Heat

How many times have you set down a hot drink, only to return to find that your drink is now cold?

When two things are at different temperatures—for example, your hot drink and the air surrounding it—you will find that your drink will cool down. Everything has an energy associated with its temperature that we call *thermal energy*. The warmer an object, the more thermal energy it has. Your hot drink has a certain thermal energy and the air around it has less thermal energy. When the hot drink cools, some of the thermal energy of the hot drink is transferred to the air. We call this transfer of energy *heat*.

The transfer of energy is very important in everyday life. For example, heat can flow from a warm house to the cold air outside. The insulation in a house is designed to prevent this flow of energy. Sometimes, you want to generate heat flow—for example, when you are defrosting a bag of frozen vegetables, you put it in warmer air outside of the freezer. Heat flows from the warmer air into the bag of frozen food.

This section will help you investigate ways in which thermal energy is transferred between different objects.

HEAT

Heat

Recommended grade levels: 4-6

Goal: Students will comprehend how heat energy is transferred between substances at different temperatures.

Process skills:

Measuring
Observing
Predicting

Frameworks: Force and Motion, Universe

Materials: (per student)

three Styrofoam cups
thermometer
hot and cold water (Caution: Do not use water so hot it could burn a student! Also, do not use ice cubes in the cold water.)
two 100-ml graduated cylinders or beakers
stirring rod (or practical equivalent)

Teacher background information:

Temperature is a measure of how hot or cold something is, and heat is the transfer of energy between substances at different temperatures. If a "hot" object is placed in contact with (or mixed with) a "cold" object, heat energy will flow from the hot object to the cold object, thus lowering the temperature of the hot object and raising the temperature of the cold object. The final temperature will be between the two starting temperatures. The amount of heat energy that must be added to a substance to raise its temperature a certain amount depends on what the substance is and on the mass of the object. In these experiments, the hot and cold substances are the same, so the only variables are the amounts of water and the starting temperatures of the water.

Procedure:

Students will:

1. Place 50 ml of cold water in one cup and 50 ml of hot water in the second cup.
2. Measure and record the temperature of each cup.
3. Predict what they think the temperature will be after they mix the two cups of water and record their predictions.
4. Pour the two samples into the third cup and stir well.
5. Measure and record the temperature, then compare the results to their predictions.
6. Repeat the experiment (Steps 1-5) using 25 ml of cold water and 75 ml of hot water.
7. Repeat the experiment (Steps 1-5) using 75 ml of cold water and 25 ml of hot water.

Discussion:

1. In which experiment were your predictions closest to the actual temperature?
2. In the first experiment, with equal volumes of hot and cold, how did the temperature of the mixture compare to the beginning temperature?
3. How can the temperature of the final mixture be predicted?

Extension:

1. Have students experiment with and record several different variations of hot and cold water proportions. They should try predicting each temperature before they do the experiment.

Teacher resources:

Cauto, Michael J. and Bruchac, Joseph. *Keepers of the Earth: Native American Stories and Environmental Activities for Children*
Gr. Pre-K through adult. Pages 40-47 specifically focus on heat energy. Other sections of this excellent multicultural resource book can be used for energy-related topics.
ISBN: 1-55591-027-0

Lafferty, Peter. *Heat and Cold.*
Gr. 4-8 Lafferty describes what heat is, how it is measured, the effects of heat and cold, and how we use them at work and home. The "It's Amazing" insert provides interesting facts for students to ponder. The book includes a chronological time line of inventions and discoveries.
ISBN: 0-7614-0033-8

Curtains Are Cool

Recommended grade levels: K-3

Goal: Students will be able to describe how curtains affect the solar heating of a house.

Process skills:
Collecting Data
Measuring
Observing

Frameworks: Matter, Universe

Materials: (for each student or student group)

- one small box (e.g. shoebox)
- clear plastic wrap
- tape
- scissors
- two thermometers
- sun (or a heat lamp)
- fabric scrap (large enough to cover box)

Teacher background information:
The amount of sunshine a house receives can make a profound difference in the temperature inside. We can take advantage of this in the winter by letting sunlight in through windows to help heat a room. In the summer, closing the curtains will help keep a room cool. Trees planted so that they will shade the house will also reduce summer heat.

Note: *This activity can easily be done indoors with a strong lamp (such as a plant light), though the temperature rise is not as dramatic. Allow three minutes between temperature readings, in this case, to compensate for the lamp's weaker light.*

Using the second thermometer makes the activity go faster, but it is not essential. If using one thermometer per group, allow enough time for it to return to room temperature before doing the second part of the activity.

If enough boxes and thermometers are available, the students could run the two trials simultaneously. In this case, it is most important that each group have two identical boxes.

Procedure:
Students will:

1. Put the thermometer in the box. Construct a "house" by taping a piece of plastic wrap over the top of the box.

2. Set their box in the sun and record the starting temperature. Check and record the temperature every minute.
3. After 10 minutes, remove the box from the sunlight, carefully peel back the plastic wrap, and exchange thermometers.
4. Retape the plastic wrap in place. Record the thermometer temperature, lay the fabric "curtain" over the plastic, and place the box back in the sun.
5. Check and record the temperature every minute for ten minutes.
6. Display and compare the results of the two trials in an age-appropriate manner.

Discussion:

1. Which got warmer, the house with a curtain, or the house without a curtain? Why?
2. How could you use this knowledge at home?

Extension:

1. Have students change one variable (e.g. the size of the box or the curtain material) and explore further.

Teacher resource:

Ardley, Neil. *The Way It Works–Heat*

Gr. 4 and up. This book defines heat and discusses its properties, origins, and uses. Sections on heat control, heating and cooling the home, and saving heat, and keeping heat in (and out).

ISBN: 0-02-705666-X

Solar

When you wiggle your finger or move your arm, you use energy that was captured from solar rays by some green plant. Almost all the movement and growth of animals and plants on this planet are fueled by this same energy. The coal and petroleum products we use to run our cars and fuel our industries are stored forms of solar energy captured by some green plant in eons past. These green plants use solar energy to build long chain carbon compounds from carbon dioxide and water. Solar energy reaches the earth in the form of light waves that differ only in length. The various lengths or parts of the spectra are known as visible light, radio waves, X-rays, ultraviolet, and infrared.

The large wing or windmill-like panels seen on satellites in space have photovoltaic cells that convert solar energy into electricity. These cells operate on the principle that light striking a photosensitive compound will loosen electrons causing a weak flow of electrical current. Compounds like indium phosphide and gallium arsenide are most efficient, but costly. In practice, silicon-based compounds are used in most cells. In Nebraska, solar panels with batteries are commonly seen on electric fences used to confine livestock. These devices are available at farm stores throughout the state. Photovoltaic, or solar cells, are also used to pump water for livestock in isolated pastures and to operate such things as microwave towers in isolated areas. Many hand-held calculators also use solar cells.

Architects have designed homes that use solar energy for space and water heating in homes. Solar-aided heat can be used by having large panels of glass on the sunny side of the building with the roof angles so that the sun's rays shine into the structure in the winter but do not in the summer. Roof panels can also heat water for home use or partially heat the home. They have a dark background that warms the air or water in tubes that circulate around water tanks or masonry .

Most of our use of solar energy centers around the photosynthetic processes of green plants. At present, we do not totally understand this process and can not reproduce it. Some of the steps in photosynthesis are understood and, if we can unravel the rest of the process, perhaps solar energy can replace the non-renewable energy sources such as petroleum and coal.

Solar Bleach

Recommended grade levels: K-3

Goal: Students will observe chemical change (bleaching) as the effect of ultraviolet radiation in sunlight.

Process skills:
Controlling variables
Observing
Predicting

Frameworks: Matter, Universe

Materials: (per student)

two sheets of colored construction paper (both sheets same color)
scissors
pencil
clock
small rocks or gravel

Teacher background information:
Most of the energy on earth begins with the sun. The sun gives us heat, light, wind, weather, fresh water, and growing plants. People continue to learn how to use solar energy to do work. For example, solar energy can be collected and used to heat buildings and water, to produce electrical energy and for lighting.

Ultraviolet radiation in sunlight causes chemical changes in the dye in paper. That is, the paper's color fades. Prolonged exposure to sunlight can also damage our skin (sunburn, suntan), causing a change in color.

Note: *This experiment should be conducted on a calm, sunny day.*

Procedure:
Students will:

1. Choose two sheets of colored construction paper. (Both sheets should be the same color.)
2. Cut out shapes or block letters of their name from one sheet of paper.
3. Place the shapes or letters on top of the second piece of construction paper. They should weigh the shapes or letters down with gravel if the day is breezy.
4. Place the construction paper in a sunny spot for three to four hours. Before returning to observe the paper, predict what changes might have happened to the top sheets of paper and the bottom sheet of paper. Return to evaluate the results when the time is up.

Discussion:

1. What did you find when you removed the shapes or letters?
2. How did the sun's energy cause a change in your paper?

Extensions:

1. Vary the colors of paper used for shapes and background.
2. Vary the time the paper is left in the sun.
3. Experiment with placing the paper in sunlight vs. shade.
4. Try various other substances to lay over the construction paper to see if the ultraviolet rays are transmitted through those objects. For example: glass, Plexiglass, petri dish (empty), petri dish with water, or old sunglasses.
5. Visit with a physician or dermatologist for further information about the effect of the sun on skin.

Teacher resources:

Burney, David. *Light*
Gr. 3-6. By the creators of the distinguished "Eyewitness" series, *Light* has high standards of writing and illustration. Three-dimensional photos accompany the text.
ISBN: 1-879431-79-3

Schoberle, Cecile. *Day Lights, Night Lights*
Gr. PreK-3. This book introduces youngsters to everyday sights and sounds.
ISBN: 0-671-87439-X

Solar-Powered Distillation

Recommended grade levels: 2-6

Goal: Students will explore the role of the sun in the water cycle.

Process skills:
Connections
Observing
Predicting

Frameworks: Universe

Materials: (for whole class demonstration, or per student group)

- one large glass or clear plastic bowl
- soil
- one small glass or bowl (shorter than the large bowl)
- one heavy object to weigh down glass
- clear plastic wrap
- masking tape
- water
- ice cubes or commercial freeze-pack (Blue Ice, Polar Ice, etc..)
- heat lamp (optional)

Teacher background information:
The water cycle is a continuous process. A very small percentage of all rainfall is taken up and used by plants. The remainder falls in the ocean, drains into rivers and lakes or seeps into the ground. Ground water eventually finds its way into rivers and back to the sea.

When sunlight warms water, some of the water evaporates into the atmosphere. The water vapor is blown about by the wind. The water vapor eventually cools, condenses and falls in droplets like rain.

In this activity, which can be a teacher demonstration or a teacher-led activity for groups of students, the water cycle and the direct use of solar energy will be observed. As the water in the bowl is warmed, some of the water evaporates. The ice cubes provide a cool surface for the evaporated water to condense in droplets. These water droplets collect on the plastic wrap. The ice cubes weigh down the plastic wrap so that the condensed water droplets are "funneled" into the glass. The empty glass will collect the clean water droplets that have formed on the plastic wrap.

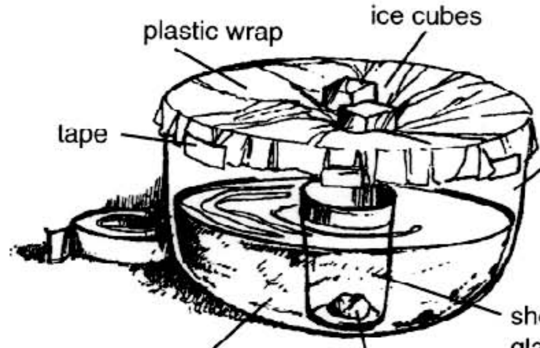
Note: *If a sunny place is not available, use a heat lamp instead. Many teachers have found this activity works with a 100 watt bulb in a goose neck lamp with a reflector shade (often included in science kits). Using a heat lamp will take longer time than when in direct outdoor sunlight.*

Procedure:

Teacher or student groups will:

1. Mix soil and water in a bowl to make muddy water.
2. Place the empty glass, with heavy object inside, in the center of the bowl. Make sure the rim of the glass is above the muddy water, but below the bowl's edge.
3. Cover the bowl with the plastic wrap and pull tightly. Fasten down with tape.
4. Place two to three ice cubes on the plastic wrap, directly above the glass. The wrap should dip down slightly, but not touch the glass. (**See Figure 1.**) Ice cubes will need to be replaced periodically as they melt.
5. Place the bowl in a sunny place. After several hours, students should observe that clean water droplets have collected on the plastic wrap and in the glass.

Figure 1.



Discussion:

1. How did the water get into the glass?
2. Was the water in the glass clean?
3. What was the purpose of the ice cubes on top of the plastic wrap?
4. How do solar energy and the water cycle clean the water?

Extensions:

1. Have students experiment with placing one bowl in the shade and one in the sun.
2. Have students discover what will happen with different bowls (different sizes, materials).
3. Have students place a glass of salt water outside in the sun to observe what happens when the water evaporates.

Teacher resource:

Rickard, Graham. *Solar Energy*

Gr. 4-6. This book explains how the sun, which is the ultimate source of energy on Earth, can be used to provide electricity and power.

ISBN: 0-83-680709-X

Solar Oven

Recommended grade levels: K-6

Goal: Students will investigate using energy from the sun to do work by building a model.

Process skills:
Collecting data
Observing
Predicting

Frameworks: Matter, Universe

Materials: (for whole class demonstration, or per student group)
- one cardboard box lined with aluminum foil
- one or two bricks
- one coat hanger
- food for toasting (bread, hot dog, marshmallow)
- glove or hot pad

Teacher background information:
Almost all the energy on earth comes from solar energy. Solar energy today is used mostly as a source of heat. A car sitting in the sun with its windows rolled up is a good example of trapping solar energy to produce heat. Sunlight passes through the windows and is absorbed by the interior of the car, causing the temperature of the air inside the car to rise. Heat radiation (infra-red light), from the hot interior, unlike visible light, is unable to pass through the windows, so the energy remains trapped inside. This process is called passive solar heating, also known as the "greenhouse effect."

There are other ways to use solar energy. A solar collector is a device that collects sunlight and uses it to increase the temperature of the collector. Inside the solar collector are rows of black tubes carrying water or air. Sunlight strikes the tubes and heats the water or air inside them. The tubes carry the heated water or air to pipes that run through the building. The heated water or air is pumped through the pipes, or stored for later use. Systems that have pumps or other moving parts are called active solar heating systems.

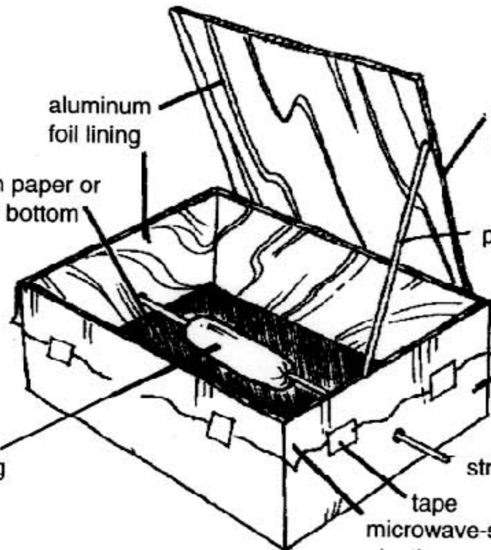
This activity demonstrates passive solar heating systems. The foil walls of the box reflect the sunlight and concentrate it in a particular volume of space. Food is placed within that volume, it absorbs the sunlight, and is heated. The teacher can demonstrate this activity, or students can do the activity in groups.

Procedure:

Teacher or student groups will:

1. Place the box in direct sunlight. If it is windy, you made need to put the brick(s) in the box to weigh it down.
2. Straighten out the coat hanger. Cut off the hook-end.
3. Make two small holes on opposite sides of the box.
4. Slide the wire through one hole.

Figure



5. Place the food item on the wire and slide the wire through the hole on the opposite side of the box. (Be sure to clean the wire first!)
6. Time how long it takes for the food to cook. **(Do not look directly at the foil.)**
7. When the food is done, turn the cooker away from the sun, and remove the food using the hot pad. Place hotdog in a bun, and enjoy.

Discussion:

1. How were we able to cook the food?
2. What form of energy was used to cook the food?
3. Could all food be cooked this way? Why or why not?

Extensions:

1. Have students cook other foods and compare their cooking time.
2. Discuss their different cooking times.

Teacher resource:

Hillerman, Anne. *Done in the Sun - Solar Projects for Children*

Gr. K-6. This book teaches the basic principles of solar energy while providing interesting experiments that can be done at home or at school. Includes a simple hotdog cooker, water from the sun, and sun treats.

ISBN: 0-86534-018-8

Sun Motor

Recommended grade levels: 4-6

Goal: Students will gain knowledge of the transfer (conversion) of energy from solar to mechanical to electric by making and observing a motor.

Process skills:

Applying concepts
Collecting data
Communicating
Observing
Predicting

Frameworks: Force and Motion

Materials: (per student group)

- aluminum foil
- one pencil with eraser
- piece of wire
- one large cardboard box
- masking tape
- scissors
- two straight pins with heads
- two bricks or two books
- heavy paper
- two or three empty tin cans with both ends removed

Teacher background information:

In this activity, the sun's light heats the air in the tin can tower. Rising hot air causes the pinwheel to turn. Energy from the sun, then, produces motion. In theory, this motion could be used in an electrical generator to produce electricity.

An electrical plant in the Mojave Desert uses a similar method to produce electricity. In this plant, mirrors are used to reflect and focus sunlight on a container of water. The concentrated light boils the water, releasing steam. The steam is used to turn a turbine, generating electricity for homes in Southern California.

Note: *When stacked, the cans should not stand higher than the box. Be sure the cans have no sharp edges where the ends were removed.*

Procedure:

Students will:

1. Cut the top and one side from the box so that three of the sides and the bottom are left.
2. Line the cardboard box with aluminum foil.
3. Cut a four-inch square of heavy paper, then make cuts in the square diagonally from each corner to 1/2 inch from the center. **(See Figure 1)**
4. Bend every other point back to the center of the square, forming a pinwheel (see "Building a Wind Turbine," p. 80), then tape the points of the pinwheel together at the center.
5. Tape their cans together end-to-end. They should have a stack of two or three cans. (Make sure the cans do not go above the box's top edge.)

6. Tape the straight pin, head down, to one end of a piece of wire and bend the wire.
7. Tape the other end of the wire to the top edge of the stack of tin cans. The pin should point up, above the center of the cans.
8. Balance the pinwheel on the pin.
9. Place their boxes in the sun with their bricks on the bottom of the box. They should leave a space between the bricks for airflow.
10. Put the stack of cans on the bricks. **See Figure 2.**
11. Observe and record what happens and draw conclusions from their observations.

Figure 1.

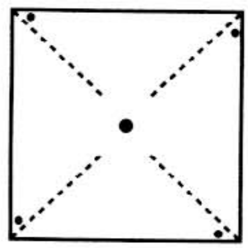
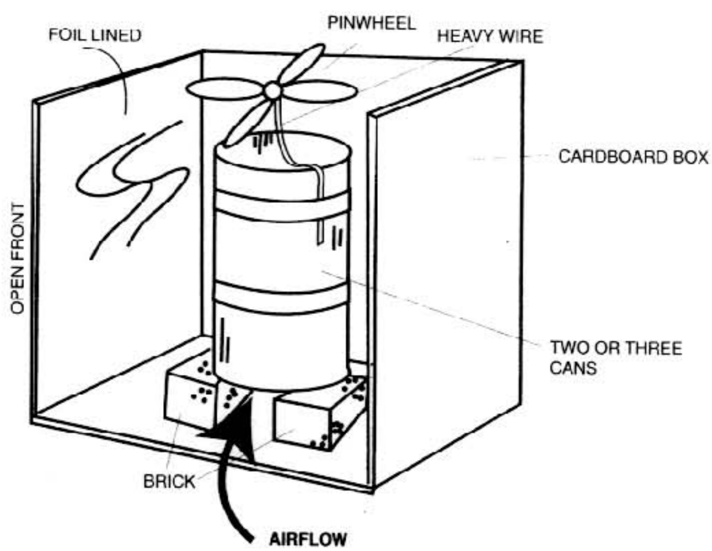


Figure 2.



Discussion:

1. What observations did you make?
2. What caused the pinwheel to move?

Extensions:

1. Try same experiment for a week, record observations.
2. Try same experiment on a cloudy day and compare findings to a sunny day.

Teacher resource:

Tomecek, Steve. *Bouncing & Bending Light*
Gr. 3-6. This book includes a section that highlights scientists and inventors.
ISBN: 0-7167-6541-1

Sound

Sound involves one of our senses—hearing—and is an important means of communication for humans and animals. We sometimes classify sounds such as speech, music or noise. Some animals, such as bats and certain aquatic mammals, use sound to locate food and to avoid colliding with obstacles by emitting sounds and listening for echoes from objects. Submarines use the same means to avoid underwater obstacles with a system called SONAR. Warships also use SONAR to detect underwater submarines.

To a scientist, sound is a traveling vibration in a *medium*. The medium is usually air, but it could be, for example, water. There must be something that starts the medium vibrating, such as a voice, a hand clap, a musical instrument, or a radio loudspeaker. The vibration travels as a wave—something like a wave that moves in water when you disturb the surface—and takes time to travel. Sound can be received by an ear or a microphone.

It should be emphasized that sound is not a substance that travels from one place to another, but a wave. For example, the sound from a hand-clap is produced by the hands pushing the air next to them, and that air pushes the air next to it, etc. The air molecules themselves do not move from the source to the receiver but rather they push the molecules in front of them and then return to where they started. (This can be contrasted with how the sense of smell works. If one person eats garlic, and another person smells the breath, there must be actual molecules of the odoriferous garlic traveling from the first person's mouth to the second person's nose.)

The wave motion involved in sound can be demonstrated using a Slinky toy (preferably an extra-long one). Lay the Slinky on a smooth floor (not carpeted), and clamp or have someone hold one end still. Stretch the other end so that the Slinky lies in a straight line on the floor. A Slinky that is three inches long in its compressed state can be stretched to about ten feet. Now rapidly push and pull the free end. (Push and pull along the direction of the Slinky, not perpendicular to it.) This produces a wave of compressions and rarefactions traveling down to the Slinky to the other end. Note that the parts of the Slinky move back and forth only a small distance, while the wave travels the whole length. The analogy to sound in air is good, with the following differences: air is transparent, so we can't actually see the waves; sound in air travels a lot faster than does the wave in a Slinky; and sound in air travels in all directions from its source, rather than just along a line.

Sound Friction

Recommended grade levels: K-3

Goal: Students will learn that sound can be produced by friction.

Process skills:
Controlling variables
Measuring
Observing
Predicting

Frameworks: Matter

Materials: (per student group)
- one tin can
- piece of string
- one nail and hammer
- one button
- rosin (*alternate*: a damp sponge)

Teacher background information:
As the string passes through your hand, variations in the friction force between your fingers and the string causes the bottom of the can to vibrate. This vibration produces sound waves.

Procedure:
Students will:
1. Use a small nail and hammer to punch a small hole through the center of the bottom of the can. The hole should be made from the outside in, so that the torn metal edges are on the inside of the can.
2. Take a piece of string two or three feet long and run it through the hole in the can.
3. Put a button on the end of the string on the open side of the can, tie a knot in the end of the string, and pull the string out until the button stops it.
4. Put rosin on the string and hold the can in one hand.
5. Hold the string tightly between the fingers of the other hand at the base of the can. To create sound, they pull their hands apart letting the string slip through their fingers.

Discussion:
1. How would putting grease, instead of rosin, on the string affect the sound?
2. Why is rosin put on violin bow strings?

Extensions:

1. Have students test different can sizes or shapes for differences in the sound produced.
2. Have students create a telephone with two cans, string and two buttons. Discuss using wire instead of string. Would this telephone work around corners?

Teacher resources:

Oxlade, Chris. *Science Magic with Sound*
Gr. 3-5. Although appearing at first to be exclusively a book about magic, this first entry in the *Science Magic* series uses tricks to illustrate the scientific properties of sound, especially the way it travels. The book might inspire kids to try several tricks or challenge them to produce a show to culminate a classroom science unit.
ISBN: 0-8120-446-1

Schoberle, Cecile. *Morning Sounds, Evening Sounds*
Gr. K-3. An African-American boy notes specific sounds as he follows his daily routine.
ISBN: 0-671-87437-3

Seeing Sound

Recommended grade levels: K-6

Goal: Students will use a model to assist them in visualizing a sound wave.

Process skills:

Applying concepts
Collecting data
Communicating
Controlling variables
Making graphs
Observing
Predicting

Frameworks: Matter

Materials: (per student group)

one coffee can, oatmeal container or other metal can
can opener
scissors
one large balloon
one small mirror (1-2 cm in diameter)
one rubber band
glue
one small radio
dark surface (screen) for reflected light (black construction paper works)

Teacher background information:

Sounds are longitudinal waves of compressed air moving outward from a vibrating source. It is the back-and-forth motion of the source that creates the sound.

One of the interesting features of sound (or any other kind of wave) is that, while a sound wave may move long distances, the material it is moving through hardly moves at all. Thus, a sound wave can travel from one side of the room to the other, but the air molecules in the room remain in the place they started. When the wave is actually moving past a given air molecule the molecule will move back-and-forth, passing on the wave's energy to its nearest neighbor, and then settle back into its original position. The greater the volume, the larger the molecule's motion, and the more energy the sound carries.

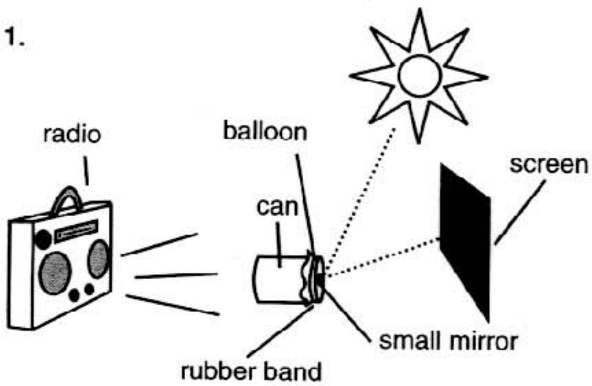
Procedure:

Students will:

1. Discuss sound as a form of energy prior to the activity. List examples of sounds at home, at school, and in the community and rank them in terms of increasing volume.
2. Remove both ends of the coffee or oatmeal container. Cut a piece of the balloon large enough to stretch tightly over one end of the container and secure it with a rubber band.
3. Glue the mirror onto the outside of the balloon, slightly off center.

4. Hold the open end of the container up to the radio. Position the mirror so that a spot of sun (or a flashlight beam) reflects from the mirror onto a dark surface. **(See Figure 1.)**
5. Predict what will happen when the radio is turned on.
6. Turn the radio on and slowly turn the volume up. Observe the light and record observations.

Figure 1.



Discussion:

1. What happened to the spot as you increased the volume?
2. Why do you think this happened?

Extensions:

Have students:

1. Experiment with different sized cans, cardboard cyliders or paper cups.
2. Construct a musical instrument using a variety of common materials.
3. Demonstrate sound with the musical instrument.
4. Donate instruments to a primary classroom.
5. Do this activity with a primary classroom that is studying sound energy.

Teacher resources:

Kaner, Etta. *Sound Science*
Gr. 2-5. This book explores the nature of sound through 40+ experiments, riddles, interesting facts, puzzles, and games.
ISBN: 0-201-56758-X

Lafferty, Peter. *Light and Sound*
Gr. 4-8. This book explains sound as being similar to light in that both travel in waves and can be reflected and refracted. The "It's Amazing" insert provides interesting facts for students to ponder. A chronological time line of inventions and discoveries is included.
ISBN: 0-7614-0030-3