Using a Laser Learning Cycle to Help Students See the Light

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Introduction and Background

Students of all ages, inspired by science fiction movies and their own imaginations, are fascinated with laser lights. This fascination with lasers can be used to spark your students' interest in a learning cycle designed to investigate light and reflection. Using inexpensive laser penlights, this learning cycle guides students to explore angles of reflection from both plane and curved surfaces. Students will see that the angle of reflection equals the angle of incidence, or the angle of the incoming light, when reflected in a plane mirror. Additional experiences with reflection in concave and convex mirrors allow students to apply the concept of reflection to more complex situations and still see how light reflects at an angle equal to its angle of incidence.

Learning cycles begin with an engagement and exploration phase where students perform experiments to gather data about a specific concept (Marek and Cavallo, 1997). The teacher acts as a facilitator, guiding the students toward the concept and encouraging students to make hypotheses about their observations. Once the students have completed gathering the pertinent data, the teacher begins the concept development phase of the learning cycle, sometimes called the explanation phase or term introduction phase. During this phase students share their data with the class and the teacher leads a discussion, asking questions and, from this discussion, the science concept is developed. New terminology is provided during this phase. Reinforcement and application of the science concept occurs in the third phase, the concept application phase. As the name implies, concept application provides review and expansion of the concept through practical applications, which may include additional experiments, readings, and/or fields trips. This phase is also known as elaboration.

Lasers are used as a light source in this learning cycle since they safely produce strong light beams with small areas of diffusion. These characteristics increase the accuracy of the angle measurements since the light path is narrower than a traditional flashlight and its intensity makes it easier to see. Most department stores sell small laser penlights that range in price from $10-15, making them both easily accessible and affordable. In the classroom, certain safety precautions must be enforced when using a laser light. You should give rules for using the laser light, including not pointing the light directly at the eye, before the start of the investigation. Reinforce to your students that the laser penlight is a laboratory tool, meant only for the purposes written in the laboratory procedures.

It is important to note that this learning cycle aligns to the National Science Education Standards (National Research Council, 1996). The activities described in the previous three paragraphs correspond to Content Standard A, grades 5-8, page 143; Content Standard A, grades 9-12, page 173; and Content Standard B, grades 9-12, page 176: *As a result of activities all students should develop activities necessary to do scientific inquiry and understandings about scientific inquiry*.

Engaging the Exploration

In this learning cycle, the exploration phase begins with students investigating the effect that incoming light angles have on planar light reflection. Before beginning the learning cycle, prepare three pieces of paper.

Paper A: Mirror line one inch from lower edge of paper.
Line A intersecting mirror line at 38 degree angle.

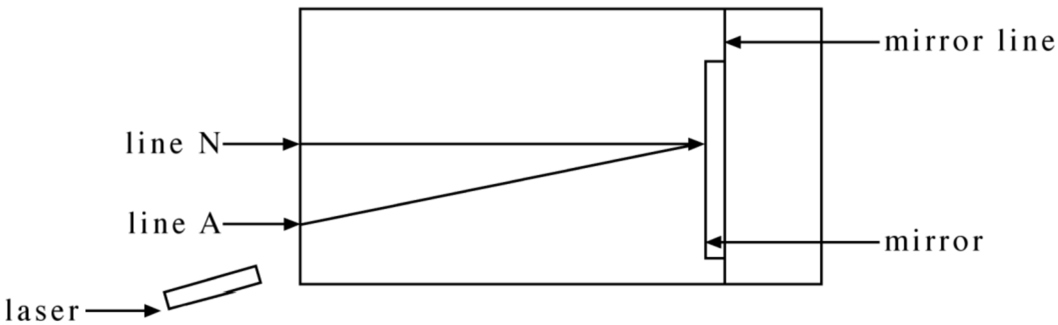
Paper B: Mirror line one inch from lower edge of paper.
Line B intersecting mirror line at 32 degree angle.

Paper C: Mirror line one inch from lower edge of paper.
Line C intersecting mirror line at 28 degree angle.

Each student group will need Papers A, B, and C, a ruler, a protractor, masking tape, a mirror mounted onto a block of wood, a shaker dispenser of cornstarch, and a laser penlight.

Tape Paper A to the table, and then place the mirror on the paper at the mirror line. Using the protractor, mark a line at 90 degrees from the mirror line. This line is called a normal. Turn off the lights in the classroom then shine the laser beam on line A toward the mirror, striking the point where the 90-degree line intersects the mirror line (Figure 1).

Figure 1: Drawing of light path



To better see the laser beam, the students could use two different methods. First, students sprinkle cornstarch over the paper and gently tap the paper. This allows small particles of cornstarch to reflect the laser light and make the reflected line visible to students. It is imperative that teachers instruct students not to inhale the cornstarch. The second method is not as dramatic. Students tilt the laser light pen toward the paper until they see the dot of laser light. By connecting the laser light dot and the vertex (Point O) the students are able to draw the laser beam's path on the paper and, using the protractor, measure the angles on each side of the 90-degree line. Repeat this procedure for Papers B and C. To better see the laser beam, sprinkle talcum powder over the paper and gently tap the paper. Draw the laser beam's path on the paper and, using the protractor, measure the angles on each side of the 90-degree line. Repeat this procedure for Papers B and C.

Note the application of Teaching Standard B, page 32: *Teachers of science guide and facilitate learning* (National Research Council, 1996). Can you identify others?

Developing the Concept

After the class completes the exploration phase, instruct the recorder from each student group to write their angle data on a chart that can be viewed by the entire class (Figure 2).

Figure 2: Class Data Chart

Angle Group	<NOA	<NOB	<NOC	<NOD	<NOE	<NOF
1						
2						
3						
4						
5						
6						
7						
8						
9						
AVG.						

The teacher begins concept development phase (or term introduction) of the learning cycle by asking a student to describe the shape of the mirror that they used in the exploration. Provide them with the term "plane mirror" to describe the flat surface on the mirror if students do not have this terminology. Ask one student to draw on the board what she or he observed when light was shined into the plane mirror. Using this drawing, ask another student to label the incoming or incident light ray, the reflective light ray and the associated incident and reflective angles. Looking at the class data on reflective and incident angles, students may be confused at the variance in results among groups. Use this opportunity to discuss sources of experimental error and how to reduce error. Your students may be ready for a discussion on relevant error, pointing out that some error in data is acceptable and expected, but if outside of certain ranges, the data must be recollected. Of course the data are averaged when values are within acceptable ranges. To conclude the concept development, have the students write in their own words the concept named *reflection: when light strikes a plane mirror, the angle of reflection will equal the angle of incidence.*

Note the application of Physical Science Content Standard B, page 127: *Light travels in a straight line until it strikes an object. Light can be reflected by a mirror, refracted by a lens, or absorbed by an object* (National Research Council, 1996).

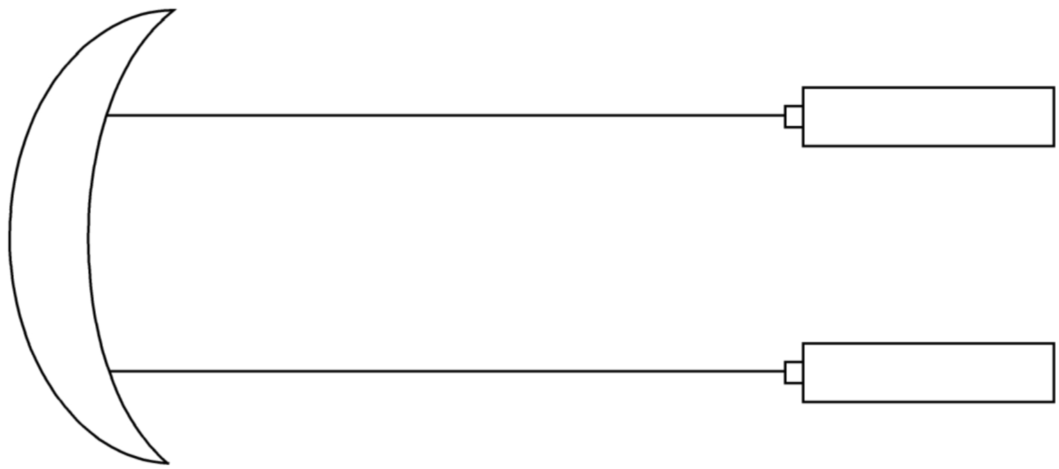
Applying the Concept

With their understanding of this concept, your students are now ready to begin the concept application phase of this learning cycle with an activity titled, "Laser Target Practice." In this exercise, students try to hit a "bull's eye" with the laser light from across the classroom after reflecting the light from three "consecutive" plane mirrors. For this exercise, each student group will need a 20 foot long piece of string, 3 protractors, 3 pieces of paper, 3 mirrors mounted on blocks of wood, one laser penlight and a pencil. Simple rules apply. First, the laser beam must reflect off all three of the mirrors before hitting the target. The mirrors may be placed anywhere on the students' table. All angles, rays and lines must be labeled (i.e., incident, reflective) and all angles must be measured. Finally, and most importantly, students cannot turn on the laser light until the mirrors are in their final places. There is only one shot at the "bull's eye." You can turn this into a competition, where the team whose laser beam comes closest to the "bulls-eye" wins extra points for the team members. Students will be surprised at how close (or far) their predictions are from the light's actual path. To eliminate the risk of misdirected laser light beams in this activity, the teacher needs to attach the laser penlight to a small block of wood with electrical tape. This provides the laser penlight a level surface that is raised from the table. Students are then instructed that the block of wood cannot be lifted from the table. The instructor would also need to check to make sure that the mirrors are perpendicular to the table surface. Finally, before the laser penlight is turned on have all students stand up to put their eyes above the level of the laser light beam.

Expanding the Concept

To expand or elaborate on the concept of reflection, give the students two more mirrors, one that is concave and one that is convex. Ask them to describe the shape of the two mirrors, then to predict it what would happen if they shined two laser lights onto the concave mirror, one on the upper third of the mirror and the other on the lower third. Distribute additional laser penlights, then direct students to position the lasers as shown in Figure 3 to test their predictions.

Figure 3: Set-up for concave mirror experiment



Draw the path of the two lights as they hit the mirror. Elaborate by introducing the term "focal point," describing it as the point where the two light beams cross. Try this with the convex mirror as well. Concave mirrors will exhibit a focal point between the two light beams, on the curved side of the mirror. Convex mirrors will not produce a focal point, instead scattering the two light beams outward, away from the curved side of the mirror. Tell the students to hold the concave mirror at arms' length then slowly bring it close to their faces. As they do this, they will observe that their images are large and inverted when at arms' length, but become more normal sized and right side up when closer to their faces. The point of image inversion is the mirror's focal point. Your students should be able to think of several applications for a concave mirror, such as satellite dishes or telescopes, where focal points are used for concentration of light and energy. Ask your students to hold the convex mirror to their faces and describe the images they see. Images will be similar to a plane mirror, but smaller. Most students will recognize the reflection as the ones they have seen in rearview mirrors or store surveillance mirrors.

Assessing with Authenticity

For evaluation, and as an authentic assessment of the concept named reflection, give your students the assignment of constructing a periscope. Encourage creativity by giving them the freedom to use any type of materials. During an initial brainstorming activity the entire class could identify possible materials that could be used for periscope construction. Pairs of students then would choose the materials needed for construction and begin the initial design work. Students can do the construction of the periscopes as an at home project or bring the materials to school to use in the classroom. The design work for the periscopes reinforces their knowledge of incident and reflective angles, and allows them to apply their ideas in a creative process. The hands on construction builds motor skills and self-confidence. Evaluate the finished periscopes on a practical level (does it work?) and on a creative level (how did the student accomplish his or her goal?).

Note the application of Assessment Standard A, page 78: *Assessments must be consistent with the decisions they are designed to inform,* and Assessment Standard C, page 83: *Assessment tasks are authentic* (National Research Council, 1996).

Concluding or Continuing?

At the completion of this learning cycle, students will be familiar with the concept named reflection, relating incident light rays to reflective light rays on different surface shapes, and testing their knowledge with construction of a periscope. This is not only an engaging way to learn about reflection, it can be a stepping stone to other learning cycles on the behavior of light. For example, refraction of light, rather than reflection, occurs when light passes through a liquid. Chemical laboratories use refraction as a measure of a liquid's composition. A study of biological optics would explain how the lens of the eye receives and focuses incoming light.

Light behavior can also be related to sound wave behavior, correlating the reflection of light waves to the “bouncing” of sound waves. Auditorium design is an excellent model for the law of reflection as it applies to sound waves. An extension activity could be to map the action of sound waves in the school auditorium, showing optimum seats for receiving sound. Whatever the next course of study for your students, this learning cycle on reflection will provide a concrete background for students. With many different applications available for the law of reflection, this is only the first step in your class’s discovery of light behavior.

References

National Research Council (1996) *National Science Education Standards.* (Washington, D.C.: National Academy Press).

Marek, E.A. and Cavallo, A.M.L. (1997) *The Learning Cycle: Elementary School Science and Beyond*. (Rev. ed.) (Portsmouth, N.H: Heinemann).