TEACHERS GUIDE

RED LASER POINTER
ITEM # 5135-00

LIGHT AND COLOR

While it excels at its traditional purpose of drawing attention to a particular object from a distance, the humble laser pointer is also an amazing tool for demonstrating and investigating several concepts of optics. With a minimum of additional tools and materials, the red laser pointer can be used for hands-on learning about light reflection, absorption, and transmission - including refraction.

Materials

- mirror
- protractor
- flour
- empty 2 liter soda bottle
- milk or Pine-Sol *(optional)*
- LED light
- gummy bears (clear, red, and green)
- green laser pointer *(optional)*
- refraction cup
- ruler
- white paper
- pen/pencil
- various liquids with different indices of refraction (oil, water, etc.)
- various light sources (LED, flashlight, room lights, red non-laser light, etc.)
- green and/or violet laser pointers
- diffraction grating

Goals & Objectives

See page 8 for Next Generation Science Standards (NGSS)

GLOSSARY

Vocabulary:

- angle of incidence
- angle of refraction
- collimated
- coherent
- incident ray
- index of refraction
- LASER
- monochromatic
- refraction
- Snell's law
- total internal reflection

CAUTION:
Laser pointers can temporarily impair vision and potentially cause permanent damage to the retina of the eye. Never look directly into the light of the laser pointer. Never point the laser pointer at another person's eyes.

How It Works

The light that emits from the laser pointer is produced by a laser diode with a p-n junction similar to a LED (light emitting diode). The laser diode produces a stream of light that is of only one specific wavelength (monochromatic), collimated (travels in parallel rays), and coherent (the light waves travel in phase). Due to these qualities, the light emitting from the laser pointer is very strong and focused. While the power of commercially available laser pointers is limited to no more than 5 mW, laser diode lights can be constructed to be very powerful and visible, even in air. The low wattage of the red laser pointer may require dimmed lights and some particles in the air in order for the actual beam of light to be seen.

DISCUSSION

Additional Discussion and Real Life Applications

1. Based on your understanding of how light is absorbed and reflected by objects, describe or diagram how we see objects. What would happen if absolutely zero light was shone upon an object? Would we be able to see it? Why or why not?

2. After fully exploring with the refraction cup, have students draw a diagram to explain their understanding of refraction.

3. What do you think would happen if you used a different color laser pointer for the various investigations? How could you test your predictions?

4. Light is a form of energy. What can you observe about the transfer of energy from one medium to another by observing refraction? Absorption? Reflection?

5. Refraction is an observable property for many materials. Discuss how refraction could be used to describe and classify different materials.

6. How is the light produced by lasers different from the light produced by other light sources? Why is this important in technology?

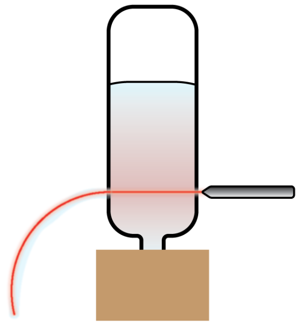
ACTIVITIES

For younger students, focus on science practice skills such as predicting, making observations, and explaining at an age appropriate level. Advance through the different activities to use quantitative measurements and math skills with middle school/high school/college-level students to more fully explore specific physics concepts such as Snell's law and characteristics of lasers.

All activities will be best observed in a darkened or dimly lit room. You may find it easier to see the beam of light by lightly sprinkling flour into the air.

1 **Reflection** – Use the laser pointer to investigate reflection optics.

- Allow students to direct the laser beam at a mirror from different angles. What do they notice? Have students use a protractor to measure the angles of incidence and the subsequent angles of reflection to determine a relationship between the two.
- Demonstrate total internal reflection by filling a 2 liter soda bottle with water and poking a hole near the bottom, allowing the water to stream out. Aim the laser through the bottle at the hole and stream of water. What happens? Students can even place their hand into the water stream to see if the light shines on their hand. You can make this demonstration even more visible by mixing in something to scatter the light. A little bit of milk or Pine-Sol should work. Have student explain verbally or create a model to explain their observations.



2 **Absorption and Transmission** – Provide students with clear, green, and red gummy bears*, a white LED light and the red laser pointer. It is also useful to provide a green laser pointer, if possible. Have students predict what they think will happen when the different light sources are shown through the different colors of gummy bears. Have students test their predictions. What colors of light are transmitted through the different gummy bears? What colors of light are absorbed by the gummy bears? Have students explain their observations in terms of absorption and transmission.

**In place of gummy bears, colored gelatin or filters could be used.*

***Note**

It is always wise to DO an experiment ahead of time to be able to best present it to the class.

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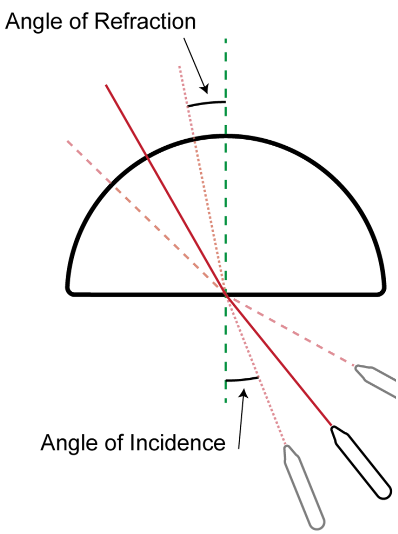
ACTIVITIES

Activities continued

3 **Refraction** – Use a refraction cup to conduct the following investigations.

- Fill the refraction cup with water and set on a flat, white surface, such as paper on a tabletop. Shine the laser beam from different angles at the center point of the flat side of the refraction cup. Try to keep the beam of light parallel to the tabletop. Observe from above how the beam of light bends as it enters the water.



- Record refraction observations by tracing the path of light on the paper under the refraction cup. Draw a straight line on the paper where the flat side of the refraction cup sits and indicate the center point. The refraction cup can be removed to complete the lines. Use different colors or dash patterns to indicate the different light paths for different initial angles (angles of incidence). Use a protractor to measure the angle of incidence and the angle of refraction. Have students describe their observations and explain what is happening.
- Have students determine the angle of incidence at which total internal reflection occurs.
- Explore refraction by changing some of the variables. Use different types of liquid such as different oils or water with different solutes. Compare the angles of refraction for different liquids given the same angle of incidence. Try different colors of laser pointers.
- More advanced students can use their measurements to demonstrate or test Snell's law. Use Snell's law to determine the index of refraction for different mediums (the index of refraction for air is 1.00029). Alternatively, use Snell's law to predict the angle of refraction given known indices of refraction. Test your predictions.
- After students have had a chance to make qualitative and/or quantitative observations about several different liquids, provide small groups with a "mystery liquid" to identify based on its refractive qualities.

4 **Laser Spirograph** – Challenge students to create a laser spirograph,

ACTIVITIES

Activities continued

a machine that uses multiple spinning mirrors reflecting the laser beam onto the wall to create different shapes and designs that we can see thanks to persistence of vision. Several options for instructions are included in the Resources, or students can engineer their own. Investigate how different patterns are created.

5 **Investigate laser light vs other light sources.**

- Demonstrate that laser lights are monochromatic - Set up several non-laser light sources at the front of the room so that students can see them from their seats. Set up one or more laser pointers at the back of the room shining on the front wall so that students can see the reflections on the wall from their seats. Provide diffraction gratings to students and have them make observations of the different light sources through the gratings. How are the laser light sources different from others?
- Demonstrate that laser lights are collimated (the rays of light are parallel and perfectly aligned). Have students measure the area of light produced by different light sources from three different distances (3 cm, 10 cm, and 20 cm). What differences do they notice between the laser and non-laser light sources?
- Demonstrate that laser lights are coherent (the light travels in phase). Have students shine a red LED light very close to a piece of white paper at a slight angle. Repeat the observations using the red laser pointer. Do students see a slight speckle pattern with the laser light that is not present with the LED? How does the speckle pattern demonstrate that the laser light is in phase, or coherent?

RESOURCES

“DIY Laser Spirograph”. Instructables.
http://www.instructables.com/id/DIY-Laser-Spirograph/

“Four-Motor Laser Spirograph”. Instructables.
http://www.instructables.com/id/Four-Motor-Laser-Spirograph/

“LASER Lissojous patterns..geometric designs /// Homemade Science with Bruce Yeany”. Bruce Yeany. Video.
https://www.youtube.com/watch?v=WMJm9sz5IF8

BACKGROUND

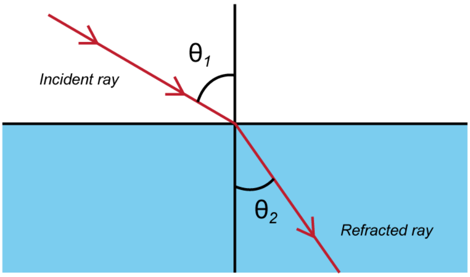
A medium's refractive index, or index of refraction, is the ratio of the velocity of light in a vacuum to the velocity of light in the medium. Here are a few refractive indices for common mediums:

Medium	Refractive Index (n)
Vacuum	1.00000
Air	1.00029
Ice	1.31
Liquid Water	1.33
Ethanol	1.37
Coconut Oil	1.45
Glycerin	1.47
Olive Oil	1.47
Quartz Glass	1.47
Ruby	1.54
Zircon	1.92
Diamond	2.42

Snell's law describes the relationship between the angle of incidence and the angle of refraction given either the velocity of light through the different mediums or the refraction indices for the different mediums:

$$Sin\theta 1/Sin\theta 2 = v1/v2 = n2/n1$$

$\theta 1$ = angle of incidence
$\theta 2$ = angle of refraction
$v1$ = velocity of light in medium 1
$v2$ = velocity of light in medium 2
$n1$ = refractive index of medium 1
$n2$ = refractive index of medium 2



Next Generation Science Standards

Students who demonstrate understanding can:

1-PS4-2. Make observations to construct an evidence-based account that objects can be seen only when illuminated.

1-PS4-3. Plan and conduct an investigation to determine the effect of placing objects made with different materials in the path of a beam of light.

2-PS1-1. Plan and conduct an investigation to describe and classify different kinds of materials by their observable properties.

4-PS3-2. Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.

4-PS4-2. Develop a model to describe that light reflecting from objects and entering the eye allows objects to be seen.

5-PS1-3. Make observations and measurements to identify materials based on their properties.

Standards Key

K = Kindergarten
3 = 3rd Grade
(numbered by grade)
MS = Middle School
HS = High School
PS = Physical Science
LS = Life Science
ES = Earth Science

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MS-PS4-2. Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.

HS-PS4-1. Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.