Heat Convection Demonstration

Introduction

Heat transfer by convection in fluids occurs continuously, but often goes unnoticed. Help students understand how convection currents form in both liquids and gases with these two hands-on demonstrations.

Concepts

- Convection
- Heat transfer
- Thermal equilibrium

Materials (for each demonstration)

Convection of a Liquid

Beaker, tall form, 1-L
Flask, Erlenmeyer, 125-mL
Food coloring, red, 1 mL
Glass tubing, 5 mm O.D., 50
Glass tubing, 5 mm O.D., 2½"
Glycerin or petroleum jelly
Paper, plain white (optional)
Rubber stopper, 2-hole, #5
Stirring rod
Thermometer, Celsius
Timer or watch with second hand
Water, cold and hot

Convection of a Gas

Aluminum foil, 30 × 12"
Butane safety lighter
Candle, birthday type
Clay, marble-sized piece
T-shaped divider, 2¾" × 50
Ruler
Scissors
Timer or clock with second hand
Towel
Tube, clear plastic, 12" × 1½0 diameter, 1⁄16" thick
Water
Weighing dish, medium

Safety Precautions

To avoid burns, use caution when working with a flame or hot water, and when handling hot glassware. Wear safety glasses and heat-resistant gloves. Protect hands with a towel or leather glove when inserting glass tubing into rubber stopper. Please follow all laboratory safety guidelines.

Preparation

Convection of a Liquid—*Rubber stopper assembly*

It is important to take steps to ensure that the glass tubing is safely inserted into rubber stoppers. Fire polish ends of glass tubing, if needed. Lubricate both the end of the tubing and the hole of the stopper with glycerin or petroleum jelly. Always protect your hands with a towel or leather glove. Never try to force glass tubing into a too-small hole. The Glass-a-Matic Hand Saver (Flinn Catalog No. AP4599) is a device that makes inserting glass tubing into a rubber stopper safe and easy.

1. Insert the 2½" piece of glass tubing through the top into one hole of the two-hole rubber stopper. Push the tubing through until about a half centimeter protrudes from the bottom of the stopper.
2. Starting from the bottom, insert the 50 piece of glass tubing into the other hole of the stopper. Push the glass tubing through the stopper until about a half centimeter of tubing protrudes from the top. See Figure 1.

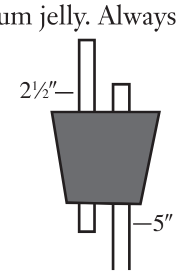

Figure 1.

Convection of a Gas

1. Cut one 2¾" × 50 T-shape from a piece of cardboard or laminated cardstock. The narrow portion of the T should just

fit into the clear plastic tube.

2. Obtain one 30 × 12" piece of aluminum foil.
3. Lay the vertical part of the T in the center of the short side of the 30 × 12" piece of foil, with the edge of the 3" side against the bottom of the cross part of the T. See Figure 2a.
4. Fold each side of the foil in, covering the vertical part of the T (like a gum wrapper). See Figure 2b.
5. Fold the bottom extra length of foil up. Part of the foil will extend beyond the top of the T. See Figure 2c.
6. Fold the tab of foil over the top of the T and press the foil down on the other side. See Figure 2d. Only the two arms of the T should be exposed. The vertical center of the T should be covered in foil. Excess overlapping foil may be trimmed.
7. The vertical center of the T should fit snuggly into the clear plastic tube. See Figure 5 on the next page.
8. Obtain a marble-sized piece of clay.
9. Press the clay into the center of a plastic weighing dish. Make sure the diameter of the 12" plastic tube will fit over the piece of clay. See Figure 5 on the next page.

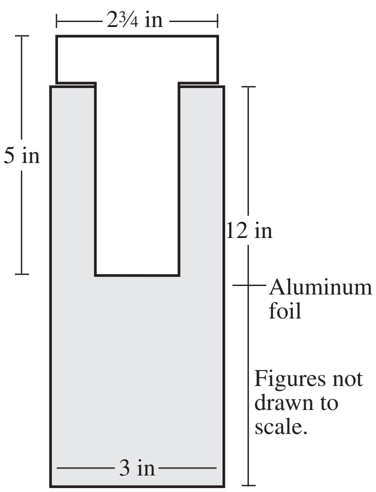

Figure 2a.

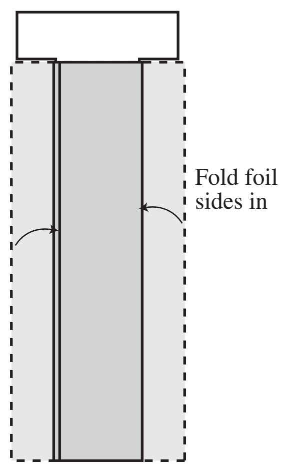

Figure 2b.

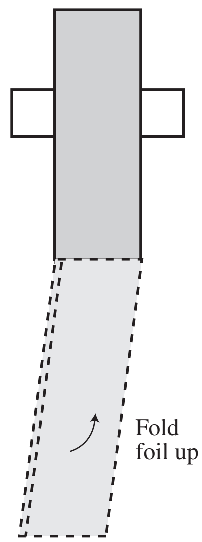

Figure 2c.

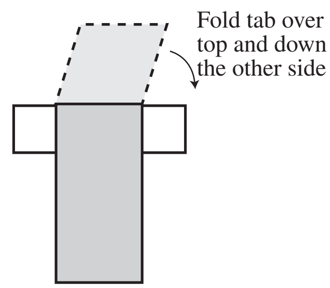

Figure 2d.

Procedure

Convection of a Liquid

1. Obtain a 125-mL Erlenmeyer flask. Wearing heat-resistant gloves, fill the flask almost to the top with very hot tap water.
2. Add 2–3 drops of red food coloring to the hot water in the flask. Stir with a stirring rod until the water is a uniform color.
3. Carefully insert the rubber stopper assembly into the flask. The shorter piece of glass tubing should reach the top of the water in the flask.
4. Obtain a 1-L tall-form beaker and slowly lower the Erlenmeyer flask into the beaker.

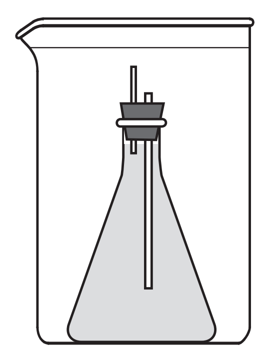

Figure 3.

5. Fill the tall-form beaker with cold tap water or ice water by carefully pouring the water down the inside wall of the beaker, not over the flask. Fill the beaker with enough cold water to cover the higher glass tube by about 1/2 centimeter. See Figure 3. Start the timer or note the time.
6. Using a thermometer, measure and record the temperature of the water near the top of the large beaker.
7. Observe any movement of water in both the flask and the beaker. *Optional:* Place a piece of white paper behind the beaker to see movement of liquid more clearly.

8. Measure the temperature of the water at the top of the beaker every minute for three minutes. Place the thermometer at the same level in the beaker each time.

Convection of a Gas

1. Obtain a new (unused) birthday candle and press the bottom of the candle into the center of the clay in a weighing dish so the candle stands up straight.
2. Add water to the bottom of the weighing dish, about halfway up the piece of clay. See Figure 4.
3. Hold the 12" clear plastic tube in one hand and, using a butane safety lighter, light the candle.
4. Lower the tube over the candle, standing the tube upright in the weighing dish. The water should prevent any air from entering the tube from the bottom.
5. Time how long the candle remains lit once the tube is in place. (The candle should go out in a few seconds.)
6. Once the candle goes out, grasp the tube near the top and remove it from the weighing dish. Dry the bottom of the tube, if necessary.
7. Obtain the foil-covered T-shaped divider. Insert the vertical part of the T into the top of the tube. See Figure 5.
8. Repeat *Convection of a Gas* steps 3–5—the candle should keep burning.
9. Allow the candle to burn for about 20 seconds.
10. Place one finger from each hand an inch above the tube, on opposite sides of the divider, for about two seconds (alternatively, have a student volunteer do this). Describe any difference in air temperature on either side of the divider.
11. Remove the T-shaped divider, but leave the tube in place. Observe any changes in the flame (the candle should quickly go out). Note how much time elapses after the divider is removed until the flame goes out.

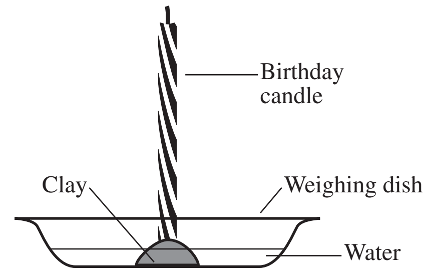

Figure 4.

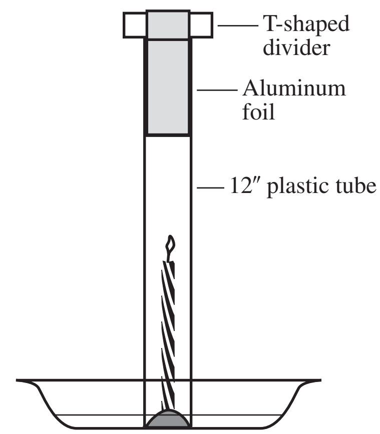

Figure 5.

Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures governing the disposal of laboratory waste. Completely cooled candles and clay may be placed in the trash according to Flinn Suggested Disposal Method #26a.

Connecting to the National Standards

This laboratory activity relates to the following National Science Education Standards (1996):

Unifying Concepts and Processes: Grades K–12
Evidence, models, and explanation
Constancy, change, and measurement

Content Standards: Grades 5–8
Content Standard B: Physical Science, properties and changes of properties in matter, understanding of motions and forces, transfer of energy
Content Standard D: Earth Science, structure of the Earth system

Content Standards: Grades 9–12
Content Standard B: Physical Science, motions and forces, interactions of energy and matter
Content Standard D: Earth and Space Science, energy in the Earth system

Tips

- In the Convection of a Liquid demonstration, the greater the difference in temperature between the two regions of water, the more noticeable the convection will be. Hot tap water is usually between 50–60 °C. A hot plate may be used to keep the water hot between demonstrations. Cold tap water is usually around 18–20 °C. A pitcher of ice water may be used to keep the water cold from one class to the next.

- Start each *Convection of a Gas* demonstration with a new candle. If the candle is too short, a convection current may not form.
- A clear plastic tube with walls at least 1⁄160 thick is necessary for this activity. A thinner tube will distort or melt from the heat.
- Be sure the candle is upright and not leaning. The heat from the flame can weaken the wall of the tube.
- Practice lowering the tube over the candle. If the flame does not go out after a few seconds without the T-shaped divider in place, it is possible the tube was lowered too slowly over the candle, allowing a convection current to be established before the bottom of the tube was "sealed." If the tube is lowered too quickly with the divider, the flame may go out before convection can be established. Lowering the tube in 2–3 seconds usually works well with and without the divider.
- Do not allow the candle to burn for more than one minute. Heat from the flame can cause distortions in the wall of the tube. Allow the tube to cool between demonstrations.
- With the divider in place, the flame height and brightness may vary quite a bit. As the air around the flame gets hotter, the "parcel" of air will rise rapidly, and may temporarily interfere with the colder descending air. The flame will then begin to diminish. The air around the smaller flame will not heat up as much as before, resulting in a slower rate of ascending air that interferes less with the descending oxygenated air. The flame will once again burn brightly.
- This activity is available from Flinn Scientific as a demonstration kit—"Heat Convection in Fluids" (Flinn Catalog No. AP7207) and as part of a student activity station kit—"Conduction, Convection, and Radiation" (Flinn Catalog No. AP7183).

Discussion

The *Convection of a Liquid* demonstration illustrates differences in densities of a liquid at two different temperatures. Each cubic centimeter of warm water is less dense than each cubic centimeter of cold water. The warm water rises to the top of the flask and flows out of one tube, while at the same time the cold water from the beaker sinks, flowing into the flask through the other tube. The addition of food coloring to the warm water allows students to observe the movement of the water. As the temperature difference between the two containers decreases, convection begins to slow down, and then eventually stops when thermal equilibrium is reached.

In the *Convection of a Gas* demonstration, the rising warm (deoxygenated) air prevents the cooler oxygenated air from flowing down into the tube. The burning candle quickly uses up the oxygen in the tube and the flame is extinguished. With the divider in place, the warm air rises up one side of the tube and the divider allows cooler, oxygenated air to flow down the other side. When the divider is removed, convection is once again disrupted and the flame goes out.

These demonstrations provide a visual image for students as they discuss real world convection patterns. Air, for example, is warmed by the sun and rises from the Earth as surrounding colder air masses sink. This continually changing temperature differential results in a global pattern of atmospheric movement that influences local weather. All bodies of water are in continual density turnover as night and day warming/cooling cycles occur. The Earth's internal heat drives convection circulation in the mantle. Many other examples of convection in fluids can be discussed and related to these demonstrations.

Materials for *Heat Convection Demonstration* are available from Flinn Scientific, Inc.

Catalog No.	Description
AP7207	Heat Convection in Fluids—Demonstration Kit
AP7183	Conduction, Convection, and Radiation—Lab Station Kit
AP4599	Glass-a-Matic Hand Saver
C0226	Candles, Birthday-type, pkg/24
GP9020	Glass Tubing, Soft Glass, 240 lengths
AP2315	Rubber Stoppers, Two-Hole, Size 5
GP1061	Beaker, Borosilicate Glass, Berzelius, 1-L

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.