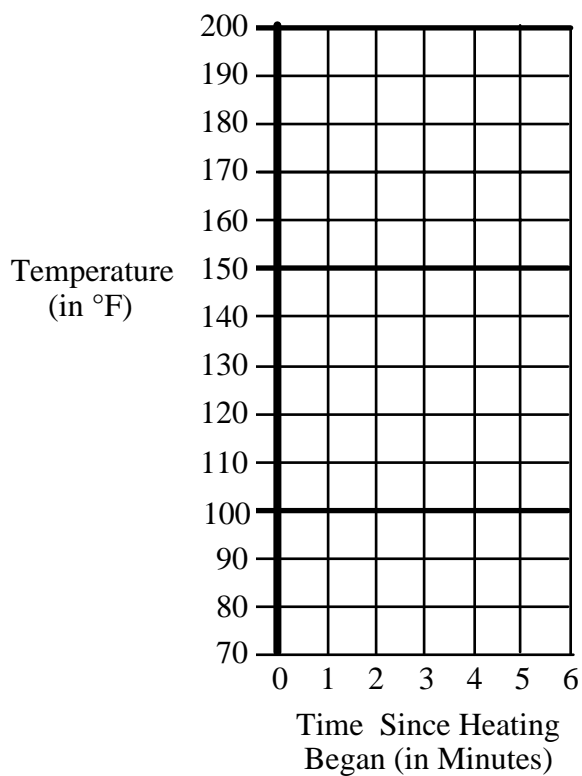
Beaker #2 (Heated from Below)		
Time Since Heating Began	Temperature near the top of the Beaker	Temperature near the bottom of the Beaker
0		
1 min		
2 min		
3 min		
4 min		
5 min		
6 min		



Graph of
Temperature vs. Time
for Beaker #1
(Heated from Above)

Red data points and line:
Temperature of the water
near the top of the beaker

Blue data points and line:
Temperature of the water
near the bottom of the beaker



Graph of
Temperature vs. Time
for Beaker #2
(Heated from Below)

Red data points and line:
Temperature of the water
near the top of the beaker

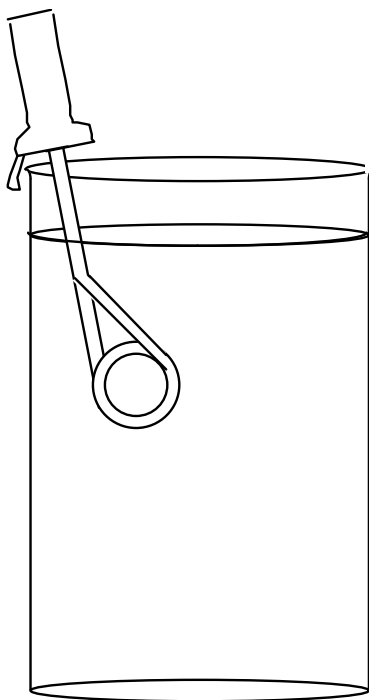
Blue data points and line:
Temperature of the water
near the bottom of the beaker

2nd Part of the Activity (Beaker #2):

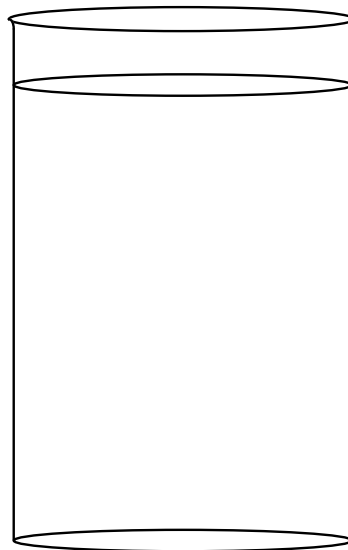
1. Fill the empty large beaker with 1000 ml of cold tap water.
2. Place the beaker of water on the cool hot plate. **DO NOT TURN ON THE HOT PLATE (YET).**
3. Complete Steps 2 and 3 as you did for Beaker #1 (see p. A-55).
4. Turn on the hot plate at a low setting.
5. Complete Steps 5 and 6 as you did for Beaker #1 (see p. A-55 to A-56).
6. Turn off the hot plate.
7. Complete Step 8 as you did for Beaker #1 (see p. A-56).

Observation Question

1. Complete the diagrams below, showing the motion of the blue-colored water immediately after heating began.



a. Beaker #1



b. Beaker #2

Thought/Interpretation Questions

2. Using the concepts you learned from Activities #2, #3 and/or #4, explain **why** any motion of the blue-colored water occurred.

3. If little or no motion of the blue-colored water occurred in one of the beakers, use the concepts you learned from Activities #2, #3 and/or #4, to explain **why** no motion occurred.

Observation Question

4. Describe the motion of the red-colored water in the two beakers. As appropriate, illustrate your explanation by adding to the diagrams on the previous page.

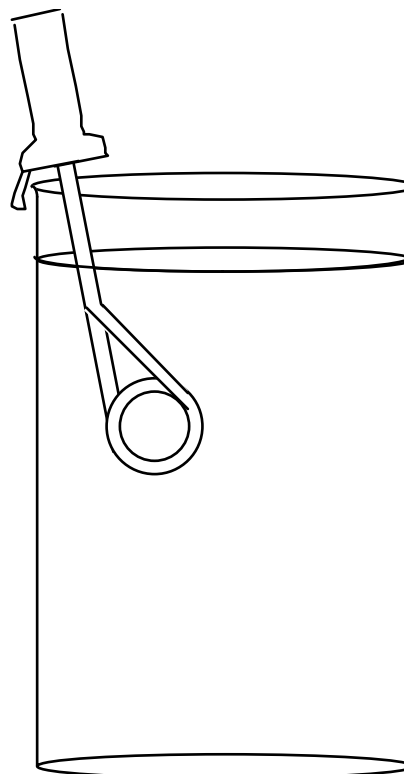
Thought/Interpretation Questions

5. Using the concepts you learned from Activities #1, #2 and/or #3, explain **why** any motion of the red-colored water occurred in the two beakers.

Putting it All Together

6. Convection in Beaker #1: Did convection occur in this beaker? If so, did it involve all of the water in the beaker or just some of the water in the beaker?

Explain, adding to the adjacent diagram as appropriate.



7. Convection in Beaker #2: Did convection occur in this beaker? If so, did it involve all of the water in the beaker or just some of the water in the beaker? Explain.



8. If you want to induce convection in a fluid by adding a heat source, should you place the heat source at the top or the bottom of the fluid? Why?
9. The higher the temperature of a given mass of water, the greater the heat energy content of that water. In which beaker was the heat energy most evenly distributed through the beaker of water?

How did that heat energy get transferred from the water located closest to the heat source to the water located farthest from the heat source?

Lab Activity #6: Cooling a Fluid from Above

Materials: 1 large (1000 ml) pyrex beaker
red and blue food coloring in plastic squeeze bottles (diluted to about half strength)
2 eye droppers
Ice

Activity

1. Fill the beaker full of tap water. Let it stand for awhile to allow the water to settle down.
2. Carefully place a dropper full of red food coloring in the bottom of the beaker, disturbing the water as little as possible. Use the procedure described on p. A-55.
3. Gently place pieces of ice into the water. Drop a few drops of blue food coloring on the ice.
4. Watch what happens.

Observation Question

1. Describe what happens. Illustrate your description by adding to the adjacent drawing of a beaker.



2. Did convection occur in the beaker? How do you know?
3. Does convection require a heat source? Why or why not?
5. Putting together everything you have learned from this lab, explain how, why and under what conditions convection occurs in a fluid.