MOTION IN THE OCEAN (2 HOURS)

Addresses NGSS
Level of Difficulty: 3
Grade Range: 6-8

OVERVIEW

In this activity, students will model the process of heat transfer by convection in Earth's oceans.

Topic: Ocean convection

Real World Science Topics:

- An exploration of how water density is related to water temperature
- An exploration of how density differences cause convection in Earth's oceans

Objective

Students will gain an understanding of how temperature differences in ocean water cause convection currents.

Materials Needed for Each Team of 2-4 Students:

one 2-inch deep baking dish

one clear glass jar or beaker

one hot plate (alternatively, a stovetop burner or a Bunsen burner may be used)

wood blocks of appropriate size and number to support the baking dish (alternatively, if a Bunsen burner is used, four ring stands may be used)

food coloring

ice

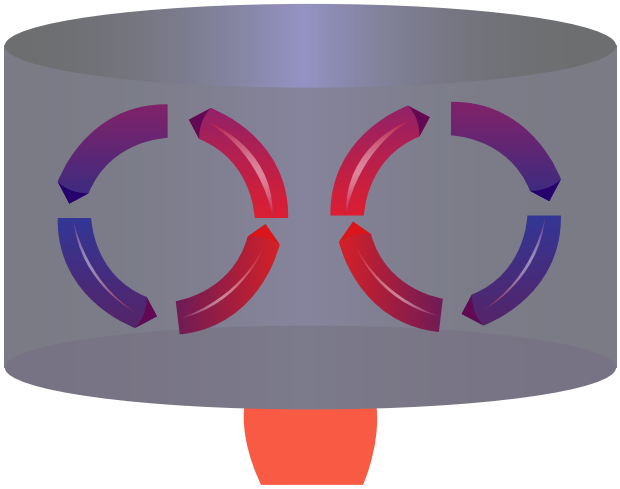
water

Additional Materials for Extension Activity:

ground pepper or toothpick segments

STEPS FOR *MOTION IN THE OCEAN*

1. **Warm-up Activity:** Open the class by showing students a diagram of a **convection cell.** Explain that a convection cell forms when the warmer parts of a fluid rise as the cooler parts of the fluid sink, causing vertical movement within the fluid. Then, ask students why the warmer parts rise and the cooler parts sink. Discuss the differences in density caused by the difference in temperature. Guide the students by describing how gravity acts on objects with different densities. Will objects that are denser than water float or sink in a body of liquid water? Why does raising the temperature of an object generally decrease its density? Why does lowering the temperature of an object generally increase its density? If necessary, remind students that an important factor determining the density of a substance is how closely packed the particles in it are, and that heating a substance generally causes its particles to move farther apart. Note also that water can be an exception to this rule. Unlike most other substances, when water freezes, it expands and its density decreases (which is why ice floats on water). However, while in the liquid state, water behaves as other liquids and becomes denser when its temperature is lowered. During this activity, students will model convection currents that occur in the ocean.



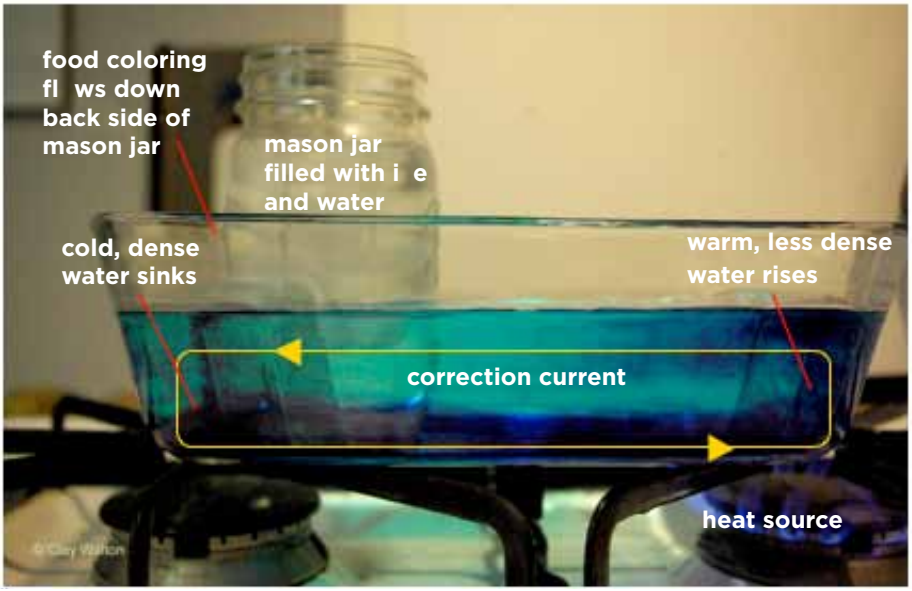
In substances that behave as fluids (that is, substances that flow in response to stress), differences in temperature caused by the addition of heat cause differences in density. Those density differences, in turn, can cause convection.

2. Divide students into groups of two to four and distribute the *Motion in the Ocean* handout and materials needed for the rest of this lab.

3. Tell the students that the goal of the project is to model the convection process that occurs in Earth's oceans. The handout includes a general description of how to model convection.

4. The students are given a basic setup, shown below, to create their convection model. Students should take special care to arrange the baking dish, wood blocks, and hot plate in a stable configuration. The baking dish should be arranged such that one end rests above the hot plate. Wood blocks can be used to support the other end of the dish. (If using a Bunsen burner, have students rest the baking dish on four ring stands such that one end of the dish is above the burner) It is important that the heat source and the clear glass jar of ice

water are at opposite ends of the pan. Although the shape and size of the baking dish also affect the formation of a convection cell, this arrangement should help simplify the model and minimize turbulence in the water as it is heated. (Note: students may use either a solid or clear baking dish. Both types are shown below.)



[Note that for the setup in which a hot plate is used, the end of the baking dish that contains the glass jar should be supported by wood blocks in the student setup.]

5. After attaining a clear example of a convection cell, students may want to experiment with different relative positions of the glass jar and heat source to see how this affects the pattern of convection. They may also want to explore different ways of introducing the food coloring. For example, rather than placing the ice in a glass jar, they may want to place the food coloring directly on cubes of ice and then place the ice directly into the water.

6. As students begin to observe how the dyed water moves in their baking dishes, ask them to explain why the dyed water moves as it does. Why does the food coloring first move down instead of up? Why does the food coloring move toward the heat source instead of away from it? Ask students to explain how heat is being transferred in this system. What changes could students make to their models to cause the convection current to change shape or direction? If students do not know how to answer, suggest that the position of the heat source could be changed, the amount of water could be altered, or an obstacle could be placed in the middle of the pan.

7. **Wrap-up Activity:** Lead the class in a discussion of the results of this activity. Ask them to identify how their models illustrate the process of convection in the ocean. Then ask them to share how their models differ from the convection that occurs in the ocean. For example, the food coloring used added to the density difference between the warmer and cooler water in the pan. Discuss the fact that the ocean is a much more complex system than that of the models used in this activity and that many different factors can contribute to convection in the ocean. For example, in the ocean, differences in salinity also cause differences in ocean water density. Guide students to understand that deep ocean currents are caused by convection, and surface currents are generally caused by prevailing winds. You may also wish to allow students to experiment with the effects of placing objects in the path of the convection current. Have students compare the motions of the water around these objects to the paths taken by deep ocean currents when they encounter a continent or large island. You may also want to ask students to identify other Earth systems, such as the atmosphere, mantle, and outer core, in which convection occurs.

Motion in the Ocean Extension Activity

Students can use the setup of this activity to explore other aspects of convection. One activity students could perform is to explore the relationship between deep currents and surface currents. Students could repeat the procedure and add ground pepper or toothpick particles to the pan before the hot plate is turned on. They can then observe how the convection caused by heating the water affects how the surface moves. Additionally, without using a heat source, students can experiment with food coloring and salt to discover how density is affected by differences in salinity.

MOTION IN THE OCEAN
BACKGROUND INFORMATION

What is convection?
Three processes transfer heat energy: conduction, radiation, and convection. In all three processes, heat is transferred from an object that is warmer to an object that is cooler until the temperature of both objects is the same. Conduction occurs when heat is transferred directly between objects that are in contact with each other. Radiation occurs when heat energy moves through a medium as electromagnetic waves. Convection occurs when heat is transferred from one region of a fluid material to another region by the movement of the fluid itself. This movement of fluid is caused by differences in density, which are caused by differences in temperature. For most fluid materials, when the addition of heat causes the temperature to rise, the material expands, becoming less dense. As a result, the warmer material rises relative to the cooler parts of the fluid.

Where does convection occur?
Two of the most familiar materials in which convection occurs are water and air. Convection can occur in any material that behaves as a fluid. Such materials include the Earth's oceans, atmosphere, mantle, and outer core, as well as the convective zones within stars.

How does convection affect ocean currents?
There are two main types of ocean currents: surface currents and deep water currents. Surface currents are caused mainly by the action of prevailing winds, but deep ocean currents are caused primarily by convection. In the ocean, convection is influenced on a large scale by the sinking of cooler surface water at the poles, where atmospheric temperatures are at their lowest. As the cooler water sinks, it slides along the ocean floor toward the equator. This forces the deep water near the equator upward toward the surface, where it can be warmed by the atmosphere. Deep ocean convection currents are also driven by differences in salinity. Salty water is denser than fresh water. Ocean water at the poles tends to be saltier than that at lower latitudes because salt is "left behind" as the ocean water freezes at the poles. The combination of high salinity and low temperature makes polar ocean water significantly denser than ocean water at lower latitudes, producing convection currents.

key Vocabulary
convection: the vertical movement of a fluid material caused by differences in density, which are commonly caused by differences in temperature
current: the organized flow of a fluid
density: the amount of matter within a given volume
salinity: the concentration of dissolved salts in water

STUDENT HANDOUT
MOTION IN THE OCEAN

Follow the directions below to model ocean water convection.

1. Fill the baking dish with tap water to a depth of about 5 cm. Use the wood blocks to provide a stable support for the pan. Place the pan so that one end is supported by the wood blocks and the other is on the heating element of the hot plate. Turn on the hot plate.

2. Fill the glass jar with ice and then add tap water so that the jar is full. Allow a few minutes for the ice to cool the jar.

3. Allow time for the water in the pan to develop tiny bubbles at the bottom of the end that is supported by the hot plate. When the bubbles appear, place the jar of ice water in the opposite end of the baking dish.

4. On the side of the jar facing away from the hot plate, place several drops of food coloring on the outside of the jar, allowing the food coloring to run down the side of the jar and into the water.

5. Observe the results. You may want to add additional drops of food coloring to the outside of the jar.

6. Draw a diagram that shows the movement of the colored water in your model. Use labels to indicate the transfer of heat and the changes in the temperature and density of the water.

What happened to the water that was dyed with the food coloring?

How does your model represent the process of ocean convection?

Identify a limitation of your model of ocean convection.

Draw a sketch that shows how your model illustrates the process of convection.

TEACHER HANDOUT
MOTION IN THE OCEAN

Follow the directions below to model ocean water convection.

1. Fill the baking dish with tap water to a depth of about 5 cm. Use the wood blocks to provide a stable support for the pan. Place the pan so that one end is supported by the wood blocks and the other is on the heating element of the hot plate. Turn on the hot plate.

2. Fill the glass jar with ice and then add tap water so that the jar is full. Allow a few minutes for the ice to cool the jar.

3. Allow time for the water in the pan to develop tiny bubbles at the bottom of the end that is supported by the hot plate. When the bubbles appear, place the jar of ice water in the opposite end of the baking dish.

4. On the side of the jar facing away from the hot plate, place several drops of food coloring on the outside of the jar, allowing the food coloring to run down the side of the jar and into the water.

5. Observe the results. You may want to add additional drops of food coloring to the outside of the jar.

6. Draw a diagram that shows the movement of the colored water in your model. Use labels to indicate the transfer of heat and the changes in the temperature and density of the water.

What happened to the water that was dyed with the food coloring?

[The food coloring ran down the side of the jar and into the water, and then the dyed water traveled along the bottom of the baking dish toward the side of the baking dish that was being heated by the hot plate. When it reached the far side of the pan, it rose to the top and then began traveling back toward the jar.]

How does your model represent the process of ocean convection?

[In the ocean, warmer, less dense water rises to the surface and cooler, denser water sinks, causing convection. The food coloring showed how the water moved as it changed in density.]

Identify a limitation of your model of ocean convection.

[Food coloring is denser than water, so adding the food coloring to the cooler water also increases its density.]

Draw a sketch that shows how your model illustrates the process of convection.

[Student sketches should include labels indicating regions of high and low temperature and density in their models.]