Bend to the Left, Bend to the Right

From prisms to rainbows, students are fascinated with the way light bends as it travels from one medium to another. This investigation is designed to help students understand concepts about refraction through the use of lasers and household materials. The main factors investigated here include: the type of medium, type of light being transmitted and the angle of incidence.

Charts, Handouts, and Station Cards

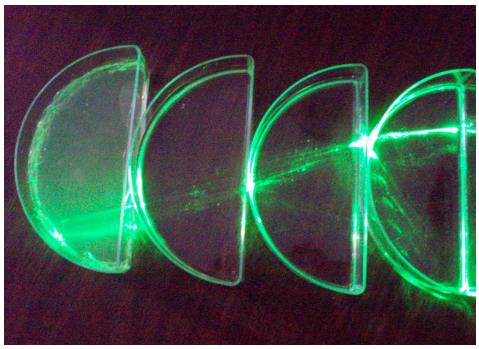
Materials

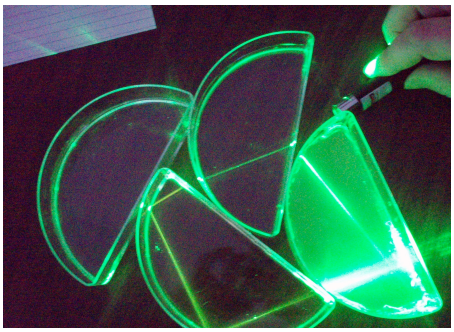
Clear refraction cups (36- approximately 3 per group)
Laser refraction tank (available from Arbor Scientific)
Assorted food coloring
Hand held laser pointers (red and green)
Water
Dairy creamer
Stirrers/Straws
Index cards
Small pencils
Polar graph paper
Straw or straight edge
Transparent solutions: Corn syrup, vinegar, clear shampoo, vegetable oil, etc
Paper towels
Protractors
Thermometers
Heat bath for solutions
Triple Beam Balance or Electronic scales
Weigh paper (Or something that can be used as such)
Clear solid blocks of glass or gelatin to cut his or her own shapes (or use cookie cutters)
Flashlights (optional- see teacher notes)
Sentence Strips
Markers
Masking Tape or Painters Tape
Waste Container

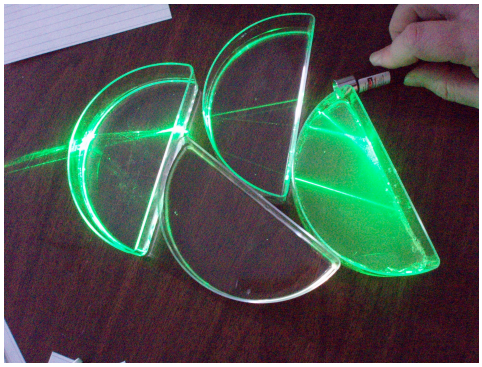
Teacher Notes:

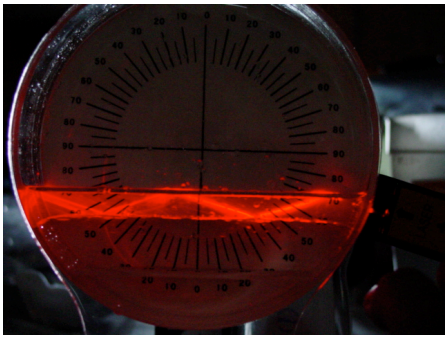
- You may wish to have flashlight available for groups to use when they are trying to write down observations while the main lights are turned off.
- Be sure to caution students on proper use of the laser
- You can make gelatin squares that will not require refrigeration all day by doubling the amount of Knox Gelatin you put in solution. For example, dissolve 4 packets in 1 cup of hot water, add one cup of warm water, pour into flat dish and refrigerate overnight prior to the lab activities. Students can cut the gelatin into different shapes and handle with no mess

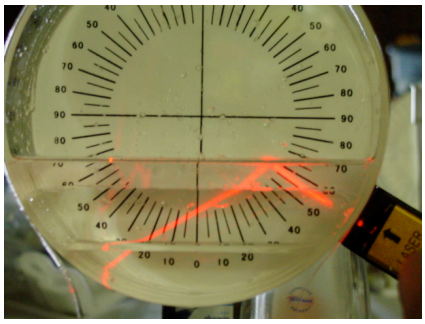
As students use different media and multiple refraction cups, they will discover fundamental principles of refraction and reflection. Some samples of what students have done are shown:











Inquiry Starter
Overview

At your table you will be investigating laser light as it travels in a transparent medium. Follow the directions on the task card at your table to complete the investigation

Be sure to record your data appropriately.

Repeat the procedure twice as indicated on the task card

Use the index cars available at your table to record any questions that come to your mind as you explored the investigation.

What if I changed……..

What would happen if……

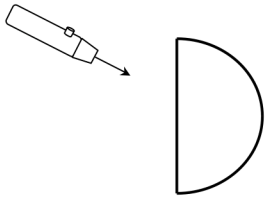
Select three questions from the index cards that you are interested in pursuing. Place each question on a sentence strip.

TASK CARD FOR INQUIRY STARTER

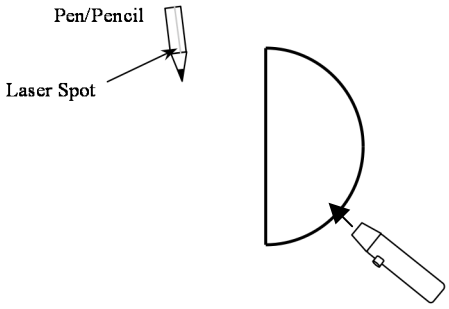
Note: It may be necessary to darken the room slightly in order to see the laser beam more easily.
Safety Note: Always use caution when using lasers. They should not be pointed directly at anyone and you should never directly shine the beam into your eyes or those of anyone else. This can result in damage and/or possible loss of eyesight.

Part I

1. Fill a refraction cup about ½ to ¾ full of water,
2. Shine the laser beam at an angle to the cup. If you cannot see the beam through the water, add a pinch of coffee creamer, and stir so the mixture is homogeneous.
3. Use a straw (or other straight edge) to help you sight a straight line. Does the laser beam always maintain a straight-line path once it enters the water? Would there be conditions where your answer to the previous question would change?
4. Record your observations. Sketch the path of the light for each trial.



5. Now shine the laser light from the other side of the cup so that the light travels through the cup as shown below. Use a pencil or index card to help mark the light path after it leaves the cup. Sketch the light path from the laser through the cup and out the flat side.



Part II

6. Use multiple cups and/or multiple lasers to redirect the light through the various refraction cups.
7. Record your observations

Focused Investigation (Introduction)
Introduce additional materials
We are going to take time to look at the questions that have been identified to see what you would like to investigate. Before you select that question you will need to know what materials are available for your investigation. The materials available include:
red and green lasers, refraction tank, food coloring, gelatin that you can cut into assorted shaped, assorted transparent liquids such as Karo® syrup, baby oil, vegetable oil, vinegar, glass, plastic, water, and shampoo.

Once you have identified your question, find someone with a similar interest in your question. If there are over four people interested in your question, please form two groups. Meet with your group to refine your question. Record the following on your template: your question, the materials, your hypothesis, and the first three steps of your procedure. When completed, bring the template to the instructor for approval.

Planning and conducting your investigation
After you have received approval from your instructor, proceed with planning and conducting your investigation. Be sure to follow all safety procedures. Create appropriate data tables, graphs and recording sheets.
Conduct your investigation in the time allocated by your instructor.
When you have completed your investigation, clean up and properly dispose of all materials you will not be using in your share out.

Concluding
Prepare a two-minute presentation highlighting what question you investigated, the procedure you followed, data collected, and what you learned from your investigation.

Synthesis
It is important to synthesize the information you have learned in a way that highlights the main findings and scientific truths. This often leads to a deeper understanding of the content and may reveal scientific misconceptions that could be addressed during further investigations. Talk about main ideas associated with the investigation.

TEMPLATE FOR INVESTIGATION

Question:

Materials:

Hypothesis:

Procedure:

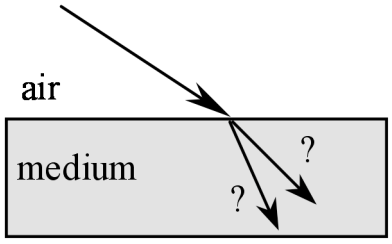
1.

2.

3.

Main Ideas

When light travels from one medium to another, the path taken is dependent upon several factors. The main factors investigated here include: the type of medium, type of light being transmitted and the angle of incidence.



The ratio of the angle of incidence to the angle of refraction is also the ratio of the speed of light in the two media and determines how much the light will be bent (refracted) as it passes through the medium. Each medium has an index of refraction which indicates how much the light will be bent as it passes through the medium. The equation for this relationship is written below:

$$n_1 \sin \theta_1 = n_2 \sin \theta_2$$

Where 1 is the first medium and 2 is the second medium, θ indicates the angles as measured from the normal and n is the index of refraction. The index of refraction for air is considered to be 1. Therefore, if the light is passing from air into another medium, the equation is often reduced to

$$\sin \theta_1 / \sin \theta_2 = n_2$$

in order to determine the index of refraction.

Each medium also has a critical angle. If the incident ray of light hits the medium at an angle greater than the critical angle, the light will not be refracted into the second medium, but instead will be internally reflected back into the first medium. This principle is widely used and has many applications including orthoscopic surgery, cutting the facets of gemstones, and communications. For example, the bottom of a diamond is cut at an angle greater than the critical angle. Therefore, light does not pass through the bottom of the diamond, but instead reflects internally into the diamond and reflects off the internal surfaces until it is allow to exit out the top of the ring, hence the "glittering" effect. Also, the top of the diamond is flat because when light enters the second medium (diamond) with no degree of incidence, it passes straight through and is not refracted. So the top of the diamond allows the light to pass through, but then it is "captured" inside the diamond and enhances the overall beauty of the diamond.

Teacher Notes
Discussions from Prior Investigations and Group Share Out:
Group 1: used water with a small amount of food coloring
Original Question; Does the light bend more at different angles? How much does light bend at different angle? How does the angle of incidence compare to the angle of refraction?
The angle of refraction corresponds to the angle of incidence. As you change the angle of incidence the angle of refractions changes about the same amount each time. This physics principles allows the students to determine the trend and predict the angle of refraction. The law of refraction states the greater the angle of incidence, the greater than angle of refraction up to the critical angle.

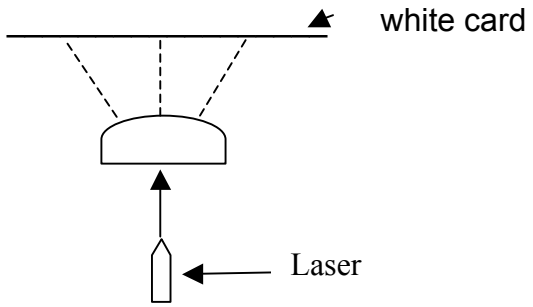
Question 2: Does the shape of the surface affect the angle of refraction?
The angle will not change when you shine the light through on the curved side because the light only hit one spot and the size of the beam was so small it acted as flat. Students will be surprised at this.

Group 2: used water with a small amount of creamer
Original Question: How does the entry angle affect the angle of reflection and refraction? How do different mediums affect refraction?
The light only went through points and the entering angle of 31 degrees and 88 degrees. There was a definite change in the angle of refraction. The entering spot was a flat surface. Even though the entering point was not always the same, the change was 21 degrees. If there was no change in medium for it to travel through it did not change.

Group 3 used the rectangular lid of the laser pointer instead of the refraction pan
Question 1: Does the type of additive affect the refraction? Do different substances affect the refraction?
We found that the light refracted differently depending on the viscosity of the substances (it could also be related to density). Hair gel didn't quite bend as much as we predicted.

Question 2: How much stuff is needed to block the laser light entry?
We added more water and creamer. Creamer was added at .02 gram increments.
Light was entirely blocked when .16 grams of creamer was dissolved.

Group 4
Question 1: How much creamer does it take to block the light ray?
Materials tested included: coffee creamer, 100 mL H_2O, digital scale, refraction dish, laser, and white paper.
Hypothesis: Regardless of amount of creamer added, the light ray will still pass through.
Procedure:



1. Add 100 mL of H_2O
2. Add creamer in .01 g increments- stir gently.
3. Shine laser- record data.

Sample Data Table

Amount of Creamer	Appearance of Light Ray	Distance through solution (cm) "Red Glow"
0 g	Clear, distinct	6cm
.05g	Clear, less distinct	6 cm
.10g	Faint	6cm
.11g	Faint	6cm
.12 g	Very Faint	6cm
.13g	Blocked- red glow	3 cm
.14g	Red glow, light ray extends partially through solution	2.3
.15g		1.8
.16g		1
.17g		.2 cm
.18 g		No distinct light ray- red glow

Regardless of amount of creamer added the light was still able to pass through?

Group 5: used water, hair gel, Karo® and hydrogen peroxide
Question1. Does the type of solution effect the refraction?
Question 2: Which solution will create the greatest angle of refraction?
Question 3: Does the density of the substance effect the angle or refraction?

During the process of testing, they changed and #3 was the final test. All of the items contained some water, therefore the group hypothesized that there was so much water that each substance acted closer to water, therefore the density of these substances did not have an effect on the refraction of light.
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Group 6
Does viscosity affect the refraction and or reflection of light?
They found no major difference and based results upon if the light went through the media or not. There were different designs that appeared with the gel. The main ingredient was water thus this is why it so closely matched the results of refraction in water.
The lower the viscosity the further the light would travel through? This ended up being the final question tested.