Sensors

Target Practice

Grade Level: 5th grade

Academic Content Areas: Science, Technology, Engineering, and Mathematics

Topics: Physical Sciences; Scientific Inquiry; Measurement; and Design

Recommended area of co-teaching for an AFRL Engineer or Scientist

Main Problem / Essential Question

Why does light act as it does when it reflects from or passes through different media?

Summary

In this activity students investigate and research the reflection and refraction of light. The speed of light will be altered by creating multiple scenarios where the light must pass through a variety of media. Through the use of a variety of objects students will learn about reflection and refraction of light.

Big Ideas / Focus

Light travels in a straight line from its source, but it bends as it passes from a medium of one density to a medium of differing density. Light bends because it travels at different speeds through mediums of differing densities. Light, as it moves through air, travels 186,000 miles per second. However, the denser the material that light is traveling through, the slower the speed will be. There is no direct relationship between density and speed of light in the material. Often, light is indeed slower in more dense materials, but that is not always the case. Speed of light is instead dependent upon the refractive index of the material, usually denoted “n”. Light passes a lot slower through water, for example. The refraction of light can be seen by using a prism or a spectrometer. The white light is separated into all colors of the rainbow. Mirages are also caused by refraction of light.

Reflection: If an object does not emit its own light, it must reflect light in order to be seen. Reflection involves two rays - an incoming or incident ray and an outgoing or reflected ray. If we draw a line perpendicular to a flat surface, this line is said to be the normal. A ray of light that hits this surface is called the incident ray. This ray of light hits the surface and bounces off (reflected ray). The angle between the incident ray and the normal will be identical in measurement as the angle between the reflected ray and the normal. All reflected light obeys this relationship, called the Law of Reflection, namely-, that the angle of incidence equals the angle of reflection. Reflection from a smooth, mirror-like surface is called specular. The angles of incidence and reflection are the same for all of the light hitting the surface. If the surface is rough, the rays of light are reflected in many directions, because the direction of the surface normal changes from place to place on the surface. The angles of incidence and reflection are still equal at each specific location but are not constant over the entire surface. As a result, the

outgoing rays are scattered. This is diffuse reflection. This diffuse reflection is how we can see illuminated objects.

Prerequisite Knowledge

Students should know or be taught how to use a protractor.

Students should understand and be able to apply a perpendicular (normal) line.

Standards Connections

Content Area: Science

Physical Sciences Standard

Students demonstrate an understanding of the composition of physical systems and the concepts and principles that describe and predict physical interactions and events in the natural world. This includes demonstrating an understanding of the structure and properties of matter, the properties of materials and objects, chemical reactions and the conservation of matter. In addition, it includes understanding the nature, transfer and conservation of energy; motion and the forces affecting motion; and the nature of waves and interactions of matter and energy. Students demonstrate an understanding of the historical perspectives, scientific approaches and emerging scientific issues associated with the physical sciences.

Grade 5 – Benchmark F: Describe the properties of light and sound energy.	5. Explore and summarize observations of the transmission, bending (refraction) and reflection of light.

Scientific Inquiry Standard

Students develop scientific habits of mind as they use the processes of scientific inquiry to ask valid questions and to gather and analyze information. They understand how to develop hypotheses and make predictions. They are able to reflect on scientific practices as they develop plans of action to create and evaluate a variety of conclusions. Students are also able to demonstrate the ability to communicate their findings to others.

Grade 5 – Benchmark A: Use appropriate instruments safely to observe, measure, and collect data when conducting a scientific investigation.	1. Select and safely use the appropriate tools to collect data when conducting investigations and communicating findings to others.
Grade 5 – Benchmark B: Organize and evaluate observations, measurements and other data to formulate inferences and conclusions.	2. Evaluate observations and measurements made by other people and identify reasons for any discrepancies. 3. Use evidence and observations to explain and communicate the results of investigations.
Grade 5 – Benchmark C: develop, design and safely conduct scientific investigations and communicate the results.	4. Identify one or two variables in a simple experiment. 5. Identify potential hazards and/or precautions involved in an investigation. 6. Explain why results of an experiment are sometimes different (e.g., because of unexpected differences in what is being investigated, unrealized differences in the methods used or in the circumstances in which the investigation was carried out, and because of errors in observations).

Content Area: Mathematics

Measurement Standard

Students estimate and measure to a required degree of accuracy and precision by selecting and using appropriate units, tools and technologies.

Grade 5 – Benchmark D: Select a tool and measure accurately to a specified precision.	7. Use benchmark angles (e.g., 45, 90, 120 degrees) to estimate the measure of angles, and use a tool to measure and draw angles.

Content Area: Technology

Design Standard

Grade 5 – Benchmark A: Design and apply a design process to solve a problem.	Scientific Ways of Knowing Nature of Science 1. Summarize how conclusions and ideas change as new knowledge is gained. 2. Develop prescriptions, explanations and models using evidence to defend/support findings. 3. Explain why an experiment must be repeated by different people or at different times and places and yield consistent results before the results are accepted. 4. Identify how scientists use different kinds of ongoing investigations depending on the questions they are trying to answer (e.g., observations of things or events in nature, data collection, and controlled experiments). Ethical Practices 5. Keep records of investigations and observations that are understandable weeks or months later. Science and Society 6. Identify a variety of scientific and technological work that people of all ages, backgrounds and groups perform.

Preparation for activity

Place targets around the room, making sure they are no higher than 4-ft.

Critical Vocabulary

Angle of Incidence – incoming angle; the angle at which a ray strikes a surface or barrier

Angle of Refraction – outgoing angle; the angle at which a ray leaves a surface or barrier; this angle is caused by a change in the speed of the light, thus causing the ray to bend

Medium – substances that allow light to travel through them

Reflection – the backward change in direction of light when it strikes a material

Refraction – the forward change in direction, or bending, of light when it passes from one material into another

Wavelength - the distance between two points on adjacent waves that have the same phase

Timeframe

Day	Time Allotment	Activities
1	45 min.	Light and Reflection
2	45 min.	Measuring Angles of Reflection
3	45 min.	Measuring Multiple Angles of Reflection
4	45 min.	Refraction Basics
5	45 min.	Calculating Refraction
6	45 min.	Internal Reflection

Materials & Equipment

- square clear glass containers (3 per group)
- milk
- water
- LASER tank / 5-gal aquarium
- small mirrors (3 per group)
- flashlights (1 per group)
- 1 roll of aluminum foil
- green LASER pointers (1 per group)
- red LASER pointers (1 per group)
- protractors (1 per group)
- target paper (1 per group)

Safety & Disposal

Use extreme caution when using the LASER pointers. NEVER aim them at another person, especially near the face or eyes, and no careless handling (waving it around without regard to where the beam is going). One of the cardinal rules of LASER use is always to know where the beam is going, and to make sure it only hits appropriate targets.

Use caution when handling the mirrors, they are breakable and sharp when broken.

Pre-Activity Discussion

 Open a discussion with students about LASERS in our world. Ask them for examples of where they have seen or heard of LASERs being used.

Show the LabTV video entitled LASER Dazzlers. This video shows a LASER that literally stops or slows traffic by flashing a "safe" amount of LASER light into the eyes of the driver causing the afterimage one would get from looking into the sun or a flash from a camera. Scientists are still experimenting with the color, power and timing of flashes to make the LASER a safe -- as well as effective -- universal stop sign.

Teacher Instructions

Day 1

Light and Reflection

A. You should dim or turn off the lights for this experiment to allow student to see the reflections better. ***Caution students to avoid moving around the room and if they must move, to do so slowly and carefully.***

B. Each group is to have a flashlight, red LASER, large piece of black construction paper, and 2 pieces of foil approximately 1-ft by 1-ft to be used during the experiment.

C. Students will first shine the flashlight onto a sheet of white paper (student direction sheet or their science notebook will work). Students are to record their observations and their response to "Why can you see the paper when the light is shined on it and not when it is in total darkness?" in their science notebooks. Their responses should include the fact that what we see is the reflection of light and without light we would not see anything.

D. Students should now set up one square of aluminum foil flat on the tabletop such that it will reflect onto a piece of black construction paper positioned perpendicular to the foil (see photo below). *If at all possible, tape the black construction paper to a wall or prop it up so no students can be behind it, making sure it is no higher that the tabletop; this is for safety when the red LASER is used.* Students should use the flashlight to reflect the light energy off the flat, smooth, one-foot square of foil onto the black piece of construction paper. You may have to tell the students during the experiment that they need to adjust the angle of the incoming beam such that the reflection occurs at the appropriate angle to line up with the black construction paper using the foil (let them try to figure this out first). Students are to record their observations and their response to "Does the light reflect? If so what does the reflection look like?" Their responses should state that the light does reflect and that the reflection looks like a circle with fuzzy edges. Students are also asked to include a diagram of the incoming light and the reflected light. Their diagrams should illustrate the light traveling in a straight line from the flashlight to the foil and from the foil to the black construction paper. It may be necessary to remind students to do this three times or more because one trial is never an experiment.

Smooth Surface

Rough Surface

E. Students should take the other piece of one-foot square foil and crumble it into a loose ball, then carefully unroll it again without smoothing out all the jagged edges. Students are to repeat the process outlined in Step D, this time with the wrinkled, jagged square of foil. Additionally, students are to record their response to, "Are there differences in the reflection coming from the smooth foil as compared to the reflection coming from the wrinkled foil?" Their responses and diagrams should include information leading them toward the discovery and understanding of specular and diffuse reflection (refer to "Background Information" section for details). They should see a clear (specular) reflection from the smooth foil and a scattered (diffuse) reflection from the wrinkled foil.

F. This process will be repeated with the red LASER, using both the smooth and the wrinkled foil. Students are then asked to respond to the challenge questions posed at the beginning of the experiment: "How does light travel?" Their response should indicate that light travels in straight lines. "How does light interact with smooth objects?" Their response should indicate that when light interacts with smooth objects the reflection is clear. "How does light interact with rough objects?" Their response should indicate that when light interacts with rough objects the reflection is diffuse or fuzzy.

G. A whole class discussion following this experiment on specular and diffuse reflection is recommended (refer to "Post Activity Discussion" Section).

Day 2

Measuring Angles of Reflection

A. Place targets around the room, making certain to ***position the targets no higher than 4-ft*** to keep the LASER light low enough that it does not get near students' eyes.

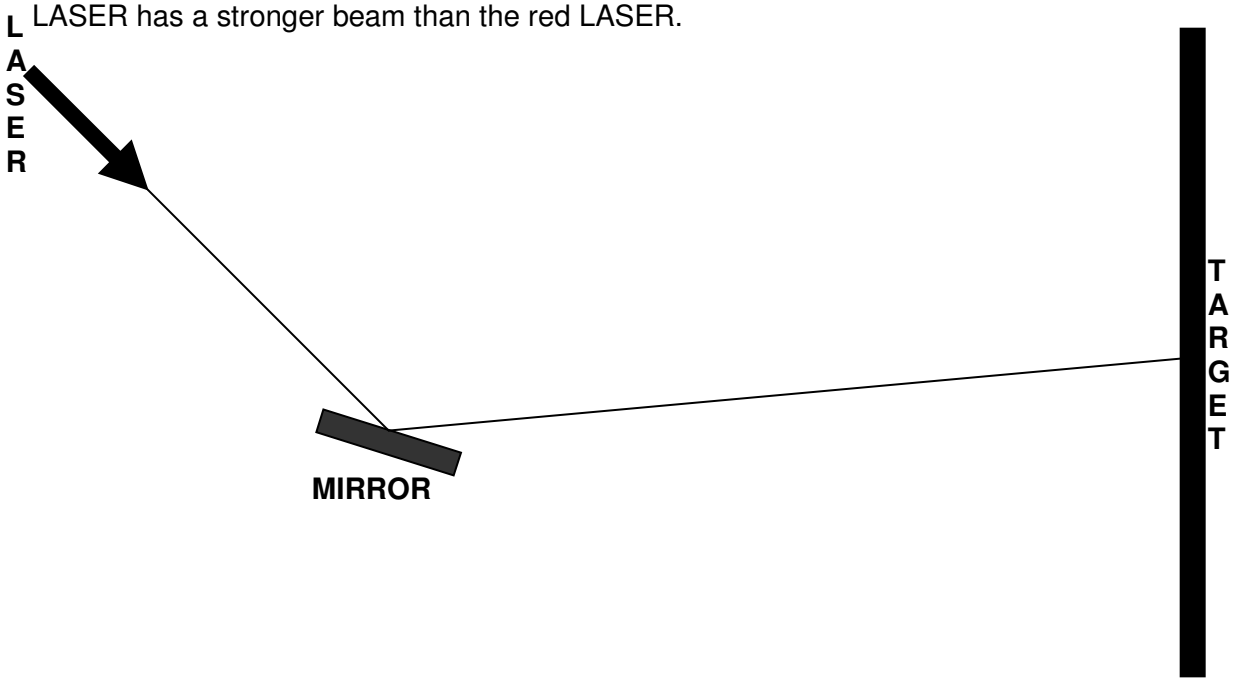
B. Each group is to have 3 plane flat mirrors, a protractor, red LASER and green LASER. Students will use the mirrors to reflect the LASER beam onto the target and measure the incident and reflection angles using a protractor.

C. Discuss with students how to measure angles with a protractor. Explain the use of the line perpendicular to the base of the protractor and the measurements from that line.

D. One group member should hold a plane flat mirror at waist height. **WATCH STUDENTS TO BE CERTAIN THEY HOLD THE MIRRORS ONLY WAIST HIGH.** Another group member should point the LASER at the mirror and the group member holding the mirror will have to angle it such that the light energy from the LASER is reflecting off the mirror toward the target. Students will have to angle both the mirror and LASER until the light hits the target paper (see diagram below). Once a group has hit the bull's eye, a third group member needs to measure the incoming (incident) and outgoing (reflecting) angles with the protractor. These angles should be measured from a normal line along the base of the protractor. If necessary, students may have to use chalk dust or water mist to view the LASER beam. Students are to record these angles and draw a diagram in their science notebooks. The angles and diagrams should illustrate the incident and reflecting angles being equal.

E. Students should now repeat Step #1, this time using the green LASER. They should observe the differences in the light between the red LASER and the green LASER and

record their observations in their science notebooks. They should notice that the green LASER has a stronger beam than the red LASER.



F. Students should now repeat Step #1 using first the red LASER then the green LASER, this time adding an additional mirror into the path of the LASER beam. They should not allow the paths of light to cross.

G. Students should repeat Step #1 again, this time adding a third mirror into the path of only the green LASER beam. They should again be careful to not allow the paths of light to cross.

H. Have students analyze their diagrams by comparing the incoming and outgoing angles in each. They should draw the conclusion based on their measurements that the incoming angle is the same as the outgoing angle (when each is measured from the line normal to the base of the protractor).

I. Have students respond to the following challenge questions in their science notebooks: "How does light reflect?" Their response should indicate that light reflects in an angle that is equal to the incoming angle. "How does the incoming angle of light affect the outgoing angle of light?" Their response should indicate that the incoming angle of light will determine the outgoing angle of light; if you increase the incoming angle, the outgoing angle will increase and if you decrease the incoming angle, the outgoing angle will decrease.

Day 3

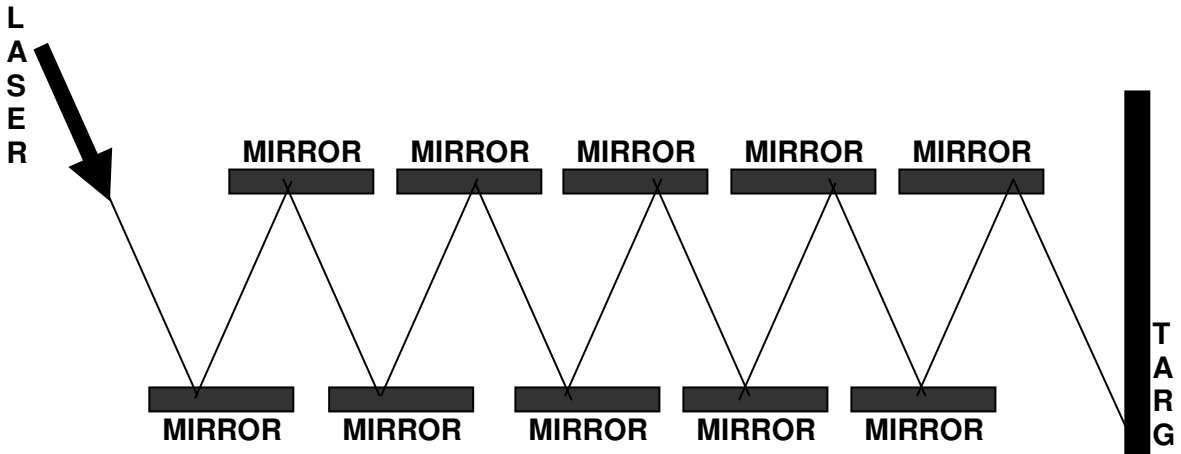
Measuring Multiple Angles of Reflection

A. Set the LASER in position and tape it down.

B. Place one target across the room, making certain to ***position it no higher than 4-ft*** to keep the LASER light low enough that it does not get near students' eyes

C. Each group should have 1 mirror and 1 protractor.

D. Each small group should reflect the beam of the one green LASER (for a total of 10 reflections) to hit the one target positioned on the opposite side of the room (see diagram below). Make sure the paths of light do not cross. A group member that is not holding the mirror should measure the incoming and outgoing angles of light energy from the mirror. Students should draw a diagram and record all angle measurements from all small groups in their science notebooks.



E. Have students respond to the following challenge questions in their science notebooks. If necessary, look for the answers in your textbook
   1. What is an angle of incidence?
   2. What is an angle of reflection?
   3. What is the law of reflection?

Day 4

Refraction Basics

A. Place targets around the room, making certain to ***position the targets such that the LASERs will strike them when placed on the tabletop and elevated by only one textbook***.

B. Each group will have a square glass container, green LASER, protractor, and access to water and milk.

C. Have students place their green LASER on the tabletop and elevate it, perhaps with a textbook, so its beam strikes the bull's eye of the target paper positioned on the wall. They should then slide a protractor under the LASER such that the protractor indicates the LASER beam is at a 75° angle. Remember this angle should be measured from the normal line which is the line perpendicular to the base of the protractor. Suggest to students that they tape the LASER to the tabletop at this point to keep it at the desired angle. Students should then place the empty square glass container directly between the target and the LASER, making certain the LASER beam passes through the empty glass container to strike the target. Students should move the protractor such that they can measure the angle of the light beam that is leaving the square container. They are to

observe the target paper and record their observations in their science notebooks. Have students draw a diagram in their science notebooks that illustrates the path the LASER beam is traveling. They should notice that the beam is refracted just due to traveling through the glass sides of the container. Their diagrams should illustrate the bending of the straight line path of light due to its interaction with the glass.

D. Have students repeat Step #1, this time filling their square glass container with water. They should record their observations and draw diagrams in their science notebooks.

E. Have students repeat Step #1, this time filling the square glass container with milk. They should record their observations and draw diagrams in their science notebooks.

F. Based on their diagrams, students should describe how what the light is traveling through (medium) affects the path of the light. Their responses should be recorded in their science notebooks.

G. Have students respond to the following challenge questions in their science notebooks. If necessary, they should look for the answers in their textbooks but they should respond in their own words.

1. What is a medium?
2. What is refraction?
3. What causes refraction?

Day 5

Calculating Refraction

A. Set up multiple stations around the room with the green LASERs positioned on the tabletop so their beams strike the target paper positioned on the wall with the square glass container directly between the target and the LASER. Tape the LASERs securely to the tabletops. Pour a different liquid into each square glass container and tape a label next to it so students will know the contents. You should have water, cooking oil (multiple varieties provide multiple viscosities), honey, sugar water, cornstarch & water solution, etc.

B. Each group will have a string and a protractor. Have the students run their string directly above the ray of light from the LASER and follow the beam to the glass container. They should measure this line with their protractor and record it in their science notebooks.

C. Remind students of the previous activity: how the different medium (water) slowed the light down which made it bend and exit the container of water (medium) along a different line than it entered. Now have students run their string directly above the ray of light coming from the glass container and follow it to the target. They should measure this line with their protractor and record it in their science notebooks.

D. Have students create drawings of the lines indicated by their strings with the appropriate angles indicated by their protractors in their science notebooks.

E. Repeat this process at each of the stations set up around the room.

F. Respond to the following challenge questions in your science notebook. If necessary, look for the answers in your textbook but respond in your own words.

1. What is the difference between refraction and reflection?
2. What causes refraction?
3. How can you calculate an angle of refraction (Snell's Law)?

Day 6

Internal Reflection

A. This lesson can be done as a whole group if supplies are limited. The materials needed for each group are: a five- gallon aquarium filled with water, a green LASER, and 5 colored sticker dots. Place one sticker dot on the side wall of each aquarium.

B. Have students shine their green LASER through the tank of water (medium) so that it strikes the center of the one target dot you placed on the side wall of the tank. *Watch that they do not shine the LASER light at an angle perpendicular to the wall of the tank because then they will not get multiple reflections.*

C. Once the students have hit the first target, have them hold their LASER in the same position and look at the opposite side of the tank (the side where the LASER is being held) for the dot showing the beam striking the tank wall. When they locate this, the students are to place a sticker target dot at that location.

D. Have students continue to add more target sticker dots to both sides of the tank in this same manner, up to a maximum of 5 target dots. The angle in which the LASER beam enters the tank may need to be tweaked in order to improve the amount of targets that can be hit.

E. In their science notebooks, have students draw an overhead view of the LASER beam reflecting back and forth such that it strikes the first 3 targets. Also have them respond to: "Is all of the light reflecting or is some of it refracting? Explain how you can tell." Their response should include that some of the light is reflecting and some is refracting because they can see some on the wall (if the target did not block it) and some reflects back into the tank of water.

F. In their science notebooks, have students draw an overhead view of the LASER beam reflecting back and forth such that it strikes all 5 targets. Also have them respond to: "Can light reflect and refract at the same time? Explain how you can tell." Their response should include yes, light can reflect and refract at the same time and we know this because we can observe it happening in the tank of water.

G. In their science notebooks, have students identify some real world examples of light being reflected and/or refracted. Some examples include standing water and two-way mirrors.

Background Information

Light is a form of energy. It is also part of the electromagnetic spectrum, like microwaves or x-rays. Light travels very fast, and can be described as a wave, although light waves are different from sound waves, or waves in water. Light can also be thought of as tiny particles called photons. Both descriptions are necessary for a complete understanding of the behavior of light.

Electromagnetic waves, like water waves, experience reflection, refraction, and diffraction. By understanding and controlling these behaviors, we can design and make many useful and interesting products: cell phones, microwave ovens, LASERs, and many others. The details in these lessons emphasize the importance of understanding waves.

Reflection: If an object does not emit its own light, it must reflect light in order to be seen.

Reflection involves two rays - an incoming or incident ray and an outgoing or reflected ray. If we draw a line perpendicular to a flat surface, this line is said to be the normal. A ray of light that hits this surface is called the incident ray. This ray of light hits the surface and bounces off (reflected ray). The angle between the incident ray and the normal will be identical in measurement as the angle between the reflected ray and the normal. All reflected light obeys this relationship, called the **Law of Reflection, namely, that the angle of incidence equals the angle of reflection.**

Reflection from a smooth, mirror-like surface is called **specular**. The angles of incidence and reflection are the same for all of the light hitting the surface. If the surface is rough, the rays of light are reflected in many directions, because the direction of the surface normal changes from place to place on the surface. The angles of incidence and reflection are still equal at each specific location but are not constant over the entire surface. As a result, the outgoing rays are scattered. This is **diffuse reflection**. This diffuse reflection is how we can see illuminated objects.

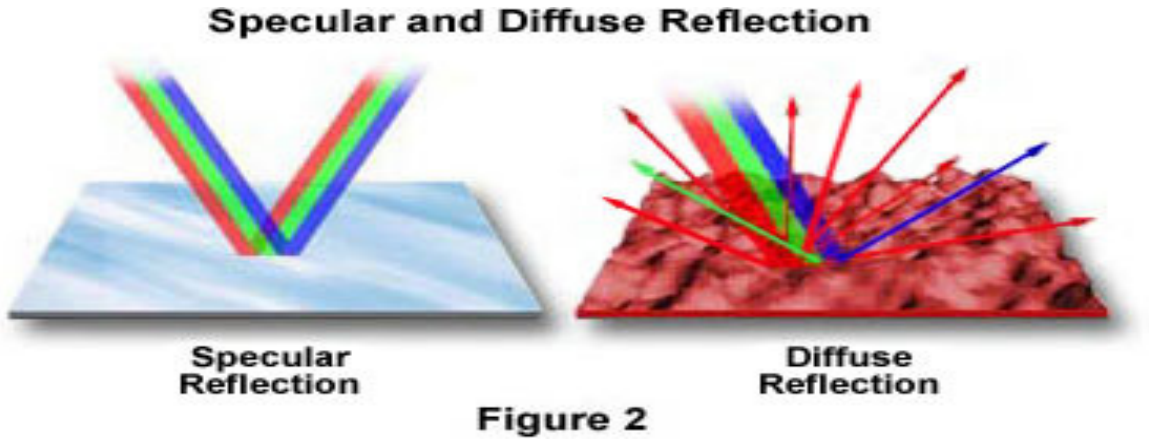
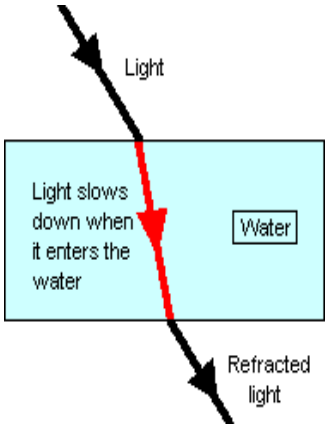


Figure 2

Refraction is one of many observable behaviors of light. Light travels in straight lines, but it bends as it passes from a medium of one refractive index to a medium of differing refractive index. Light bends because it travels at different speeds through mediums of differing densities. Light, as it moves through air, travels 186,000 miles per second. However, the higher the refractive index of the material that light is traveling through, the slower the speed will be. Materials with higher refractive index are often denser than those with lower index, but not always. For example, light passes much slower through water than air.

REFRACTION occurs when the light ray changes media. Light traveling through air and then going through water is an example of a light ray-changing medium. The speed of the light ray changes when it enters a different medium, and unless the angle of incidence is zero (normal

incidence), the direction of the light also changes. We say the light bends. The direction in which the light is bent, and its new speed, are determined by the refractive index of the new medium. If it is higher than that of the previous medium, the light will bend toward the normal and will travel slower, as shown in the figure where the light goes from air to water. If it is lower, the opposite will occur, as where the light goes from water back to air. (Note that this is true in either direction; in other words, whether the light is coming from the top of the figure, as indicated by the arrows, or from the bottom.) Light rays slow down about 25% when passing through water and 35% when passing through glass.



Reflection occurs when light bounces off objects. The nature of this reflection depends upon the roughness of the surface, and the refractive index of the material. If the surface is rough, the light experiences diffuse reflection and scatters. If the surface is smooth and flat, the light will experience specular reflection and bounce off it at equal angles. That is why a flat mirror reflects a good likeness of the object being reflected. The material's refractive index determines how much of the light will be reflected, as opposed to being absorbed or transmitted. This fraction will be different for wavelengths (colors) of light.

Instructional tips

In order to view the LASER beam it may be necessary to use chalk dust, baby powder, or water mist. Give each of these options careful consideration before using as each has its pros and cons.

Assignment of Student Roles and Responsibilities:

Students will assume different roles:

Every student in each small group is responsible for performing experimental tests, manipulating equipment safely & properly, recording data, writing results and conclusions. In addition, each student will be assigned one of the following roles:

Role Name	Brief Description
Manager	Responsible for organizing team and keeping team on task to meet goals and deadlines. Will also serve as team spokesperson, if one is required.
Tester	Responsible for performing experimental tests and manipulating equipment properly.

Safety Officer	Responsible for making sure team observes all safety measures during experimentation.
Technical Writer	Responsible for recording data during experimentation and overseeing the writing of results and conclusions.

Student Instructions

Refer to Appendices for the lab papers that correspond to each days experiment.

Formative Assessments

Teacher should be walking around and observing the students' use of the LASERs on the mirrors during Day 1, measuring light sources, and recording observations.

Post-Activity Discussion

Discussion to follow the Day 1 Activity: Students have recorded responses and diagrams with information leading them toward the discovery and understanding of specular and diffuse reflection (refer to "Background Information" section for details). They should have seen a clear (specular) reflection from the smooth foil and a scattered (diffuse) reflection from the wrinkled foil, using both the flashlight and the red LASER. This should be discussed to be certain every student did see this and the proper vocabulary should be attached to these concepts.

Discussion to follow the Day 2 Activity: Students have recorded responses and diagrams with information leading them toward the discovery and understanding that the incoming (incident) and outgoing (reflecting) rays of light will have the same angles. Through the use of multiple mirrors, they will see that they can manipulate the incoming angle of light and the result will be an identical outgoing ray of light. You should be telling them to measure the angle from the normal line, but regardless of where they measure the angle, they will still see identical angles for the incoming and outgoing rays of light.

Discussion to follow the Day 3 Activity: Students have recorded responses and diagrams with information to reinforce their understanding that the incoming (incident) and outgoing (reflecting) rays of light will have the same angles. Since you had all of the small groups involved in this activity, you should have seen multiple angles used and every group took data from all the groups so you know they were exposed to the data for all the various angles even if they did not try them on the previous day. At this point make sure the students are using the correct vocabulary words: incident rays = incoming rays and reflecting rays = outgoing rays. This is also the time to identify the Law of Reflection which states that the angle of incidence equals the angle of reflection.

Discussion to follow the Day 4 Activity: Students have recorded responses and diagrams with information leading them toward the discovery and understanding that a ray of light bends when it passes through another medium because the speed of light decreases and how much it decreases depends upon the medium it enters. Discuss with students the bending of the ray with just the glass, then with the glass full of water, and finally with the glass full of milk. The glass could be used as the control or counted as a medium.

Discussion to follow the Day 5 Activity: Students have recorded responses and diagrams with information to reinforce their understanding that different media will cause a ray of light to refract differently. There should be a minimum of four different media for students to

measure the refraction of the LASER beam. Students should be able to explain how the decrease in the speed of the light causes the light to bend. This is the time to discuss Snell's Law and practice it.

Discussion to follow the Day 5 Activity: Students have recorded responses and diagrams with information leading them toward the discovery and understanding that a ray of light will reflect and refract when it strikes a surface. Students should observe the internal reflection of the beam in the tank of water and see how its intensity decreases with each bounce.

Pre-Test / Post-Test

See Appendix A.

Pre-Test / Post-Test Rubric

See Appendix A.

Technology Connection

The **ADISC** Model of technology created by ITEL:

Integration Model	***Application Description***
Technology that supports students and teachers in **dealing effectively with data**, including data management, manipulation, and display	MS Excel
Technology that supports students and teachers in **simulating** real world phenomena including the modeling of physical, social, economic, and mathematical relationships	LabTV
Technology that supports students and teachers in **communicating and collaborating** including the effective use of multimedia tools and online collaboration	MS Word

Interdisciplinary Connection

Language Arts – Students could be asked to complete a formal lab report with correct sentence structure, grammar, punctuation, and spelling.

Home Connection

Students can use the different light sources that are available at home to look at spectral lines, and display to their parents and siblings how reflection happens in the world around them. They can bring adults into the activity and explain to them how this is used in the field of astronomy, meteorology and forensics.

Differentiated Instruction

The teacher could use the grouping of the students to aid in differentiation through process.

Extension

Connect the behaviors of light with the behaviors of sound (transmission, reflection, etc.)

Career Connection

Light behaviors are used in many fields to measure the material composition of objects that emit, reflect, or transmit optical radiation. For example, astronomers routinely use spectrometers to understand the nature of the sun, planets, and stars.

Airborne and satellite spectrometers are also used by scientists, geologists, meteorologists and others to study the properties of the earth's surface and atmosphere.

Finally, chemists, crime scene investigators, and other scientists use spectrometers of various types in the laboratory to determine the chemical composition of materials under study.

Additional Resources

Resource:	Purpose and Application:
http://www.ndep.us/Laser-Dazzlers	LabTV video to illustrate a new use for LASERS.

Credits

Derek Flatter – Primary Author

Jason Diebel, Ph.D. – Contributing Author

Norma Howell – Contributing Author, Editor

Teacher Reflections

- Were students focused and on task throughout the lesson? *Insert answer here.*
- If not, what improvements could be made the next time this lesson is used? *Insert answer here.*
- Were the students led too much in the lesson or did they need more guidance? *Insert answer here.*
- Did the students learn what they were supposed to learn? *Insert answer here.*
- How do you know? *Insert answer here.*
- How did students demonstrate that they were actively learning? *Insert answer here.*
- Did you find it necessary to make any adjustments during the lesson? *Insert answer here.*
- What were they? *Insert answer here.*
- Did the materials that the students were using affect classroom behavior or management? *Insert answer here.*
- What were some of the problems students encountered when using the …? *Insert answer here.*
- Are there better items that can be used next time? *Insert answer here.*

- Which ones worked particularly well? *Insert answer here.*

Additional Comments

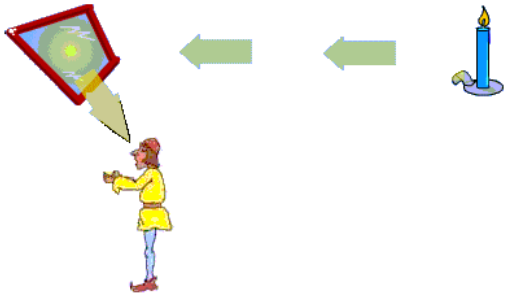
Appendix A:

Target Practice – Pre-/Post-Test

Name: _____

1. In the picture below, a ray of light hits a surface and changes direction. What is this bouncing off action called? _____Reflection_____ (2 pts)

2. Place the following events in the correct order based on their occurrence: (4 pts)



The mirror reflects the light.
Derek sees the flame.
The candle flame gives off light.
Light enters Derek's eyes.

1. The candle flame gives off light.
2. The mirror reflects the light.
3. Light enters Derek's eyes.
4. Derek sees the flame.

3. What is the term that describes the bending of light due to a change in its speed when it passes from one material to another? (2 pts)

   Refraction

4. Which of the following statements about light waves is true? (2 pts)
   A. Light waves need matter to travel, but they cannot travel through some matter.
   B. Light waves do not need matter to travel, and cannot travel through matter.
   C. Light waves need matter to travel, and they can travel through any matter.
   D. Light waves do not need matter to travel, and can travel through some matter.

5. Which of the following surfaces reflects the most light? (2 pts)
   A. ceramic tiles
   B. wood shingles
   C. aluminum foil
   D. plastic cards

6. Use the terms reflection and refraction to describe how a beam of light behaves when it encounters the glass wall of a tank of water. (4 pts.) PS-5-5

A light beam is emitted from a LASER source.

The beam strikes the barrier/surface; some of the light is refracted and some is reflected back toward the source.

The reflected beam is lower in intensity because some of it passed through the barrier/surface.

This process may continue several times.

7. List 3 mediums light can travel through and describe how they affect the speed of light differently. (4 pts.) PS-5-5

1. Water – as light travels through water, it's speed decreases.

2. Glass – as light travels through glass, it's speed decreases.

3. Milk – as light travels through milk, it's speed decreases.

4. Cooking oil – as light travels through cooking oil, it's speed decreases.

Appendix B:

Light and Reflection

Student Guide – Day 1

Today's experiment will challenge you to answer the following:

- How does light travel?
- How does light interact with smooth objects?
- How does light interact with rough objects?

Supplies:

- ☑ Flashlight
- ☑ Red LASER
- ☑ Foil – 2 pieces (1-ft x 1-ft each)
- ☑ Black construction paper

Procedure

1. With the lights dimmed/off in the classroom, shine the flashlight onto this sheet of paper. Why can you see the paper when the light is shined on it and not when it is in total darkness? Record your observations and your response in your science notebook.
2. Use the flashlight to reflect the light energy off a flat, smooth, one-foot square of foil onto a black piece of construction paper. Make sure that you position the flashlight, foil and black paper no higher than the tabletop. Does the light reflect? If so what does the reflection look like? Record your responses and observations in your science notebook; include a diagram of the incoming light and the reflected light.
3. Crumble the other piece of one-foot square foil into a ball and then carefully unroll it again without smoothing out all the rough edges. Repeat Step #2, this time on the wrinkled square of foil. Does the light reflect? If so what does the reflection look like? Are there differences in the reflection coming from the smooth foil as compared to the reflection coming from the wrinkled foil? Record your responses and observations in your science notebook; include a diagram of the incoming light and the reflected light.
4. Repeat Steps #2 & #3 with the red LASER.
5. How does light travel? Record your response in your science notebook.
6. How does light interact with smooth objects? Record your response in your science notebook.
7. How does light interact with rough objects? Record your response in your science notebook.

Measuring Angles of Reflection

Student Guide – Day 2

Today's experiment will challenge you to answer the following:

- How does light reflect?
- How does the incoming angle of light affect the outgoing angle of light?

Supplies:

☑ 3 Plane flat mirrors
☑ Red LASER
☑ Green LASER
☑ Target paper (positioned on wall)
☑ Protractor

Procedure

1. Locate the target paper already positioned on the wall. One group member will hold a plane flat mirror at waist height. **BE CERTAIN TO HOLD THE MIRROR ONLY WAIST HIGH.** Another group member will point the LASER at the mirror and the group member holding the mirror will angle it such that the light energy from the LASER is reflecting off the mirror toward the target. Angle the mirror and LASER until the light hits the target paper. Once your group has hit the bull's eye, have a third group member measure the incoming and outgoing angles with the protractor. Record these angles and draw a diagram in your science notebook of the path the light energy took from the LASER to the target.
2. Repeat Step #1 using the green LASER. Observe the differences in the light between the red LASER and the green LASER. Record your observations in your science notebook.
3. Repeat Step #1 using first the red LASER then the green LASER, this time adding an additional mirror into the path of the LASER beam. Do not allow the paths of light to cross. Once your group has hit the bull's eye, have a third group member measure the incoming and outgoing angles with the protractor. Record these angles and draw a diagram in your science notebook of the path the light energy took from the LASER to the target.
4. Repeat Step #1 again, this time adding a third mirror into the path of the green LASER beam. Do not allow the paths of light to cross. Once your group has hit the bull's eye, have a third group member measure the incoming and outgoing angles with the protractor. If necessary, use chalk dust or water mist to view the LASER beam. Record these angles and draw a diagram in your science notebook of the path the light energy took from the LASER to the target.
5. Analyze your diagrams by comparing the incoming and outgoing angles in each. What conclusion can you draw from your measurements? Record your responses in your science notebook.

6. Respond to the following challenge questions in your science notebook: How does light reflect? How does the incoming angle of light affect the outgoing angle of light?

Measuring Multiple Angles of Reflection

Student Guide – Day 3

Today's experiment will challenge you to answer the following:

- What is an angle of incidence?
- What is an angle of reflection?
- What is the law of reflection?

Supplies:

☑ 1 Plane flat mirror per group
☑ 1 Green LASER (for the whole class)
☑ 1 Target paper (positioned on wall)
☑ 1 Protractor per group

1. **Whole class procedure.** Each small group will reflect the beam of one green LASER (for a total of 10 reflections) to hit one target positioned on the opposite side of the room. Do not allow the paths of light to cross. A group member that is not holding the mirror should measure the incoming and outgoing angles of light energy from the mirror. Record all angle measurements from all small groups in your science notebook. Draw a diagram in your science notebook of the path the light energy took from the LASER to the target.
2. Analyze your diagram by comparing the incoming and outgoing angles from each mirror. What conclusion can you draw from your measurements? Record your response in your science notebook.
3. Respond to the following challenge questions in your science notebook. If necessary, look for the answers in your textbook but respond in your own words.
    1. What is an angle of incidence?
    2. What is an angle of reflection?
    3. What is the law of reflection?

Refraction Basics

Student Guide – Day 4

Today's experiment will challenge you to answer the following

- What is a medium?
- What is refraction?
- What causes refraction?

Supplies:

- ☑ Clear square glass container
- ☑ Green LASER
- ☑ Water
- ☑ Milk
- ☑ Protractor
- ☑ Target paper (positioned on wall)

Procedure

1. Place the green LASER on the tabletop (elevate it with a textbook) so its beam strikes the bull's eye of the target paper positioned on the wall. Slide the protractor under the LASER such that the protractor indicates the LASER beam is at a 75° angle. Place the empty square glass container directly between the target and the LASER, making certain the LASER beam must pass through the empty glass container to strike the target. Move the protractor such that you can measure the angle of the light beam that is leaving the square container. Observe the target paper and record your observations in your science notebook. Draw a diagram in your science notebook that illustrates the path the LASER beam is traveling.
2. Repeat Step #1, this time filling the square glass container with water. Record your observations and draw your diagrams in your science notebook.
3. Repeat Step #1, this time filling the square glass container with milk. Record your observations and draw your diagrams in your science notebook.
4. Based on your diagrams, how does what the light is traveling through (medium) affect the path of the light? Record your response in your science notebook.
5. Respond to the following challenge questions in your science notebook. If necessary, look for the answers in your textbook but respond in your own words.
   a. What is a medium?
   b. What is refraction?
   c. What causes refraction?

Calculating Refraction

Student Guide – Day 5

Today's experiment will challenge you to answer the following

- What is the difference between refraction and reflection?
- What causes refraction?
- How can you calculate an angle of refraction (Snell's Law)?

Supplies:

☑ Clear glass container
☑ Green LASER
☑ Water, oil, honey, etc.
☑ Target paper (positioned on wall)
☑ String
☑ Protractor

Procedure

1. The teacher will have multiple stations set up around the room with the green LASERs positioned on the tabletop so their beams strike the target paper positioned on the wall with the square glass container directly between the target and the LASER. Each square glass container will have a different liquid in it and will be labeled.
2. Run a string directly above the ray of light from the LASER and follow the beam to the glass container. Measure this line with your protractor and record it in your science notebook.
3. As you learned in the previous activity, the different medium (water) slowed the light down which made it bend and exit the container of water (medium) along a different line than it entered. Now run the string directly above the ray of light coming from the glass container and follow it to the target. Measure this line with your protractor and record it in your science notebook.
4. Create a drawing of #2 and #3 in your science notebooks and label the angles.
5. Repeat Steps #2 - #4 for each of the stations set up around the room.
6. Respond to the following challenge questions in your science notebook. If necessary, look for the answers in your textbook but respond in your own words.
    4. What is the difference between refraction and reflection?
    5. What causes refraction?
    6. How can you calculate an angle of refraction (Snell's Law)?

Internal Reflection

Student Guide – Day 6

Today's experiment will challenge you to answer the following
Can light reflect and refract at the same time, if so how?

Supplies:
Whole Group:
- ☑ 1 five-gallon fish tank
- ☑ 1 Green LASER
- ☑ 5 Colored dots as targets
- ☑ 5 gallons of water

Procedure

1. Students will shine the green LASER through the water (medium) so that it strikes the center of one target dot placed on the side wall of the tank. *Do not shine the LASER light at an angle perpendicular to the wall of the tank.*
2. Students will keep the LASER pointed in the same position while placing a second target on the opposite side of the fish tank as the first target such that the LASER beam strikes it also.
3. Students should continue to add more targets to either side of the tank up to a maximum of 5 target dots. The angle in which the LASER beam enters the tank may need to be tweaked in order to improve the amount of targets that can be hit.
4. In your science notebook, draw an overhead view of the LASER beam reflecting back and forth such that it strikes the first 3 targets. Is all of the light reflecting or is some of it refracting? Explain how you can tell.
5. In your science notebook, draw an overhead view of the LASER beam reflecting back and forth such that it strikes all 5 targets. Can light reflect and refract at the same time? Explain how you can tell.
6. In your science notebook, identify some real world examples of light being reflected and/or refracted.