Energy and Waves
Grade 6

The activities in this teacher's guide were created by the Center for Inquiry-Based Learning (CIBL) to accompany the materials in the Energy and Waves kit for Grade 6. The Energy and Waves Kit was specifically designed to meet the North Carolina Essential Science Standards for grade 6 physical science. Activities in this guide require students to think and assume responsibility for investigating forces, matter, and energy. These materials and activities are available only with prior professional development. The goal is to help students deepen their understanding of underlying concepts through concrete experiences.

This pilot version is under development, and CIBL welcomes any feedback you are willing to provide. We may be contacted through the CIBL web site on the "contact us" tab at http://ciblearning.org. If you have questions, feel free to call 919 294-9881.

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Throughout the guide, teaching tips are in red.

Activity Description & Estimated Class Time

These activities are designed for four 50-minute class periods. Part 1, *Waves and Energy*, explores examples of energy transmission through waves. Students discuss how energy moves from place to place in these examples, then simulate transverse and longitudinal waves with a spring. Afterward, they begin exploring concepts of frequency and amplitude using the spring. In part 2, *Transverse Waves*, students analyze properties of transverse waves during two 50-minute periods. Students manipulate a computer wave simulation to develop and demonstrate understanding of cycle, period, frequency, wavelength, and amplitude. As a math extension, students find a proportional relationship between a wave's period and its frequency. In part 3, *Types of Waves*, students connect what they have learned to sound, light, and earthquakes during one 50-minute period.

Objectives

Students will demonstrate knowledge and understanding of the following ideas and content:

- waves transmit energy
- frequency of waves
- wavelength
- amplitude of waves

Students demonstrate this knowledge and understanding by responding to challenges to change frequency, wavelength, and amplitude in a computer simulation, and to change these factors in a wave that they make with a spring. They also apply these ideas to examples in earthquakes, light, and sound.

Correlations to NC Science Standards

6.P.1.1 *Compare the properties of waves to the wavelike property of energy in earthquakes, light and sound.*

Correlations to Selected Common Core State Standards for Mathematics

Ratios and Proportional Relationships 6.RP: Understand ratio concepts and use ratio reasoning to solve problems.

3. Use ratio and rate reasoning to solve real-world and mathematical problems, e.g., by reasoning about tables of equivalent ratios, tape diagrams, double number line diagrams, or equations.

   b. Solve unit rate problems including those involving unit pricing and constant speed. For example, if it took 7 hours to mow 4 lawns, then at that rate, how many lawns could be mowed in 35 hours? At what rate were lawns being mowed?

   d. Use ratio reasoning to convert measurement units; manipulate and transform units appropriately when multiplying or dividing quantities.

Brief Science Background

Many forms of energy travel as waves through space and through materials. Forms of energy that travel as waves include sound, light, radiant heat, radio, and earthquakes. Generally, some form of energy starts a wave going, and when the wave reaches its destination, it adds some energy to the place it arrives. Sometimes, a wave can start out as one form of energy and become a different form of energy when it arrives. For example, a light wave travels from its source to a solar collector, where it becomes electricity.

As a wave travels, it cycles between a high (peak) and low (trough) value. The distance from peaks and troughs to the zero line is called amplitude. The wave completes a cycle in a specific amount of time, called the period, and the cycles occur at a set rate. The rate of cycling is called frequency. When waves move through a medium at a constant speed and cycle at a constant rate, the distance between peaks (or troughs) is constant. That distance is called wavelength.

Waves come in several forms. Some move side-to-side or up and down as they travel. For example, some earthquake waves travel horizontally but the earth they travel through moves up and down. These are called transverse waves. Other waves alternately compress and spread out the material they travel through. For example, as a sound wave travels through air, it alternately compresses the air in one place and spreads it out in another. These are called longitudinal waves. Still other waves, such as water waves, combine different kinds of motion, causing the earth they move through to shift in a variety of patterns.

Part 1 — Waves and Energy –50 minutes

Materials

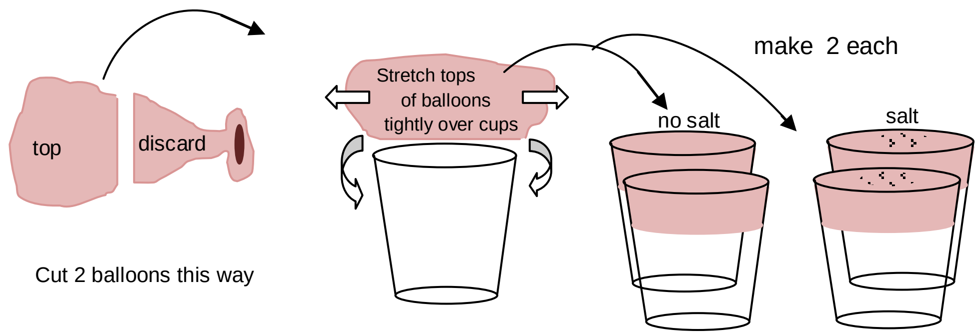
Materials for the whole class or the teacher

- four tall 9-oz cups
- four balloons to stretch over the cups
- five restaurant salt packets
- two photovoltaic cell-motor-light setups
- one plain white sheet of copier paper, cut in half across its width (supplied by teacher)
- two 5 x 8 inch plastic trays
- water (supplied by teacher)
- two ping-pong balls
- two 1-oz cup lids
- two copies of BLM 2 *Directions for Wave Stations* in Black Line Masters
- copies of *Student Exploration Sheets*, BLM 3, 1 full sheet per student
- spring toys, 1 per pair of students
- science notebook for each student (to be supplied by the teacher)
- two clamp lights with 75-watt bulbs and extension cords

Preparation

Set up six stations as follows:

1. Two stations with cups and balloons   Stretch balloon tops over four tall 9-oz cups, as shown below. Open one salt packet and put a pinch of salt on top of the balloon on one cup, then do the same with another cup. Leave the other two cups without salt. Place a pair of cups, one with salt and one without, at each of the two stations. Leave a copy of balloon cup directions from BLM 1 at both stations.



2. Two stations with water in trays - Put about 3/4 inch of water in two 5 x 8 plastic trays. Set up two stations with a tray, a cup lid, and a ping-pong ball at each. Leave a copy of water tray directions from BLM 1 at both stations.

3. Two stations with a light, solar cell, and motor - Be sure the motor runs when the light is on. Leave the light off after you check. Leave a sheet of paper and a copy of clamp light and solar cell directions from BLM 1 at both stations.

Procedure

Stations

1. Divide the class into 6 groups of roughly equal size. Leave one copy of BLM 2 Student Worksheets for each student who will visit each station.

2. Explain that there are six stations around the room, but only three different types of station. Each group will go to a station, follow the directions there, record what they find out on their worksheets, and move to a station that is different from the one they just visited. They are to go to all 3 different types of station. Tell the class that at each station, you will allow 1 minute to do the activity, call time, then 4 minutes to write, and then call time to move to the next station.

3. Ask each team to go to a station.

4. *Demonstrate only if necessary*. Be ready to:

- Hold the cup with no salt about 8-10 inches away from the cup with the salt grains on it. Then pinch the balloon on the cup you are holding, pull it back, and release it with a snap such that the salt on the other cup moves.
- Put a cup lid in one end of the water tray, and drop the ping-pong ball in the water at the opposite end.
- Switch on the light over a solar cell and motor; then switch it back off.

Part 1 cont.

5. After all students have filled out their record sheets, ask them to return to their seats.

6. Hold a whole-class discussion. Ask students to describe what they saw, including a cause and an effect. *For example, snapping a balloon on one cup made salt grains move on the other cup; light made the motor turn; the ball dropping in water made the plastic lid move.*

7. Continue the discussion by reminding the class that any change or movement requires energy. Starting with the ping-pong ball and water tray, ask students to describe what changed or moved and what kind of energy caused it. Ask the following questions to get students' ideas. Don't explain anything until you get all responses. Ask:

   - What was the source of the energy?
   - How did the energy travel from place to place?
   - What medium did the energy go through as it traveled?

Answer Key

Rather than go over these answers with students, try to facilitate the discussion to tie their responses to these ideas.

Water tray: a student put energy into the ping-pong ball by lifting it up against gravity. That energy became kinetic energy when the ball fell. The kinetic energy moved the water where the ball landed. That movement traveled as a wave across the tray. When the wave reached the other end, it moved the cup lid. The wave moved through water.

Balloon cups: stretching the balloon on the plain cup put mechanical energy into the balloon. When the balloon was released with a snap, the mechanical energy vibrated the air surrounding the cup and became sound energy. The sound traveled to the other cup as a wave that traveled through the air and hit the balloon on the other cup. That balloon responded to the sound wave by vibrating and moving the salt.

Light, solar cell, and motor: electrical energy came into the light bulb through wires from generators at a power station. The light bulb gave off light energy that traveled as a wave. When the light wave struck the solar cell, it produced enough electricity to turn the motor. The energy traveled through the air.

Wrap-up

Summarize the main ideas as follows:

- Energy caused things to move.
- Some of the energy in these examples moved as waves. **In some cases, students have to take your word for this. For example, with the light/solar cell, their experience does not support this claim. They saw energy but not waves.**
- Waves can move through different substances, such as air and water.

Part 1 cont.

Wave Simulations Using a Spring

Use tabletops if they are five feet long or more. If these are not available, this activity can be done on an uncarpeted floor. Ask students to work in pairs and give a spring toy to each pair.

1. In each pair, have one of the students hold one end of the spring and the other student hold the opposite end. Then ask them to work together to stretch the spring until it is 5-8 feet long. Next, challenge them to find different ways to send energy from one end of the spring to the other without lifting either end from the surface. They can move the ends of the spring in any way except lifting it from the surface.

   Notebook Prompt: Describe the ways you sent energy through the spring. Use a labeled drawing that fills a page. Give evidence to support your claim that energy traveled from one end of the spring to the other.

   Discuss ways that students described energy moving along the spring.

2. Still working in pairs, ask students to make an S-like wave and describe two things about it:

   - the motion of their hand (including the direction) in making the wave;
   - the motion of the wave moving on the spring (including the direction).

   Tell students that this is called a <u>transverse wave</u>. It is the way water waves and light move.

3. Ask students to make the other kind of wave and to describe the same two things:

   - the motion of their hand (including the direction) in making the wave;
   - the motion of the wave moving on the spring (including the direction).

   Tell students that this is called a <u>longitudinal wave</u>. It is the way sound waves travel from the source of a sound to a person's ears.

   Notebook Prompt: Define both types of wave in your own words.

Part 2 — Transverse Waves – two 50-minute class periods

Materials

Materials for the whole class or the teacher

- access to computers, 1 per pair of students
- Smartboard™ or computer projector
- one copy each for projection: BLM 3 Challenges (2 pages); BLM 4 Things You Can Do With the Wave Simulator; BLM 5 Wave Simulations; and BLM 6 Wave Timer.
- Wave Components descriptions (BLM 8), either one copy for projection or as one copy per pair of students
- *Transverse Waves Exploration* student worksheets (BLM 7a,7b); one set per student
- science notebook for each student (to be supplied by the teacher)

Part 2 cont.

Materials for groups of 2 students

- a computer connected to the internet
- Wave Components descriptions, if this will not be projected for the whole class to see (see Materials for the whole class, above)
- science notebook for each student (to be supplied by the teacher)

Preparation

1) Schedule access to the computer lab.

2) Post the web site http://ciblearning.org/lesson-materials. Ask students to click on "Grade 6 Materials," then "Wave On a String Animation." Enter the user name cibl6 and password learn12* to allow students to use the wave simulation.

Procedure

With all students in pairs at computer terminals, ask them to go to the web site you posted. Have students enter the login and password.

1) Project BLM 3 Challenge 1. Ask everyone to try out features of the simulation. Challenge them to find and list 13 things that they can change or do with the simulation. Let them know that everyone will share what they find out after 5 minutes. When 5 minutes have elapsed, list the things students tell you they discovered. Afterwards, show the complete list found in BLM 4:

- change the frequency setting
- change the amplitude setting
- move the vertical ruler
- move the horizontal ruler
- move the reference line
- pause (stop the moving wave)
- play (make the wave move)
- step along the path the wave makes
- move the timer
- start and stop the timer
- step-time wave motion
- reset the wave motion
- reset the timer

Allow a few minutes for students to learn how to do things on the list that they did not discover themselves. Let students who figured out things teach those who did not. Do not be concerned if students do not figure out how to step-time wave motion. They will get directions for this later on.

2) Ask students to manipulate the simulator to make a wave that looks like a wave they made with the spring. Ask which type it is **transverse**. Ask the class

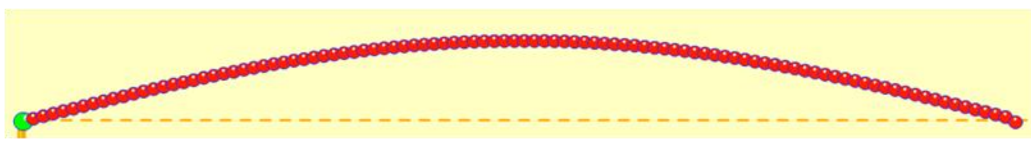
Part 2 cont.

to share things they notice about the computer-generated wave. **Students might notice:**

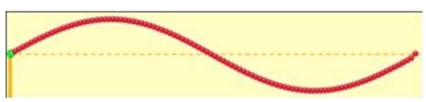
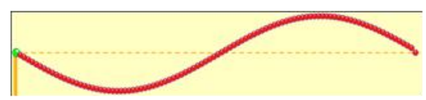
- **it seems to travel from left to right**
- **it goes up and down with a dotted line in the middle**
- **it can go faster or slower**
- **it can be taller or shorter**
- **it makes a pattern in which the wave shape repeats**

3) Project BLM 3 Challenge 2. Ask students to use their simulators to make a wave in which both ends touch the dotted yellow line and no ball is completely below the line. The amplitude setting must be between 20-100. Remind them to use the pause and step functions to put both ends of the wave on the line. Do not otherwise direct them. Ask them to pause the wave once they have it. Circulate to check. To show them what it should look like, project Figure 1 from BLM 5:

Ask students to call out or report first the amplitude and then the frequency reading **look for frequency settings around 5** that accomplish this. Waves should look like the diagram above. Ask students if they notice any pattern in the readings **frequency settings are all similar but amplitude settings can be anything above 20**.



4) Project BLM 3 Challenge 3. Ask students to set the amplitude between 20 and 100 and then make the waves shown:

 and 

Students will need to use the pause and step functions to put both ends of the wave on the yellow dotted line. Ask students to call out or report their amplitude and frequency readings **look for frequency settings around 10**. Ask students to find the shape of the wave from Challenge 2 (step 3 above) within the new wave they just generated in this step (Challenge 3). **The shape from Challenge 2 is the first half of the Challenge 3 wave shown in the left-hand figure above, and it is also the second half of the Challenge 3 wave shown in the right-hand figure above**. Ask: "What is the relationship between the frequency setting of the first (Challenge 2) wave and this new (Challenge 3) wave? **The new wave has a frequency setting that is twice that of the old wave.**

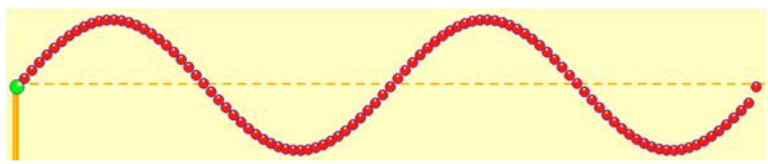
5) Ask students to describe what they notice about this wave. **They might say some of the following:**

- **It has one dip and one high spot.**
- **It touches the dotted line in three places.**
- **The bottom is the same as the top, only upside down and moved to the right.**

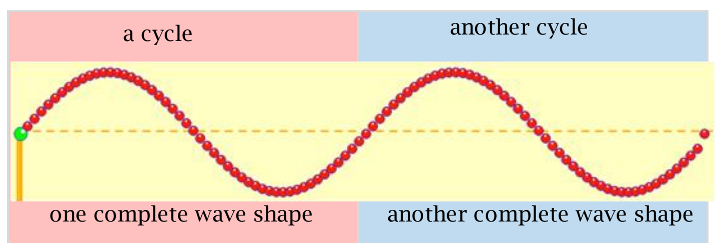
Part 2 cont.

6) Introduce the terms *crest* and *trough*. Tell students that the crest is the high point of a wave. A trough is a low point of a wave. Point these out on the screen.

7) Ask the class for ideas about how the waves generated by the computer change as the frequency setting is increased but the amplitude is kept the same. (They've just seen that increasing the frequency caused more wave parts to be shown on the screen.) Project BLM 3 Challenge 4 and ask students to draw their predictions. Then let them change the frequency to 20, run and pause. The wave should look like BLM 5 Figure 2:



8) Ask students what they notice about this wave. Accept all responses. If students do not notice that the wave form repeats twice, point it out. You can highlight half of this wave as in Figure 3:



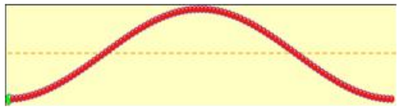
9) Introduce the term *cycle*. A wave cycle is one complete wave shape. There are two complete cycles in figure 3. Ask students to respond to the notebook prompt below and allow them to use the wave simulator to check and revise definitions as needed. Point out that this example of a cycle starts on the dotted yellow line, but a cycle can start anywhere on a wave.

Notebook Prompt: Without using the words "complete wave shape," write your own definition of a wave cycle so that someone else could identify a cycle when they see one.

10) Project BLM 5 Figure 1 again. Ask students what part, or fraction, of a cycle this figure represents **1/2 cycle**. Also project Figure 4. Ask students if these waves represent one full cycle, and why they do or do not. **Both of them do represent full cycles because they each end at the same place where they began, in relation to the yellow-dotted center line, and they also form only one wave shape.**

Part 2 cont.

Figure 4:



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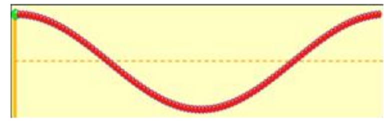
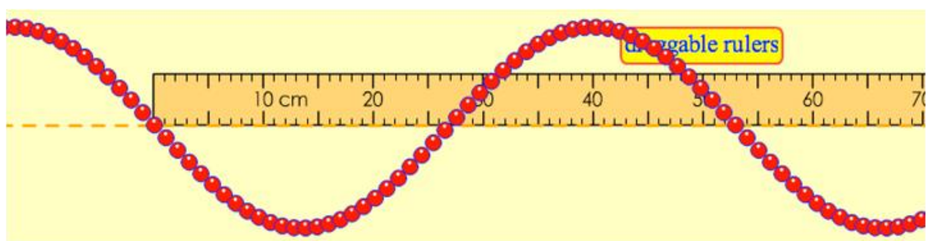


11) As a check, ask students to set their frequency controls to 30, 40, and 50, and at each setting ask them to report how many crests and how many troughs are showing **3, 4, and 5 crests and troughs, respectively**. Then ask them how many cycles are showing at each frequency setting **3, 4, and 5 cycles**.

12) Project BLM 3 Challenge 5. Ask students for their ideas about how they could measure the length of one whole cycle. In particular, ask them where they think the measurement should start and end. They might suggest starting from the dotted reference line, or measuring from crest to crest as shown below, but other ways also work. After individual students or pairs of students have chosen a way to measure one cycle and recorded their measurements, ask them to measure again using a different starting point. Ask if they got the same result. **The two measurements should be identical.**



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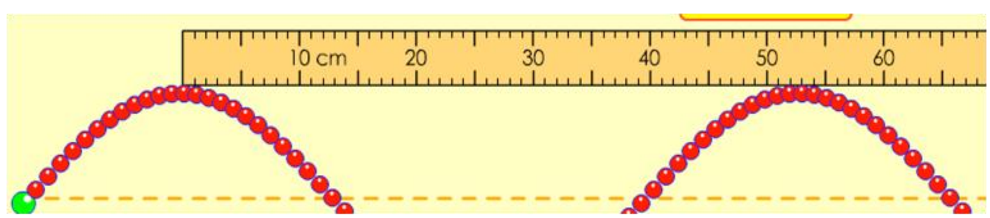


For a frequency setting of 20, look for measurements near 53 cm.

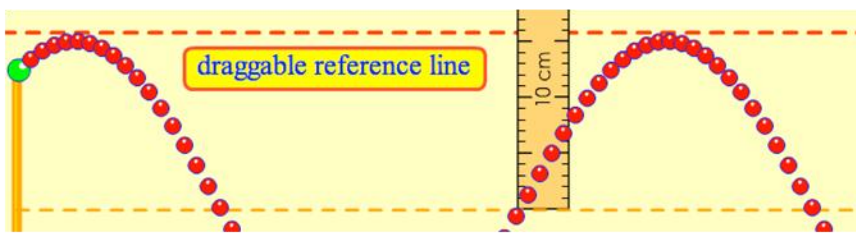
Part 2 cont.

13) Introduce the term wavelength: the length of a wave's complete shape, for example:

- from crest to adjacent crest or trough to adjacent trough
- from where it crosses the yellow-dotted center line heading downward, to where it crosses the center line going downward again

Interesting wave fact: the waves produced by microwave ovens are about one foot long.

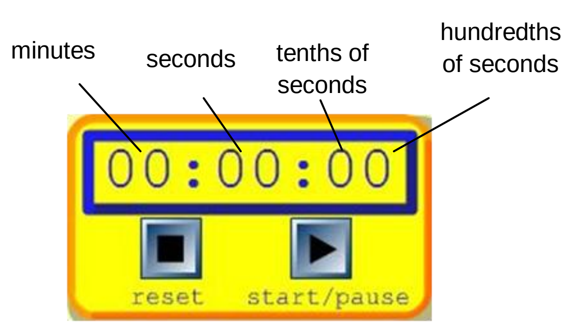
14) Project BLM 3 Challenge 6. Ask students to set the amplitude to 80, run a wave and pause it. Then ask them to use the draggable vertical ruler to measure the height in centimeters from the dotted center line to a crest. Discuss reasons for using these measurement points. Point out the draggable reference line as a tool. There are many ways to do this. Most students can find their own way or learn from others. A student might measure the height of crests by setting the reference line to touch the tops of the highest balls and setting the vertical ruler to measure the distance between the dotted center line and the reference line, as pictured below. Look for measurements just under 16 cm.



15) Introduce the term *amplitude*. Explain that amplitude is the distance from the center point of a wave to the highest *or* lowest point of a wave. It is NOT measured from lowest to highest points.

16) Point out that so far, the class has measured lengths and heights of waves. It is also important to know how fast a transverse wave moves up and down (or side to side). Ask students what additional tool or tools they would need to measure how quickly a wave rises and falls. **You need a timer to measure how fast something happens.**

17) Project BLM 3 Challenge 7. Ask students to time one cycle of a wave. Use BLM 6 to explain how to use the timer in the wave simulator.



Part 2 cont.

18) Give these instructions:

- set the frequency to 30
- use the step function and any location you choose to set the wave in a position where you can know when you have finished a whole cycle
- when you are ready to measure, reset the timer to 0
- use the step button to step through exactly one cycle of a wave
- record the time it took for a whole cycle in your notebook

Look for times around 0.91 seconds.

19) Introduce the term *period*. Students have just now measured the period of a wave: the time it takes for a wave's shape to repeat, for example, from a crest to the next crest. Also introduce the related term *frequency*. Frequency is the number of cycles of a wave that occur in a given amount of time. It is also the number of periods in a second. Frequency is often given as the number of cycles per second.

Interesting fact: FM radio towers send out waves that have a period of about one 100 millionth of a second. That's a pretty short time. By the time a second has gone by, that wave has made 100 million cycles.

20) Project BLM 8 Wave Components list and leave it up. Give out BLM 7 Transverse Wave Exploration student worksheets. Students should complete these worksheets individually but work in pairs at computers to collect the data needed. Ask them to complete only through Step 5, stop, and minimize the simulation window. Step 6 of the worksheet asks students to predict what doubling the frequency will do to the time of the period. Make sure students record their predictions on their worksheets before they use the simulation to test their predictions and record their results.

Wave Exploration Answer Key:

1) A little more than 22 cm

2) 9.5 cm for both crest and trough

3) Amplitude could be anything, but the frequency should be around 53. Frequency controls the wavelength, or distance between crests. Changing amplitude does not affect distance between crests.

4) Amplitude around 77. Only the amplitude control matters. Changing frequency does not alter the distance from the zero line to a crest or trough.

5) 1.11 seconds. There are many ways to do this. Some students time the movement of the green ball as it starts and returns to the same place on the center line in a full cycle. Some students set the vertical ruler at a crest and time until another crest reaches the ruler. Any point that can be precisely located as a wave moves through it will work.

6) Doubling the frequency should cut the time of a cycle in half. If a setting of 25 yields 1.11 seconds, a setting of 50 should yield 0.55 seconds.

Part 2 cont.

MATH EXTENSION: The period of a wave is the time it takes to go through a complete cycle. The frequency is the number of times a wave goes through a complete cycle in one second, so it is also the number of periods in a second. Give each student a copy of **BLM 9** and challenge everyone to fill in the missing periods and frequencies in the table.

Period (in decimal fraction of a second)	Period (fraction of a second)	Frequency
0.5 second	½ second	2 cycles per second
0.33 second	1/3 second	3 cycles per second
0.25 second	1/4 second	4 cycles per second
0.67 second	2/3 second	1 and ½ cycles per second
0.2 second	1/5 second	**5 cycles per second**
0.125 second	**1/8 second**	8 cycles per second
0.1 second	1/10 second	**10 cycles per second**
0.01 second	**1/100 second**	100 cycles per second
2.0 second	**2 seconds**	½ cycle per second
0.8 second	**4/5 second**	1 and ¼ cycles per second
0.6 second	3/5 second	**1 and 2/3 cycles per second**

Part 3 — Types of Waves –50 minutes

Materials

Materials for the whole class or the teacher

- Spring toys, 1 per pair of students
- wave simulation projection (Smartboard™ or computer projector)

Materials for groups of 2 or 3 students

- 1 spring toy and a flat surface, either a 5' table or uncarpeted floor space
- science notebook for each student (to be supplied by the teacher)

CIBL

Preparation

1. Check to see that wave animations requiring Quicktime function. Try the animation at http://www.physics.nyu.edu/~ts2/Animation/Trans_Long_Periodic_Waves.html. **If it does not work on your PC, download Quicktime for the PC** at http://support.apple.com/downloads/QuickTime_7_5_5_for_Windows. If you are using a Mac, you have Quicktime.

2. Arrange space for students to make waves with the springs.

Procedure

Longitudinal waves - 15 minutes

1) Give a spring to each pair of students, and ask them to use it to make a transverse wave. Then ask them to:

- increase the wave's frequency and describe what they did to increase it,
- give evidence that the frequency increased (how it looked different from when its frequency was slower),
- increase the amplitude and describe what they did to increase it,
- give evidence that the amplitude increased (how it looked different from when its amplitude was smaller).

2) Ask teams to make a longitudinal wave with the spring . Then ask them to:

- increase the frequency of the longitudinal wave and describe what they did to increase it,
- give evidence that the frequency increased.

3) Show http://www.physics.nyu.edu/~ts2/Animation/Trans_Long_Periodic_Waves.html on a Smartboard™ or computer projector. This page includes 3 types of waves. DO NOT run the top example labeled "transverse wave." Run the bottom two simulations only—"longitudinal wave" and "periodic transverse wave." After students watch, ask them to make an "alike and different" chart for the two types of waves with at least three similarities and three differences.

4) Discuss the students' lists. **Possible answers include:**

Similar:

- **Both waves have a regular repeating pattern. The longitudinal wave has denser and more spread out areas that regularly repeat (a frequency). The transverse wave has ups and downs that repeat (a frequency).**
- **Both waves move along the spring.**
- **Both waves start with movement at one end.**

Different:

- **The red balls in the longitudinal wave move forward and back, but in the transverse wave the balls move side to side or up and down.**
- **The transverse wave takes up more space above and below the line while the longitudinal wave moves straight down the spring. Does that mean the longitudinal wave doesn't have an amplitude? Or might the longitudinal wave have a different kind of amplitude?**
- **The balls in the longitudinal wave are sometimes spaced close together and sometimes farther apart, but those in the transverse wave seem to stay spaced more the same distance apart.**

Part 3 cont.

5) Pose the following question: If both kinds of waves have similar parts and properties, what do you think a crest or a trough might look like on a longitudinal wave? How might you measure a wavelength on a longitudinal wave?

Introduce the terms *compression* and *rarefaction* (see Detailed Background Information). As longitudinal waves pass through a medium, the waves press the medium together in some places, or compress it. In other places, the waves separate particles of the medium, or rarefy it. With longitudinal waves, compressed and rarified areas of the medium alternate along the path of the wave.

With longitudinal waves, a complete wave (or cycle) is one compression and one rarefaction. A wavelength is the distance between one compression and the next compression (or between one rarefaction and the next rarefaction). A crest in a transverse wave corresponds to the place in a longitudinal wave where the medium is most compressed. A trough in a transverse wave corresponds to the place in a longitudinal wave where the medium is most rarefied. A longitudinal wave's amplitude is a measure of how tightly the compressions are packed together and how spread out the rarefactions are.

Interesting wave fact: the lowest pitch a human can hear is a sound wave with a wave length of about 7.3 yards, about the length of a classroom.

6) Explain that sound energy travels in longitudinal waves. Demonstrate with sound cups by having a student place a finger lightly on the balloon of one cup while, a few inches away, you snap the balloon of the other cup. Ask the student what they feel. Explain that the vibrations they feel are the compressions in the air striking the balloon they are touching.

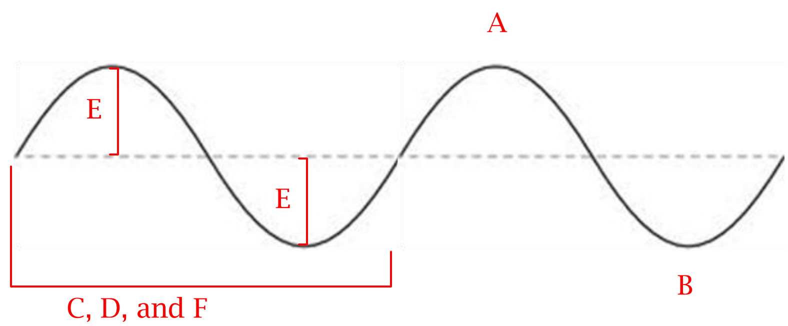
Part 3 cont.

Wrap-Up

1) Give each student a copy of BLM 10. Ask students to define each term and label, as best they can, where each term occurs on the wave diagram. Let them know they can add lines to the diagram if they need to. Students will not be able to label frequency (G), but you do not need to tell them this.

Answer Key:

A. Crest
B. Trough
C. Wavelength
D. Cycle
E. Amplitude
F. Period
G. Frequency



Student definitions should be as in step 2 below, but in their own words.

2) Go over the answers after they are done. Use BLM 8 to review these terms:

- crest and trough: crest is the highest point of the wave; trough is the lowest point
- Wavelength is the distance over which a wave's shape repeats, for example, from crest to the adjacent crest or from trough to adjacent trough.
- A cycle is one complete shape of the wave, for example, from crest to crest or trough to trough.
- Amplitude is the distance from the center point of the wave (also called the rest point) to the highest or lowest point.
- The period is the time it takes for a wave's shape to repeat, for example, from crest to adjacent crest or trough to adjacent trough.
- The frequency is the number of cycles of a wave that occur in a given amount of time. Frequency is often stated as the number of cycles per second.

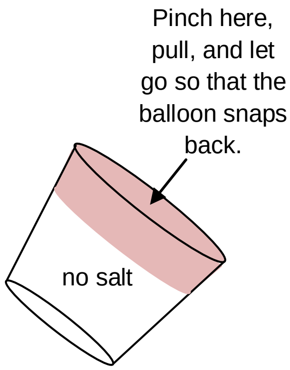
3) Ask students to imagine that each one of them is in charge of a group of 8 people. Explain that their task is to plan how these 8 people would move to demonstrate a transverse wave to the class. Give the students 5 minutes to work alone on their plans. Then divide the class into groups of 8 and give them 5 minutes to prepare their demonstrations.

4) Let each group present its wave. After all groups have done so, ask a group to demonstrate their wave again. At some point during the demonstration, call out "freeze!" With the wave frozen, ask other students in the class to identify a trough, a crest, and where a cycle starts and ends on the wave.

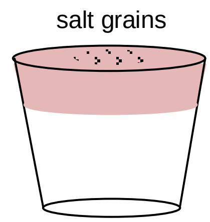
5) Challenge the groups to demonstrate a longitudinal wave. Give the groups five minutes to prepare, and then have them present their waves.

BLM 1: Station Directions

Cut these out and place at the appropriate stations.



Lift the cup without salt a few inches above the table and hold it 8-10 inches from the cup that has salt on it. Pinch the center of the balloon on the lifted cup and stretch the balloon away from the cup. Let go with a snap. Watch the salt grains on the other cup.

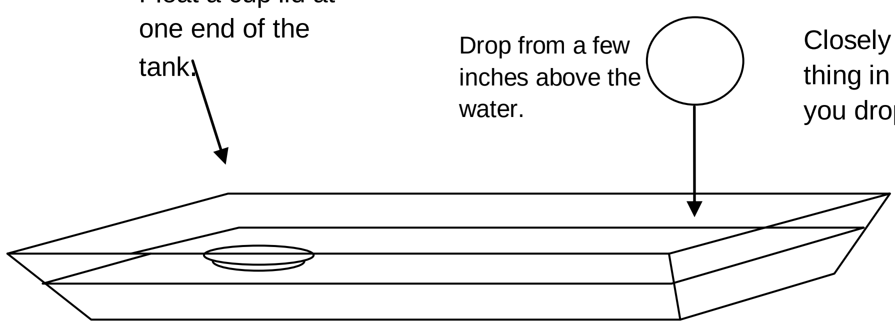


Drop a ping-pong ball at the opposite end of the tank.

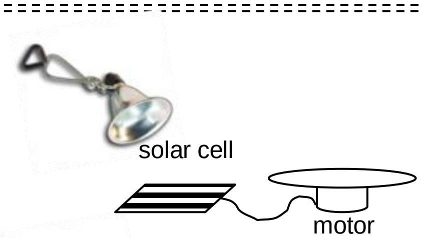
Float a cup lid at one end of the tank.

Drop from a few inches above the water.

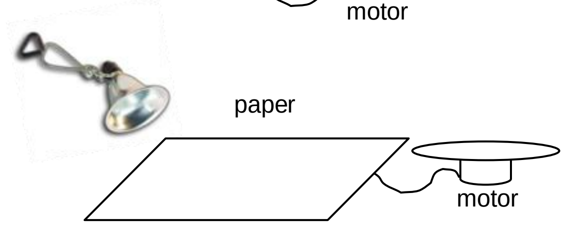
Closely watch every-thing in the tank when you drop the ball.



Start with the clamp light off and the motor still. Turn the light on. Watch what happens when the light is turned on, and again when it is turned off.



With the clamp light off and the motor still, put a piece of paper over the solar cell and then turn on the light. Watch what happens. Then, with the light still on, re-move the paper covering the solar cell. Observe what happens.



BLM 2: Student Exploration Sheets

Make 1 copy of the page for every 2 students. Cut to make 1 cutout per student who will visit each station.

Name___________________________________

Check the station you are observing: balloon cup ▫ water tank ▫ light and motor ▫

Describe what you observed. Include both a cause and an effect.

Name___________________________________

Check the station you are observing: balloon cup ▫ water tank ▫ light and motor ▫

Describe what you observed. Include both a cause and an effect.

Name___________________________________

Check the station you are observing: balloon cup ▫ water tank ▫ light and motor ▫

Describe what you observed. Include both a cause and an effect.

BLM 3 *1 of 2 pages*

Challenges (show one at a time)

Challenge 1 - Try out features of the simulation. Find and list 13 things that you can change or do with the simulation. Everyone will share what they find out after 5 minutes.

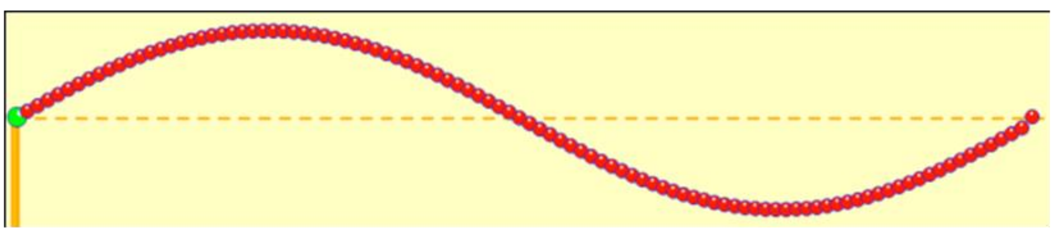
Challenge 2 - Use the wave simulator to make a wave in which:

- **both ends touch the dotted yellow line**
- **no ball is completely below the line**
- **the amplitude setting is between 20 and 100**

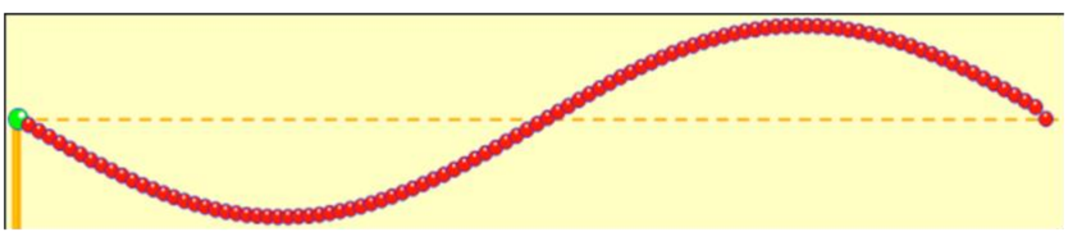
TIP: Use the step function to get the green ball on the far left of the dotted yellow line and a red ball on the far right of the dotted yellow line.

Challenge 3

1. **Make a wave that looks like this:**



2. **Record your amplitude and frequency settings**
3. **Make a wave that looks like this:**



4. **Record your amplitude and frequency settings**

BLM 3, *2 of 2 pages*

Challenges (show one at a time)

Challenge 4

1. Without using the computer to look at a wave, draw a wave that would be made by setting the frequency to 20.
2. After you have drawn your prediction, set the frequency at 20, run and pause. Compare the wave to your prediction.

Challenge 5 – Using a frequency setting of 20, measure the length of one whole cycle.

Challenge 6

1. Set the amplitude to 80, run a wave, and pause it.
2. Measure the height in centimeters of a crest, measuring from the dotted center line.

Challenge 7 - Time one cycle of a wave.

1. Set the frequency to 30.
2. Use the step function and any marker you choose to stop the wave in a position where you can know when you finish a whole cycle
3. When you are ready to measure, reset the timer to 0
4. Use the step function to step through one cycle
5. Record the time it took for a whole cycle in your notebook.

BLM 4

Things You Can Do With the Wave Simulator

- change the frequency setting
- change the amplitude setting
- move the vertical ruler
- move the horizontal ruler
- move the draggable reference line
- pause (stop the moving wave)
- play (make the wave move)
- step along the path the wave makes
- move the timer
- start and stop the timer
- time between steps
- reset the wave motion
- reset the timer

BLM 5: Wave Simulations

Figure 1

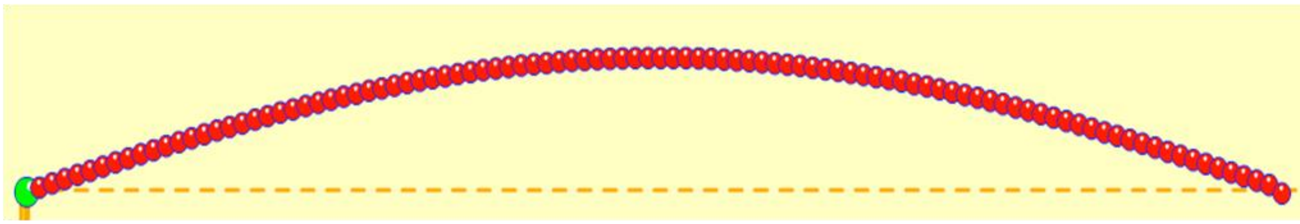


Figure 2

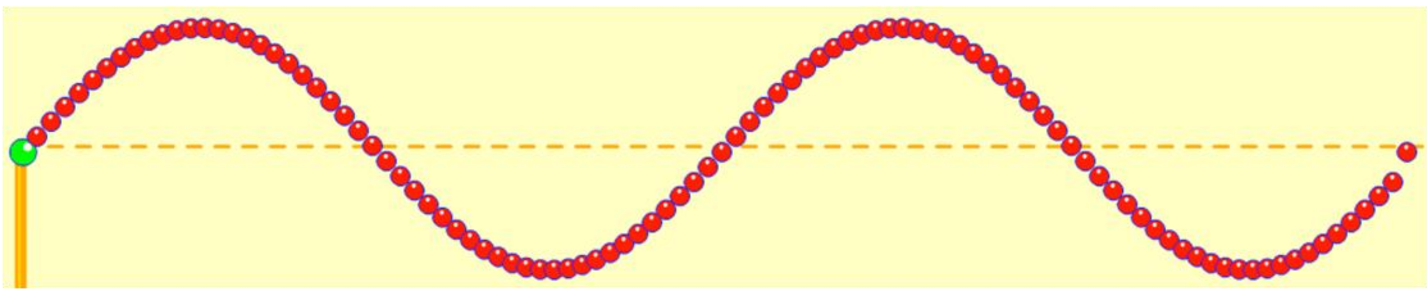


Figure 3

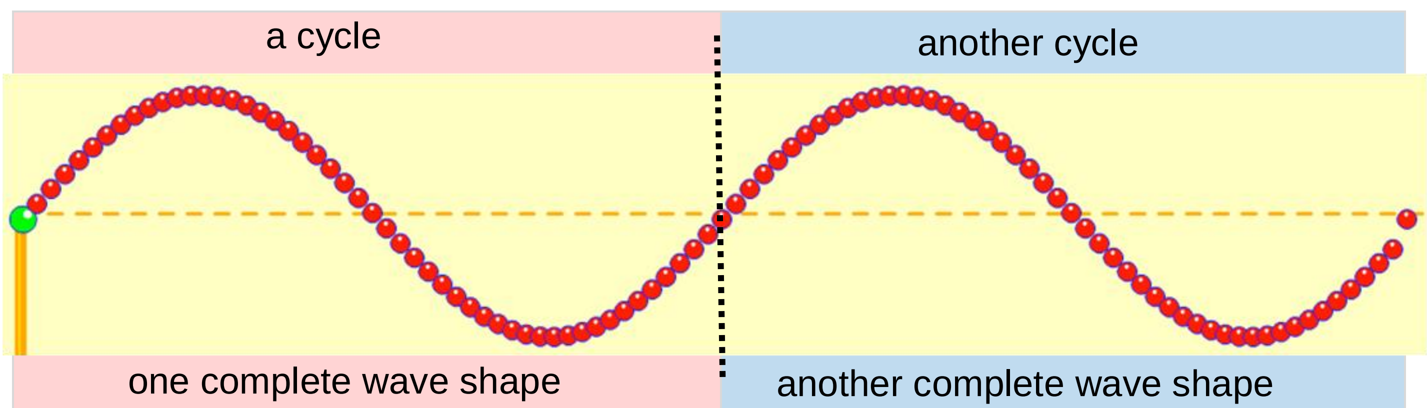
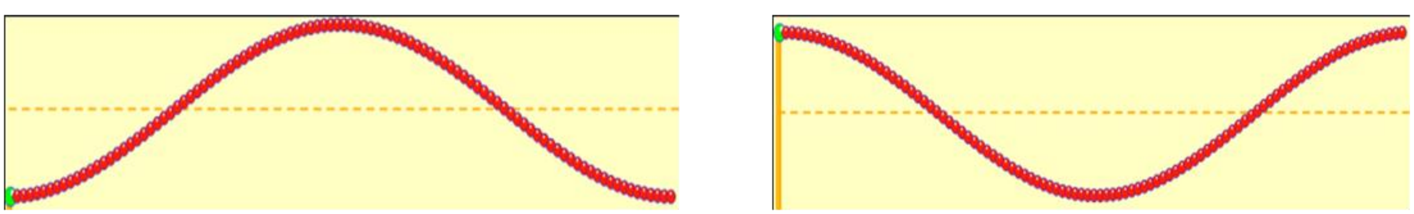
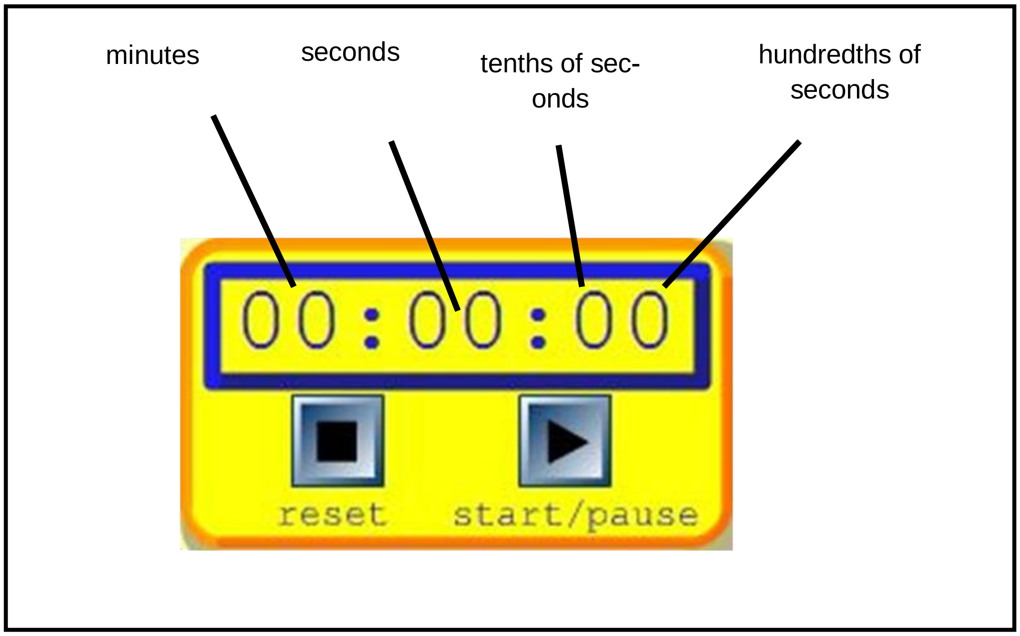


Figure 4



BLM 6: Wave Timer



BLM 7: Transverse Wave Exploration

Name ___________________________________

1. Set the frequency and amplitude controls at 48 and begin running the wave. Use the pause button to stop the wave. Measure a wavelength. The wavelength measurement is____________________________________.
2. With the wave stopped and the frequency and amplitude still set at 48, measure the amplitude of the wave. The amplitude measurement is_____________________.

3. Make a wave that has a length of 20 cm. Record the control settings that achieved this length.

   Amplitude __________Frequency ____________

   Which of the two controls made the most difference in length?_______________________________________

   What difference did the other one make?____

   What do you think might explain this? ____

   ____

4. Adjust the controls to make a wave measuring 15 cm in wave height..

   Amplitude setting______________ Frequency setting ______________________

   Which control makes the most difference in wave height?____

   What difference does the other one make? ____

   What do you think might explain this? ____

   ____

5. Set the frequency to 25 and use the timer to find how long one complete cycle takes. Record the time (to the nearest .01 sec.): __________seconds.

   Describe how you knew when the wave looked exactly like it did when you started: ___________________

   ____

   With the frequency set to 25, measure the length of a cycle in centimeters. Length of cycle:_________cm.

6. Minimize the window on the screen. Predict the time the wave will take to go through a cycle with the frequency set to 50. Your prediction: _________Describe how you went about predicting this.

   ____

   ____

   Open the window and test your prediction. Compare your prediction to what actually occurred:

   ____

   ____

7. How does the frequency control relate to actual frequency? ____

____

BLM 8

Wave Components

Crest: the crest is the highest point of the wave. The trough is the lowest point of the wave.

Wavelength: wavelength is the distance over which a wave's shape repeats, for example, from crest to the adjacent crest or from trough to adjacent trough.

Amplitude: amplitude is the distance from the center point of the wave (also called rest point) to the highest or lowest point. It is how high and how low a transverse wave goes.

Cycle: a cycle is one complete shape of a wave. For example, a cycle may be measured from crest to crest or trough to trough.

Period: the period is the time it takes for a wave's shape to repeat, for example, from crest to adjacent crest or trough to adjacent trough.

Frequency: the frequency is the number of cycles of a wave that occur in a given amount of time. Frequency is often stated as the number of cycles per second.

BLM 9

Name________________________________

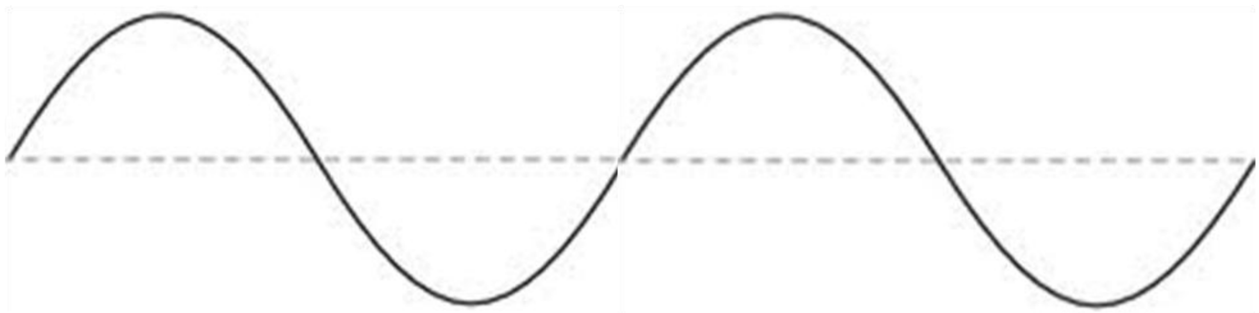
Fill in the blank squares with the correct number.

Period (in decimal fraction of a second)	Period (fraction of a second)	Frequency
0.5 second	½ second	2 cycles per second
0.33 second	1/3 second	3 cycles per second
0.25 second	1/4 second	4 cycles per second
0.67 second	2/3 second	1 and ½ cycles per second
0.2 second	1/5 second	
		8 cycles per second
0.1 second	1/10 second	
		100 cycles per second
		½ cycle per second
		1 and ¼ cycles per second
0.6 second	3/5 second	

BLM 10

Name________________________________

Define each term below and label all the ones that you can on the wave diagram. You may add lines to the diagram if you need to.



A. Crest________________________________

B. Trough________________________________

C. Wavelength________________________________

D. Cycle________________________________

E. Amplitude________________________________

F. Period________________________________

G. Frequency________________________________

Appendix

Common Student Preconceptions About This Topic

Children generally do not think of light, radio waves, sound, or earthquakes as waves in the same category as waves on water. These phenomena appear to be very different. Their wave nature is invisible. It is difficult to directly experience these forms of energy as waves in the way we experience waves rolling on the ocean. As a result, most people, including children, take scientists' word for it that these forms of energy travel in similar ways.

Detailed Background Information

In physics, a wave is defined as a repeating disturbance that carries energy as it moves through a medium from one place to another. While we can see ocean waves and feel the kinetic energy they carry, the waves we most commonly experience are light and sound waves, which we can neither see nor feel in the same way as ocean waves. Nevertheless, in the 19th century several physicists conducted ingenious experiments that led to the widely accepted wave theories of light, sound, and several other forms of energy.

Light waves are examples of transverse waves, which resemble the S-shapes a child's spring toy (*e.g.*, a Slinky™) can make when lying on a flat surface. These are similar to the way ocean waves move with their characteristic high parts (peaks) and low parts (troughs). Transverse waves can vary in their amplitude and wavelength.

Amplitude is the height of the peaks from a horizontal line that splits the waves into equal top and bottom halves. It is also the depth of the troughs from that same line. The amplitude of a wave is related to the amount of energy it transports. High amplitude waves carry more energy than low amplitude waves. High-amplitude sound waves sound loud, and low amplitude sound waves sound quiet.

Wavelength: The distance between two adjacent peaks or two adjacent troughs. In other words, it is the horizontal distance traveled by one complete wave. A complete wave consists of one whole peak and one whole trough; it can also be thought of as an S lying on its side (rotated 90°). The shorter the wavelength, the more energy the wave carries.

The period is the amount of time it takes for one complete wave form. For example, the time that elapses from the moment when one crest passes a point until the next crest passes the same point. Periods are measured in seconds. The shorter the period, the more energy the wave carries.

Frequency is the number of complete waves that occur in a certain amount of time. Frequencies are generally stated in cycles per second, with one cycle being the same as one complete wave. Physicists use the term *hertz*

Appendix cont.

(named for the German Physicist Heinrich Hertz) instead of cycles per second to describe a wave's frequency. One hertz is equal to one cycle per second. A hertz is abbreviated as *Hz*. This abbreviation is often preceded by another, such as *k*, meaning kilohertz (one thousand hertz, or kHz) or *M*, meaning megahertz (one million hertz, or MHz). The higher the frequency, the more energy the wave carries.

Radio waves are a subset of a broader category known as electromagnetic waves, which also includes microwaves, infrared light, visible light, ultraviolet light, X-rays, and gamma rays. Of these transverse waves, radio waves have the lowest frequencies – as low as 3 kHz (3000 cycles per second), although the frequencies used by commercial radio stations range from 535-1700 kHz for AM stations, and 88-108 MHz for FM stations. Radio waves also have the longest wavelengths – up to 100 km (about 64 miles), but commercial radio waves range from 560 meters (AM) to 2.8 meters (FM). Besides radio stations, many common consumer devices use radio waves, including cell and cordless phones, garage door openers, and GPS units.

Starting with radio waves and followed by microwaves, infrared light (also known as radiant heat), and the rest of the electromagnetic waves listed in the order above, wavelengths decrease as the list proceeds. Microwave ovens, for example, typically produce wavelengths of about 10-30 centimeters. Light that is visible to humans travels in waves of lengths from about 700 nanometers (700 billionths of a meter) for red, to 400 nanometers for violet. Medical X-rays machines produce waves that are about 10,000 times shorter than those of violet light.

Gamma rays, which are another form of radioactive waves that travel to Earth through outer space, have even shorter wavelengths, and they also have the highest frequencies of the electromagnetic waves. In fact, for all of these waves, there is an inverse relationship between wavelength and frequency. Radio waves, having the longest lengths, have the lowest frequency range, from 3,000 Hz up to about 1 billion Hz. The waves produced by microwave ovens have frequencies of about 1-3 billion Hz, while the frequencies of visible light range from about 250 trillion Hz (for red) to 850 trillion Hz (for violet). Medical X-rays cycle at the unimaginable rate of 1 quintillion (1,000,000,000,000,000,000) Hz.

Although their wavelengths and frequencies differ, all types of electromagnetic waves have one thing in common: they all travel at the same speed of 299.8 million meters per second, also known as the speed of light.

Sound waves move in a very different way than light and the other electromagnetic waves. While electromagnetic waves are all examples of transverse ways, sound waves are examples of longitudinal waves. Keeping in mind that a wave is a repeating disturbance within a medium, which carries energy as it moves from one place to another, a transverse wave displaces particles of the medium in directions that are perpendicular to the direction the wave is traveling. An ocean wave models this idea very well:

the wave moves horizontally toward the shore, but the water (the medium) moves vertically as peaks and troughs form.

In longitudinal waves, however, the particles of the medium move back and forth in the same direction as the wave itself, that is, parallel to the wave's movement. In longitudinal waves, the particles are alternately pushed together, or compressed, and then bounce back to their original, uncompressed positions. Physicists refer to the compressed regions as *compressions* and the uncompressed regions as *rarefactions*. If we could actually see the particles, the wave would look like alternating bands of lighter (rarefied) and darker (compressed) areas moving in a straight line, as if they were traveling through a pipe. Excellent animations of both longitudinal and transverse waves can be found at http://www.acs.psu.edu/drussell/Demos/waves/wavemotion.html.

In a longitudinal wave, just as in a transverse wave, the wavelength is the distance spanning one complete wave. Therefore, a longitudinal wavelength is the distance from the start of one compression to the start of the next compression (or the start of one rarefaction to the start of the next rarefaction). Likewise, the period of a longitudinal wave is how long it takes for one complete wave, that is, one compression plus one rarefaction, to pass a given point. The frequency is the number of complete waves that pass a given point in one second, just as in transverse waves. In sound waves, the pitch of the sound is determined by its frequency, with lower pitches having lower frequencies and higher pitches having higher frequencies.

The amplitude of a longitudinal wave is a measure of how closely packed together the compressions are, or how spread out the rarefactions are. It takes more energy to pack particles of the medium together in a longitudinal wave, just as it takes more energy to move particles vertically in a transverse wave. Louder sounds have higher amplitudes, and vice versa.

While both transverse and longitudinal waves transport energy from one place to another, they do not move particles of the medium from one place to another. If they did, sound waves, for example, would push particles of air ahead of them and we would feel a breeze at our ears every time we hear a sound, or wind gusts if the sound was very loud. Instead, the disturbance that moves through the air is only temporary, and the displaced particles return to their original positions once the wave passes. The animations seen at the website above show this very clearly.

Waves travel through a variety of media. Light waves from the sun travel through the vacuum of space, and then through air once they reach the atmosphere. They can also travel through water, but not through solid materials. Radio waves can travel through the air and then through solid materials to reach our radios (receivers), where the energy they carry is converted to the sound energy we hear as music and speech from the radio speakers. Sound waves can travel through liquids, which is how dolphins and whales communicate, and gases (such as air), but they can't travel in a vacuum. While in orbit, NASA's Space Shuttles travel at speeds of about 17,500 miles

Appendix cont.

per hour, but they do so in silence.

The waves of kinetic energy that occur in an earthquake travel through the solid materials comprising the earth's surface. The very first waves that occur are longitudinal waves, known as the P-waves, or primary waves. These radiate out from the location where a pair of tectonic plates move relative to each other, either colliding or pulling apart. These longitudinal waves are followed within seconds by the secondary waves, known as S-waves, which are transverse waves. The last, slowest moving waves are the most destructive, because they produce both the side-to-side motions of a longitudinal wave and the up-and-down motions of a transverse wave. These waves are known as Rayleigh waves. An animation of Rayleigh waves can also be found at http://www.acs.psu.edu/drussell/Demos/waves/wavemotion.html. All three types of earthquake waves have higher amplitudes in major earthquakes than in minor earthquakes.

The waves of tsunamis are examples of water waves having very high amplitudes, and thus carrying a lot of damaging energy. In order to keep things simpler, throughout this set of lessons we use water waves as an example of transverse waves. However, water waves are actually a combination of transverse and longitudinal waves, as shown in another animation at the website above. This animation, like those of the other wave types, also clearly demonstrates the fact that the particles of the medium (water) do not travel with the waves. If they did, there would be no water left in the middle of our oceans!

Throughout the guide, teaching tips are in red.

Activity Description & Estimated Class Time

This lesson consists of two 50-minute sessions. In the first session, students mix colored light to produce white light and investigate how light combines to make colors. In the second session, students use color filters to explore the spectrum. In both sessions, students investigate our perception of color and its relationship to the electromagnetic spectrum.

Objectives

Students will demonstrate knowledge and understanding of the following ideas and content: visible light is a section of the electromagnetic spectrum that human eyes can see. A quality of electromagnetic waves that distinguishes one from another is the speed at which it vibrates. The electromagnetic waves we cannot see are vibrating too slow or too fast for our eyes to register. Ordinary light is usually composed of multiple waves vibrating at different rates, and white light is composed of all of the wavelengths in the visible range.

Students demonstrate this knowledge and understanding by using three color filters and flashlights to make many different colors. They also use their own words to describe colors in terms of the colors that do (and do not) make them up.

Correlations to NC Science Standards

6.P.1.2 *Explain the relationship among visible light, the electromagnetic spectrum, and sight.*

Brief Science Background

Electromagnetic waves are made of fluctuating electrical and magnetic energy. With our senses, we cannot perceive them as waves, such as a wave on the water. In fact, most electromagnetic waves are invisible altogether. A quality of electromagnetic waves that distinguishes one from another is the speed at which they vibrate. The electromagnetic waves that vibrate too slowly to see include radio waves and radiant heat. Those that vibrate too rapidly to see include ultraviolet light and x-rays. Only a narrow band in the middle of the spectrum is visible to human eyes. Ordinary light is usually composed of many different waves vibrating at different rates. White light is composed of all of the wavelengths in the visible range. Our eyes have receptors for only three colors: red, green, and blue, which span all of the wavelengths in the visible range. Our brains combine the signals from these three receptors to make all of the colors that we see.

Part 1 — Mixed Colored Light and Shadows –50 minutes

Materials

Materials for three students

- 1 copy of BLM 1
- 3 flashlights
- 1 piece of black construction paper in which to cut a 2-inch circle
- 1 set of 3 pieces of transparent colored plastic: red, green, blue
- 3 rubber bands
- 1 3-inch paper plate
- 1 toothpick
- 1 cotton swab
- scissors (to be supplied by teacher)

Preparation

- Make a copy of BLM 1 for each team of 3
- Make the light dim but not completely dark.

Procedure

1) Ask students to follow the directions on BLM 1. They can work independently, or you can try to keep the whole class together step by step.

2) Students will cover the lenses of three flashlights each with a different colored piece of colored plastic. They will hold the plastic in place with rubber bands. They will also cut a 2-inch hole out of the center of a piece of black paper, poke a hole in the center of a paper plate, place the paper plate face down, then center the hole in the black paper over the plate. After they do this, dim the lights.

3) Each team member (3 per team) will shine a colored light on the circle in the black paper, evenly spreading the flashlights around the circle. Afterward, turn on the room lights and ask each student to record what they saw in their notebooks. **Most but not all will record seeing white light in the circle. They should record whatever they see.**

4) After recording what they have seen, students will push the cotton swab into the hole in the plate so that the swab stands straight up. They will place the black paper back over the plate in the same position.

5) Dim the room lights. Students will shine the three colored lights on the white circle and record the colors of the three shadows and their locations relative to the positions of the three colors of flashlights. **Most students will be surprised by a cyan, magenta, and yellow shadow. Yellow will be opposite the blue light. Magenta will be opposite the green light. Cyan will be opposite the red light.**

6) Finally, students are challenged to make yellow, cyan, and magenta light on the paper plate without using the cotton swab to make a shadow. Be sure each student records the colors they used to do this.

Part 1 cont.

Content Wrap-Up

1) What were the colors of the shadows? Why do you think they were those colors? **Cyan, magenta, and yellow. In each shadow, only 2 of the colors are blended, and the 3rd color is blocked out. Ask students which color is blocked for each color of shadow.**

2) To make the three other colors, how did you decide which color flashlights to use? Ask each team to describe the cyan, magenta, and yellow light in terms combinations of red, green, and blue light.

3) Ask each team to come up with an argument from this evidence that white light is composed of a combination of colors.

Part 2 — The Visible Spectrum –50 minutes

This activity helps students understand how the visible spectrum is composed and how we see color.

Materials

Materials for the whole class

- 1 diffraction grating and overhead mount
- 1 slit mask (provided as a black line master at the end of these exercises)
- 1 piece of black construction paper to make the slit mask
- 1 retractable knife
- tape
- 1 white sheet of paper (supplied by the teacher)
- 1 overhead projector (supplied by the teacher)

Materials for pairs of students

- 1 set of 6 colored transparent plastic sheets: red, green, blue, cyan, magenta, and yellow
- science notebook (supplied by the teacher)

Part 2 cont.

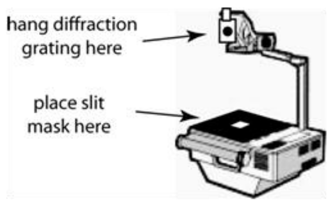
Preparation

1) Use the slit mask template BLM 2 and retractable knife to cut a slit mask out of black paper.

2) Hang the diffraction grating in front of the overhead projector lens.

3) Set up the overhead projector 8-10 feet from a screen, wall, or poster board that is white.

4) Dim the room lights. Orient the slit mask and projector so to project a spectrum.



Procedure

1) Explain that the object you are putting on the projector is a tool that breaks white light into all of its components (like a prism), and that the class will use it to explore light. **The tool is called a diffraction grating, but it is not necessary to explain this.**

2) Put the diffraction grating and slit mask in place. Dim the lights and turn on the projector. **Straight ahead, you'll see a white vertical bar. Complete spectra will appear on both sides.** Ask students to describe what they see.

3) Remove the diffraction grating and place the red transparent plastic on the slit mask so that it covers the slit. Ask students what they see and ask them what they think the tool that breaks light into its components will do with red light. After you get some predictions, replace the grating, and ask what they see. **The red plastic will turn the green and blue to black. After students look and comment, you slide the red plastic to cover just the bottom or top half of the slit, making it possible to compare red and white light broken into their components.**

4) Repeat step 3 with the green and blue filters. **The red plastic is the purest color, and works most definitively. The blue and green plastic are not as pure, and will let some other colors pass. In other words, that color of blue has a little green in it, and that color of green contains a little blue.**

6) Repeat step 3 again with the yellow, cyan, and magenta plastic, each time asking students to predict what they will see when you put the grating in place. **It is not necessary for students to make this connection, but notice that in the previous activity, the yellow shadow was opposite the blue light. In the yellow light spectrum, the blue band turns black. The magenta shadow was opposite the green light. In the magenta spectrum, green goes black. Likewise for cyan.**

7) Explain that our eyes have only 3 color receptors (cones): green, red, and blue. Remind that students of the previous lesson in which these three produced white light. Two colors produced yellow light. Our brains assemble all colors from red, green, and blue. The colored plastic varies the amounts of these three colors to create the other colors. White light contains all of the colors.

Part 1 cont.

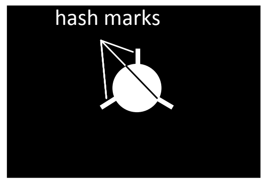
Wrap-Up

1) Say that a color TV or computer screen has 3 types of light-emitting material. Ask the class what colors do you think they are. **Red, green, and blue**

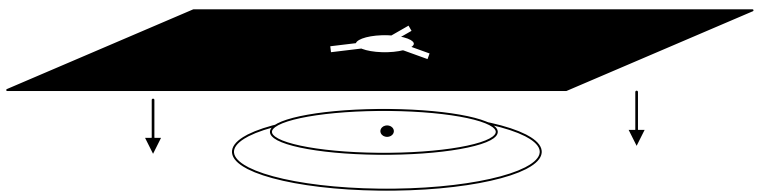
2) Ask how a TV screen might show yellow light? **Turn on red and green but no blue.** How would it show black? **Turn on nothing.** How would it show white? **Turn on red, green, and blue.**

BLM 1

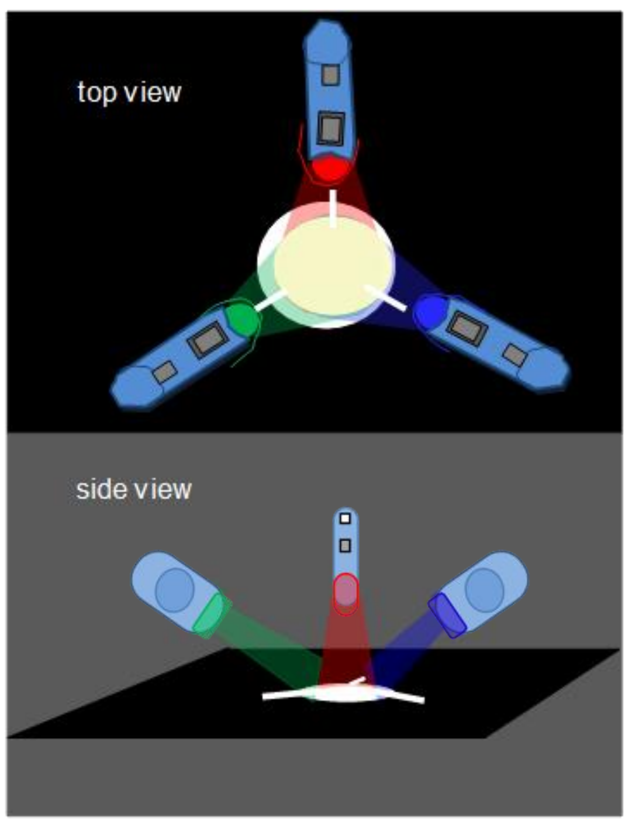
1. Cover a flashlight lens with the red filter and hold it in place with a rubber band. Do the same with another flashlight and the green filter, and a third flashlight and the blue filter.
2. Cut a 2-inch hole in the center of the black paper sheet and divide the circle into even thirds with white hash marks about 120° apart.



3. Poke a small hole in the center of the paper plate with a toothpick.
4. Place the paper plate face down on your workspace so that everyone on the team can reach it. Put the black paper over the plate with the hole centered over the plate.

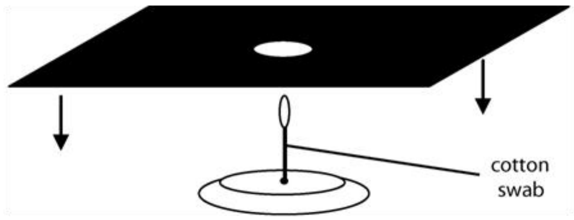


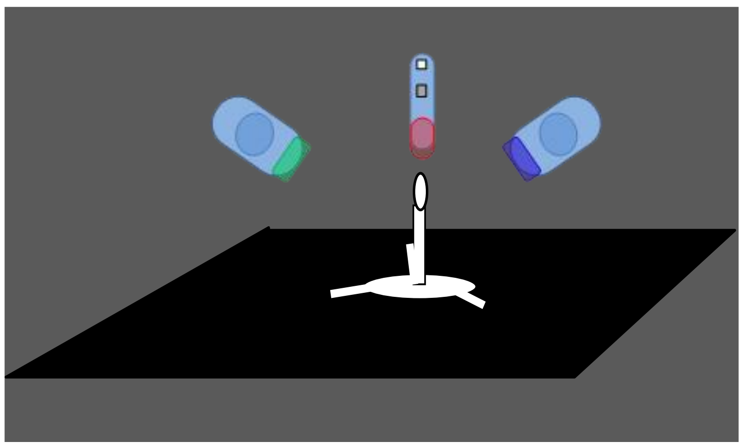
5) Hold each of the three flashlights above a hash mark on the setup as shown, 6 inches above the table. Angle the light to shine on the circle in the black paper. Try to get all flashlights at the same distance and angle. Record what you see in your notebook.



BLM 1, *continued*

6) Turn off the flashlights. Uncover the paper plate. Push the cotton swab into the hole in the plate so that the swab stands straight up. Place the black paper over the plate in the same position as before as shown below:





7. When the teacher dims the lights, shine the three colors on the circle in the paper the same way you did before, with the flashlights over the hashmarks so that white light appears on the plate. In your notebooks, record the colors of the three shadows and their locations relative to the positions of the three colors of flashlights.
8. Use what you have learned to make yellow light appear on the paper. Try it, and record how you did it. Do the same to make cyan and magenta, and record the colors you used.

Black Line Master 2

[redacted]

Throughout the guide, teaching tips are in red.

Activity Description & Estimated Class Time

In this 50-minute activity, students begin by discussing sound and problems with hearing. Pairs of students then assemble a model of the ear from components, using only prior knowledge. Afterward, the teacher leads the class through the functions of each component of the ear, and students reassemble their model of the ear. The teacher then introduces a diagram of the ear and a series of hearing maladies. The class uses these to discuss the path of sound from the ear to the brain.

Objectives

Students will develop an understanding of the relationship between vibration and hearing.

Note: Rate of vibration and variations in medium are covered in the activity "6.P.1.1 Properties of Waves," in this unit. The teacher can connect longitudinal waves taught in that lesson to hearing and the ear in this lesson.

Correlations to NC Science Standards

6.P.1.3 Explain the relationship among the rate of vibration, the medium through which vibrations travel, sound, and hearing.

Brief Science Background

Physical vibrations in materials can produce sounds, and sounds can produce physical vibrations in materials. Plucking a guitar causes the string to vibrate, producing sound. Likewise, sound striking a guitar can cause its strings to vibrate. Vibrations travel from place to place through solids, liquids, and gases. A person with an ear pressed to a solid door can hear sounds on the other side. Whales hear each other under water. Vibrations from a thunderclap move through miles of air to rattle windows. No matter what material sound moves through, it causes tiny movements (vibration) all along its path. The ear uses these vibrating movements that sound produces. The ear funnels the vibrations to a small drum attached to tiny bones. The drum moves in response, and moves the bones. The bones transmit the movement to a tube filled with liquid, causing the liquid to move. Sensitive hairs in the liquid respond to movement by sending a signal to the brain. To become the nerve impulses that we hear as sound, vibrations travel through air, solid bone, and a liquid.

Materials

Materials for the Whole Class

- BLM 1 Ear Component Functions
- BLM 2 Ear Diagram
- BLM 3 Ear Problems

Materials for Pairs of Students

- one set of ear component cards
- 1 science notebook per student
- removable tape

Preparation

Punch out the ear component puzzle piece sheets and place one complete set of randomly-numbered (unlabeled) ear component puzzle pieces in an envelope. Be ready to give these out, one per pair of students, but withhold them until step 2 of the procedure.

Procedure

1. Ask for a show of hands responding to the following questions:
   - Who had or knows someone who has had “tubes” in their ears when they were younger?
   - Who had or knows someone who has had “swimmer’s ear?”
   - Who has had people tell them not to turn up their earbuds too loud?
2. Explain that we will explore the ear to make sense of some of the things that happen to the ear. Point out that sound comes in the ear and then somehow gets to the brain. If that pathway is clear, there is no problem. However, lots of things can go wrong with that pathway.
3. Give each pair of students the puzzle pieces and 12 inches of removable tape. Ask each team to spread out the puzzle pieces so that they can see them all and say that these are components of the ear. Say that all of these are necessary for people to hear sounds. Ask teams to tape the pieces together the way they think they are arranged inside the ear. They will have to explain how they think sound gets into the ear, through each component, and to the brain. Allow 5 minutes.
4. As teams finish, ask them to meet with another team and compare models. Ask them to justify to each other why they have put the pieces where they have them. If class discussion seems reasonable at this time, it could be useful to get a lot of ideas out.
5. After teams finish comparing models, say that you have information that explains what each part of the ear does, and names each part. Tell the class that they have exactly 10 minutes to get as much of this information from you as they can. Tell them that when you finish giving this information, each team will use what they learned in this 10 minutes to reassemble the ear model.

6. Ask: “Which number part do you want to know about?” When someone gives you a part number, read the description of the function and the name of the part. Repeat this until you have gone through all of the parts of the ear.

7. Give students another 5 minutes to reassemble their ear models based on what they have learned. As teams finish, again ask them to meet with another team to compare models. **The path of sound from the air to the brain is k, t, x, d, r, b, m, i.**

Wrap-Up

1. Project BLM 2, Ear Diagram. Give the class a minute or so to reassemble their models according to the diagram. Together with the class, trace the path of sound through the ear. Try to get students to do as much explaining as possible. Point out where sound travels as a vibration in air, in a solid **bone** and in a liquid **fluid in the cochlea**. Point out the outer, middle, and inner ear.

2. Project BLM 3, Ear Problems. Discuss with the class how each problem interferes with the path of sound from the ear to the brain. As you go through ear problems, give the following symptoms and ask students to “diagnose” the problems and relate them to the models of the ear.

   - Ringing in the ear
   - Muffled hearing

Guided Practice

Guided Practices are similar to typical tests, but require students to reveal their thinking about content. They serve as a practice before a test and should not be graded. They are intended to expose misconceptions *before* an assessment and to provide opportunities for discussion, re-teaching, and for students to justify answers. They are best given as individual assignments without the manipulatives used in the activity. In that context, pose the following “test items” to the class. Ask them to write responses in notebooks.

1. Complete the following sentence with the correct response: To be heard, sound travels…

   a. …as a ray that passes through the eardrum and excites nerves in bones of the skull.

   b. ...as movements in air that vibrate the outer ear, which is connected to the eardrum, causing it to emit nerve impulses.

   c. ...as vibrations in air that are channeled down the ear canal and strike the eardrum, which transfers vibration to a set of tiny bones that move fluid in a canal that triggers nerve impulses to the brain.

   d. …as a ray that travels into the ear canal through the cochlea, then through bones connected to nerves that send impulses to the brain.

   Ask students to explain why the wrong answers are wrong.

2. Complete the following sentence with the correct response: Sound travels…

   a. …as a vibration through many different kinds of materials, including, solids, liquids, gases.

   b. …through a vacuum or through air, but it cannot travel through solids or liquids.

   c. …as very fast vibrations through solids, slower vibrations through liquids, and the slowest vibrations through gases such as air.

   d. …through air, and because of this, the ear must transmit the signal to the brain through air.

   Ask students to explain why the wrong answers are wrong.

Answer Key

#1 b. is correct. Sound travels as a vibration in air that is channeled down the ear canal and strikes the eardrum, which transfers the vibration to tiny bones that move fluid in a canal, triggering nerve impulses to the brain.
Explanations of wrong answers should touch upon the chain of events as sound travels through the ear.

#2 a. is correct. Sound travels as a vibration through many different kinds of materials, including, solids, liquids, gases.

Sound cannot travel in a vacuum, but it can travel through solids, liquids, and gases. The ear transmits the signal to the brain through solids and liquids.

BLM 1

b. This fluid-filled snail-shaped sack in the inner ear contains hair cells attached to nerves, which transmit sound information to the brain. Attached to it are three fluid-filled tubes containing hairs that sense movement to provide the sense of balance: **Cochlea**

d. One of three tiny bones in the middle part of the ear between two other tiny bones, receiving vibration from one and transmitting it to the other: **Anvil Bone**

i. This part receives nerve signals and makes sense of them as sound: **The Brain**

k. This part gathers sound from the air and channels vibrations through a canal to the eardrum: **Outer Ear and Ear Canal**

l. This tube connects the middle ear and the back of the nose. It allows fluids to drain from the middle ear and lets air pass to equalize pressure between the middle ear and the atmosphere: **Eustachian Tube**

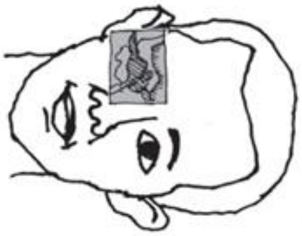
m. This nerve sends all of the information from the nerves in the cochlea to the brain: **Auditory Nerve**

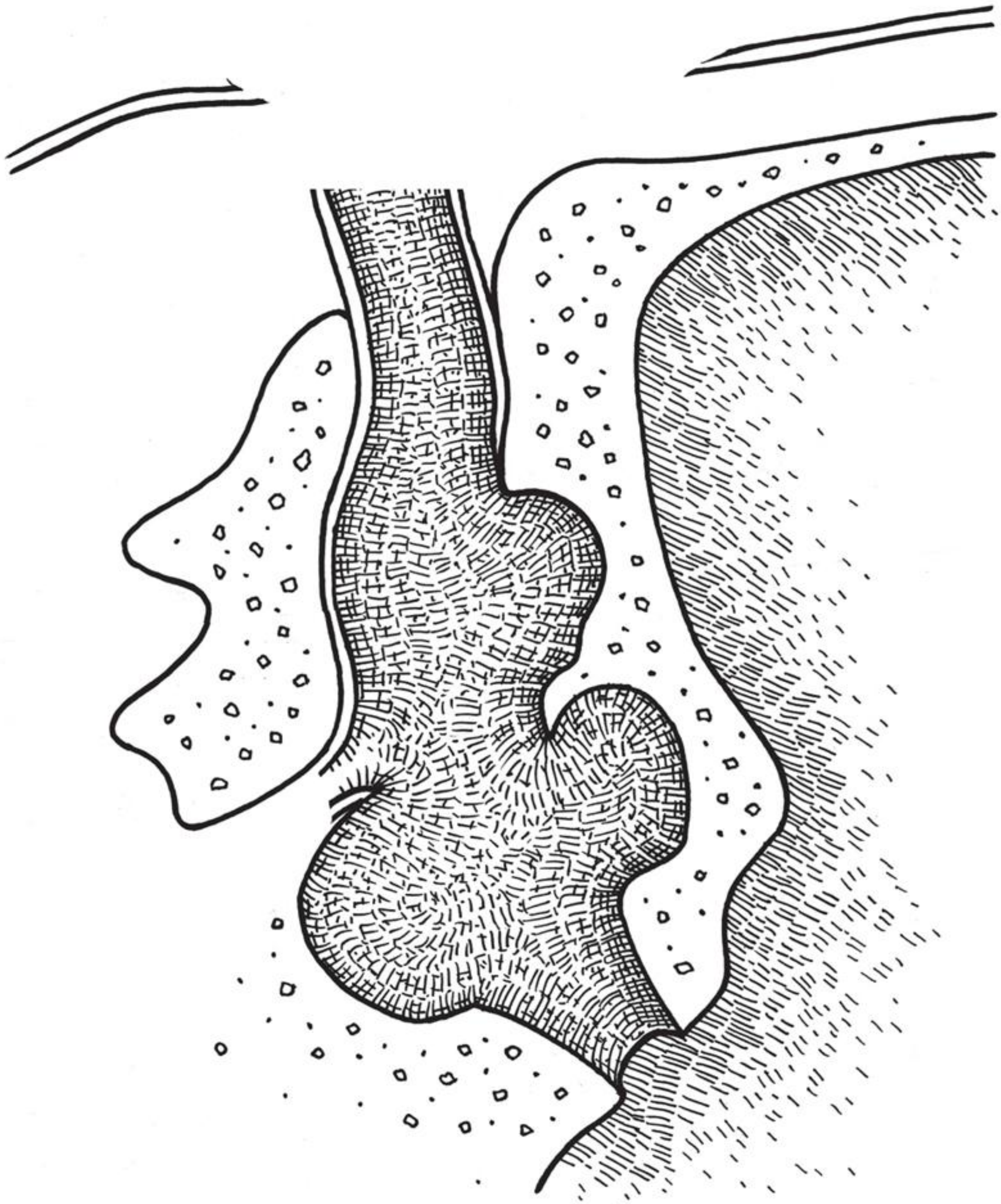
r. One of three tiny bones in the middle ear, the smallest bone in the body, this bone receives vibrations from the other small bones and transmits them to the inner ear: **Stirrup Bone**

t. This thin, sensitive membrane stretched over the entrance to the middle ear vibrates when sound strikes it. It passes vibrations on to the tiny bones in the middle ear : **Ear Drum**

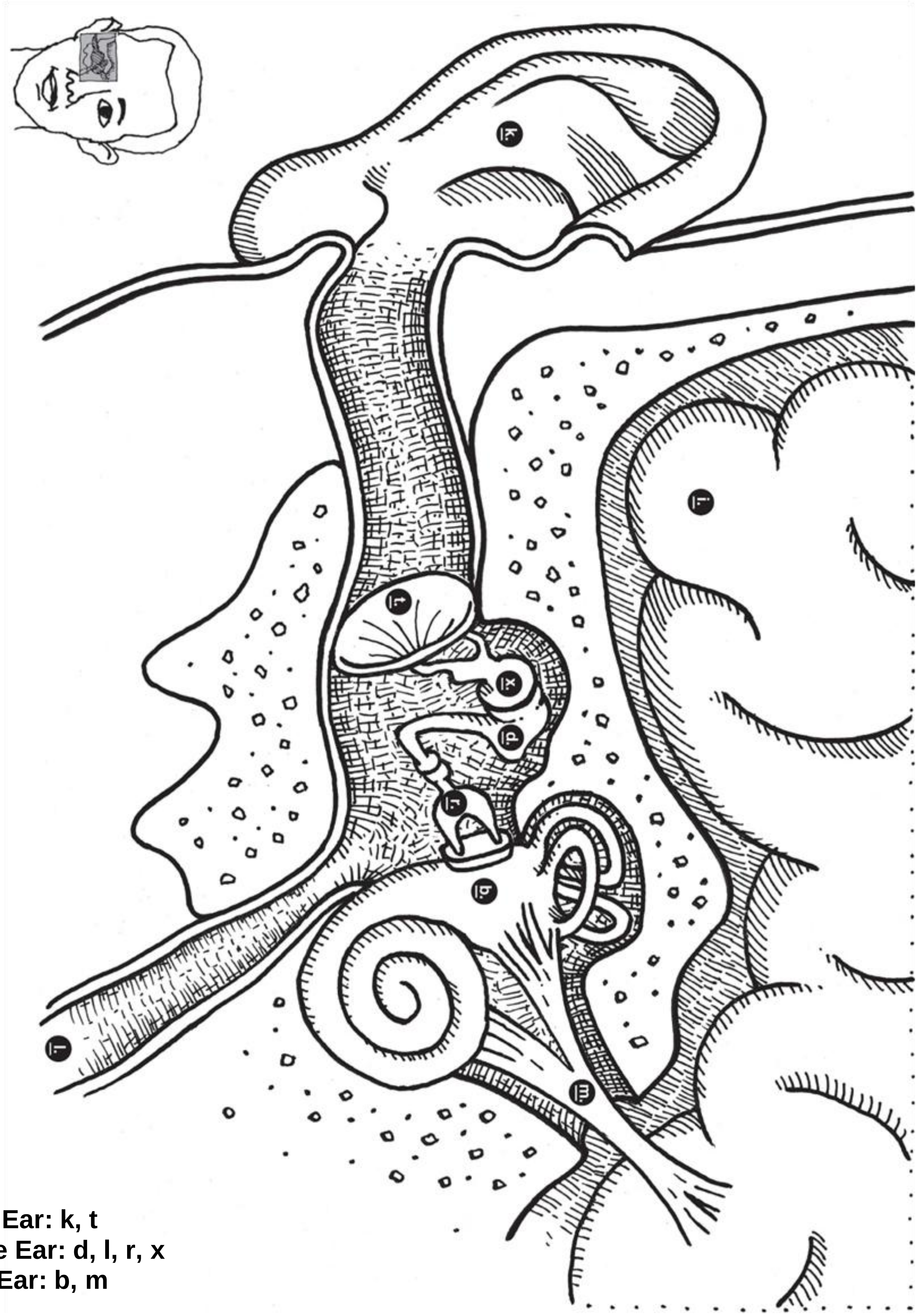
x. One of three tiny bones in the middle ear, attached to the eardrum and to another bone. When the eardrum vibrates, it passes vibration to the other bone, which passes it to another bone attached to the inner ear: **Hammer Bone**

BLM 2 Ear Puzzle Base





BLM 3 Ear Diagram



Outer Ear: k, t
Middle Ear: d, l, r, x
Inner Ear: b, m

BLM 4 Ear Problems

Tubes in Ears

Young children who have colds, allergies, or small ear canals can have a middle ear blocked with mucus, leading to infections and muffled hearing. Normally, a passage between the middle ear and back of the nose, called the eustachian tube, equalizes air pressure with the outside world, but the tube can be closed for many reasons, and pressure builds up. To relieve all of these problems, doctors can insert spool-shaped plastic tubes through the ear drum to equalize air pressure in the middle ear, reduce pressure, and allow fluid to flow out. The tubes generally reduce pain in the ear.

Swimmer's Ear

Sometimes, the outer part of the ear and ear canal can become infected because the ear canal has been compromised. Normally, the ear canal is lined with antibacterial ear wax and fine hairs to trap debris, but extra moisture from showering or swimming can alter the antibacterial qualities of ear wax, allowing bacteria and fungi to invade. Ear plugs, ear buds, hair dyes, bleaches, and shampoos in the ear canal can also disrupt the protective lining. The result is a red ear (usually just one), painful when touched. In severe cases, the ear canal may swell shut and drain clear, white, or yellow fluid that can crust over the ear. Severe cases can result in some temporary hearing loss, ringing in the ear, and dizziness.

The Problem With Ear Buds

Damage to the cochlea can reduce hearing impulses to the brain. When tiny hair cells in the cochlea are damaged or degenerate as we grow older, people notice a loss of high-pitched sounds, then difficulty understanding speech in noisy surroundings. About half of people over 70 have impaired hearing for this reason. Young people get it when loud noises damage hair cells in the cochlea. Playing music through ear buds at high volume can damage these cells. As of now, damaged hair cells cannot be replaced. Sometimes, hearing loss is accompanied by a ringing sound with no external cause, called tinnitus. About 1 in 5 people between 55 and 65 report tinnitus.

Conductive Hearing Impairments

Sometimes malformation or malfunction of bones in the middle ear can reduce the vibrations that are conducted to the cochlea. Injuries such as a severe blow or infection to the ear can damage the hammer, anvil, and stirrup bones so that they transmit less vibration. Sometimes, the hammer and anvil are separated, or the anvil bone is broken or eroded from recurrent ear infections. Some injuries or infections can also separate the anvil from the stirrup or erode the stirrup so that it no longer connects with the inner ear. Any of these conditions greatly reduce hearing.

Ruptured Eardrum

The eardrum is a thin membrane separating the outer and middle ear. A blow to the ear, foreign objects in the ear (often a cotton swab used to clean the ear), or pressure from infection inside the ear can break the eardrum or put a hole in it. When the eardrum is damaged, hearing decreases because the middle and inner ears receive less vibration coming from the outer ear.

Appendix

Common Student Preconceptions About This Topic

When young children are asked how they hear a clock ticking, they often say something like, “I hear the clock because I am listening,” or “I hear the clock because it is ticking.” About half of 11-12 year-olds give descriptions of this kind, but by age 16, most children can refer to vibrations traveling through air and the eardrum. However, a significant number of 12-16 year-olds also give explanations involving an active ear that “picks up sound” by tapping into and seeking out the source of sounds around it. Some children in this age range also view light and sound as similar, traveling in “rays.”

Throughout the guide, teaching tips are in red.

Activity Description & Estimated Class Time

In this 50-minute activity, students explore heat moving from a can of hot water into and through several materials, including metal, air, wood, plastic, and cardboard. They develop an understanding of the processes of convection, conduction, and radiation by using electronic temperature probes to track and compare the movement of heat through the different materials. Students are also challenged to use what they've learned to predict the warmest and coolest places in a system, and then gather the data needed to test their predictions.

Objectives

Students will develop an understanding of conduction, convection, and radiation of heat, and demonstrate understanding of these ideas by tracking and describing the means by which heat flows in a system they set up.

Correlations to NC Science Standards

6.P.3.1 *Illustrate the transfer of heat energy from warmer objects to cooler ones using examples of conduction, radiation and convection and the effects that may result.*

Brief Science Background

Heat is a restless form of energy, always moving from hotter places to cooler ones. Heat moves in three different ways. It can radiate through space the way heat from the sun crosses millions of miles of empty space to warm your skin. It can move directly through an object or material, such as a metal spoon in a cup of hot tea. It can also warm a region of gas or liquid, causing it to float upward and carry the heat with it, the way hot air rises over a stove. Heat can move in any one of these ways, or in any combination, including all three ways at once.

Part 1 — Restless Heat –50 minutes

Materials

Materials for the whole class

- 1 box cutter (to be used by the teacher)
- 1 hot pot
- 2 half-gallon thermos containers
- 1 funnel
- 2 pot holders
- 15 cone-top cans
- hot water (supplied by the teacher)
- 15 clean 2-liter bottles with labels removed (supplied by students)
- roll of aluminum foil

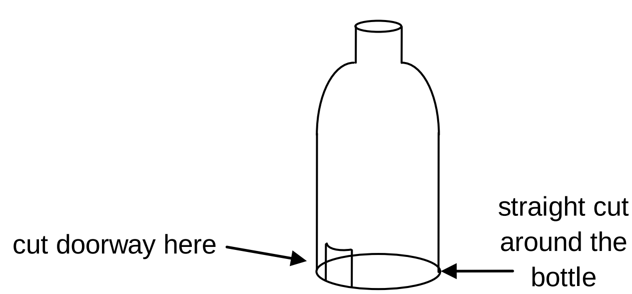
Materials for groups of 2 students

- 1 temperature probe and meter
- 1 steel cone-top can of hot water with lid on
- 1 two-liter soda bottle prepared by teacher (see Step 2 in the Preparation section)
- 1 piece of aluminum foil, prepared by the teacher (see Step 4 in the Preparation section)
- a small cardboard square
- a larger cardboard square
- Figure 5: Directions for Hot Can in a Bottle, one per team of two students

Preparation

1. A week or two before the activity, ask students to bring in enough clean 2-liter soda bottles to assemble 15 bottles. Bottles can be shared between classes.

2. Use the box cutter and scissors to remove the bottoms of the bottles. Cut straight around the bottles (see Appendix for tips on how to do this) so they sit on a flat surface without gaps between the bottom edge and the surface. Cut out a 1” x 1” square at the base of the bottle as shown below. It should look like a small doorway with no door.



Preparation cont.

3. Turn the temperature meter dials to the position shown on the right in Figure 1 (pointer to ˚C). If numbers do not appear on the screen, replace the batteries (included in the kit with a small screwdriver to remove the meter cover). When all meters work, insert the red and black probes in the jacks shown in Figure 1. *Note:* The temperature readings will not be the same on all the meters, but they should be within about 2˚ C of each other. (The temperature differences are a reflection of the accuracy, or lack thereof, of the probes. Other types of probes might measure more accurately, but they would be more expensive.) After checking all the meters, turn them off and remove the probes.

4. Tear off pieces of aluminum foil that are about one foot long. You will need one piece for each pair of students. Fold each one in half, and then fold again to make a strip that is about 3” wide. Use scissors to cut through all four layers of foil and make the circle-with-a-tongue shape shown below. Cut the circle about 3” in diameter with the tongue ½” wide, 2 ½” long.

5. Working around the shape’s perimeter, pinch the foil layers together and fold them under the shape by about an eighth of an inch (this keeps the layers together). It should look like the picture below. **If you have enough scissors, students can make these shapes when they set up the system. It would be best to make one yourself ahead of time to serve as a model.**

6. About 20 minutes before the activity, heat the water in the hot pot to about 46˚C (115˚ F). It will feel hot but will not scald. Just before the activity, use the funnel and pot holders to transfer hot water to the thermos. Pour the hot water into the cone-top cans only when students are ready for them and not before.

Procedure

Ask students to work in pairs. Give each team a meter and a probe. Project an image of the meter (see Black Line Master Figure 1: Temperature Probe Meter) to show students how to plug in the probe and set the meter.

1. Ask students to find the air temperature and record it in their notebooks. Ask students to call out readings. Write the readings for all to see. Ask students to tell you the range they see. It might be several degrees. Ask them to speculate some reasons for this range. **Reasons might include someone touching the probe tip with their finger, reading while numbers are still changing, non-uniformity of the probes, different temperatures at different places in the room, etc.**

2. Ask students to touch the probe to their skin and the surface of the desk and record both of these temperatures. Ask them to call out readings for both. Write the readings for all to see.

3. Ask students what they notice about reading the probe. **Students might notice that the reading keeps changing or that it takes some time before the reading stays the same.** Ask how readings might be made more accurately. **Ideas might include waiting for readings to stop changing, or reading the meter after the probe has been at a spot for a specified time.** Incorporate the improved technique, try again, and record readings to check for a smaller range. **The class might not be able to reduce the range, but the exercise is useful anyway because it focuses the class on being more accurate. The probes are not perfectly calibrated to actual temperature, so two probes measuring the same thing at the same time could vary.**

4. Before distributing cans, project the image of a can (Black Line Master Figure 2). Ask students to draw it in their notebooks large enough to fill a page. After they have drawn it, distribute the hot cans. Project the following instructions (Black Line Master Figure 3):

   A. Leave the can where it was put down (don't move it).

   B. Pick five different spots on and around the can. On your drawing of the can, mark five large dots to show the spots you chose. Number them one through five.

   C. Starting with your first spot, measure the temperature. Record it and the time on your drawing next to the place you marked dot number one. Do the same thing for the rest of the spots on your can and on your drawing.

   D. Predict what you think the temperature will be at each spot 15 minutes from now. On your drawing, write a p near each dot. To the right of the p's, write your predicted temperatures. Underneath each p, write a letter a where you will record actual temperatures in 15 minutes.

5. After all the groups have made their predictions, assign two students to keep track of time and announce when 15 minutes are up.

6. When the 15 minutes are up, have students measure the can temperatures at their five spots and record them under their predicted temperatures on their drawings. Ask students to call out results, and record these for all to see.

Part 1 cont.

7. Ask: “Where did the heat go?” Accept all answers and discuss students’ ideas. When the discussion is complete, ask students to move the can aside and quickly use the probe to take the temperature of the desk’s surface that had been under the can. Compare this reading to the reading of the surface of the desk they took in Step 2 above. Ask for ideas about how the change occurred, specifically: did the table get hot from heat that was in the can? If so, has it left the can and how did the heat move? **Students might say that the heat sank down into the table, leaked into the table, or got into the table from touching the hot can. Some might think that the heat is still in the can. Some might know the term “conduction.” Some might say “I thought heat rises, so how could the table be warm?”**

8. Project Black Line Master Figure 4: Hot Can in a Bottle. Give each team Black Line Master Figure 5: Directions for Hot Can in a Bottle, and ask the teams to follow the setup directions..

9. Ask students to follow the directions on Black Line Master Figure 5 “Directions for Hot Can in a Bottle” and record their measurements <u>directly on the diagram</u>. In step 1, be sure they take temperatures at A, in the mouth of the bottle; B, on the foil where it touches the bottle; and C, 5 mm away from the can (not touching the probe to the can). If needed, show Black Line Master Figure 6: “Probe Close to Can.” Students also pick five additional spots and predict temperatures at those spots, recording their predictions on the diagram. They should indicate which spot they think is warmest and which spot they think is coolest. After recording all predictions, let students make their temperature measurements and record results below the corresponding predictions. Be sure they turn off the meters when finished. Students will need about 15 minutes.

10. Ask students to fill out Black Line Master Figure 7 “How Heat Moved.” Ask them to speculate how the heat might have moved from the can to each of the three spots.

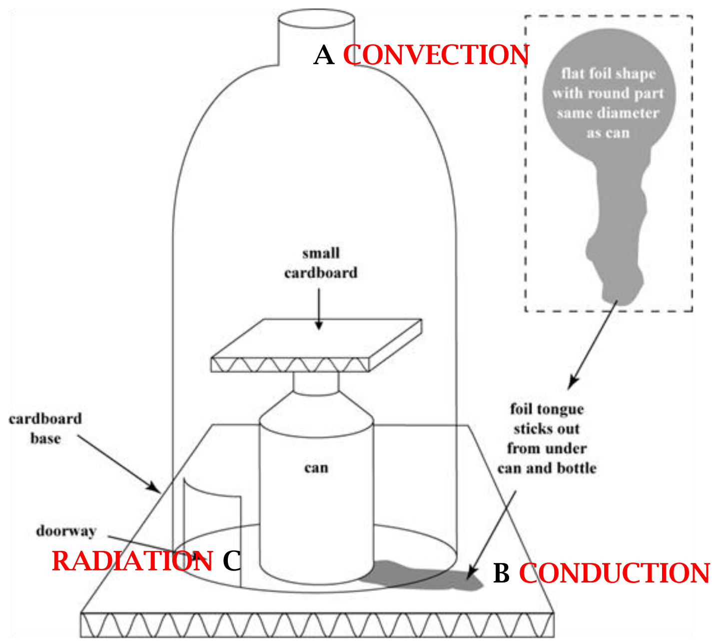
11. Discuss student’s ideas. As each type of heat transfer comes up, connect it to the word (conduction, convection, radiation) to tie students’ speculations to the three ways heat can move. As you summarize, ask students to fill in the column titled “Science Term for This Type of Heat Movement.” You might summarize by projecting Black Line Master Figure 8 “Ways Heat Can Move,” but avoid projecting it until students have made all the connections they can.

    - Heat moves between and through objects that are touching each other. This is how a metal spoon handle gets hot in a cup of hot chocolate, even though the handle is not down in the drink. This is called CONDUCTION.
    - Heat moves when one portion of a gas or liquid is warmer than the rest of the gas or liquid around it. When that happens, the warm area floats upward, moving its heat through the cooler parts to rise above them. This is why hot air balloons can fly, and why smoke from a fire rises through the air. You may have heard that “hot air rises.” When it does, it carries heat

Part 1 cont.

with it. This is called CONVECTION.Heat can move the same way light moves, by traveling through space as waves. You can't see it the way you can see light, but you can feel the way heat from the sun or a hot fire radiates out to a cooler surface like your skin. This is called RADIATION.

12. On the illustration, at the locations marked A, B, and C, have students label the type of heat transfer (Conduction, Convection, or Radiation) they think occurred there, along with reasons supporting their responses. After the activity is completed, discuss the results as a class.



Answer Key

A. Convection happens at A. The can heats the air inside the bottle, and that warm air rises up and out through the bottle's top. The probe is not touching anything that touches the hot can, so it is not conduction. It could be radiation, but the piece of cardboard blocks most of the radiation from the hot can.

B. Conduction happens at B. The metal is touching the hot can and heat is conducted between things in direct contact, especially metal. No air heated by the can could affect the probe because the probe is outside the bottle, so it is not convection. The temperature next to the foil (not touching it) is not the same as that of the foil, so it is not radiation.

C. Radiation happens at C. The probe does not touch the can, so conduction does not transfer the heat. The probe is low in the bottle, so it would not catch rising air there. The heat must be radiating from the can to the probe.

Part 1 cont.

Discuss what students noticed about the temperatures in the other locations they picked. What kind of heat transfer occurred in these spots? Where were the warmest and coolest spots? What might be some reasons that these places were the warmest or coolest? **It's likely that a spot near the top of the can (touching the can) will be hottest because convection concentrates heat in the water inside the can near the top of the can. Spot A will probably be the warmest place not touching the can. Convection brings warm air upward and the bottle's shape concentrates the warm air in the neck. The coolest spot will likely be in the doorway because convection is drawing cool air in there.**

Wrap-Up

1. Project Figure 9: Concept Cartoon A. Ask students to identify the type of heat transfer that each person is describing and give reasons for each one. Discuss with the whole class the type of heat transfer that each person in the cartoon is describing.

   Answer Key

   - The boy with no hat is describing conduction. The heat is moving from the part of the spoon that is touching the hot tea and through the handle of the spoon. Conduction occurs by direct contact.
   - The girl is describing convection. The heat is warming the air above the cup, which causes the air to rise up and carry heat with it.
   - The boy with the hat is describing radiation. Without touching the cup, and without feeling warm air rising above the cup, the boy with the hat can feel heat radiating from the cup.

2. Project Figure 10: Concept Cartoon B. Ask students to explain which person they agree with and what is wrong with each of the other students' ideas about heat transfer.

   Answer Key

   - The boy in the T-shirt is correct: people feel heat radiating from the fire
   - Hot air rises over the fire (notice the smoke rising), but because no one is leaning over the fire, rising hot air does not cause the people to feel heat.
   - It doesn't make sense that the wind is blowing the heat toward them because all of them feel heat. Wind doesn't blow in all directions at once.
   - Air can conduct some heat, but not to the people around the fire. Any air that is conducting heat from the flames rises up, so very little of it would touch the people around the fire.

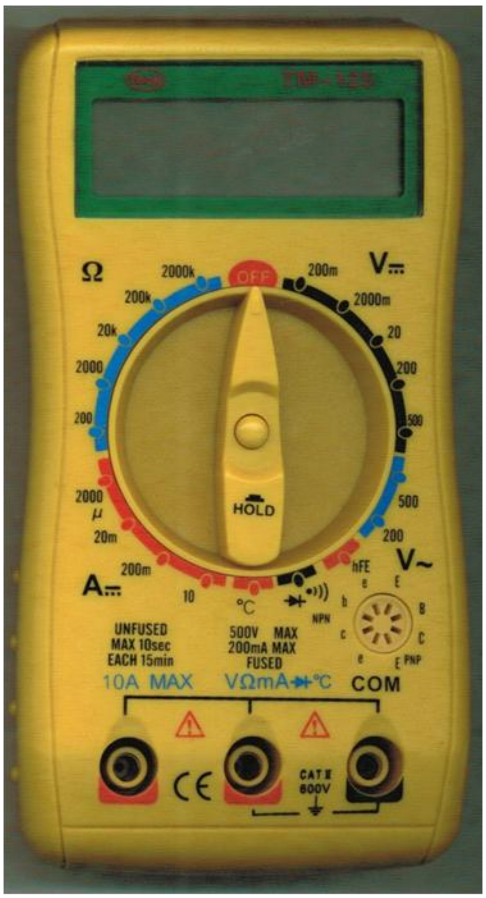
3. Ask:

   - What process of heat transfer moved heat to the tabletop under the can? **conduction**
   - What process of heat transfer moved heat to the neck of the bottle? **convection**
   - What process of heat transfer moves heat from the sun to the earth? **radiation**

BLM 1 Temperature Probe Meter

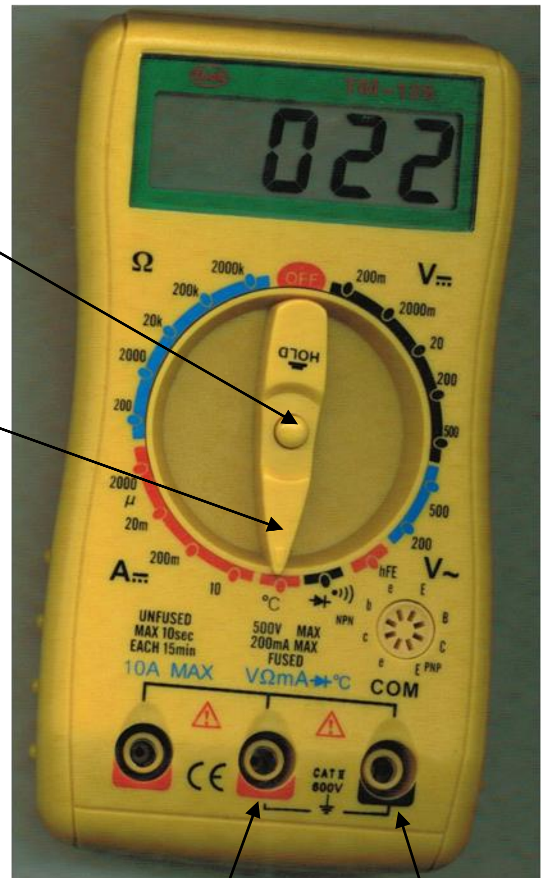
The meter comes out of the box with the pointer in the OFF position. **RETURN TO THE OFF POSITION WHEN FINISHED.**

To use the meter as a temperature probe, put the red and black plugs in the holes shown, and set the pointer as shown (°C). Avoid the hold button.



don't push this in

set pointer at °C



red plug here

black plug here

BLM 2 Hot Can

BLM 3 Instructions for Hot Cans

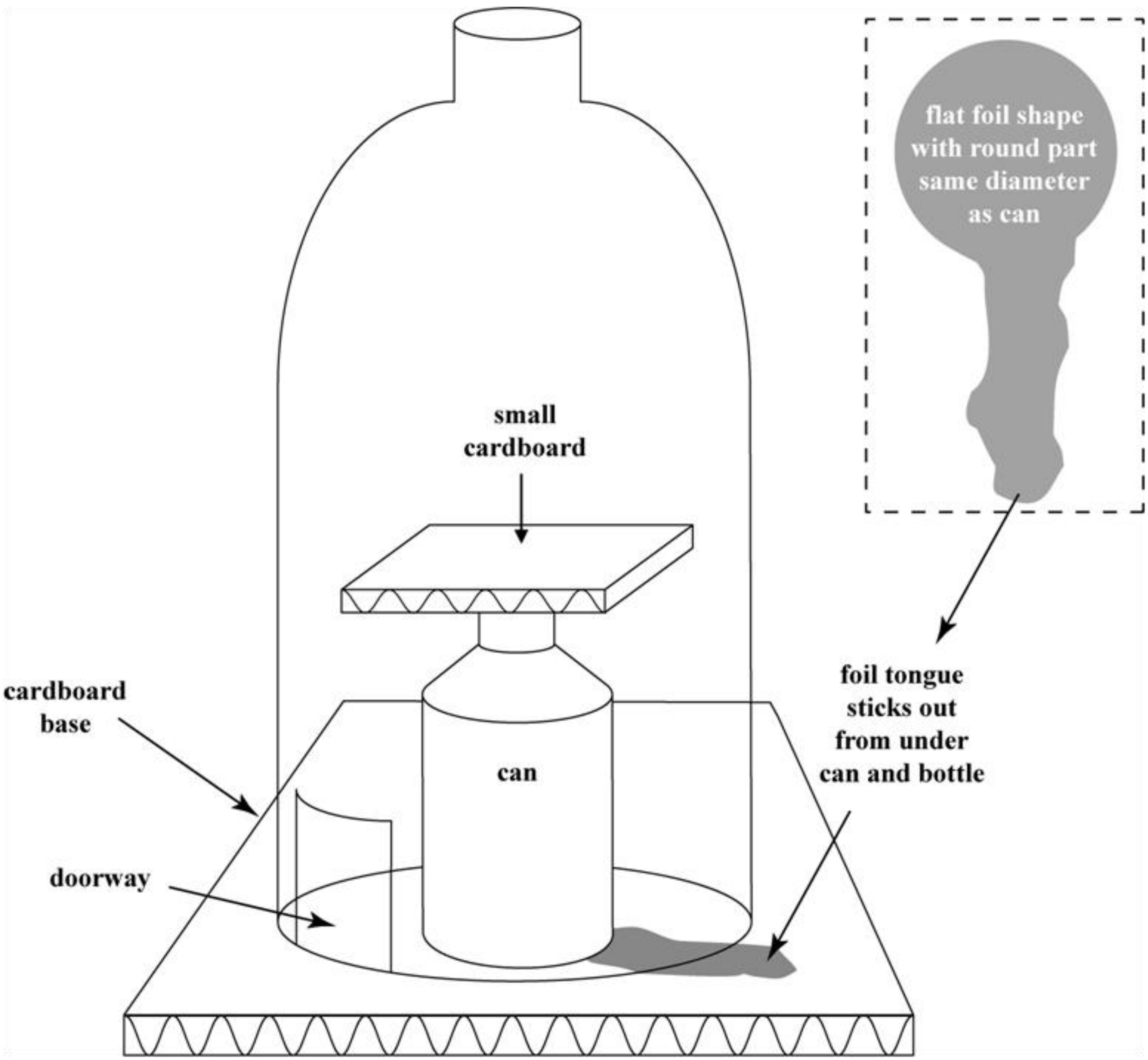
a. Leave the can where it was put down (don't move it).

b. Pick five different spots on and around the can. On your drawing of the can, mark five large dots to show where the spots you chose are. Number them one through five.

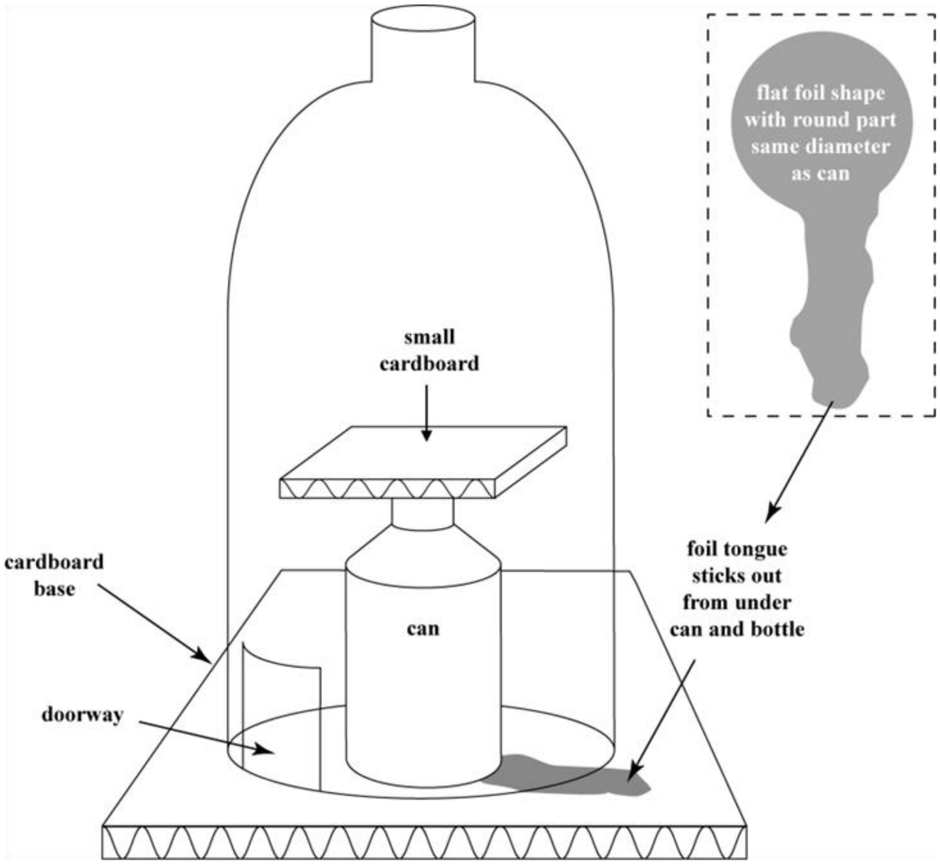
c. Starting with your first spot, measure the temperature. Record it and the time on your drawing next to the place you marked dot number one. Then do the same thing for the rest of the spots on your can and on your drawing.

d. Predict what you think the temperature will be at each spot 15 minutes from now. On your drawing, write a p near each dot. To the right of the p's, write your predicted temperatures. Underneath each p, write the letter a. This is where you will record the actual temperature in 15 minutes.

BLM 4 Hot Can in a Bottle



BLM 5 Directions for Hot Can in a Bottle



Setup

- Place the round part of the foil in the middle of the large square of cardboard. Put the can on top of the foil shape so that the tongue will extend out from the bottle when the bottle is put in place.
- Balance the small cardboard on top of the can. Put the plastic bottle over the setup with the can in the center. Take care not to knock off the small piece of cardboard. Make the foil extend under the bottle on or near the opposite side of the bottle from the doorway.

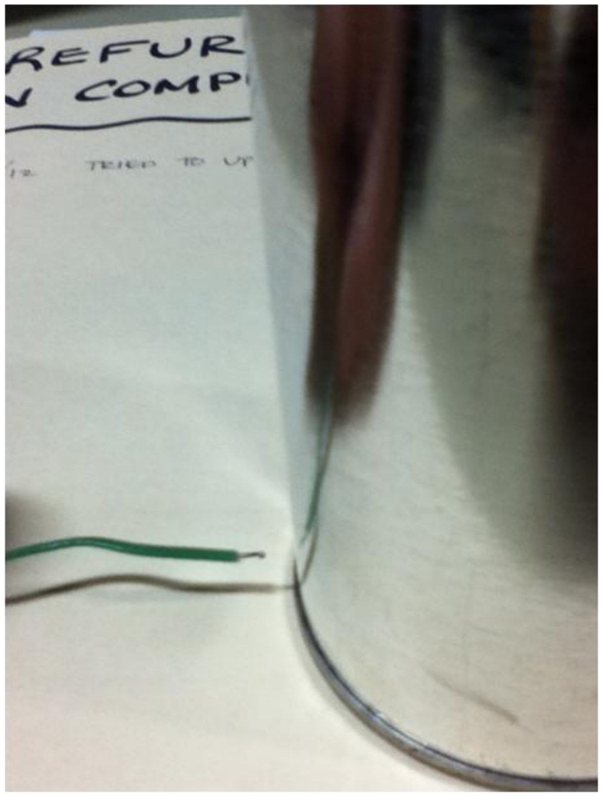
Where Does the Heat Go?

1. Measure the temperatures at each of the three locations marked A, B, and C on the diagram: **A** is in the mouth of the bottle, **B** is on the foil where it touches the bottle, and **C** is a few millimeters from the can (about the thickness of a nickel away) but not touching the can. Record the temperatures on the diagram next to the letters marking their locations. Turn off the meter when you are done.

2. With the meter off, predict temperatures at five places around the setup other than A, B, or C. Write your five predictions on the illustration, and put a “p” by these predictions. Include the spots that you think are warmest and coolest and mark these “warmest” and “coolest.”

3. Turn the probe meter on. Measure temperatures at your five prediction spots. Record the actual temperatures beside your predictions. Label the actual temperatures “a.” When you are finished, turn off your meter.

BLM 6 Probe Close to Can But Not Touching



probe a few millimeters from the can (about the thickness of a nickel)

BLM 7 How Heat Moved

Spot on the can	Your explanation for how the heat moved from the hot can to this spot:	Science term for this type of heat movement.
A		
B		
C		

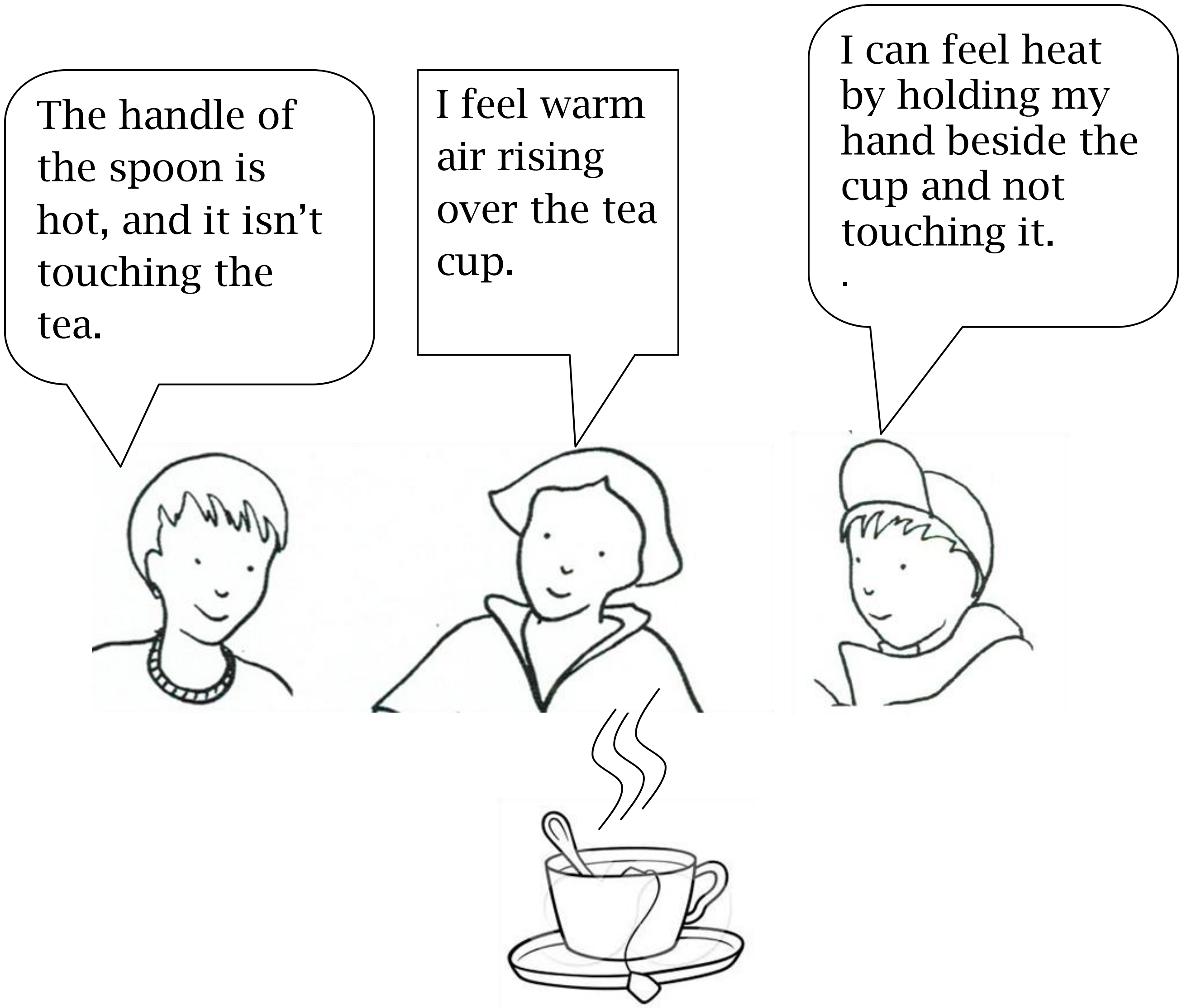
BLM 8 Ways Heat Can Move

- Heat moves between and through objects that are touching each other. This is how a metal spoon's handle gets hot in a cup of hot chocolate, even though the handle is not down in the hot drink. This is called **CONDUCTION.**

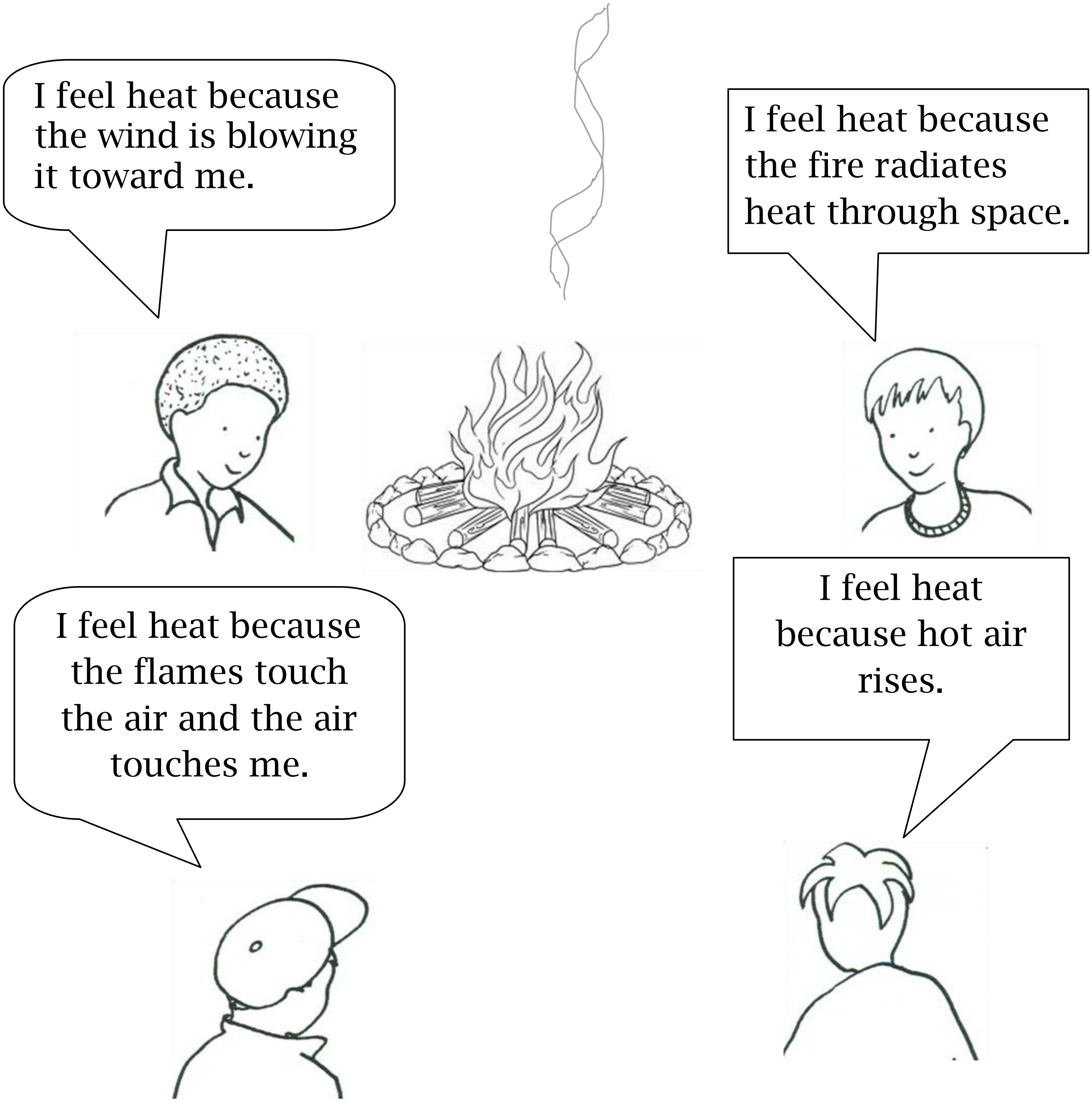
- Heat can move when one portion of a gas or liquid is warmer than the rest of the gas or liquid around it. When that happens, the warm area floats upward, moving its heat through the cooler parts to rise above them. This is why hot air balloons can fly, and why smoke from a fire rises through the air. You may have heard that "hot air rises." When it does, it carries heat with it. This is called **CONVECTION.**

- Heat can move the same way light moves, by traveling through space as waves. You can't see it the way you can see light, but you can feel the way heat from the sun or a hot fire radiates out to a cooler surface like your skin. **RADIATION**

BLM 9 Concept Cartoon A



BLM 10 Concept Cartoon B



Appendix

Common Student Preconceptions About This Topic

Children ages 11-16 tend to view heat as a kind of material. For example, when a long piece of metal is heated at one end and the other end eventually warms, students often think that excess heat in one spot "overflows" to another place, like a liquid. Alternatively, they might say that hot molecules move along the metal until they cool down and stop moving. Similarly, they think of the sensations of hotness or coldness as something entering or leaving the body. Feeling dense objects as cooler than insulators, many children say the dense objects "let heat in easier" or transfer coldness to their skin. Few see cold as absence of heat and heat as moving from warmer places to cooler ones. They may also say that metal parts of a bicycle feel colder than plastic parts because the metal attracts coldness. In general, few students, even beyond grade 8, understand heat transfer in terms of behavior of atoms and molecules.

Detailed Background Information

Conduction occurs because molecules are in motion, and as heat is added, the molecules move more. Conduction can occur in any material. For example, when a metal cooking pot sits on a hot stove, the metal molecules touching the stove begin vibrating more than their unheated neighbors. The energetic vibrations of these heated molecules cause them to bump repeatedly against their unheated neighbors, causing them to vibrate more quickly, too. These, in turn, bump their neighbors, who bump their neighbors, and so on, until the heat from the stove is distributed throughout the pot by the process of conduction. The pot's now rapidly vibrating metal molecules also bump against water molecules inside the pot. The bumps give the water molecules an extra push, so they bounce more vigorously against other molecules that aren't touching the pot. Those molecules in turn bounce more energetically off their neighbors, etc. In this way, heat from the pot transfers to the water by the process of conduction. Conduction can occur *within* a material, and *between* different materials.

Some materials conduct heat better than others, and metals do this especially well. Glass and ceramics, such as those used in baking also conduct heat well. Wood, plastic, and rubber are conduct heat poorly. This is why wooden spoons are good for stirring hot soup and most frying pans have plastic handles. Pot holders are such poor heat conductors that we call them *insulators.*

Less conduction occurs in gases because conduction requires molecules to contact one another. Molecules in gases are far apart and don't touch as often. In gases, heat is more commonly transferred by convection. Heating a gas causes the molecules to bounce vigorously off each other, spreading them out and producing lots of empty space between molecules. As a result, a heated gas such as warm air is less dense than cool air. In a mixture of warm and cool air, the less dense (warmer) portion floats upward because it is buoyant in the denser (cooler) portion. Convection is the phenomenon behind the well known phrase, "Hot air rises".

Common examples of convection are steam rising out of a tea kettle and the smoke rising from a fire. If you have a step ladder or can safely stand on a table, you can feel and measure a result of convection in your classroom. Turn off any ceiling fans for a few minutes, and measuring the temperature of the air near the ceiling and the air just above the floor. It is often several degrees warmer near the ceiling.

Convection occurs in liquids in the same manner as in gases, due to the motion of molecules and their distances apart. If students have swum in a lake during the summer, they might have noticed that the surface is warm, but a few feet below the surface, it is cooler. The surface water has been warmed a little by conduction from warm air and much more by radiation from the sun. The warm water is buoyant in the cooler water, and the cooler water sinks down because it is denser than the warm water.

When water is heated in a pot, the water at the bottom gets warm first, but it quickly rises to the surface by convection. Cooler water sinks to the bottom to replace it, and that water in turn is heated, and so on, until all the heat is distributed throughout the pot.

The third type of heat transfer, radiation, does not involve the motion of molecules. Radiation is the transfer of heat energy through space by means of infrared light waves and visible light waves. We are all familiar with it because radiation is the way energy from the sun warms the earth. We feel the heat given off by a light bulb or the flame of a candle, and we feel it without touching the bulb or the flame. Unlike conduction, direct contact is not necessary to transfer heat by radiation. Radiation moves outward in all directions, so we feel the heat of an overhead light while standing under it and the heat of a fire when sitting next to it.

Heat transfer by radiation is the result of light waves. It can be blocked, just like light, when a solid material is placed between the heat source and an object that would otherwise be warmed. On a hot day, the shade of trees provides such an obstacle, and makes it feel cooler. Dark surfaces absorb more radiated heat than pale-colored surfaces. Pale colors reflect more heat similar to the way a mirror reflects light. Sheets of black and white construction paper placed in a sunny window feel noticeably different a few minutes later. It is fairly easy to measure the temperature differences between the two colors.

Regardless of whether heat transfer occurs by conduction, convection, or radiation, heat is only transferred in one direction: from warmer to cooler. It might seem like something cold, such as an ice cube, makes as a glass of warm water cooler by transferring its coldness to the water. In fact, heat moves from the warm water into the ice cube by conduction, which makes the ice melt. Before long, the water in the glass is at a temperature that is warmer than the ice cube but cooler than the water was. Now the two materials, the formerly frozen water in the ice cube and the water already in the glass, are at a new equilibrium temperature. This is the end result of all heat transfers: heat flows from warmer things to cooler things until equilibrium is reached between them.

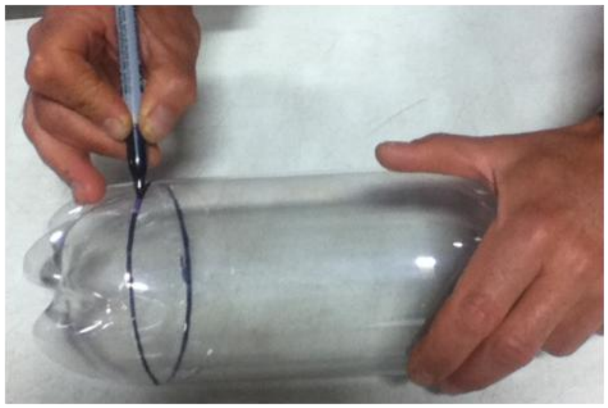
Tips for Cutting Plastic Bottles

To mark and cut the bottles you will need the following materials provided with the kit:

- 1 fine point permanent marker
- 1 box cutter (provided in kit materials)

You will also need a pair of scissors that is not provided in the kit.

1. Put the point of the marker in the groove at the top of the thick plastic at the base of the bottle. Hold the marker steady and rotate the bottle to draw a line around the bottle at the top of the base.



Appendix cont.

2. Use a box cutter to cut about an inch along the line you just drew. Use scissors to finish the cut around the bottle's circumference.

Cut around this line

Throughout the guide, teaching tips are in red.

Activity Description & Estimated Class Time

This lesson consists of six 50-minute sessions that investigate the interactions of light and matter. In the first two sessions, students measure changes in temperatures of differently colored cards placed in direct sunlight. In the third and fourth sessions, students measure the amount of light the cards reflect. Students are challenged to compare data sets from the first and second sessions to find a pattern in the reflectance and heating data. In the fifth and sixth sessions, students experiment with colored transparent plastic to gain understanding of materials that let some colors of light pass through while absorbing others. The lesson culminates with a challenge to write a secret message that can only be read when viewed through a piece of colored plastic.

Objectives

Students will develop an understanding that light is a form of energy, some of which we see, and some of which we do not. Students will demonstrate knowledge and understanding by:

- using materials to measurably absorb light;
- using materials to measurably reflect light;
- comparing absorption and reflection in the same materials; and
- using materials to manipulate light to change colors.

Correlations to NC Science Standards

6.P.3.2 *Explain the effects of electromagnetic waves on various materials to include absorption, scattering, and change in temperature.*

Correlations to the Common Core State Standards for Mathematics

Students generate their own graphs in the first of these lessons. That activity is set aside and labeled as a mathematics extension. Under the common core mathematics standards, grade 6 students evaluate data in a number of ways, including statistically and graphically. As a number of common core math standards apply, we have not specified a standard, but left it to teachers to decide which skills to work with here.

Brief Science Background

Electromagnetic waves are comprised of both electricity and magnetism. Like all waves, they can vibrate at different rates, and their characteristics depend on how quickly or slowly they vibrate. They do not look like waves on water or a string, and in fact, most do not look like anything at all because they vibrate too fast or too slow to interact with our eyes. Even though we can't see them, we know they exist because they interact with matter. When they do, both the electromagnetic waves and the matter are affected. Depending on the type of matter, electromagnetic waves may be reflected, absorbed, scattered, refracted (as with a prism), or they might simply pass through. Light

Brief Science Background, cont

waves are examples of one type of electromagnetic wave. When they are absorbed, they may heat the matter that absorbs them, or cause a chemical reaction, such as when light strikes a green leaf and causes the reactions that support plant life (photosynthesis). Other types of electromagnetic waves create an electrical current in conductors. These are examples of ways that electromagnetic waves transfer energy.

Part 1 — Soaking Up Some Rays – Two 50-minute Sessions

Materials

Materials for the whole class

- 15 digital thermometers
- several rolls transparent tape
- 16 envelopes
- class set of color sample cards (orange, brown, white, light green, yellow, red, and blue) to be cut into 1” x 3” strips.
- 16 copies of BLM 2
- 15 copies of BLM 3
- some means of timing in 30-second intervals (provided by teacher)
- graph paper
- optional if no shade: umbrellas (provided by teacher and students)

Materials for pairs of students

- 1 digital thermometer
- transparent tape
- an envelope containing orange, brown, white, light green, yellow, red, and blue 1” x 3” color sample strips
- 1 copy each of BLM 2 and BLM 3
- 2 sheets of graph paper
- 2 student science notebooks (provided by teacher)

Preparation

1. This activity requires an outdoor location, a sunny day, relatively still air, and nearby shade. If there is no convenient shade, provide umbrellas for shade.
2. Cut the color sample cards to make as many 1” x 3” strips as you can from each card. Students will fold the 1” x 3” strips in half lengthwise and tape the sides as shown in BLM 1. When folded in this way, a sleeve fits over the thermometer and in the reflectance meter sample holder. Place 7 different color strips (folded and taped or not) in envelopes, one envelope per team.
3. Have thermometers, tape, color sample sets, and envelopes arranged so that students can pick these up.

CIBL

Procedure

1. Start by asking, "When light hits a surface, what can happen to the light, and what can happen to the surface it hits?" **No direct teaching here. Accept all answers.** After brief discussion, explain that the class will try to find some things out about this.

2. Give out the envelopes with color samples. Ask a student from each pair to take an orange, a black, and a white color sample from their envelope.

3. Say, "We will go outside to investigate how light and these color samples interact. Before we go out, I will show you what each team will do." Give a volunteer team a copy of BLM 2 and project BLM 2 for the class. Walk the volunteer pair through the following for the class:

   a. Say "We will start outdoors in the shade. When we are outdoors, keep everything in the shade until we start timing and put everything back in the shade when we finish timing."
   b. Ask the volunteer team (in the shade) to set a thermometer to ° F, place the orange sleeve on the thermometer, and call out the temperature when the reading stops changing. Ask them to record this temperature on BLM 2 under the "Starting Temp" column for the orange color.
   c. Say to the whole class, "When I say 'START,' move into the sun. I will begin timing and call time after 3 minutes. When I call time, record the temperature in the Final Temp column of BLM 2 and turn off your thermometer. Then, calculate the change in temperature. When we go outdoors, we will do this three times with three different colors."

4. When all teams have their materials, go outside to a shady location. Remind students to stay in the shade while they prepare thermometers, put the orange sleeves over the thermometer tips and record their starting temperatures. When ready, call "start" and follow the procedure above.

5. Have students return to the shade and remove the orange sleeves from their thermometers. Ask each team to pick the color they think will get *hotter* than the orange sample when held in the sun and record it on the top part BLM 2. Follow the above procedure with the new color. **Be sure students turn the thermometers off and on before testing the new colors. The thermometers time out after a few minutes and this resets them.**

6. Ask each team to pick a color they think will stay *cooler* than the orange sample when held in the sun, and record it on the top part of BLM 2. Repeat the above procedure.

7. Bring the class inside. Ask, "What happened to the temperature of the orange sample when it was in the sun? What are some possible explanations for what happened?" After they share ideas, explain that when light strikes an object such as a piece of paper or a rock, some light energy is "absorbed" in the surface. The absorbed light becomes heat. Therefore, the amount of light absorbed is closely related to the increase in temperature.

8. In shade (or indoors), remind students that they tested colors they thought would either get warmer or stay cooler than the orange sample. Show the four new color samples and list them. Ask students to think about what they

Part 1 cont.

discovered regarding temperatures of the orange, black, and white samples, and then, in the bottom chart on the BLM 2 data sheet, predict the order of all seven colors, from highest temperature gain to lowest temperature gain. Wait for all teams to record their predictions before going on.

9. Assign each team one of the seven color samples, making sure that each color is assigned to at least one team. Have teams assigned to one of the four new colors make their corresponding thermometer sleeves.

10. Project BLM 3 so that students can see the information they will collect. Point out that the procedure will be the same as before, but this time, teams will record temperatures every 30 seconds for 3 minutes (at 30, 60, 90, 120, 150, and 180 seconds) as you call time.

11. Take the class outside to test their samples.

12. Bring the class inside. Ask each team to calculate the temperature change between the final and starting temperatures and record it on BLM 3. Compile the class results and post or project them for all to see. (For two teams with the same color, average the results). Have students use the class data to complete the bottom section of BLM 2.

13. Ask the class to examine the data for all colors. In particular, ask students to compare their predictions to the experimental results. Were they surprised by any of the results? Ask students what they notice, for example, which colors warmed most and least, whether those that warmed most had anything in common. Discuss observations.

Content Wrap-Up

At this point, simply check for understanding. More formal teaching and a guided practice will occur after the next activity.

1. Give the following challenge: “Write two or three sentences that use the terms color, absorption, sunlight and heat to explain our results.” **This writing could be in notebooks or on separate paper.** Discuss their responses if necessary.

2. Point out that even though all the colors were exposed to the same amount of light for the same amount of time, all colors did not heat up by the same amount. Ask the class what they can infer from this. **All colors did not absorb the same amount of light.** Ask what they think might be happening to the light that is not absorbed? Accept all answers.

Math Extension

1. Have students individually use the data their team entered on BLM 3 to graph the change in temperature over time. The most informative and easiest graph to make shows change in temperature from the starting temperature at each time interval (rather than actual temperature at each time interval).

Part 1 cont.

2. Point out to the class that in order to make the graphs easy to compare, each student should use the same grid and the same axes with the same range. Ask the class to come up with a way to make the axes the same for every student. If they have trouble with this, discuss the range of the temperature data.

3. Remind students to include a title on their graph, which should indicate the color of their sample. Post all students' graphs. Discuss and compare what the graphs show in terms of *rates* of heating.

4. Combine all teams' data in one Excel spreadsheet and make a multiple-line color-coded graph so that data from the whole class appears one sheet. Often, a breeze or a passing cloud causes a change in slope during a 30-second interval. If so, all of the graph lines will track together, each in their own way. This provides a good opportunity to interpret the graphs.

Part 2 — Reflection – Two 50-minute Sessions

Materials

Materials for the whole class

- 15 8" x 8" x 1.5" pizza boxes, unassembled
- 15 black punch cards to make 15 sets of light baffles, solar cell stands, and sample retainers
- several staplers (supplied by the teacher)
- 15 solar cells with red and black banana plug leads
- 15 multimeters
- a bag of small rubber bands
- several transparent tape dispensers
- 15 flashlights
- 15 color sample sets, 7 colors each, (folded sleeves from previous lesson)
- 15 envelopes
- BLM 11 to project
- 15 copies of BLM 12

Materials for teams of two

- 1 reflectance measuring device (see Preparation, below)
- 1 multimeter
- 1 flashlight
- 1 7-color sample set in an envelope
- 1 copy of BLM 12
- student notebooks (provided by teacher)

Part 2 cont.

An efficient way to prepare the reflectance measuring devices is to get 3 or 4 students to help outside of class time. If you assemble a prototype for your helpers, 5 people can make 15 boxes in about 30 minutes. Once made, these setups can be re-used for all classes.

Preparation

1. Refer to **BLM 5** (photo of a completed setup) as you assemble a prototype reflectance measuring device:

   a. Punch out the items listed below and sort them into three stacks:
      - light baffle punch-outs
      - solar cell stand punch-outs
      - sample holder flaps

   b. Ask your helpers to assemble the pizza boxes.

   c. Staple in the sample holder flaps so that one of them touches but does not cover the slot used for the pizza box tab, as shown in BLM 6. The flaps should be about ¾ inch apart. Be sure there is room to insert a folded color sample sleeve between the stapled areas of the flaps.

   d. Fold the solar cell stand so that the triangle (base of the stand) makes a right angle with the rectangle (see BLM 7). Attach the solar cell to the upright rectangular portion of the solar cell holder with a rubber band. The solar cell goes on the side opposite the triangular base (BLM 8).

   e. Thread the solar cell wires through the tab slot near the corner of the box, as shown in BLMs 5 and 9. Once the wires are through, tape the solar cell assembly to the bottom of the box (BLM 9) with the edges of the triangular base parallel to the sides of the box.

   f. Tape the upright section of the light baffle (the part with the slit) to the wall of the box (BLM 10). The upright portion should just touch the right edge of the right-hand sample holder flap. With that in place, tape the light baffle to the floor of the box (BLM 10).

2. Put out 15 of these setups for students to pick up.

3. Set out the flashlights, multimeters, and solar cells.

4. Set out an envelope of 7 color sample sleeves for each team.

5. Be ready to *show* BLM 11 for all to see.

6. Make 1 copy of BLM 12 for each team.

Part 2 cont.

Procedure

1. Remind students of the question asked at the end of the last class: what happens to the light that does not get absorbed? Explain that you have some measuring devices that can be used to find out a little more about this.

2. Ask students to charge the flashlights for 30 seconds, turn them on, and place them in the box so that only one LED is positioned in front of the slit to make the brightest possible circle of light between the sample holder flaps. Ask teams to leave flashlights in place and turn them off.

3. Project BLM 11 and ask students to put the solar cell plugs in the multimeter as shown, matching wire color to hole color. Instruct students to set the multimeter dials to the 200m position as shown. The meter should read above zero. Ask teams to close the box and press down the lid. With the box closed and flashlights off, the reading should be zero. If not, check for light leaks. Nearly all light leaks disappear when the lid is pressed down carefully. If not, check the assembly of the box.

4. Ask teams to turn on flashlights, pick them up, shine them directly on the solar cell, and record the multimeter reading in notebooks. Ask "What does the meter measure?" **The amount of light reaching on the solar cell.**

5. Ask teams to slide the orange color sample into the sample holder flaps and put the flashlight in place with one LED shining directly through the slit to make a bright circle on the sample. Ask them to close the lids and take a reading. **It is not necessary to record the reading at this time.** Ask "How does this reading compare to when you shined the light directly on the solar cell?" Ask "What does the meter measure?" **The amount of light reaching the solar cell. It should be a lower number than when the flashlight shined directly on the solar cell.** This reading has no units such as lumens, a unit of light. The number on the multimeter is only a way to compare different amounts of light.

6. Ask students to open the pizza box lid and turn off the flashlights and multimeters. Ask them to view their setup from above and use a finger to trace the path of light from the flashlight to the solar cell.

7. Ask each team to turn on the flashlight and multimeter, close the lid, take a reading for the orange sample, and record it on BLM 12. Remind them that this number represents the amount of light reaching the solar cell.

8. Remind students that in the previous lesson each team chose a color they thought would get hotter than orange. Ask each team to pick a color that got hotter than orange and write it in the appropriate place on BLM 12. Ask teams to predict whether that color will give a larger or smaller reading than orange. Before testing the sample, ask them discuss their reasons and write them in their notebooks. **Students will likely predict the number to be greater than the number for orange.**

9. Ask students test their predictions, and write their multimeter readings on BLM 12 under "Amount of Light Measurement." **These numbers will likely be less than what they expect. The class will discuss this later.**

10. Say, "In the previous lesson, you predicted a color that would heat up less than orange." Ask teams to identify that color on BLM 12 and predict whether it will produce a larger or smaller light measurement than orange.

Part 2 cont.

11. Ask teams to test their predictions and record results on BLM 12.

12. Lead a whole-class discussion about the following ideas: When light strikes the color sample, it is either absorbed or reflected. Light that bounces off of something is called "reflected" light. The box measures reflected light. The thermometers measured absorbed light. Use the information we gathered in both this lesson and the previous one to account for the light readings we just obtained. **Students should begin to understand that if a sample absorbs more light, it reflects less light, and vice-versa.** End the discussion by projecting or writing the sentences below on the board and asking students to complete them in their notebooks:

    A color sample that heats up more in the sun reflects ________light.

    A color sample that heats up less in the sun reflects _________light.

13. Say, "We now have a theory about absorbing and reflecting light. Use the theory to order the colors in the bottom part of BLM 12, from those you think will reflect the most light at the top to those you think will reflect the least light at the bottom. After your team makes its predictions, use the light measuring box to test all of the colors. That way you will test the theory." WHEN STUDENTS FINISH, BE SURE THEY TURN OFF FLASHLIGHTS AND MULTIMETERS. (Leaving either one on ruins the batteries).

Wrap-Up

1. Hold a class discussion comparing the class results to the theory.

2. Ask students which colors from the sample set would be best to wear on a hot summer day.

3. Say that a group of people are playing flashlight tag at night. They can wear any of the seven colors from the sample set. Which color would be best to wear to avoid getting tagged? Ask for reasons and evidence to back up student responses. **The color that reflects the least light would be best. That is the color with the lowest light reading.**

Part 2 cont.

Guided Practice

Ask students to write responses in notebooks. This guided practice covers both Part 1, “Soaking Up Some Rays,” and Part 2, “Reflection.” Discuss all answers, especially “wrong” ones, and ask students to explain why they are wrong.

1. Complete the following sentence with the correct response: The amount of light that a material reflects

   a. is less than the amount of light that is absorbed.
   b. is a property of the material that is exposed to the light.
   c. is based on the weight of material exposed to light.
   d. is equal to the amount of light that is absorbed.

Provide a reason for your answer:______________________________________

____

2. Which of the following materials reflects more light?

   a. something that is very light colored, close to white
   b. something that is an intense, deep color, such as deep red
   c. something that is transparent, such as glass
   d. something that is very dark colored, close to black

Provide a reason for your answer:______________________________________

____

3. Complete the following sentence with the correct response: A material that does not reflect much light

   a. appears to be very bright, even in dim light.
   b. absorbs very little light that strikes it.
   c. absorbs much of the light that strikes it.
   d. might not reflect much light now, but could reflect more light later on.

Provide a reason for your answer:______________________________________

____

Part 2 cont.

4. Complete the following sentence with the correct response: The light that strikes a material

   a. is all reflected.
   b. is usually both reflected and absorbed.
   c. is all absorbed.
   d. is all converted to heat.

Provide a reason for your answer:______________________________________

____

5. Complete the following sentence with the correct response: When more light is reflected,

   a. more is absorbed.
   b. none is absorbed.
   c. all of the light is absorbed.
   d. less is absorbed.

Provide a reason for your answer:______________________________________

____

Answer Key

Discuss all of the answer choices, especially "wrong" ones, and ask students to explain why they are wrong.

1. b. the amount of light that a material reflects is a property of the material. Only the surface of an object affects how much light is reflected. The interior of the object does not matter with regard to reflection. a, c, and d are all wrong for the same reason: the amount of light reflected can be more than, less than, or equal to the amount absorbed.

2. a. something that is light colored (close to white) reflects more light. Deep or intense colors do not necessarily reflect more. Transparent things are not very reflective because light goes through them. Dark colored materials absorb more light and reflect less.

3. c. Materials that reflect less light absorb more of the light that strikes them. These materials do not appear bright. They do, however, always reflect the same amount. This does not vary over time because the amount of light they reflect is a property of the material on the surface.

4. b. The light that strikes a material is usually both reflected and absorbed. Students saw this in their data. It is rarely all reflected or all absorbed. The absorbed light turns into heat.

Part 2 cont.

5) d. The more light that is reflected, the less is absorbed. In the cases the class investigated, a certain amount of light struck each of the color samples. Some of that light was reflected and some was absorbed. If a color reflected more of the light, less remained that could be absorbed. Likewise, if a color reflected less of the light, it meant that more could be absorbed.

Part 3 — Secret Color Message – Two 50-minute Sessions

Materials

Materials for the whole class

- either 15 copies of BLM 13 or the ability to project it
- 30 sheets of paper (provided by teacher)
- 15 sets of 6 colors of transparent plastic: red, green, blue, cyan, magenta, and yellow
- 15 sets of colored pencils

Materials for groups of 2 students

- 2 sheets of white paper
- a set of colored pencils
- 1 set of 6 transparent color filters: red, green, blue, cyan, magenta, and yellow
- 1 copy of BLM 13 or the ability to see it projected.

Preparation

Assemble envelopes containing 6 colors of transparent plastic, one for each pair of students. Be ready to project BLM 1.

Procedure

Start by asking students what they know about light so far. Remind them of previous lessons about the composition of white light, absorption, and reflection. Let them know that in this activity they will investigate another way that light interacts with different materials.

1. Pass out the sets of transparent plastic, have students look through them, and ask them to find three things that appear to change when viewed through the colored pieces. Ask them to describe what changed.

2. Project the first secret message example on BLM 13. Challenge the class to find which one of the colored plastic pieces they can look through to see the message. When most students have seen the message, ask which colored plastic pieces worked.

3. One at a time, show the second and third examples from BLM 13. Repeat the process in steps 2 and 3.

Part 3 cont.

4. Project all three examples, one at a time, and ask students for ideas about how the colored plastic makes messages readable.

   - Ask students if they know of other transparent materials that let light pass through. **Glass, Air, Water** What are some things that seem to color light? **Sunglasses, Colored Glass**
   - Explain that the pieces of colored plastic are certain types of filters. Ask students to describe what a filter does and give some examples. **Filters allow some things to pass through them while other things get caught. Some familiar examples are coffee filters, Brita™-type water filters, oil filters in cars, and air filters in home heating systems.**
   - Inform students that they are using color filters. What could they be filtering? In other words, what passes through and what gets caught? **Some colors of light pass through but other colors do not. They seem to be caught by the filter, so they are absorbed.**

5. Make sure each student has a sheet of white paper and each pair of students has some colored pencils and/or markers. Ask students to make three marks on their paper, using a different color for each mark. Then ask, "How does a colored mark interact with light? **Where there is a colored mark, the place that is marked reflects only that color and absorbs all the other colors.** Next, ask the class, "If a colored mark reflects that color, where is all of the other light going?" **It is absorbed by the mark.**

6. Challenge each individual student to use markers and colored pencils to design a hidden message on the paper, which can only be read by looking at it through a color filter.

7. When students are finished, have each pair trade papers with another pair and try to read the message in white light (without a color filter or using only the uncolored filter). Then have them use the colored filters until they find one that works. *Note:* The message works only if it can be read through a filter, but can't be read without a filter. Advise students to be prepared to explain how they designed their messages.

Wrap-Up

Project **BLM 14** and explain that the four people in the cartoon are looking at a red mark through blue plastic, and they see the red line as black. However, each one explains what they see differently. Ask each student to pick someone they agree with and someone they disagree with, and come up with arguments for and against. Find students with opposing views and assign them to make their points to each other in small groups.

- White light has all colors and a red mark reflects everything but red. The blue filter takes out all of the blue light, making the mark look black. **The red mark reflects only red, not everything but. The blue filter lets all of the blue light pass through.**
- It looks black because no light, including white light, goes through the blue filter. **Blue light does go through the blue filter. If no light went through, everything would look black.**

Part 3 cont.

- A colored marker reflects the color that we see and absorbs the rest. White light contains all of the colors. A color filter allows one color to pass through and absorbs all other colors. **This is true but it doesn't explain anything. It has all the pieces to address why they see a red line as black, but it doesn't put them together.**
- White light is all colors. Only red light reflects off of the red marker, but a blue filter absorbs red light, so the mark looks black. **This is correct. The only color that the red mark is giving off cannot get through the blue plastic.**

Guided Practice

Guided Practices are similar to typical tests, but require students to reveal their thinking about content. They serve as a practice before a test and should not be graded. They are intended to expose misconceptions *before* an assessment and to provide opportunities for discussion, re-teaching, and for students to justify answers. They are best given as individual assignments without manipulatives used in the activity. In that context, pose the following "test items" to the class. Ask them to write responses in notebooks. You might also ask them to identify the wrong answers and explain why they are wrong.

Choose the response that most correctly completes the following sentences:

1. The colored plastic pieces…

   a.…allow all colors to pass through.
   b.…reflect most colors.
   c.…let all colors pass through except the color of the plastic.
   d.…let only the color of the plastic pass through, and block the rest.

   Provide a reason for your answer:________________________________
   ____

2. A red mark looks black through a blue filter because…

   a.…the red mark absorbs all the red light and the blue filter absorbs all of the blue light, so no light from the red mark remains to reach your eye.
   b.…the red mark reflects only red light and the blue filter does not let red light through, so no light from the red mark remains to reach your eye.
   c. … the red mark reflects blue light and the blue filter absorbs blue light, so light from the red mark is able to reach your eyes.
   d. …the red mark reflects all colors and the blue filter lets the red light pass through, so light from the red mark is able to reach your eyes.

Part 3 cont.

Answer Key

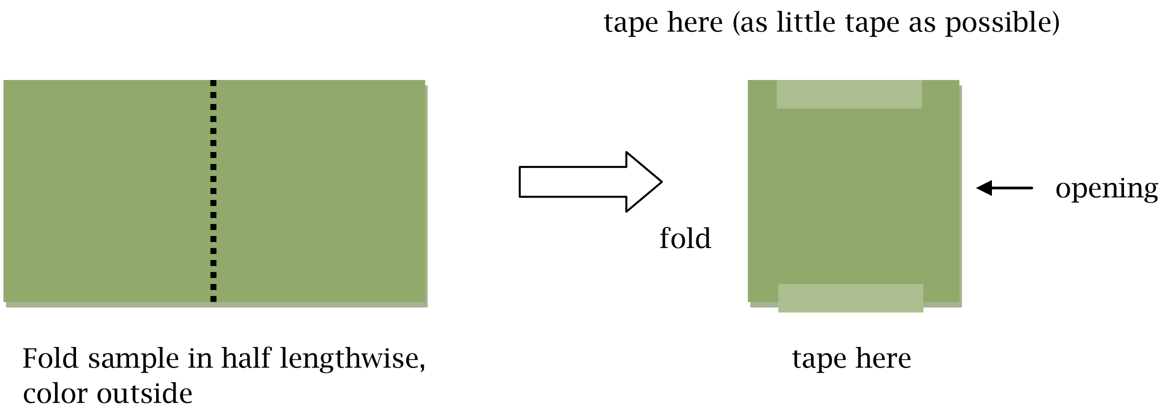
1. The colored plastic pieces (d) let only the color of the plastic pass through and block the rest.

   - a. is wrong because the colored plastic pieces let only their own colors pass through.
   - b. is wrong because the colored plastic pieces reflect only their own colors, not most colors.
   - Answer c. is the opposite of what they do. If they let all colors pass through except the color of the plastic, white objects seen through them would look like every other color combined minus the color of the plastic, which would probably be some shade of brown.

2. The red mark looks black through a blue filter because (b) the red mark reflects only red light and the blue filter does not let red light through, so no light from the red mark remains to reach your eye. If students ask how they see a mark if no light from it reaches their eyes, explain that light reaches their eyes from all around the mark - everywhere there is a color that the filter lets pass. The mark is visible the same way a shadow is visible.

   - a. is wrong because the red mark does not absorb all the red light, and instead reflects it.
   - c. is wrong because the red mark reflects red, not blue, and the filter lets blue pass, not red.
   - d. is wrong because the red mark reflects only red, not all colors, and the blue filter does not let red light pass through.

BLM 1


tape here (as little tape as possible)
fold
opening
Fold sample in half lengthwise,
color outside
tape here


855
CDN

BLM 2

NAMES________________________________Date______________

Color	starting temp °F	final temp °F	change in temp °F
orange			
Color Predicted to Warm More: ___________________________			
Color Predicted to Warm Less: ___________________________			

	Rank Order: Amount of Temperature Change in °F ***Our Prediction***	Amount of Temperature Change in °F ***From Class Results***
1 heats most		
2		
3		
4		
5		
6		
7 heats least		

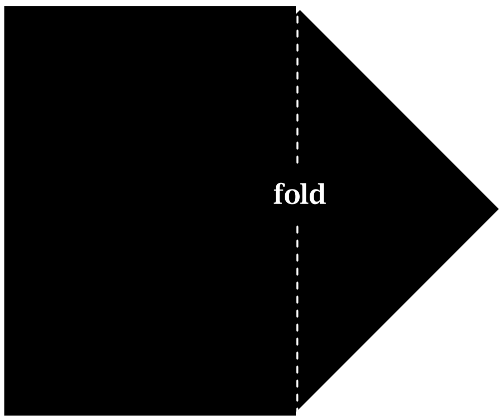
BLM 3

NAMES:_____________________________DATE:________________

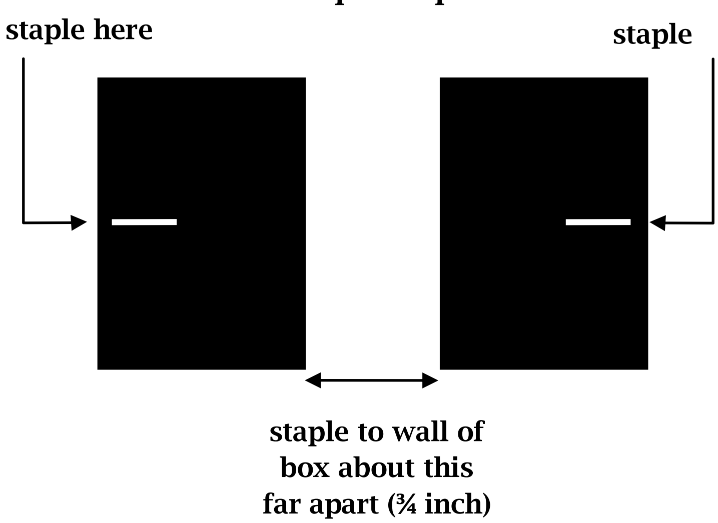
	Your Assigned Color_________________________							
	Starting Temperature	30 sec	60 sec	90 sec	120 sec	150 sec	180 sec	Final Change in Temperature
Temperature ˚F								

BLM 4

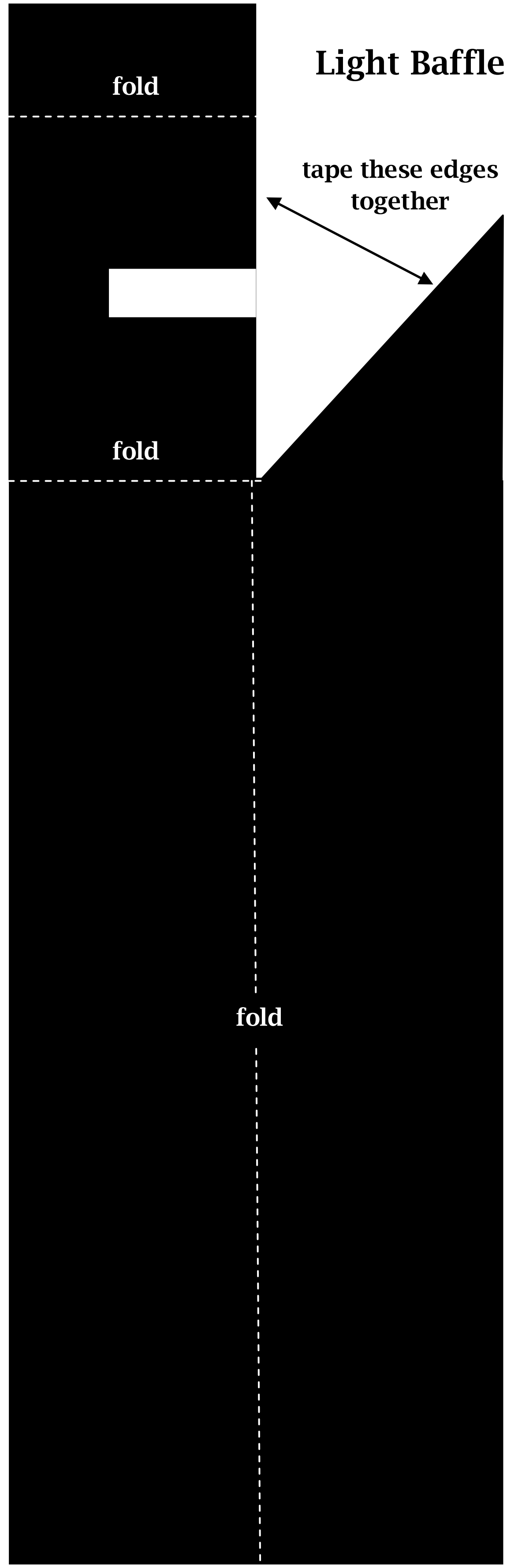
Solar Cell Stand



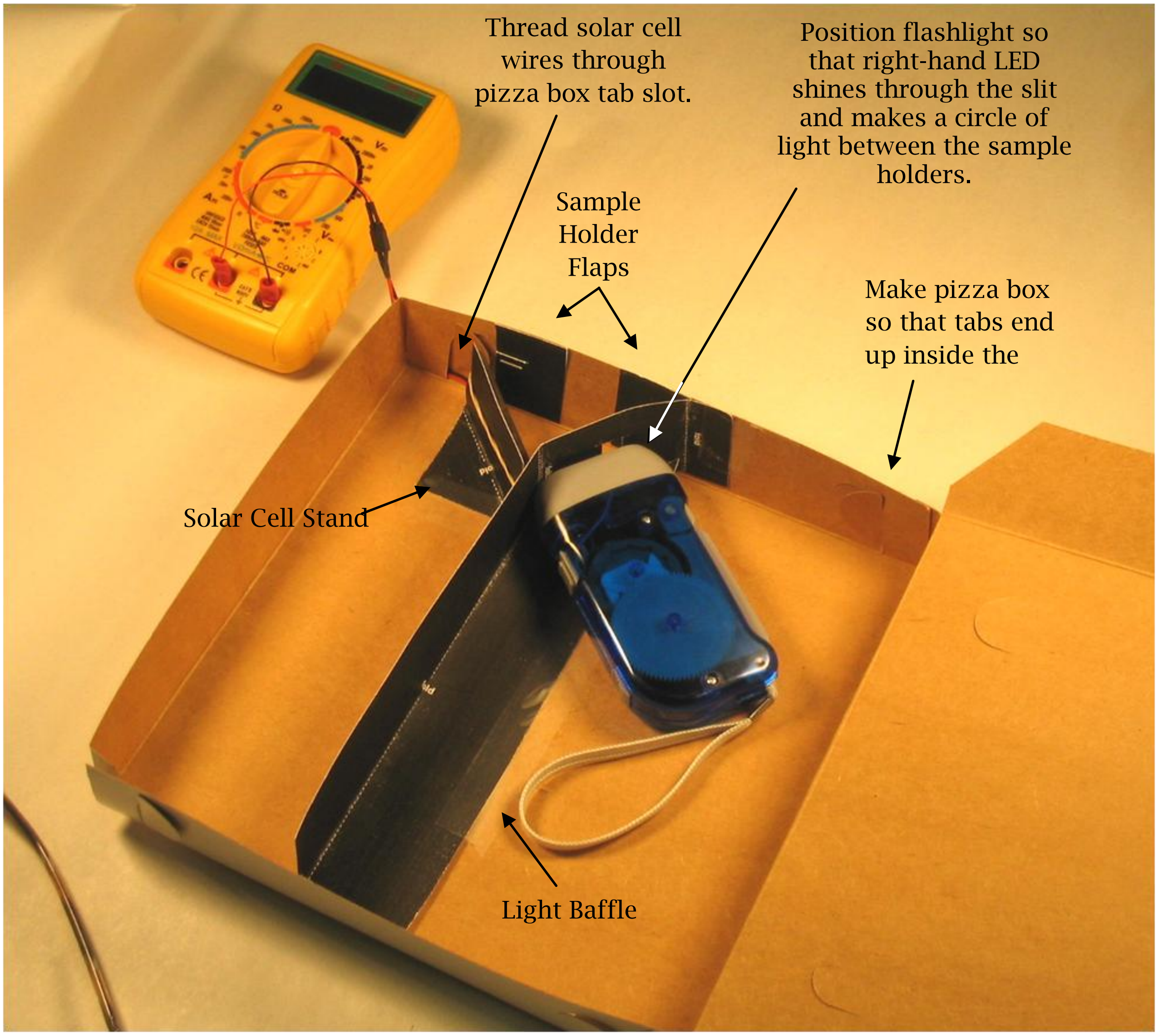
Sample Flaps



Light Baffle

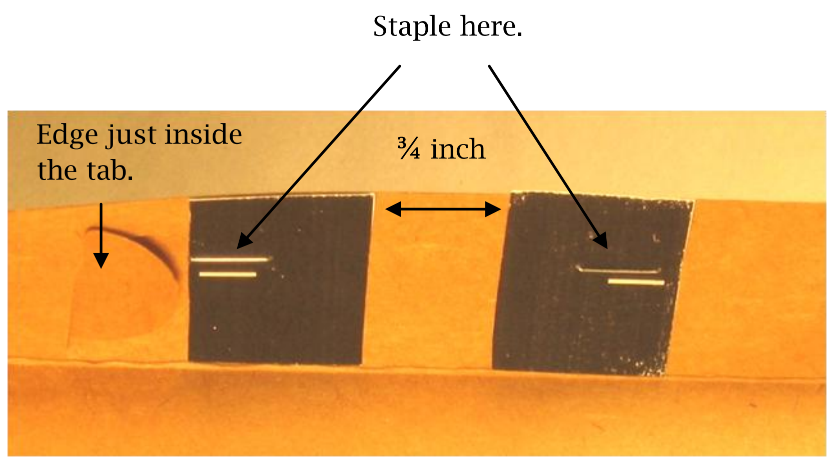


BLM 5


Thread solar cell wires through pizza box tab slot.
Position flashlight so that right-hand LED shines through the slit and makes a circle of light between the sample holders.
Sample Holder Flaps
Make pizza box so that tabs end up inside the
Solar Cell Stand
Light Baffle
COM

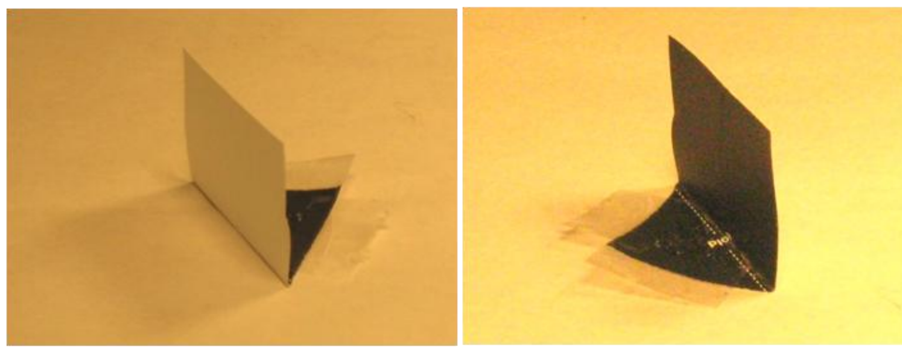
BLM 6

Placing the sample holders



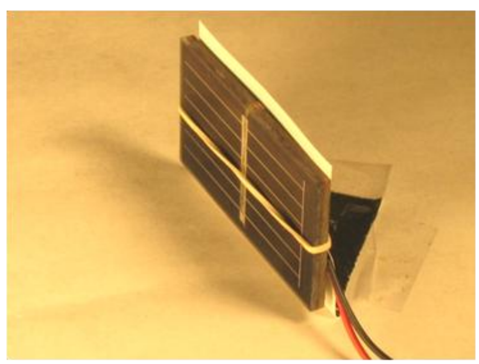
BLM 7

Fold the solar cell stand at a right angle (2 views).



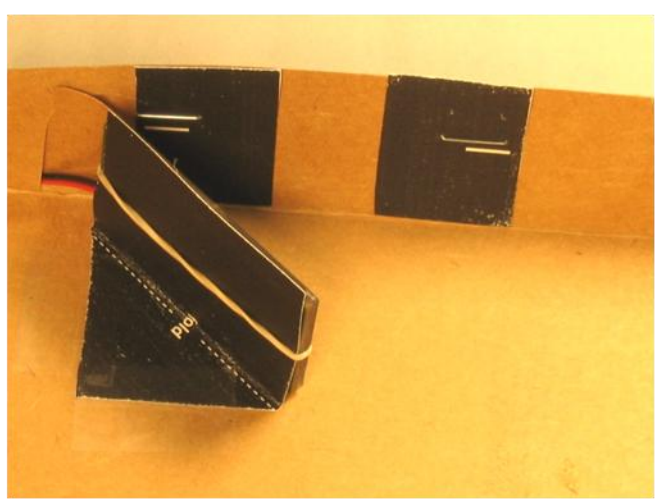
BLM 8

Attach the solar cell to the white side of the stand with a rubber band.



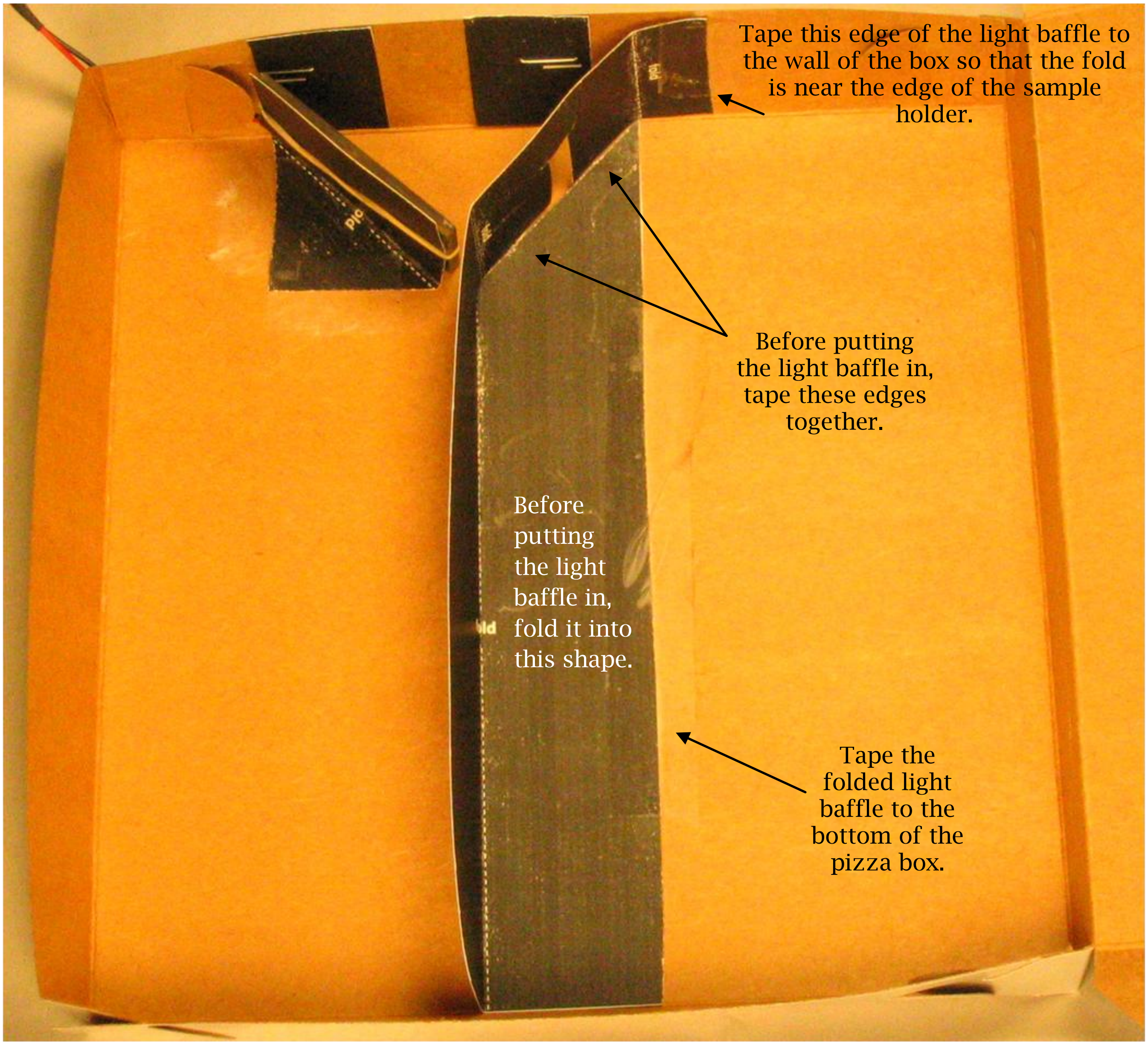
BLM 9

Tape the triangular solar cell stand base to the floor of the pizza box so that the edges of the base are parallel to the walls of the box. The edge of the solar cell should be near the box tab, as shown.



BLM 10

Light box setup

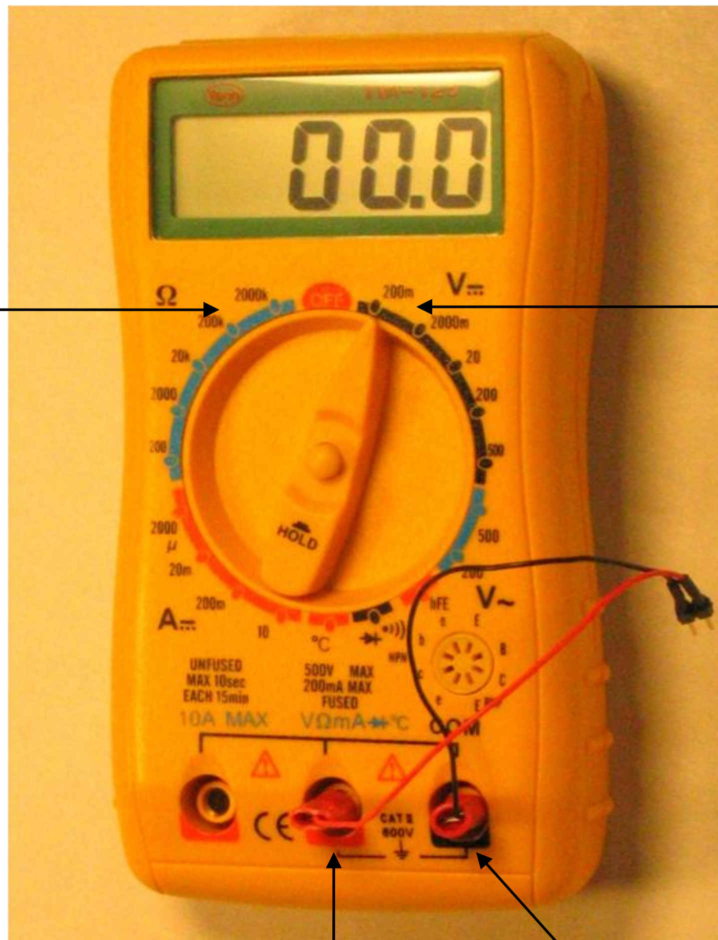


The box should be able to close completely with the top flaps outside of the box. Closed "completely" means no light gets in.

BLM 11

Return the pointer to OFF when finished

Set the pointer to 200m



red wire here

black wire here

BLM 12

Names____ Date______________________

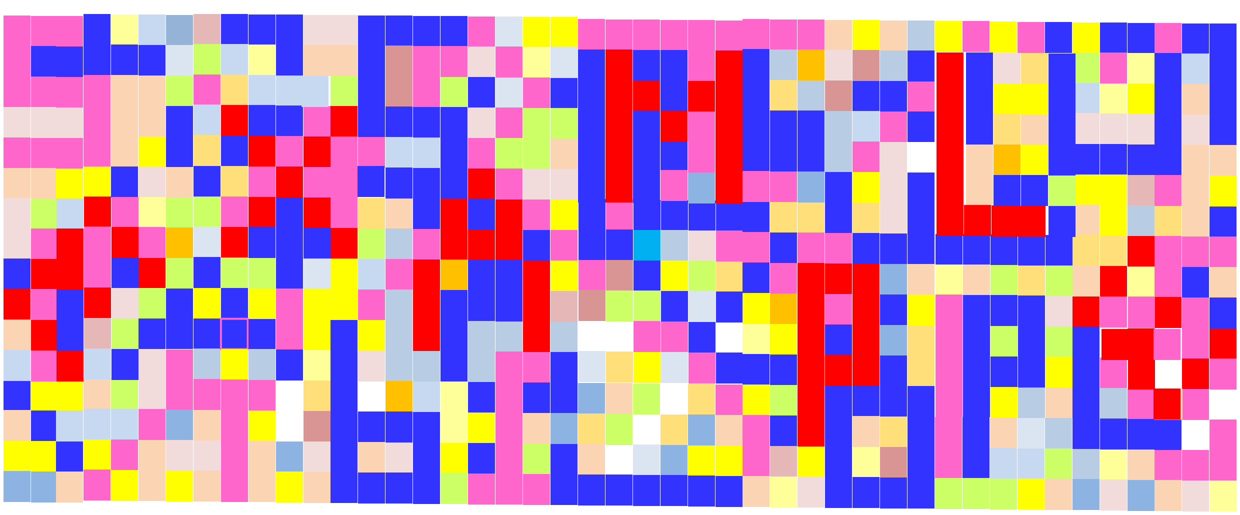
Color	Light Measurement
Orange	
color that got hotter in sunlight	
color that stayed cooler in sunlight	

	Predicted order of light reflected for each color	Class measurements of light reflected for each color
1 reflects most		
2		
3		
4		
5		
6		
7 reflects least		

BLM 13

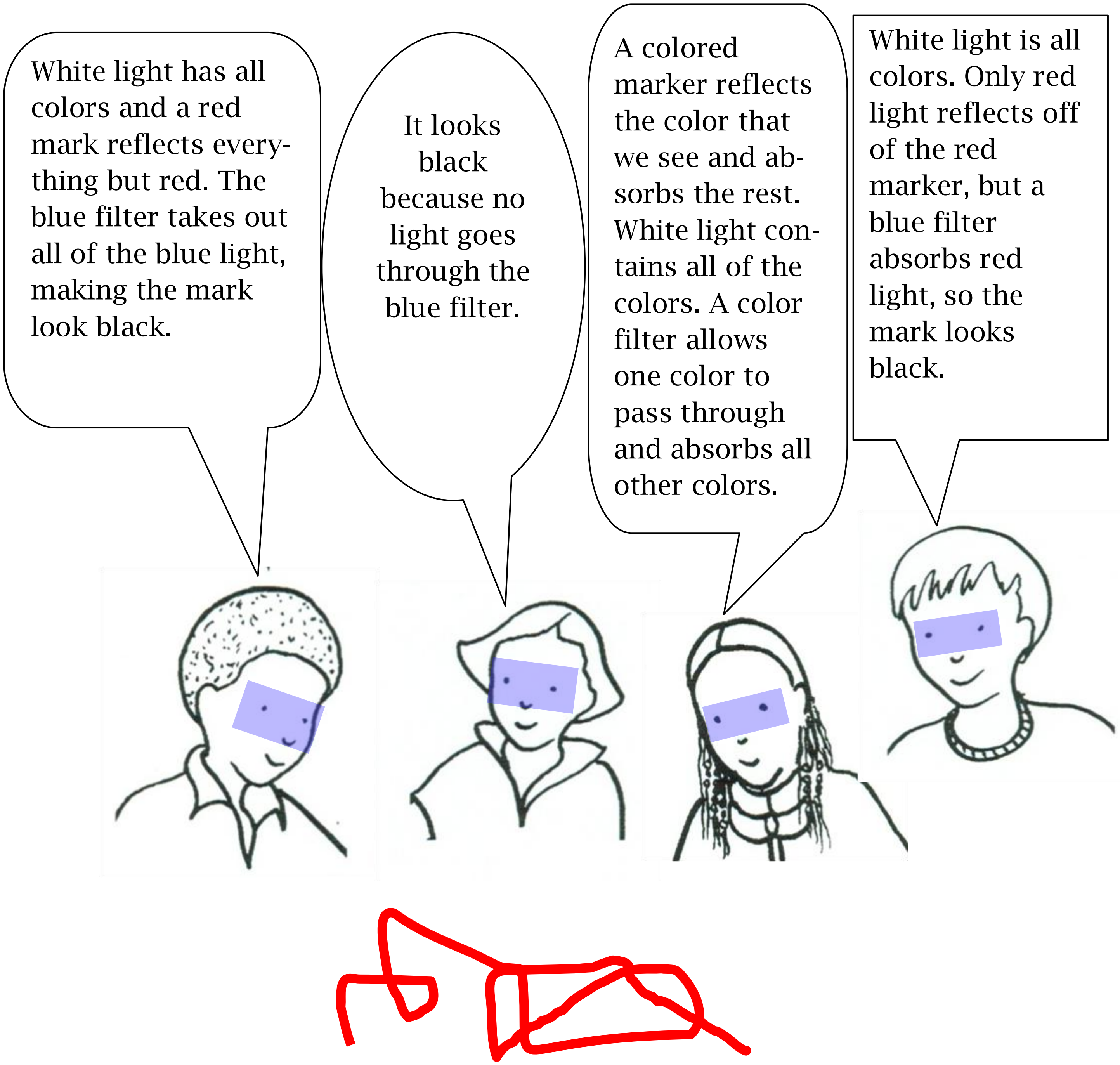
Secret Writing Examples

SEIQBCNROLEPZITMR



BLM 14

Students are looking at a red mark through a blue colored plastic filter. They all see the line as black. Each one has an explanation for why they see it that way. Explain why you agree or disagree with each of them .



Appendix

Common Student Preconceptions About This Topic

Many children ages 10-14 conceive of light as either a source such as a light bulb, an effect such as a patch of light on the ground, or a state such as brightness or dimness. Students tend to think of light as traveling in long, thin, flashing rays. Many also think of light as a medium that transports colors. Students rarely imagine that when they see a non-luminous object such as a piece of paper, they are seeing the light reflected from it. When asked how a lamp brightens a room, about ¾ of children can give no mechanism for this. Similarly, although many understand that light bounces off of mirrors, they do not conceive of it bouncing off of other objects. Even those who accept that light bounces off of opaque objects do not relate this to how we see. Very few children (or adults) grasp the pure abstraction that light is electromagnetic waves with different colors at different frequencies. Instead, colors are seen as discrete things unto themselves, and often as a property of objects rather than as a property of light.