TEACHERS GUIDE

REFRACTION CUP
ITEM # 3350-01

LIGHT AND COLOR STUDY

While our eyes may not detect it very often, light travels at different speeds through different mediums. When light passes from one medium to another it slows down or speeds up. If the light is traveling at an angle to the medium the change in speed causes the light to bend. This bending of light is known as refraction.

Refraction cups are simple tools that allow younger students explore the basics of refraction optics and even use refraction as an additional observable quality for describing and categorizing materials. Refraction cups can also be used in conjunction with a protractor, allowing more advanced students to mathematically test and manipulate Snell's law (the law of refraction).

Materials

- various liquids with different indices of refraction (oil, water, etc.)
- protractor
- ruler
- laser pointer
- white paper
- pen/pencil

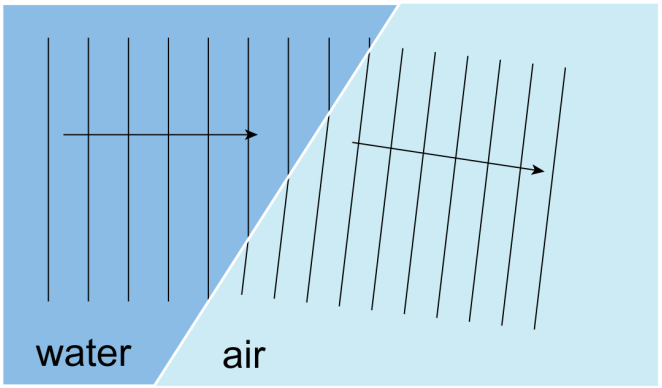
Goals & Objectives

See page 7 for Next Generation Science Standards (NGSS)

HOW IT WORKS

Light travels through different mediums at different speeds. Refraction cups allow students to observe how light travels through different liquids. As the beam of light moves from one medium to another at an angle, it bends due to the change in speeds.

To fully understand why the light bends, it is helpful to remember that light is a wave and has width. As the width of the wave crosses the boundary from one medium to another it slows down or speeds up. If the light is at an angle to the boundary, one edge of the wave changes speed before the other edge. In order to maintain the integrity of the wave, the light must bend.



ACTIVITIES

All activities will be best observed in a darkened or dimly lit room.

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.

1 Observe refraction by using a laser pointer. 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.

2 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 try to explain what is happening.

(see Figure 1)

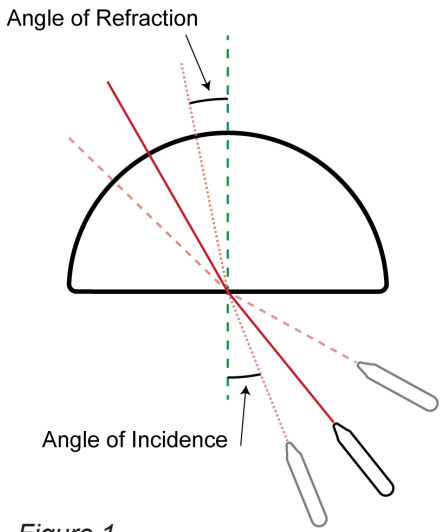


Figure 1

***Note**

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

ACTIVITIES

Activities continued

3 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 changing the color and/or intensity of the light.

4 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.

5 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.

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:

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

θ1 = angle of incidence

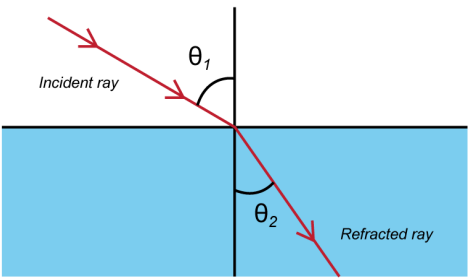
θ2 = angle of refraction

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



DISCUSSION

Additional Discussion and Real Life Applications

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

2. What do you think would happen if the refraction cup was rectangular rather than a half-circle? How could you test your prediction?

3. What do you notice if you place a straw or a pencil in a glass of water? What about placing a penny in the bottom of a glass of water? How are these phenomena related to refraction?

4. Can you think of other instances in which refraction affects the way things look?

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

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

GLOSSARY

Vocabulary/Scientific Concepts:

- angle of incidence
- angle of refraction
- incident ray
- index of refraction
- refraction
- Snell's law

Next Generation Science Standards

Students who demonstrate understanding can:

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.

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

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.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