January 2017

Dumpster Optics

BENDING LIGHT – REFLECTION

WHAT KINDS OF SURFACES REFLECT LIGHT? CAN YOU FIND A RULE TO PREDICT THE PATH OF REFLECTED LIGHT?
In this lesson you will test a number of different objects to see if they reflect light. Then you will use a protractor to find a rule for reflection.

MATERIALS

Activity 1 (Warm Up):

- None required

Activities 2 and 3 – What Color is a Tennis Ball? Does a Tennis Ball Reflect Light?

- Small rough textured white ball like a tennis ball or small plastic foam ball
- Flashlight
- Piece of thin red balloon (or other source of red light like a red LED)

Activity 4 – What Reflects Light?

- Assortment of objects such as finished and unfinished wood samples, plastic or metal spoons, paper, cardboard, etc

Activity 5 – Reflection Rule

- Printed protractors
- Small mirrors that can be made to stand vertical. CD jewel case lined with black paper will work.

OPTIONAL ACTIVITIES: There are lots of related activities and we have included a few. Materials are described in the instructions below.

- Who Can See the Teddy? (a good test of understanding of the law of reflection)
- Where Does the Image Form?
- Laser Target Shoot
- Images with Two Mirrors
- Giant Kaleidoscope

Where to find materials:

The first activity use both white (flashlight) and red sources of light. Red LEDs such as key chain or finger lights work well. You can also produce red light by stretching a thin red balloon over the end of a flashlight. The light will be very dim, however, so the room lights will need to be off. If that is a problem, omit the red light portion of the activity.

While mirrors are very common, it can be difficult to find ones suitable for these activities. For young children it is preferable to avoid glass, but plastic mirrors can be expensive especially purchased from science supply houses. If you have small household mirrors you can use wooden blocks or building toys to make them stand

vertically. For most of these activities a CD or DVD plastic jewel case works well. Open it slightly so it stands vertically on the table. Remove the label and insert a piece of black paper inside to enhance reflection and prevent the laser beam from passing through the plastic. "Who can see the teddy?" uses a long mirror like those hung on the back of a door. This activity is based on a research article on understanding reflection and we find it is a good way to test students' abilities to predict the path of reflected light.

VOCABULARY:

- Reflection
- Illuminate
- Shiny
- Dull
- Rough
- Ray
- Parallel
- Perpendicular
- Reflective angle
- Incident angle
- LASER SAFETY

TEACHER NOTES:

LASER SAFETY: Review laser safety before handing out any materials. Laser pointers are generally low power and safe (when bought from a reputable source). As with any bright light there is always a danger if someone tries to stare into the beam. Remind students that it is not safe to stare at ANY bright lights because they might damage the delicate sensors in their eyes.

Either provide the students with rules or have them come up with rules such as no high sticking (waving the laser around) and make sure they understand the consequences, for example, they will lose the privilege of using a laser pointer. Other important rules are

- Leave the laser on the table
- Put a book or other block at the far end of the table to keep the beam from entering other students' space
- Stand when working. Do not bend down when the laser is on so that your eye is at laser level

Many students (and adults) believe that only mirrors reflect light. The first activities are designed to show students that "if you can see it, it's reflecting light". The "Reflection Rule (the reflection angle is equal to the incident angle), is easy to deduce from a few careful measurements. The angles are always measured from a line drawn perpendicular to the surface (see detailed notes below) so this activity is a chance to review terms such as perpendicular and parallel as well as to practice protractor use.

Throughout this lesson students are expected to discuss their findings with teammates and with the whole class.

ACTIVITY 1 – WARM UP (THINKING ABOUT LIGHT)

This activity asks students to think about where light comes from in their world. You can choose an object and hold it up, asking "Where does the light come from that illuminates this object?" (You will probably need to define the word "illuminate".)

Light sources mentioned might include the sun, overhead lights, computer screens, smart board, desk lamps, outside hall lights, LED power indicators – anything that emits light. The actual path taken from the source to the object may be complex and involve multiple reflections but students aren't expected to know that. Some students will suggest that a reflective object (for example the face of a clock) is providing light and the concept of reflection can be discussed at that point. Students sometimes will suggest that the electrical outlets or rooftop solar panels are providing light. This is an opportunity to discuss the difference between the power sources for lights and the light sources themselves.

ACTIVITY 2 – WHAT COLOR IS A TENNIS BALL?

If you can't find white tennis balls you can use plastic foam balls or any white ball with a rough texture. You can also use a square of rough-textured white fabric (like felt).

Turn off the room lights. Before shining the flashlight on the tennis ball, ask students to predict what color the ball will be and why they think it will appear that color. The ball appears white because it reflects all wavelengths (colors), that is, the flashlight produces the entire visible spectrum and all these colors are reflected by the ball's surface, making it appear white.

Repeat the experiment but with red light rather than white light. You can produce white light by covering the end of the flashlight with a thin red balloon or using a red LED. If the light is dim you'll need to have the room as dark as possible. Shine the red light on the tennis ball. The tennis ball appears red because it is now only reflecting red wavelengths. The surface is "capable" of reflecting all the colors, but only red is available so that is the color reflected and perceived.

ACTIVITY 3 – DOES A TENNIS BALL REFLECT LIGHT?

Some students will not be convinced that a rough surface can reflect light. Since students generally accept that mirrors reflect light, you can demonstrate what reflection with a mirror. Hold the mirror up and use it to reflect light from a flashlight onto a wall. Ask students to trace the path of the light from the flashlight to the bright spot on the wall. Can this method be used to show that a tennis ball reflects light?

The "reflection test" shows reflection from a surface explicitly –light goes from the flashlight to the ball and then reflects to a surface (desk or table). It's best to hold the light pointing somewhat upward (as shown on Slide #5) and then move the ball into the beam to reflect the light back onto the table underneath. This will emphasize the

reflected light on the table since it appears only when the ball is put in place. Again ask students to trace the light from the flashlight to the ball to the table.

Students should conclude that the rough-surfaced tennis ball does reflect light and they have proved this by seeing the light on the table. Emphasize that the reason they can see the tennis ball is because it reflects light into their eyes.

ACTIVITY 4 – WHAT REFLECTS LIGHT?

Guiding questions for this activity are

- Do all these objects (that you have before you) reflect light? (Yes!)
- How can you find out? (Do the "reflection test".)
- How can you tell if an object reflects light? (You can see it!)

We review the vocabulary terms "shiny", "dull" and "rough" at this point and ask students to provide examples. Students then sort a variety of items by surface type. Before testing each object students first predict and record on the observation sheet whether or not they expect it to reflect light. The test is performed as in Activity 3: the object is moved into the flashlight beam and the reflection is observed on the desk beneath.

NOTE: Make sure the objects are large enough to produce sufficient reflection to be observed. For example, spaghetti reflects light but the light reflected from a single strand will be difficult to see. On the other hand, reflected light from a bunch of spaghetti will be bright enough to be visible. Good objects to use include paper plates, spoons, pieces of paper (various colors, textures), cardboard, cloth and books and other items from around the classroom. Students can also test their own hands, arms – one child tested his head and his partner confirmed that yes, his head reflected light! This result led students to be careful to not include their own hands in the test as they moved objects into the light beam.

Ask students if any objects did not reflect light, then have them repeat the reflection test more carefully to show that they in fact do reflect light. Ask students how the reflection of light is important for vision.

ACTIVITY 5 – A REFLECTION RULE (LAW OF REFLECTION)

Show an example of reflection from the mirror first, using a laser pointer. Review math to make sure all students understand how to use a protractor ands measure angles. Remind the students that it is important to be precise for the measurements to be accurate (the mirror must be vertical and on the designated line).

Classroom management: Review laser safety before handing out any materials. Either provide the students with rules or have them come up with rules such as keep lasers flat on the table, only turn laser on for the duration of the measurement, be aware of other students, make sure your beam doesn't go beyond the edge of your work space (block with a book or other object) and no high sticking with the laser beam. Make sure

they understand the consequences of breaking these rules, for example, they will lose the privilege of using a laser pointer.

Be sure to have the students make a prediction before measuring the reflected angle. Have the students record and discuss their results and see if they agree. If not, discuss possible reasons for the discrepancy and repeat the measurement if necessary.
After several angles have been measured, students should discuss their results and see if they can make up a rule before giving them the "law of reflection." (Angle of reflection equals angle of incidence.)

The slide show includes animation illustrating the law of reflection. How is the animation different from actual light? (It's very, very slow!) The following slides illustrate the difference between reflection from a mirror ("specular" reflection) and from a rough surface ("diffuse"). For the rough surface, it is helpful to isolate individual rays so they can see how they hit the "bumps" and reflect according to the law of reflection.

Conclusion: Rough objects, like the tennis ball we began the lesson with, reflect light but in a disorganized way.

OPTIONAL ACTIVITY – WHO CAN SEE THE TEDDY? (APPLICATION OF REFLECTION LAW):
If time permits, this is a good way to test understanding of the law of reflection. Be sure to check the placement of the mirror for both parts of this activity before having students participate. It helps to mark student and object positions on the floor with tape and to mark the two positions of the mirror as well. An inexpensive door or wall mirror works well; it can be placed on the chalk or marker tray in the classroom. The mirror can be covered with a piece of cloth while students are making their predictions.

In the first case, both students should clearly see the object (teddy). Only the student on the right can see it in the second case. Be sure students make a prediction before uncovering the mirror and encourage them to use the law of reflection to do so. Try other positions of the students and teddy as well.

OPTIONAL ACTIVITY – WHERE IS THE IMAGE?
Research shows that many students think an image forms on the surface of a mirror. This experiment uses a small piece of glass or plastic that allows both the real object (a small light bulb) and its image to be seen at the same time. A CD jewel case will work as well as a piece of glass, and is not breakable. Empty the case and open it slightly so it stands up vertically and use one of the sides as the reflecting surface.

For this experiment to work, the room lights on the viewing side may be on, but the lights on the other side of the glass or plastic should be off. The effect is the same one you notice looking out of your house windows at night: you can see the outside but you also see your reflection in the glass.

The light can be an LED or it can be any type of small bulb. Mark the position of the bulb on the table in front of the mirror. The student should reach over the glass and touch the image on the other side. A partner can then mark the image location, where the observing student is touching. Ask students to measure the distance from the mirror to the bulb and from the mirror to the image. The image should be the same distance behind the mirror as the light is in front of the mirror.

OPTIONAL ACTIVITY – LASER TARGET SHOOT

This is a fun way to reinforce the law of reflection and to practice measurement with a protractor. You don't have to use all of these materials, just use what you need.

- 1 laser pointer (may need to place on a block to make beam high enough so it doesn't graze the table). The laser should be taped down so it cannot move. Do not allow it to be turned on until the mirrors are in place.
- 3 mirrors (one for the first round, two for the second round, all three for the third round). Use blocks to keep the mirrors upright, or use CD jewel cases for mirrors; put black paper behind the side used as a mirror so light does not pass through.
- Printed protractor(s)
- String
- Meter stick
- Ruler
- Target (also taped to table so it cannot be moved) Tape the target to a block so it stands upright.

You can limit the time students have to take each target "shot" if you wish. We have allowed as many attempts as students can make in a given amount of time (say, 10 minutes) with the score being the average of all attempts. If you do this activity with a large group it helps to have a couple of observers to make sure students aren't turning the lasers on to make the alignment easier.

OPTIONAL ACTIVITY – IMAGES IN TWO MIRRORS

This activity can be used to help explain how a kaleidoscope works. In an early version this was a college physics experiment where the number of images was plotted versus angle to show a function that had steps rather than a smooth curve.

You can use a CD jewel cases for the mirrors, although the images are more difficult to see than with real mirrors. Tape black paper to the back surfaces to enhance reflection. To add some mathematics, ask students to record the angles where two, four and six full images appear (that is, only count the images in the mirrors, not the one located where the mirrors meet at the center). Ask students to derive an equation to predict the angle, using their data. The number of images is 360 degrees divided by the angle between the mirrors.

OPTIONAL ACTIVITY – GIANT KALEIDOSCOPE

Students enjoy making kaleidoscopes but we have had difficulty finding good inexpensive mirrors for small, individual kaleidoscopes. However, large mirrors designed to hang on the backs of doors or on walls can be found inexpensively at

surplus and big box stores. Tape three mirrors together securely by the long edges to create a triangle of mirrors as shown in Slide #19. We use wide packing or duck (duct) tape. If you want you can decorate the back sides of the mirrors with stickers, stick-on jewels or painting. A favorite activity is to have students look at each other, one at each end of the kaleidoscope. Carefully stored, this will last for years.

VIDEOS and REFERENCES

Comparison of Central Appalachian In-service Elementary and Middle School Teachers' Understanding of Selected Light and Force and Motion Concepts. This paper inspired some of the activities in this lesson
http://files.eric.ed.gov/fulltext/EJ851875.pdf

Video showing the "Hit the Target" game
https://www.youtube.com/watch?v=onGF3v6fXtI