MUSEUM OF THE ROCKIES
MONTANA STATE UNIVERSITY

Lesson: How Light Moves
(from Montana PBS and the Montana University System)

Grade level: 4-12
Lesson duration: two 45-minute class periods

Objectives:

- Understand that light travels in a straight line
- Examine how light can be reflected by a mirror or refracted by a lens
- Explore how light is reflected off an object and understand that the angle of the outgoing light is equal to the angle of the incoming light (the law of reflection)
- Understand that light follows the law of reflection when it reflects off smooth objects (like a mirror) and rough objects (like a piece of paper)
- Understand that when light reflects off rough surfaces, it is scattered in all directions, which prevents the formation of an image
- Explore how light changes direction when crossing the boundary between two different transparent materials in a process called "refraction"

Lesson materials:

- Copies of Flashlight Predictions document
- Copies of Light and Shadow Walk document

Part 1

For each group of two to three students:

- Flashlight Predictions Document
- Mirror—cosmetic mirror or 3-inch square of silvered Plexiglas, fastened with tape or elastic to a small wooden block so it can stand upright
- Paper
- Rock
- Pane of glass (or clear plastic), 3-inch square
- Glass of water

- Eyeglass lens (convex, such as used for reading up close)
- Flashlight
- Index cards
- Scissors
- Video or computer for playback of resources
- Clear plastic container
- Straws

Part II

For each group of students:

- Container of water (best with transparent sides)
- Penny
- Straw
- Pencil or 2-3 strands of dry spaghetti
- Scissors
- Spear Fishing Challenge Image

Lesson preparation:

- Arrange computer access for each group of two to three students.
- Prepare all materials.
- Ask students to take a light and shadow walk around their neighborhood. Depending on weather, this may have to be done one to two days in advance. Distribute the Flashlight Predictions document for students to record their observations during their walk.
- Have students complete the Light and Shadow Walk worksheet.

Lesson procedure:

Part I: Exploring How Light Travels

1. Before the first day of the lesson, students should have taken a light and shadow walk around their neighborhood. On the day of the lesson, begin by having students discuss their light and shadow walks. Where did they see shadows? Did the shadows change? Under what circumstances? Students may indicate different light sources (the Sun, the Moon, or a streetlamp) depending on where and when they took their walk. Do all shadows have to have something that blocks light, thus creating the shadow?

2. Ask students to suggest some "rules" about how light moves based on their observations from the light and shadow walks. Write some of these rules on the board. Whenever possible, try to demonstrate the suggested rules. For example, if someone suggests that light travels in a straight line, you can test this by doing the following demonstration. Darken the room and have one student hold an index card while another student shines a flashlight at the card. Then have a third student hold a pencil so that it casts a shadow on the card. Ask the student holding the pencil to slowly move it to the left or right, and challenge the student with the index card to keep the shadow of the pencil on the card without moving anything but the card. As the student with the pencil moves around the room, observe what the student with the card has to do as the shadow "keeper." If time permits, have all students try this experiment in their small groups with different objects.
Next, have students view the How Light Travels QuickTime Video to see another demonstration of how light travels in straight lines.

3. Tell students that they will now explore what happens when light shines on different kinds of objects that are opaque, clear, or shiny. Distribute the Flashlight Predictions PDF Document and ask students to pretend that they have a flashlight that they can shine on various objects. Have students discuss and record on paper what they think they would see if they shone the flashlight on the objects as shown. They should pay particular attention to where the light would go after it hits the object and record this for each object. With equity in mind, if students have not ever had a chance to explore with a flashlight before making these predictions, the lesson may need to be expanded to allow time for these explorations.

4. In a darkened room, have students test out their predictions. Students should shine flashlights on each object and record how the light interacts with the objects, starting with the paper and the rock. They should note that on opaque objects, there will be definite shadows. On shiny objects such as the mirror, some of the light will be blocked from its original direction, making a shadow. Some of the light will be redirected in a beam. This beam will be noticeable if there is dust in the path of the light. It can also be seen if the flashlight is placed flat on a table along with the mirror that is

mounted on the block of wood, so that some of the light spills onto the table. On clear objects, the light will pass right through.

5. Next, have students work in pairs or small groups to explore the properties of the mirror more precisely. Students should begin by placing their mirror (mounted on a wood block so it can stand upright) in the middle of the lab table on top of a piece of white paper. Then they should place their flashlight on the table so that it shines directly at the mirror. Ask students to observe and trace with a pencil the ray of light from the flashlight to the mirror, as well as its reflection. They should put arrows on their lines showing the direction in which the light is traveling. Ask students what they think would happen if they turn the mirror. Then have students turn the mirror and trace the path of the light and its reflection using a different colored pencil, again adding arrows to show the direction in which the light is traveling. Does the reflection move with the mirror? Finally, have students turn the mirror one more time and trace the lines in a third color. Ask students to reflect on the following questions:

a. Turn off the flashlight, aim it at the mirror, and draw the incoming light line and your predicted path of reflected light. How do you think the light reflects when entering the mirror and leaving the mirror? Write a general rule.
b. Were you able to measure the angle of reflection compared to the angle of light coming in? Remember, you are measuring the angle between the flashlight beam and the mirror on one side, and the angle between the reflection of the flashlight beam and the mirror on the other side.
c. If you trace the path of the light on the paper and on the edge of the mirror, how do the two angles compare? (Note: Younger students can color in the wedges and see that they are the same shape and area, while older students can measure the angles with a protractor.)

6. Ask students to place an index card in front of the mirror. Then have them point the light at the index card and observe the ray of light across the table. They should notice how the ray continues beyond the card as it did with the mirror. Ask students whether or not they think the index card is reflecting light.

7. Show students the Light and the Law of Reflection QuickTime Video. Ask students what they think determines whether or not there is a reflection.

Part II: Exploring Refraction

Students will now work on the Spear Fishing Challenge. Set up the equipment by putting the penny in the container of water. Cut the straw in half lengthwise so that the pencil can slide down it. Alternatively, you can use a thin piece of dry spaghetti instead of a pencil so that there is no need to cut the straw. You may also want to display the Spear Fishing Challenge JPEG Image on a projector or computer so that students can see an example of the activity setup. Then, have each group do the following:

a. Stand beside the container and look at an angle through the water to the penny. Hold the straw to your eye like a telescope so that you can just see the penny. Without moving the straw, insert the pencil and release. What happened? Did you spear the penny fish? If you were not successful, rethink your strategy and try again. Where do you need to position the straw to be able to hit the penny with the pencil? Try hitting the penny from directly above the water.
b. Construct a diagram of what you think is happening with light that makes it difficult to spear the penny. Include arrows to indicate direction.

Darken the room. For each group of students, place a sheet of paper on the lab tables. Then place a glass of water on top of the paper. Ask students to move the flashlight around until they can pass most of the light through the glass of water. Where do they see light? Can they draw the path of the light from the flashlight through the water and out again?

For a visualization of how the glass bends light, see the Refraction of Light Demonstration Flash Interactive.

Have students try to shine light through the eyeglass lens onto the paper. Does the light hitting the paper change depending on how the eyeglass is held? Can they find a spot where the light is the most concentrated?

Check for Understanding

After students put away their lab materials, discuss with the class what they learned from the Refraction of Light Demonstration Flash Interactive. Can they predict how the light will bend as it enters or leaves a transparent material?

Darken the room, and ask for a student volunteer to stand close to a piece of white poster board. Direct the class to closely observe the student's face as you turn a flashlight pointed at the poster board on and off. (Note: Do not let any of the light from the flashlight hit the student's face directly.) Ask students to observe the student's face as the flashlight changes, and then draw arrows representing the path of the light from the flashlight to their eyes in their journal.