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Overview

In this Delta Science Module, students investigate the refraction and reflection of light by lenses and mirrors. In doing so, they see how light can be manipulated to help us see things. From eyeglasses and telescopes to bathroom and rear-view mirrors, lenses and mirrors are part of our daily lives.

In Activity 1, students learn that light travels in straight lines called rays. They shine a flashlight beam at a flat mirror and then observe the behavior of the rays as they reflect back off. They measure the angles of the incoming and reflected rays and discover that light is reflected by a flat mirror at the same angle at which it strikes the mirror.

In Activity 2, students investigate the connection between the location of an object and the apparent location of its reflection. They discover that the reflection of an object appears to be exactly as far behind, or "inside," the reflective surface of the mirror as the actual object is in front of the mirror. Students then play a new version of a familiar board game based on their understanding of this concept.

In Activity 3, students use the ray theory of light—that light travels in straight lines—to explain why rays passing through a very small hole produce an inverted image.

In the next two activities, students discover what happens when light is reflected off more than one flat mirror. In Activity 4, students build a maze and use mirrors to reflect a beam of light through the maze to a target. They also learn why images formed by flat mirrors are often inverted left-to right.

In Activity 5, students investigate the reflection patterns produced by two hinged mirrors and discover that multiple reflections can be made using only two mirrors.

Activity 6 takes multiple reflections one step further, as students place three mirrors at right angles to each other and observe how reflections can be inverted upside-down as well as left-to-right.

Curved mirrors are the subject of Activity 7. Students learn that light reflects off curved surfaces just as it reflects off flat surfaces, but that the curved surfaces cause the light rays to converge or diverge. This explains why an image in a curved mirror often looks quite different than an image in a flat mirror.

In Activity 8, students investigate lenses and discover that they change the appearance of things much the same way curved mirrors do: by causing light rays to converge or diverge.

In Activity 9, students learn the difference between real and virtual images and how to tell which types of lenses and mirrors will produce which kind of image.

In Activity 10, students learn the different parts of the eye and how they work with the brain to produce visual images. They discover that the eye provides a natural model for many of the concepts they have learned in previous activities.

In Activity 11, students administer eye tests to one another. They learn what ratings such as 20/20 mean and how lenses are used in eyeglasses to correct vision.

Finally, in Activity 12, students learn how complex optical instruments such as telescopes, microscopes, binoculars, and cameras are really combinations of lenses and mirrors. Then they design and construct their own instruments using different combinations of lenses and mirrors from the kit.

Materials List

Qty		Description
1		acetate, frosted
1	c	adhesive dots, p/96
32	c	batteries, C-cell
8		blocks, wooden, green triangle
8		blocks, wooden, orange square
8		blocks, wooden, red trapezoid
8		blocks, wooden, yellow hexagon
8		colored windows, 15 cm x 15 cm
1	c	cups, paper, p/50
8		cups, plastic
4		eye charts, Snellen
8		flashlights
16	c	graph paper
32		holders, plastic
8		lenses, double concave
8		lenses, double convex
8		lenses, plano-convex
24		maze slats, large
24		maze slats, small
8		mirrors, concave
8		mirrors, convex
24		mirrors, flat
24	c	paper, construction, black, 22 cm x 30 cm
1	c	paper, waxed
2	c	paper, white, p/30
1		pins, straight, p/180
80		plastic chips
2		slit cards, plastic, p/4
1	c	tape, masking
2	c	tape, transparent
1		video, *Lenses and Mirrors*
1		teacher's guide

Teacher provided items

Qty	Description
8	books, hardcover
3	containers, 1-L
-	eyeglasses
32	markers, felt-tip
-	paper towels
8	pencils
8	rulers, metric
16	scissors
1	tape measure
1	VCR and monitor
-	water, tap

c = consumable item

Activity 1
Mirrors and Reflection

Objectives

In this activity, students learn that light travels in straight lines called rays. Then they investigate how light rays behave when they strike a reflective surface.

The students

- simulate rays of light by shining a flashlight through a narrow slit
- observe the behavior of light rays as they strike a mirror at various angles
- discover that light is reflected by a mirror at the same angle at which it strikes the mirror
- learn that the movement of light is represented in diagrams by straight lines with arrows, called rays

Schedule

About 40 minutes

Vocabulary

beam	ray
law of reflection	reflect

Materials

For each student

1	Activity Sheet 1, Part A

For each team of four

1	Activity Sheet 1, Part B
2	batteries, C-cell
1	flashlight
4	holders, plastic
1	mirror, flat
1	slit card, plastic

For the class

1 sht	acetate, frosted
1	*ruler, metric
1 pair	*scissors
1 roll	tape, masking

*provided by the teacher

Preparation

1. Make a copy of Activity Sheet 1, Part A, for each student. Make a copy of Activity Sheet 1, Part B, for each team of four.

2. Load each flashlight with two C-cell batteries. Test the flashlights to make sure they work. Each team of four will need one flashlight.

3. For each flashlight, cut a square of frosted acetate 5 cm on a side. Tape the square over the end of the flashlight so the light will shine through it. (The acetate disperses the intensity of the flashlight beam, which might otherwise obscure the results of the experiment. Depending on how dark you are able to make your classroom, you may find that the flashlights work better without the acetate.)

4. Each team will also need four strips of masking tape 7–10 cm (about 2.5–3 in.) in length, one slit card, one flat mirror, and four plastic holders (to hold up the mirror and the slit card).

Background Information

We see objects in the world around us because light is reflected off those objects and enters our eyes, which are specially adapted to send messages to the brain so it can interpret it as information. The light that is *reflected* off objects is basically the same as the light that comes from any other light source—such as an overhead light, or even the sun—in that it travels in straight lines called *rays.*

Reflections in a mirror are formed when light rays bounce off an object and strike the mirror. When light rays strike the surface of a mirror, they again bounce off, or are reflected by, the mirror.

Because the surface of a flat mirror is smooth and shiny, light rays are reflected off of the mirror at the same angle at which they strike the mirror. Thus they form an exact replica "inside" the mirror of the object in front of the mirror. This principle is known as the *law of reflection* (see Figure 1-1).

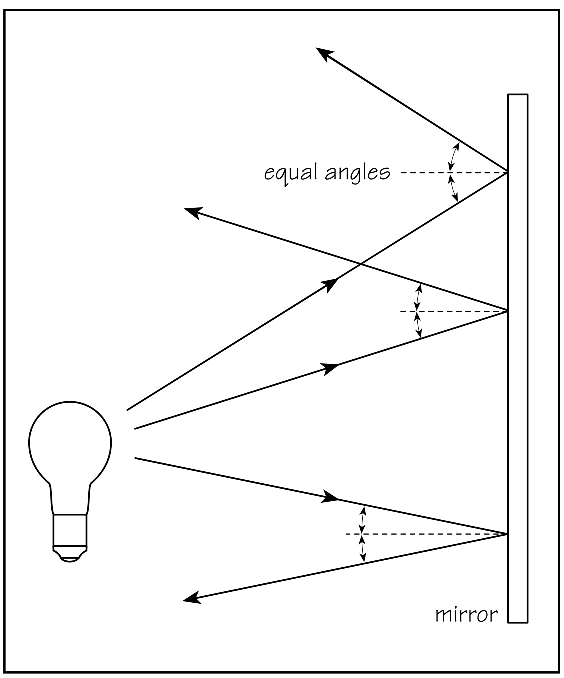
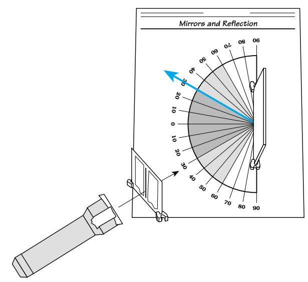


Figure 1-1. Light rays are reflected by a flat mirror at the same angle at which they strike the mirror.

Name ______________________ Activity Sheet 1, Part A

Mirrors and Reflection

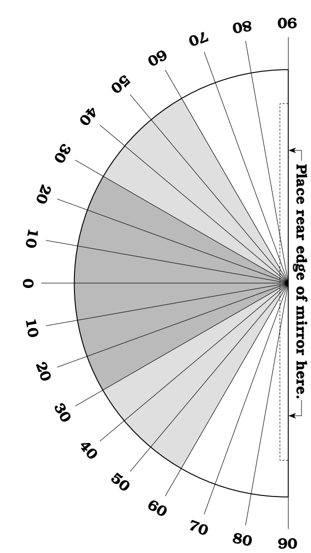
1. Set up your experiment as shown in the diagram below. Use the plastic holders to hold the mirror and slit card perpendicular to your work surface. Align the rear edge mirror with the side of the protractor between the two 90° marks.
2. Shine the flashlight through the slit card. For your first measurement, adjust the position of the flashlight and slit card so that the beam of light follows the path of the 30° line on the protractor. The beam should hit the mirror right at the black spot in the middle of the protractor.
3. In the diagram, draw a line with an arrow at one end to indicate the path of the reflected beam of light. Then record the size of the angle (in degrees) in the table below. Repeat the experiment five or six more times, using different angles of incoming light each time.



Angle of Incoming Light Rays	30°						
Angle of Reflected Light Rays	30°		Same as incoming angle.				

Name ______________________ Activity Sheet 1, Part B

Mirrors and Reflection



Teaching Suggestions

Additional Information

1

Divide the class into teams of four and distribute a prepared flashlight and a flat mirror to each team. Tell the students that in this activity, they are going to study mirrors.

Write the words *ray* and *reflect* on the board. Ask, **What does a mirror do? How does it do it?**

Students should already be familiar with the term *reflection,* and may say that a mirror reflects images of objects or people. Some students may know that this is a result of light rays bouncing off the mirror—a phenomenon that will be discussed in more detail later in the activity.

Write the word *beam* on the board. Ask, **What happens when you turn on a flashlight? Can you predict where the light will go before you turn the flashlight on?**

Flashlights emit a beam of light. A beam is a group of closely related rays. (A beam may also be used to mean one ray.) Light from a flashlight essentially travels in a straight line from the flashlight.

2

Ask, **Has anyone ever seen what happens when a bright light is shined into a mirror?** Suggest that the students see what happens by shining their flashlights at the mirrors.

The mirror reflects a bright spot of light, as though it were another flashlight. If students look into the mirror, that is exactly what they will see.

After students have had an opportunity to experiment, ask, **When you shined the light at the mirror, did the light disappear into the mirror or did it go somewhere else?**

The light bounced off the mirror and continued in a different direction.

3

Ask the students, **Do you think you could predict where a light beam will go after it hits a mirror?**

Answers may vary. Some students may guess that when light hits a mirror at a certain angle, it will bounce off at the same angle in the other direction.

Explain to the students that they are going to shine a flashlight at different angles into a mirror to learn what happens when light rays strike a reflective surface.

4

Distribute a copy of Activity Sheet 1, Part A, to each student, and a copy of Part B, one slit card, four plastic holders, and four strips of masking tape to each team.

Suggest that it will be easier for the students to observe their results if they narrow the beam of light emitted by the flashlight. Instruct them to place strips of masking tape over all but one of the slits on the plastic slit cards.

Next, explain that the protractor printed on Activity Sheet 1, Part B, is designed to help them measure the angles at which light strikes—and is reflected by—a mirror. Have the students read the instructions and use the diagram on Activity Sheet 1, Part A, to guide them in setting up and conducting the experiment.

The mirrors consist of a silvery reflective surface onto which a piece of clear plastic has been attached. Since the actual reflective surface is at the back of the mirrors, the rear edge is what should be aligned with the 90° line on the protractor, not the front plastic edge. Help students as needed to align their mirrors correctly.

5

While students are gathering data, copy onto the board the table and diagram from Part A of the activity sheet. Make the table large enough to record two responses from each team. Also, be available to answer questions and to help students who are having difficulty obtaining results.

Students may have trouble producing a bright enough and narrow enough beam of light and getting it to strike the mirror in the right spot and at the desired angle. Encourage the students to experiment with different methods to find what works best, or to ask other teams for suggestions.

Students may also have trouble determining the angle of the reflected light, since a beam of light tends to spread out as it travels farther from its source (which, in the case of the reflected light, is the mirror). Instruct them to take a reading where they estimate the center of the beam to be.

6

After all teams have had an opportunity to take five or six measurements, ask each team to report one or two of them. Record the angles of both the incoming and outgoing (reflected) light rays in the table on the board. Try to get measurements based on as many different incoming angles as possible.

In most cases, the outgoing angles measured by the students will be within 10° of the incoming angles.

Write the term *law of reflection* on the board. Ask the students, **Judging from these results, would you say there is a relationship between the angle at which light hits a mirror and the angle at which it is reflected by the mirror? If so, what is the relationship?**

Students may say correctly that the incoming and outgoing angles are always the same. Some teams, however, may not have gotten this result. Have students think about the many variables in the experiment that could have affected their results. For example, if the mirror was not perfectly aligned with the edge of the protractor, or if the beam of light did not hit the mirror at the center point of the protractor, the light would still be reflected at an equal angle from the mirror, but where the reflected light landed on the protractor might indicate an outgoing angle different from the ingoing angle.

Explain that the results they obtained from their experiments support the law of reflection, which states that a light ray is reflected by a mirror at the same angle at which it strikes the mirror.

7

Ask for a volunteer to complete the diagram on the board by drawing the reflected beam from the students' first trial (in which the beam struck the mirror at a 30° angle). Instruct the student to indicate the light ray by a straight line with an arrow at the end. Then ask, **Does this agree with what everyone else observed?**

The answer will depend on what the student drew. The line indicating the reflected beam should be on or near the 30° mark on the other side of 0°. If this is not the case, ask the class where the ray should go, and have the same volunteer draw it in correctly on the diagram.

Underline the word *ray* on the board. Next to it draw a straight line with an arrow at one end. Explain that scientists often represent light beams or paths of light by drawing a straight line with an arrow at one end. This symbol is called a ray. A diagram that uses rays to show where light travels is called a ray diagram. Ask, **Does it make sense to represent light with straight lines? Why?**

Yes, because light travels in straight lines. If students are unsure, you may be able to convince them by pointing out that objects cast shadows when they block some of the light rays from a light source. The remaining rays cannot reach behind the object because to do so they would have to bend, and light rays only travel in a straight line.

Reinforcement

R

Have students repeat the experiment, but this time, instead of holding the mirror still and changing the angle of the incoming light beam, have students shine the beam of light along the 0° line of the protractor and change the angle of the mirror. Encourage them to try to predict where the reflected light beam will go.

Cleanup

C

Tell students to remove the frosted acetate squares from the flashlights and remove the masking tape from the slit cards. Return these items, along with the plastic holders and mirrors, to the kit.

Connections

Science Challenge

Give students the following instructions for making a beam tank: Put a large, clear glass container (such as a fish tank) on a dark surface, fill it with water, and add a few drops of milk to make the water cloudy. Position a slide projector (or other source of very bright light) at one end of the container so its beam shines straight into and through the container. Poke several small holes in the center of a sheet of cardboard, and tape it to the end of the container so the light beam passes through the holes and into the water. With the room darkened as much as possible, have students observe the narrow light rays in the cloudy water. They can hold a mirror in the rays and change its angle to see what happens. Let students experiment with the amount of milk added to the water, the position of the projector, and the size of the holes in the cardboard to find the arrangement that allows them to see the rays most clearly.

Science Extension

The following activity demonstrates that light rays travel only in straight lines. Have each team use a paper punch or nail to make a small hole in the exact center of at least three file cards. (Students can determine the exact center by drawing diagonal lines to connect opposite corners of each card; the point at which the two lines intersect is the exact center.) Tell the teams to arrange their cards in a row, about 6 inches apart, and hold them upright with lumps of clay. Have them align the holes in a perfectly straight line by passing a string through them and pulling it taut, adjusting the cards as needed. Darken the room, and have one student on each team hold a lighted flashlight so its beam passes through all the holes. Each team member should look through the holes to observe the light beam, then move one card slightly to the left or right to observe that the beam can no longer be seen. Ask students to explain this observation. (The light rays cannot bend to go through the hole in the offset card.)

Give each team a small pane of plate glass with its four edges covered with masking tape to prevent cuts. Let students hold the glass and turn it at different angles to try to see their reflection. Then have students repeat their observations while holding a sheet of white paper behind the glass, then a sheet of black paper, and finally a sheet of aluminum foil. Which material makes the glass most reflective? (the foil) How can they explain their results?

Give each team of three a wide-toothed comb, a mirror, and a flashlight, and darken the room. Tell one student to hold the comb upright, teeth downward, on one edge of a sheet of white paper while a second student shines the flashlight beam directly at the comb. The third student should hold the mirror upright on the paper so the light rays passing through the comb hit the mirror at an angle. Students will see that the rays are reflected at the same angle at which they strike the mirror. Let team members take turns trying the mirror at different angles to the comb. For each mirror position, students could trace the incoming and reflected rays on a new sheet of paper, then draw a center line out from the mirror and measure the two angles.

Science and Language Arts

Ask students to look up the literal meaning and derivation of *reflect.* (“to bend back,” from the Latin *re-*, meaning “back, away,” and *flectere,* “to flex, bend”) Ask a volunteer to write the term and derivation on a tagboard strip and post it on the bulletin board for comparison later with *refract* in Activity 8.

