Bending Beams of Light

Summary

Students will learn about light beams, the concept of refraction and bending.

Materials

Activity #1

- Bowl
- Coin or washer
- Water
- Glass
- Pencil
- Paperclip or thin wire
- Cans (both ends removed)
- Round bottles filled with water,
- Square bottles
- Concave and convex lenses
- Shoe box top or lens holder
- Flashlights
- Slit blocks
- Protractor
- Compass
- Several round bottles same size (spice bottles)
- Refraction Experiment Log
  or Journals

Activity #2

- Variety of viscous liquids (oil, dish soap, honey)
- Planning Form for Inquiry
  , Refraction Experiment Log or Journals

Activity #3

- Box -- the kind copier paper come in is ideal
- Equilateral prism
- Cardboard cutters
- White paper
- Overhead projector
- Slide projector or strong light source
- Yarn or string
- Cardstock
- Compass
- Protractor
- Pencil with point
- Student Journal or Prisms and Rainbows

Additional Resources

Books

- *Science Alive: Light*
  , by Crabtree Publishing Company ISBN 0-7787-0560-9
- *The Science Book of Light*
  , Neil Ardley; ISBN 0-15-200577-3

- *Light and Optics*
  , John Farndon; ISBN 0-7614-1090-2

Videos

- *Light*
  , Series in Elementary Science. Visual Learning Company, © 2004. ISBN 1-59234-084-0, 1-800-453-8481
- *ight Optics, Bill Nye*
  , (Disney Educational Productions) Product ID 68A86VL00 1-800-295-5010
- *Light and Color, Bill Nye*
  , (Disney Educational Productions) Product ID 68C01VL00 1-800-5010

Background for Teachers

Light rays slow down and may bend when they pass from one material to another. This bending is called refraction. Refraction happens because light travels at different speeds in different materials. Light changes its speed when it passes from one material into another. It travels at lower speeds through dense materials such as water and at higher speeds through materials that are less dense such as air. A beam of light will travel at a slower speed in a denser material. It will maintain that same, slower speed until it exits that material where upon it will resumes it original speed. (speed of light: in a vacuum: 186,000 miles/sec, air: slightly less than 186,000 miles/sec, water: 140,000 miles/sec, glass: 124,000 miles/sec, diamond 77,500 miles/sec)

Light refracts only when it hits another substance at an angle. When light impacts the boundary of another substance head-on (perpendicular or 90-degrees) it will slow down but will not refract. When light hits the substance at any other angle, it will refract. The angle of refracted light will increase in proportion to the angle of the entry. The angle at which the light crosses the media boundary and the angle produced after refraction is a very precise characteristic of the material producing the refraction.

Lenses are used to bend light. They are made of curved glass or other transparent material. Light always bends towards the thickest part of the lens. There are two types of lenses. A concave lens is thick on the outside ends and thin in the middle (think of a cave). A convex lens is thin on the outside edge and thick in the middle.

The electromagnetic spectrum (EM) is a name given to a group of different types of radiation. Radiation is energy that travels in waves through empty space as well as through air and other substances. The length of the wave determines the type of radiation energy it is. At one end of the EM are long, low-energy waves. These are radio and TV waves. At the other end of the EM are very short, high-energy waves which include x-rays and gamma-rays. Near the middle of the EM is a very small area of waves that we can see. This visible, white light is actually made up of all the colors. Each color has a different wavelength which is why our eyes are able to see the different colors. Red light has the longest wavelength (lower energy), and violet the shortest wavelength (higher energy). The Spectrum refers to this series of colored bands that can be seen when passing light through a prism. The major colors are: red, orange, yellow, green, blue, indigo, and violet. (ROY G. BIV)

Misconceptions to avoid:

> Sound waves and radio waves are not the same thing. Sound waves cannot travel through a vacuum. Radio waves do not need a medium to travel through and they travel much faster than sound waves. Sound travels at speeds on the order of hundreds of meters per second. Radio waves, travel at speeds on the order of hundreds of millions of meters per second.
>
> The spectrum is not made up of just seven distinct colors. In reality, there are a large number of color variations in the spectrum and there are no distinct boundaries between them. How many variations we see depends on the viewer's eye and what is refracting the light.

Science language students should use: refraction, angle of incidence, angle of reflection, spectrum.

Intended Learning Outcomes

1 Use Science Process and Thinking Skills.
4. Communicate Effectively Using Science Language and Reasoning.

Instructional Procedures

Invitation to Learn

Students will experiment with various ways of magnifying objects;

Fill round bottles of various sizes with water. Place the bottles over a printed page. The print will appear enlarged. (Students will observe that print viewed through trapped air bubbles appear smaller.)

Make a lens out of an empty can. Remove both ends. Cover one end with clear plastic. Secure with rubber band. Press plastic to form a bowl shape. Fill with water. Place "Tin Can Magnifier" over print and objects.

Collect soap bubble wands or make them out of bent paperclips or thin wire. Dip in water. Read print through the bubble.

After students have had time to try out the various magnifiers ask: What is happening? Why does everything look bigger?

Record their ideas on a K-W-L-H Chart -- even if they are incorrect. Later, as they discover new information, they can compare the K column (what we know) with the L column -- (what we learned). The middle column, What We Want to Find Out, will be used to record more ideas they would like to explore. These will be generated during class discussions. The H column is to be used for brainstorming How students could find the answers to their questions.

Instructional Procedures

Activity #1 Refracting Light -- a watery journey

Place the slit block at one end of a half sheet of plain paper. Set the water-filled bottle in the center of the paper. Trace the shape of the bottle. Shine a flashlight through the slit block. Move it until two clear lines can be seen from the slit block going into the bottle. Trace those two lines. Observe the two lines exiting the bottle and notice where they cross each other. (The point where they cross is called the Focal Point.) Carefully trace these lines.

Remove the bottle. Use a ruler to measure the distance from the bottle to where the lines cross. Use a protractor to measure the angles the two lines form. Compare the angle of incident light (light coming from the flashlight to the bottle) with the angle of incident light (light coming out of the bottle).

Light will slow down whenever it enters another medium but it will only bend if it hits that medium at an angle. Experiment with square bottles. Place a square bottle on the same place as the previous bottle. Arrange it so a flat side is parallel to the slit block. Observe that the lines do not bend or refract. Then turn the bottle so that the flat side is at an angle to the slit block.

Have students explore light refracting through lenses. Explain what lenses are (see Background). Use the slit block to shine parallel lines of light through each lens. You should see the lines converge through the convex lens and diverge through the concave lens. (You can make a lens holder with the top of a shoe box. Cut a slit in the box top just large enough to stand the bottom part of the lens in.)

Explain how light beams slow down in denser materials. Place the chart of speeds of light in various materials (from Background) on the board. Then discuss how analogies can help us understand complicated concepts. Scientists frequently use analogies to help understand and explain complicated events.

Examples of analogies that illustrate light slowing down when entering another substance

Imagine riding your bike on the paved sidewalk. Then the sidewalk ends and you hit a patch of sand. What happens? You will slow down and your bike may not be able to continue in a straight line.

Imagine running through an empty room versus one filled with people furniture? Would you have to slow down in a full room?

An example of analogies that illustrate light only refracts when it enters at an angle.

Imagine pushing a shopping cart across a paved parking lot and onto a grassy area. If you push the cart straight onto the grass, it will slow down because the grass offers more resistance but it will continue in a straight line. However, if you push the cart at an angle onto the grass, the result will be different. If the front right wheel hits the grass first, it will slow down while the left wheel is still on the pavement. Because the left wheel is briefly moving more quickly it will cause the cart to turn to the right. When you move through the grassy medium and back onto the sidewalk on the other side, the wheel that hits the sidewalk will speed up causing the cart to turn in that direction.

Have each group come up with at least one analogy of their own to share. Have each student write their own analogies.

Activity #2 Refracting Light -- in heavy liquids

Presenting the Challenge:

Ask: Will different fluids refract light differently? Will the distance from the liquid to the focal point (where the light beams cross) be different? Will the size of the angles be different? Why do you think that? Refer to the sand analogy. Would a bike act differently in mud, gravel, etc? Have the class brainstorm different liquids they might want to try (dish soap, oil, honey, hand sanitizer, karo syrup, glycerin, etc.) Write their ideas in the W column of the K-W-L-H chart.

Planning the Inquiry

Talk about experimental design. If we are testing liquids, that is the variable. Everything else must be the same, otherwise we cannot be sure what is affecting the beams of light. Have students point out everything that needs to be the same (size and type bottle, quantity of liquid, distance of bottle from light source, and same flashlight). Review the steps that were taken in Activity #1. Tell students that scientists keep detailed, accurate records of their experiments so they can be duplicated. Students may use the Refraction Experiment Log--included at the end of this section--or they may design their own log.

Conducting the Inquiry

Students can be assigned to work in cooperative groups. Depending on time constraints, each group could either experiment with several liquids or each group would choose a different liquid from the list generated earlier and share their results with the rest of the class. Students could use the same paper they used for Activity #1. Use a colored pencil for the new liquid. It will make the comparison easier to see. Follow steps one through three in Activity #1.

Interpreting and Presenting Results

Each group should share their results with the class. If each group just tested one liquid, they could record their results on a large, class chart. A graph could be created which would show the relationship between the distance of the focal point (where the beams cross) from the bottle and the angle it makes.

Questions to consider: How do you know? What was your evidence? What makes you think this was true?

Students should be made to understand that their results and conclusions are valid for the materials they tested. Their sample was very small. Scientists might conduct hundreds of tests on hundreds of different kinds of materials before drawing conclusions.

Considering Implications for Future Research

An important part of the inquiry-based instruction is having students reflect on their activities. Consider the following: If you had to do it over again what would you do differently? Why? Did this inquiry raise new questions? Brainstorm what else we want to know. Write ideas on the K-W-L-H chart. What would happen if we: increased the size of the container? Changed the shape? Tried different temperatures? How did this activity show why scientific knowledge is always subject to change? Visit http://www.learner.org/jnorth/tm/inquiry/menu.html. This is an excellent site. A "Menu of Inquiry Strategies" includes lists of questions teachers could pose.

Activity #3 Refracting Light to Make Rainbows

Cut a rectangular notch, the length of the equilateral prism, in the middle of the top edge of the narrow side of the box. The prism should fit snugly into the notch with one flat side resting on the cardboard wall. Place a sheet of white paper in the bottom of the box. Position a strong, focused light source about four to five feet from the box.

Before starting the lesson, ask the students to draw a rainbow. Ask them to list the major colors in order. Have them show which color they think is on the top. Record their ideas on the K column of the KWL chart.

Students should work in their teams with a prism box. They may need to move the light source back and forth until they get a clearer rainbow. Students should record their observations in their journal or *Prisms and Rainbow* handout. They should be evaluated on thoroughness, accuracy, and neatness.

What colors do you see? Describe as many as you can.

What is the order of the colors? Draw the spectrum that you see.

Draw the light box set up from the side. Make note of the angle of the prism to the light source. Draw the path of light from the light source, through the prism and to the paper. Refer back to what they learned in Activity #1 about the necessary conditions for light to refract. (Light does not refract when it enters a substance at 90 degrees.)

Place the box in the sunlight. Tilt it, if necessary so that the light goes through the prism and a spectrum is visible inside the box. Make the same observations as in step 3. Are there any differences between the rainbow or spectrum produced by the projector or flashlight and that produced by the Sun? Explain.

This additional activity could demonstrate that each color refracts at a different angle. Trace the spectrum on floor of the prism box with colored markers. Use two strings (or a piece of red yarn and violet yarn). Run the strings from the prism to the two outside boundaries of the spectrum--red yarn to the red side, violet yarn to the violet side.

Have students measure the width of the different colors. A good way to do this is to tape a ruler onto the wall or screen so that it crosses the colors of the rainbow. Are all the bands of colors the same width?

Experiment with a variety of other ways to break up light into the pattern of colors called the spectrum.

Fill a bowl or clear plastic shoebox with water. Place a flat mirror at an angle inside the bowl. Place the bowl in a window so Sunlight shines directly onto the mirror (or use another light source such as a mirror). Hold a white sheet of paper in front of the mirror and move it around until the rainbow spectrum appears. Or move the mirror until the spectrum appears on a wall or ceiling. The wedge, or triangular shape of water between the mirror and surface of the water acts as a prism.

Place a glass of water on the edge of a stool or chair. Put a sheet of paper on the floor. Cover the flashlight with cardboard that has a slit cut into it. Hold the flashlight at an angle to the surface of water. Move the flashlight and paper around until you see the spectrum. Shine light from an overhead projector or slide projector through a prism held just a few inches from the light source. Move the prism until the spectrum appears.

Shine flashlights through prisms. Have them notice at what angle to the prism the light has to shine in order to see the spectrum. For better effect, mask off most of an overhead projector stage with some cardboard, leaving a narrow vertical strip of light to hit a screen. Hold the prism within the strip of light and a few feet from the screen. A slide projector works well. Convert a slide by covering it -- leaving a small vertical slit for light to pass through.

Try recombining the spectrum to form white light. Position a convex lens or hand lens between the prism and a screen. You will need to move the lens around to find the right spot for the colored beams to converge.

Newton's Color Disc is one way to demonstrate that white light is made up of all the colors. When spun fast enough our eyes perceive the mixture of colored light as white light. Students can make a color spinner similar to the professional ones.

Directions: Use a compass to make a four or five-inch circle on cardstock. Cut it out. The circle needs to be divided into seven equal sections -- the seven main colors of the spectrum. Point out how many degrees a circle is. Ask how do we figure out how many degrees each section will be? (51) Use a protractor to measure the sections. Color each section one of the colors of the spectrum. Color them in the correct order. Make a hole in the center of the disk. Push a pencil through and spin. (If you have an old phonograph turntable with adjustable speed, try spinning your disc on it.)

Have students create a mnemonic sentence (other than the common ROY G BIV) to help remember the order of the major colors. red, orange, yellow, green, blue, indigo, violet)

(Adapted from a lesson found at NASA's Stargazer website.)

Extensions

Curriculum Extensions/Adaptations/Integration

For advanced learners:

Students can research how lenses work in microscopes, telescopes, and prescriptive glasses. There is an interesting explanation and demonstration of how "motion cards" work using refraction. (The pictures on motion cards change depending on the angle you hold them.) The How Stuff Works website is one good source of information.

The color spectrum is actually made up of dozens of colors--not just the main seven. Students could research word colors (teal, cyan, fuchsia, magenta, etc.) find samples and make posters for display. This would be a useful resource for more "colorful" writing. The internet has several good sites with lists of colors and pictorial representations. The site http://www.main.cz/colors/color_names.htm has color names in six different languages.

For learners with special needs:

Post science objectives on a wall along with science words students should use. Have students work in pairs and groups. Strategies to help English Language Learners and other special needs learners are incorporated into this unit. They include: use hands-on activities, work in collaborative groups, model expected behavior and how to complete a task, provide real material to help make concepts concrete, prepare multiple forms of assessment, utilize graphic organizers, and minimize lecture format.

Family Connections

Look for objects at home that bend light and create rainbows or spectrum. One item to consider is, white light reflecting off beveled mirrors. (New vocabulary word--sloping or slanted). Some examples of faceted objects (many small surfaces) are pendants, cut glass bowls, diamond rings, CDs, soap bubbles, and spray from a hose.

Provide a list of websites and encourage families with computers and internet connections to explore some of these excellent sites, other families could visit a local library.

If you have a good color printer, print out one of the color charts from the internet, or find color charts at a paint store. Have students find examples around school and at home. Students might be given just one family of colors such as red and look for items that match the various shades (pink, rose, maroon, etc.).

Assessment Plan

Use a K-W-L-H chart to record class responses and assess group progress. A large, poster-size chart can be hung on the wall and fill in during the unit. Individual ones could be used and kept in the students' log books.

Write analogies that illustrate what happens to light when it enters another medium.

Pantomime what happens when light is refracted. You could use props to represent different mediums. Have students act out reflected light and have them make comparisons between the two types -- refracted and reflected. This is an example of incorporating movement into the class -- even into assessment.

Have groups of students show prism dispersion with yarn. Provide each group with the seven major colors of the spectrum as well as two lengths of white yarn. (Strips of colored butcher or construction paper could be used.) Use one length of white yarn to construct the outline of the prism. The other represents the white entering the prism. Use the seven colored strands of yarn to show what happens. Check for entry angle of white yarn -- it should not be perpendicular to the entry face of the prism. The colors should be in order. To include more beneficial physical movement, use longer lengths of yarn. Have the students work in the hall, gym, or outside.

Inside Outside Circles. Have the class form two circles. The inside circle faces the outside circle. Instruct the inside circle to explain what refraction is to their partners in the outside circle. Ask the outside circle to clarify or make corrections. Have the inside circle move three places to the left and tell their new partner about refraction (or how a prism works, etc.) This activity gives students a chance to move around and explain concepts in their own words. It provides the teacher an opportunity to make informal assessments.

Student journals or the worksheets included in the activities are good assessment tools.

Bibliography

Colburn, Alan. (2004) Inquiring scientists want to know. *Educational leadership*: Sep 2004, Volume 62.1, pp. 63-66.

Inquiry-based instruction is shown to be a realistic middle ground between hands-on verification activities and open-ended discovery learning. Colburn gives examples of how to take incremental steps in moving a bread mold verification activity towards a guided inquiry lesson. The crucial role of assessment is emphasized. This includes assessing the students' abilities to develop further questions to investigate.

Heber, Richard., Moore, Christopher J. (2002). *A model for extending hands-on science to be inquiry based*. Database: Academic search premier. Retrieved 12/11/2005.

Hands-on activities are typically presented as step-by-step instructions for students to follow to find a pre-determined answer to an assigned question. This model provides structure and guidelines for extending this traditional approach into a more valuable Strategies include: discrepant events to engage students in inquiry, brainstorming activities to facilitate planning investigations, written job performance aids, requirement for a product -- usually including a graph, class discussion and writing activities to facilitate student reflection.

May, David B., Hammer, David. (2004) Elements of expertise in the use of analogies in a 3rd-grade classroom discussion. *AIP Conference Proceedings*; Volume 720.1, pp. 149-152. EBSCO Host

Scientists regularly employ analogies to communicate their knowledge. Using analogies in the classroom, including those generated by students, has been shown to improve student conceptual learning. This article studies how one 3rd grader generated and used an analogy while engaging in an inquiry in a science lesson about earthquakes. The authors identify some of the elements of expertise in analogy use that can be taught.

Jensen, Eric. (2005) Movement and learning, *Teaching with the brain in mind*. ISBN 1-4166-0030-2

"The part of the brain that processes movement is the same part of the brain that processes

learning." Jensen cites many studies and laboratory research showing the relationship between physical activity and increased cognition as well as better memory. In addition to providing for daily recess and physical education, Jensen makes many recommendations for how to incorporate physical activity into the daily curriculum.

Ways to build movement into the school day:

- Drama and role-plays: Have daily or weekly role-plays, play charades to review main ideas, pantomime to dramatize a key point, do one-minute commercials to review content.
- Energizers: use the body to measure things around the room, play a Simon Says type game with built-in content.
- Quick games: use ball toss for review, vocabulary building, rewrite lyrics to familiar songs in pairs or as a team incorporating content. Then have students choreograph and perform them.

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