Thermal Convection of a Fluid

http://web.ics.purdue.edu/~braile/edumod/convect/convect.htm

Focus on Inquiry

The students will calculate the velocity of convection currents using vegetable oil and thyme leaves.

Lesson Overview

In this activity, students will conduct an experiment on thermal convection using vegetable oil and thyme leaves. They will calculate the velocity of convection currents and relate the components in their experiment to our understanding of the convection that is inferred for the Earth's mantle. They will also relate how their experimental model can produce horizontal flow that can cause (or is related to) plate motions.

Duration	Setting	Grouping	PTI Inquiry Subskills
2 – 45 minute classes	Classroom	Either a teacher demonstration or Student groups of 4	**1.3, 3.1, 3.2, 3.5, 3.6, 3.7, 4.2, 4.3, 5.2, 5.3, 5.8, 5.9, 7.2, 7.3**

Lesson Components	Estimated Time	Inquiry Subskills Used	Technology Used	Level of Student Engagement	Brief Description
Engage (Day 1)	5 min.	5.8	None	1	Teacher demonstration and comparison of Earth's layers to peach.
Explore	35 min.	3.1, 3.2, 3.5, 3.6, 3.7, 4.2, 4.3, 5.8	None	3	Students complete an experiment using vegetable oil, thyme, and a heat source to measure the velocity of the fluid in the convection cells in the experiment.
Explain (Day 2)	25 min.	5.2, 5.3 5.9, 7.2, 7.3	None	3	They relate the components in their experiment to convection currents in the Earth's mantle.
Expand	15 min.	1.3, 3.7, 5.2, 5.4, 7.2	None	3	Students further explore convection using hot and cold water.
Evaluate			None	3	Student handout can be used for assessment of student knowledge.

Level of Student Engagement

1	Low	Listen to lecture, observe the teacher, individual reading, teacher demonstration, teacher-centered instruction
2	Moderate	Raise questions, lecture with discussion, record data, make predictions, technology interaction with assistance
3	High	Hands-on activity or inquiry; critique others, draw conclusions, make connections, problem-solve, student-centered

National Science Education Standards – Inquiry

Use appropriate tools and techniques to gather, analyze, and interpret data.
Develop descriptions, explanations, predictions, and models using evidence.

National Science Education Standards – Earth Science

The solid earth is layered with a lithosphere; hot, convecting mantle; and dense, metallic core.

Louisiana Grade Level Expectations – Inquiry

Gr. 8, Inquiry GLE#6 – Select and use appropriate equipment, technology, tools, and metric system units of measurement to make observations (SI-M-A3)
Gr. 8, Inquiry GLE#7 – Record observations using methods that complement investigations (e.g., journals, tables, charts) (SI-M-A3)
Gr. 8, Inquiry GLE#8 – Use consistency and precision in data collection, analysis, and reporting (SI-M-A3)
Gr. 8, Inquiry GLE#11 – Construct, use, and interpret appropriate graphical representations to collect, record, and report data (e.g., tables, charts, circle graphs, bar and line graphs, diagrams, scatter plots, symbols) (SI-M-A4)
Gr. 8, Inquiry GLE#12 – Use data and information gathered to develop an explanation of experimental results (SI-M-A4)
Gr. 8, Inquiry GLE#13 – Identify patterns in data to explain natural events (SI-M-A4)
Gr. 8, Inquiry GLE#14 – Develop models to illustrate or explain conclusions reached through investigation (SI-M-A5)
Gr. 8, Inquiry GLE#15 – Identify and explain the limitations of models used to represent the natural world (SI-M-A5)

Gr. 8, Inquiry GLE#19 – Communicate ideas in a variety of ways (e.g., symbols, illustrations, graphs, charts, spreadsheets, concept maps, oral and written reports, equations) (SI-M-A7)
Gr. 8, Inquiry GLE#22 – Use evidence and observations to explain and communicate the results of investigations (SI-M-A7)

Louisiana Grade Level Expectations Earth Science

Gr. 8, GLE# 8 – Identify and describe the four density layers of Earth (ESS-M-A1)
Gr. 8, GLE# 10 – Illustrate the movement of convection currents (ESS-M-A2)

Materials List

For ***Explore*** experiment (per group):

- 1 glass bread loaf dish (a larger size can be substituted if additional candles are used as the heat source)
- 2 ceramic coffee cups
- 2 (or more) small candles
- vegetable oil (about 800-1000 ml)
- 10 ml (~ 2 teaspoons) thyme
- spoon
- matches
- metric ruler
- stopwatch
- funnel (to pour oil back into container)
- 3 pieces of thin (about 2mm, or 1/16" thick) balsa wood, each 4x10 cm

For ***Expand*** experiment:

- Four empty identical bottles (mouth of the bottle should be at least 1 1/2 inches in diameter)
- Access to warm and cold water
- Food coloring (yellow and blue)
- Two 3x5" index cards or old playing cards

For ***Explain*** section:

- Peach

Advance Preparation

- This activity can be done as a teacher demonstration or in student groups of four. Teacher should decide if students are capable of creating the model and investigating on their own. If done as a teacher demonstration, teacher should prepare model as stated in the "Thermal Convection Experiments" section of activity website.
- Download the entire lesson from the website.
- Run copies of **Blackline Master 1** for students.

Other Information

Learning Objectives

The learner will…

- Experiment with thermal convection.
- Create a model and illustrate how thermal energy can generate motion in a fluid.

Prior Knowledge Needed by the Students

None.

Procedure

Engage

1. Show students a peach. Tell student that the Earth can be compared to a peach. Compare the parts of a peach to the layers of the Earth. The skin of the peach is like Earth's thin crust. The fruity part of the peach is like Earth's mantle. The seed of the peach is like Earth's core. Explain to students that they will investigate to find out more about the nature of the Earth's mantle.

Explore

1. Distribute **Blackline Master 1**, "Thermal Convection Investigation," to students.
2. If necessary, mix vegetable oil and thyme in a loaf dish for the students and place dish on top of the heat source and arrange materials as shown in Figure 1 on the **Blackline Master 1**.

Explain

1. Students draw illustrations and answer questions to explain their observations on **Blackline Master 1**, "Thermal Convection Investigation."
2. Students record the velocity of the liquid from their model on the handout.
3. Students record the velocity of the piece of balsa wood on their handout.
4. Students record their comparison of fluid velocity pre and post balsa wood.
5. Have students relate the components that they used in their experiment to the earth's mantle and crust. Have students explain how these components represent a model of the earth's convection in the mantle. In what ways is the model accurate? In what ways could the model be improved?

Expand

1. Fill two bottles with warm water from the tap and the other two bottles with cold water. Use food coloring to color the warm water yellow and the cold water blue. Each bottle must be filled to the brim (or slightly overflowing, i.e. with a water bubble on top) with water.
2. *Hot water over cold water demonstration*: Place the index card (or old playing card) over the mouth of one of the warm water bottles. Hold the card in place as you turn the bottle upside down and rest it on top of one of the cold water bottles. The bottles should be positioned so that they are mouth to mouth, and the card is separating the two liquids. Try to do this so that there are no air bubbles caught in either bottle.
3. Ask students to predict what they think will happen to the two fluids when you invert the hot water over the cold water.
4. Carefully slip the card out from in between the two bottles. Make sure that you are holding onto the top bottle when you remove the card. Observe what happens to the colored liquids in the two bottles.
5. *Cold water over hot water demonstration*: Again, have your students predict what will happen when you invert the cold water over the hot water. Repeat steps 2 and 3, but this time place the bottle of cold water on top of the warm water. Observe what happens.
6. Have students explain what they observe based on what they learned in today's lab.

Evaluate

1. Student illustrations and answers to **Blackline Master 1**, "Thermal Convection Investigation" can be used for assessment.

Supplementary Resources

A variety of resources are located on the activity website.

Student name _____ **Class** _____

Thermal Convection Investigation

Follow the procedures to set up the model. Your teacher may have completed the first two steps for you. Answer the questions when appropriate.

1. Mix the vegetable oil and the thyme (spice) in the loaf dish.
2. Stir thoroughly to distribute the flakes of thyme. Arrange loaf dish and other materials as shown in Figure 1. (Note: The heat source should not yet be lit.)
3. Observe the oil and spice mixture.
4. Describe your observations. _____
   _____
   _____
   _____
5. Light the heat source and let the liquid heat up for a couple of minutes. As the oil heats and begins to flow, observe the pattern of fluid flow (circulation) by noting the location of individual flakes of thyme over time. **Be sure to view the model several times during the experiment, both from <u>above</u> the dish and from the <u>side</u> of the dish.** Draw a sketch of the circulation in the loaf dish of Figure 1 (below). Use arrows to show the direction of flow.

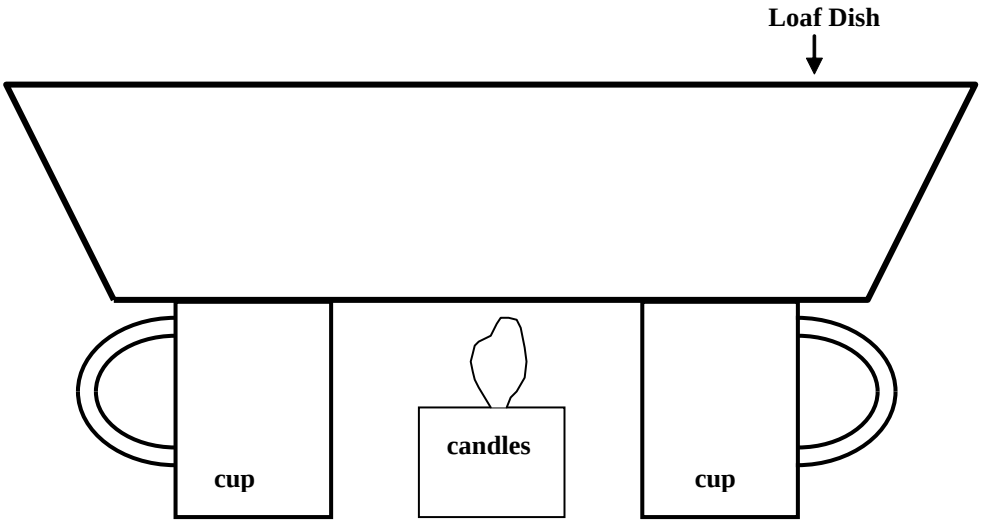


Figure 1

6. Answer the following questions:
   a. Is the pattern approximately symmetric on the two sides of the heated area?

   b. Where do you observe upward flow?

   c. Where do you see downward flow?

   d. Where do you observe horizontal flow?

7. Measure the horizontal velocity of the convective flow near the surface of the liquid by placing a metric ruler on the top of the loaf dish (oriented along the long direction). By looking down on the convecting fluid from above, observe an individual flake of thyme, and measure the distance that one flake moves in 20 seconds using a clock or stopwatch.

   Record the distance (cm): _____

8. Divide the distance (in cm) by the time (in seconds) to determine the velocity in cm/s.

   Record the velocity (cm/s): _____

9. Measure the velocity and direction of movement at several locations to obtain the near-surface flow of the liquid. Do this the same way as you did in Step 7 above, but choose different flakes of thyme in different locations in the pan. Do this for five (5) different flakes of thyme.

   A. Record the velocities (cm/s) below:

   Measurement 1: _____

   Measurement 2: _____

   Measurement 3: _____

   Measurement 4: _____

   Measurement 5: _____

   B. Draw the path of each of your 5 flakes of thyme in this diagram of your pan. Number each path with the corresponding measurement number.

   a. Are all of the measurements approximately the same? _____

   b. Where are the velocities the largest?

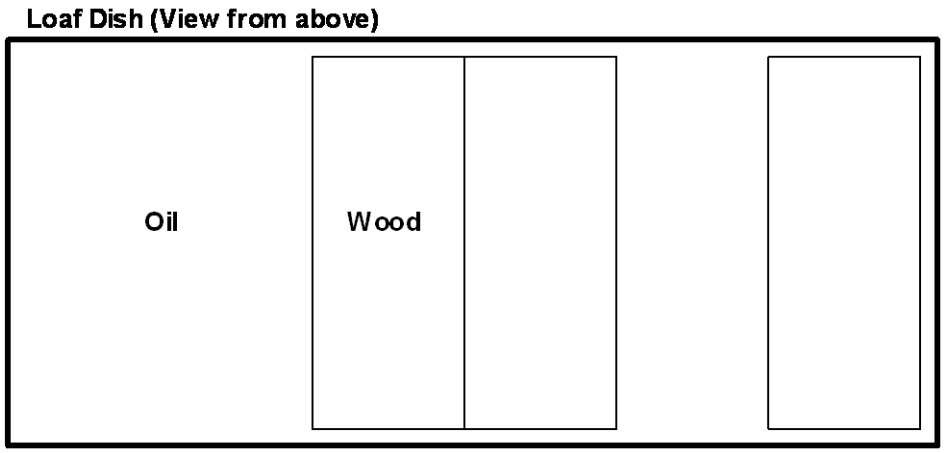
   c. Where are they the smallest?

   d. What could explain these variations in velocity?

   e. Are the directions of flow "away from" the heated central area of the container?

   f. What effects or characteristics of the model might cause variability in the velocities?

10. Place the thin pieces of balsa wood on the surface of the liquid as shown in the figure below.



a. Observe the motion of the pieces of wood. Describe the motion of the wood below.

b. Using a metric ruler and stopwatch or clock as in step 7, measure the velocity of one of the pieces of wood.

c. How does this velocity compare to the fluid flow velocities that were obtained previously (steps 7-9)? Record your comparisons below.