Convection Currents and Thermal Energy

Strand Force, Motion, and Energy

Topic Investigating radiation, convection, and conduction

Primary SOL 6.3 The student will investigate and understand the role of solar energy in driving most natural processes within the atmosphere, the hydrosphere, and on Earth's surface. Key concepts include
- b) the role of radiation and convection in the distribution of energy;
- c) the motion of the atmosphere and the oceans;
- e) the role of thermal energy in weather-related phenomena including thunderstorms and hurricanes.

Related SOL 6.1 The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which
- i) models and simulations are designed and used to illustrate and explain phenomena and systems.

6.2 The student will investigate and understand basic sources of energy, their origins, transformations, and uses. Key concepts include
- b) the role of the sun in the formation of most energy sources on Earth.

Background Information

The atoms and molecules that make up the various layers in the atmosphere are always moving in random directions. Despite their tiny sizes, when they strike a surface, they exert air pressure. Since molecules move in all directions, they can even exert air pressure upwards when they smash into object from underneath. Air pressure can be exerted in all directions.

Each molecule is too small to feel and exerts only a tiny bit of pressure. However, when we add up all the pressures from the huge number of molecules that strike a surface each moment, the total pressure is considerable. This is air pressure. As air is compressed, the density of the air increases and the number of strikes per unit of time and area also increases.

Earth's atmosphere energy balance is the balance between incoming energy from the sun and outgoing energy from Earth. Energy released from the sun consists of energy wavelengths of the entire electromagnetic spectrum. When light waves reach Earth, some are reflected back to space by clouds, some are absorbed by the atmosphere, and some are absorbed at Earth's surface.

Both high-pressure and low-pressure air/atmospheric systems are driven by solar energy. Heat causes air to expand and become less dense, which then causes that air to rise in Earth's atmosphere, resulting in an area of low pressure. Because the cooler air higher in the atmosphere is denser, it then sinks and replaces the air that has risen, resulting in an area of high pressure. Once this cooler, denser air has sunk toward Earth, it is eventually warmed, and the cycle continues. The replacement of the warmer (less dense) air by cooler (more dense) air is called a *convection current.*

Materials

- Hot Potato game supplies
- Recording of Glen Frey song, "The Heat is On"
- Small latex balloon
- Rubber bands
- Large salad dressing bottle
- Hot water
- Large rectangular pan (about 33 x 23 cm)
- Science journals

Vocabulary

atmospheric pressure, conduction, convection, heat transfer, radiation, thermal energy, thermal expansion

Student/Teacher Actions (what students and teachers should be doing to facilitate learning)

Introduction

1. Have students sit in a large circle to play a short game of Hot Potato. Discuss what happened when each student received the potato. (He or she passed it on quickly to someone who did not have the potato.) Explain that heat transfer works much the same way, with thermal energy (heat) being passed from one molecule to another.
2. Have students stand fairly close together in the center of the room. Tell them you are going to play a song, and you want them to dance to the beat. Play the song "The Heat Is On" by Glen Frey. When the song ends, have students note their positions, and point out the fact that while dancing they bumped into one another and the distance between them expanded. Relate this to conduction and thermal expansion.

Procedure

(Adapted from an activity, "Things Are Heating Up!" included in the Educator's Guide for the NASA SciFiles™ video program "The Case of the Phenomenal Weather." Used with permission.)

1. Attach the mouth of the balloon to the top of the salad dressing bottle.
2. Place rubber bands over the balloon on the neck of the bottle to ensure a tight fit.
3. Pour the hot water into the pan to a depth of about 2.5 cm from the top.
4. Carefully place the bottle in the hot water, and hold it down, if necessary.
5. Have students observe what happens and record their observations.
6. Carefully place the bottle and balloon in a refrigerator or a tub of ice for 10 to 15 minutes.
7. Again have students observe what happens and record their observations.

Observations and Conclusions

1. Use the following questions and student responses to prompt class discussion:
   - What happens to the air in the bottle? *(It was heated by the hot water. As the molecules got hot, they moved farther away from each other. Therefore, the air expanded.)*
   - How do you know that is what happened? *(Because the balloon began to inflate)*
   - What heats the air in Earth's atmosphere? *(The sun)*

- How did what happened demonstrate convection? *(In convection, the air is heated at the surface of the Earth, which causes the molecules to move away from each other, creating less dense air. This less dense air is lighter, so it begins to rise. As it rises, it begins to cool. As it cools, the molecules move closer together, and the air becomes denser. This denser air is heavier, so it begins to fall back toward Earth. The cycle of convection was demonstrated when the balloon increased in size as the air warmed and then became smaller as the air cooled.)*
- How are low-pressure systems formed? *(When the air near the surface of Earth is heated, the air molecules spread out so there are fewer air molecules in the same space. Warm air weighs less than cool air, which means that warm air presses down on Earth less than cool air does.)*
- How are high-pressure systems formed? *(When air cools, the air molecules come closer together, so there are more air molecules in the same space. Cool air weighs more than warm air, which means that cool air presses down on Earth more than warm air does.)*
- Does the sun heat Earth's surface equally around the globe? *(No, Earth's surface is heated unequally.)*
- What types of weather might form as a result of land or water that is more strongly heated by the sun? *(Clouds, thunderstorms, and hurricanes develop in such areas. As the mass of hot air rises, it is replaced by the surrounding cooler, more dense air, which we feel as wind. These movements of air masses can be small in a certain region, such as local cumulus clouds, or large cycles in the troposphere, covering large sections of Earth. Convection currents are responsible for many weather patterns in the troposphere.)*

Assessment

- **Questions**
  - What are the three types of energy transfer discussed in this lesson? *(radiation, conduction, convection)*
  - How does convection affect the weather?
- **Journal/Writing Prompts**
  - Explain how high- and low-pressure areas are formed in Earth's atmosphere.
  - Draw a comic strip to explain convection.
- **Other**
  - Have students draw a diagram to model three forms of energy transfer: radiation, conduction, and convection.
  - Have students change the lyrics to a favorite "camp song" to reflect their new understanding of radiation, conduction, and convection.

Extensions and Connections (for all students)

- Have students find poems that describe examples of energy transfer, and then sort them into the categories of *radiation*, *convection*, and *conduction*.

Strategies for Differentiation

- Establish groups to complete activities and assign roles based on learning profiles. Have student in each group work to record their observations together.

- Have students create a foldable with a definition, picture, and everyday example described in a phrase or word for *radiation*, *convection*, and *conduction.* (A foldable is a three-dimensional graphic organizer that can be made by folding a piece of paper into sections—halves, thirds, quarters, etc. based on the amount of information that needs to be recorded. Related information is written in each of the folded sections, and the foldable can then be used to help the student organize, remember, review, and learn the information.)
- Have student make a comparison table, such as a Venn diagram, relating to thermal energy transfer methods of radiation, convection, and conduction.
- Encourage students to keep a journal of current air pressure systems, as reported in local newspaper or television weather maps. Have them graph the results daily. Monitor and discuss the impact of air pressure changes as they relate to the weather.
- Have students work in pairs or small assigned groups to complete a graphic organizer of the experiment and answer Reflection Questions.
- Have students review vocabulary by writing each word on an index card along with its definition, a sentence that uses it, and a picture of the concept.
- Have students use a Venn diagram to compare and contrast high- and low-pressure systems.