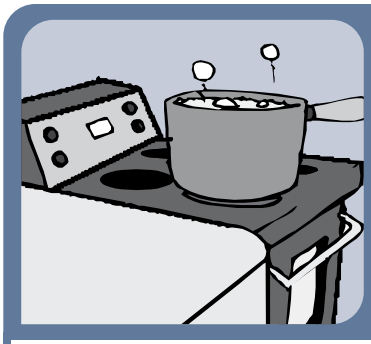

Exploring Heat

Students conduct simple experiments to explore properties of thermal energy and heat.

Grade Level: K–4

Subject Areas: English Language Arts, Science

Setting: Classroom

Time:
Preparation: 30 minutes
Activity: Two 50-minute periods

Vocabulary: Conduction, Convection, Heat, Molecule, Radiation, Thermal energy

Major Concept Areas:

- Definition of energy
- Natural laws that govern energy
- Energy flow in nonliving systems

Getting Ready: ***CAUTION: This activity uses a heat source and hot water. Use a heat source such as a hot pot to keep water hot but not boiling.*** Caution students to walk carefully around the heat source and not to splash the water. You can try the investigations using very warm water from the tap but the results may not be as effective. Use ice water for the investigation that requires cold water.

Objectives

Students will be able to:

- define thermal energy and heat; and
- illustrate examples of conduction and convection.

Rationale

Understanding heat and thermal energy helps students appreciate the presence of energy in their lives. The investigative approach used in this activity introduces students to abstract thinking and reasoning skills.

Materials

- A clear container, such as a glass jar
- Oven mitts or gloves
- Ten pennies, each with a different date
- Water (hot and cold)
- Heat source (like a hot pot; optional—see **Getting Ready**)
- See ***Heat Investigations 1-4*** for other materials needed
- Find additional resources related to this activity on keepprogram.org > Curriculum & Resources

Background

Feeling comfortable while sitting by a cozy fire. Getting upset when your car's radiator boils over. Satisfying a hunger while biting into a hamburger fresh off the grill. What do all these things have in common? One thing is heat. Heat has a major influence in our lives. It can influence our moods and it keeps us healthy and well-fed. Heat is given off whenever energy is being used. You can tell if a television has been on by feeling if it's warm. When you run up a flight of stairs you feel warm because you are burning food energy.

What exactly is heat? Heat is the transfer or flow of energy from a hot object to one that is cooler. When you feel a warm object, you are feeling heat being transferred from the warm object to you. The object feels warm because it contains thermal energy (the energy of the moving molecules that make up the object—See ***Temperature, Thermal Energy, and Heat*** for more information).

Heat energy can be transferred three ways: by conduction, by convection, and by radiation.

Conduction is the transfer of heat energy from one molecule to another. This transfer occurs when molecules hit against each other, similar to a game of pool where one moving ball strikes another, causing the second to move. Conduction takes place in solids, liquids, and gases, but works best in materials that have simple molecules that are located close to each other.

Convection is the movement of heat by a liquid such as water or a gas such as air. The liquid or gas moves from one location to another, carrying heat along with it. This movement of a mass of heated water or air is called a current.

Heat travels from the sun by a process called radiation. Unlike convection and conduction, radiation does not travel from one molecule to another. Instead, heat energy travels as infrared rays, which are one form of invisible light. When infrared rays strike a material, the molecules in that material move faster. In addition to the sun, light bulbs, irons, and toasters radiate heat. When we feel heat around these items, however, we are feeling convection heat (warmed air molecules) rather than radiated heat. In other words, we are feeling the air molecules that are energized by radiation rather than feeling the infrared rays. (See **Extensions**.)

You can't see heat, but you can see the evidence of heat. You might see the air shimmering over a radiator (convection), put your hand on a warm spoon that's been sitting in a hot bowl of soup (conduction), or notice that the sunshine feels warm on your skin (radiation). If you need more evidence of thermal energy or heat in your life, just feel your arm. Your body generates heat 24 hours a day!

Temperature, Thermal Energy, and Heat

Thermometers measure temperature; they measure the level or degree of thermal energy in a substance. In other words, they measure how fast the molecules that make up the substance are moving. The molecules move faster in hot objects than they do in cooler materials. So, a thermometer helps us understand how hot or cold something is by letting us know how fast (the degree to which) its molecules are moving. The unit of measurement in a thermometer is degrees.

To measure the total amount of thermal energy in a substance, a different instrument is needed. A calorimeter determines the total quantity of energy contained in all the moving molecules within a substance. The measurement unit for thermal energy is calories.

For example, let's say you put a large pot of stew on the dinner table. If you remove one ladleful of the stew, the temperature of the stew in the pot and in the ladle will be the same because the molecules in both are moving at the same rate. The large pot of stew has more thermal energy, though. This difference in thermal energy is simply because there is more stew in the pot—the more stew, the more moving molecules, the more thermal energy. Proof of this is seen after some time has passed. The ladle of stew (with less thermal energy) cools off more quickly. The pot of stew will stay warm longer because it has more thermal energy.

Both stews will eventually cool down, of course. This is because of heat energy moving from the hot stew to the cooler surrounding air. Heat is the transfer or flow of energy from one object to another (such as from the hot soup to your tongue or from a radiator to the surrounding air). When something is "heated" this means energy flowed into it. You can measure the change in temperature by using a thermometer to record how fast the molecules are moving now compared to before the heat transfer. It is incorrect, however, to say a thermometer measures heat.

Procedure

Orientation

Show students the ten pennies and put them in a container. Have one student select a penny out of the container and hold it tightly for a couple of minutes. Announce to the class that you will be able to identify which penny the student chose. Ask the student to replace the penny and mix them up inside the container. Select the penny which is the warmest; this should be the correct penny. See if the class can figure out how you knew which one to pick. Help students to understand that the student's body heated the penny.

Steps

1. Ask students how they know something contains thermal energy. To help students understand how thermal energy is stored in objects and makes them feel warm, have them participate in ***Moving Molecules***. Depending on the level of your students, explain that heat is the flow of energy from one object to another (from a hotter object to a cooler one). Sometimes the object can be air. Heat energy is always flowing from the body to the surrounding air.

2. Tell the class that they will become scientists and investigate other properties of heat. Discuss how scientists observe things and try to explain (sometimes guess) what happened. Refer back to the "magic trick" where you selected the penny. Ask students what they observed and review their guesses or explanations for what happened. What did they have to do to find out the correct answer? They may have asked you outright or perhaps someone already knew the answer.

3. Have students conduct ***Heat Investigations 1-4***. You may want to conduct each investigation as a class and discuss the results. With older students you can set up stations around the room and have students conduct independent investigations. Whether you demonstrate the investigations or have students work independently, encourage students to work in pairs or small groups and discuss their answers.

4. Tell students that they will be asked to figure out or explain what happened in the investigations. They should think carefully about their answers and then discuss what they think with friends. If you had students participate in the ***Moving Molecules*** demonstration, they can use that experience to help them explain the flow (transfer) of heat energy in these investigations.

Moving Molecules

Tell students that objects, even air, are made up of tiny particles (too tiny for us to see without a very powerful microscope) called molecules. These molecules are always moving. Compare a pot of boiling water to one that is cold. How would students imagine that the molecules are moving in the hot water compared to the cold water? Have students simulate the movement of molecules. Tell students to stand together near one end of the room. Instruct them to stand in place, but to move around. This represents molecules in a cold object (the molecules are moving—so they have some energy—but not too much). Now tell students that they are molecules that are getting more thermal energy. They should begin moving about. Note how much space they need compared to when they had less energy.

Closure

Have students share the results of their explanations. Discuss how they developed their explanations. If students were uncomfortable not knowing the answer, remind them that scientists often do not know the answer and often have to study for many years before they can provide a logical explanation. Because scientists have figured out how heat transfer energy, students can look up in a book or ask someone else for the right answer.

Review the definitions of conduction and convection. If students participated in ***Moving Molecules***, challenge them to revise the simulation to illustrate each form of heat transfer.

Assessment

Formative

- How carefully did students observe or conduct the investigations?

- Were students' explanations thoughtful? Did they seriously discuss their answers with each other?
- Can students provide a definition for thermal energy, convection, and conduction?

Summative

Have students identify how a pot of boiling water on a hot stove illustrates both conduction and convection. Tell them to draw a picture of this situation and use arrows to identify each type of heat energy. For example, to represent convection, you can draw spiraling arrows to show current (convection currents are in the water as it boils and in the air surrounding the pot). Short arrows can show where conduction is taking place (the pot is heated by the coil through conduction and heat travels throughout the pot and to the water through conduction). NOTE: If students have studied radiation, they can add this form of heat energy as well.

Extensions

Older students can explore heat transfer by radiation. Heat travels from the sun by a process called radiation. Unlike convection and conduction, radiation does not travel from one molecule to another. Instead, heat energy travels as infrared rays, which are one form of invisible light. When infrared rays strike a material, the molecules in that material move faster. Certain materials, such as dark-colored materials, absorb infrared rays better than others do. Other substances do not absorb radiant heat very well; they reflect it instead. Shiny or white surfaces reflect more radiant heat than they absorb.

Students are probably familiar with several things that transfer heat via radiation (for example, they emit infrared light rays). These include irons, stoves, flames, and light bulbs. Help students to understand that the heat they feel is most likely from convection, though, because these items are surrounded by air molecules (the radiated heat is transferred to the air molecules).

- An ideal way to show heat transfer by radiation is with a radiometer. A radiometer is available from science supply stores. Radiometers look like a light bulb with a windmill inside (see illustration, right. Each wind mill blade has one side covered with a light colored material that reflects light and the other side covered with a darker colored material that absorbs light. A flashlight will make a radiometer spin, but a hair dryer is not as effective.
- Students can also compare how different-colored objects absorb radiation. Put ice cubes in plastic bags and set the bags on pieces of colored construction paper. Then place each bag out in the sun. Which one melts the fastest?

Related KEEP Activities

The activity "Exploring Heat" provides an introductory overview of energy transfer. "Taking Temperature" complements this activity; however, use the activities to help students understand the difference between heat and temperature. Other activities that cover energy basics include "Evidence of Energy" and "Potentially Kinetic." The concept of heat is also discussed in "Station Break" and "Where Does It Get Its Energy?"

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Heat Investigation 1

Explore Heat Transfer and Expansion

Materials: Saucepan filled with hot water; Oven mitts or gloves; Empty glass bottle (such as a ketchup or syrup bottle); Rock or pennies to weigh down bottle; Balloon

Directions: Put a balloon over the top of an empty ketchup bottle (you may need to put a rock in the bottom of the bottle for weight). Give the bottle to your teacher to place in a saucepan of hot water. **Caution: Water is very hot!**

1. **Describe or draw what happens:**

2. **Provide an explanation for what happened:**

3. **Discuss your explanation with a friend and rewrite your explanation if you think it needs it.**

Teachers' Note: You may want to demonstrate this activity, as the water may need to be very hot. The balloon should expand because the air inside the bottle gains heat energy and the molecules move around more, filling the space inside the balloon (see ***Moving Molecules***).

Heat Investigation 2

Explore Thermal Energy and Density

Materials: Hot and cold water; Oven mitts or gloves, Large clear pitcher/bowl/vase, Small clear glass canning jar/beaker; Aluminum foil, Food coloring (1 color), Rubber band, Skewer

Directions:

1. Fill a small clear jar/beaker with colored hot water. **Caution: Water is very hot!** Cover the top of the jar/beaker with aluminum foil and place a rubber band around it to hold it in place.
2. Set the jar/beaker into the large clear pitcher/bowl/vase.
3. Pour cold water into the pitcher/bowl/vase until the water completely covers the top of the jar/beaker.
4. Use a skewer to poke a small hole into the aluminum foil that is covering the jar/beaker.
5. Watch the warmer, colored water rise through the pitcher/bowl/vase of clear, cold water.

Why do you think the warmer water rises to the top?

Teachers' Note: This investigation should help students understand that warm water is less dense than cold water. It will also demonstrate the Second law of thermodynamics - heat flows spontaneously from warmer to cooler temperatures, not the reverse.

Heat Investigation 3

Explore How Heat Travels through Conduction

Materials: Spoons made of different materials (like wood, stainless steel, aluminum, plastic); Hot water in a saucepan

Directions: Give the metal spoon to your teacher to place in a saucepan of hot water. **Caution: Water is very hot!** After a few minutes, with your teacher's permission, feel the end of the spoon. It should feel warm.

1. **Describe how you think the heat moved from the water through the spoon.**

2. **Discuss your explanation with a friend and rewrite your description if you think it needs improvement.**

3. **Heat traveled through the spoon by the process of conduction. Ask your teacher for the definition of conduction and compare it to your description.**

Directions: Collect a bunch of spoons made of different materials and determine which is the best conductor of heat. Have your teacher put the spoons in hot water and after a few seconds feel the tip of the handle of each spoon.

1. **Which is the hottest?**

2. **Arrange the spoons from the best conductor to the worst. Write or draw the order below.**

3. **Why do you think some spoons are better conductors than others?**

Heat Investigation 4

Explore How Heat Travels through Convection

Materials: Paper; Scissors; String; Incandescent light bulb or other heat source such as a radiator or candle

Directions: Cut a spiral out of a piece of paper and tie a string through the center of the spiral. Hold the spiral or coil above an incandescent light bulb, radiator, or candle. **Caution: Incandescent light bulbs get very hot. If you are using a candle, have your teacher hold the coil and make sure the paper does not touch the flame.**

1. **Describe or draw what happens.**

2. **Provide an explanation for what happened.**

3. **Discuss your explanation with a friend and rewrite your explanation if you think it needs improvement.**

4. **Heated air moving by the process of convection caused the paper to spiral. Ask your teacher for the definition of convection and compare it to your description.**

5. **What is the difference between conduction and convection?**