



Refraction – Marc Royster

Purpose

The manipulation of light through refraction is an important phenomenon that is utilized in the construction of the lenses in refracting telescopes. In this lesson students will learn what refraction is, where light refracts, and how different materials refract light differently. This is fundamental in understanding the mechanics of an optical telescope.

Overview

The lesson is made up of two parts. The discussion will consist of three demonstrations that display the physics of refraction in action. This will be an inquiry based discussion that attempts to gather the classes own observations to develop a description and model of refraction. After the discussion, the students will investigate the physics further with a NetLogo simulation of refraction.

Student Outcomes

- Students will be able to describe where exactly light bends.
- Students will be able to define the index of refraction and list the refractive index for a few materials.
- Students will be able to cite the general relation between the refractive index and density.
- Students will be able to describe how the apparent speed of light changes in different mediums.
- Students will be able to explain the differences between refraction and reflection.

Time

One class period should be sufficient. The students may need to finish the worksheet as homework.

Level

The lesson was presented to a junior/senior level astronomy course. However, the lesson plan should scale to any high school level physics/astronomy classroom.

Materials and Tools

The suggested demonstrations require:

- Laser Pointer
- Aquarium or similar
- Small and large glass beaker
- Penny and Ruler (or pencil)
- Cooking Oil

The NetLogo activity requires:

- Computer with working NetLogo (natively or through applet)
- Worksheet

Preparation

The NetLogo simulation should be verified as working on the computers the students will be using.



Reach for the Stars is a GK-12 program supported by the National Science Foundation under grant DGE-0948017. However, any opinions, findings, conclusions, and/or recommendations are those of the investigators and do not necessarily reflect the views of the Foundation.

This can be done through the web applet linked above or by downloading the NetLogo software and running the model natively.

Prerequisites

A unit on radiation and the EM spectrum is helpful but not necessary.

Background

In order to build a telescope and investigate the universe we need to be able to manipulate light to our advantage. The first step of manipulating light is investigating how it behaves.

Teaching Notes

You can begin the lesson with the demonstrations. The most important physics to highlight is where the bending of light actually takes place and that the light can be considered to 'slow' down. It is difficult to describe *why* this happens without complicating matters tremendously, but a useful colloquial analogy is a shopping car being pushed into sand. When it hits the sand, the cart will slow down. In addition, if it hits the sand at an angle the wheel that hits the sand first will slow down first, causing the cart to turn towards that wheel.

There are also a few real-world examples of refraction . One is spearfishing where refraction must be considered before throwing the spear at a fish. Another astronomical example is the aberration of light. This is due to the light of a star being refracted before it reaches our eyes or telescopes so the apparent position is not the actual position.

Possible demos:

- Place a penny at the bottom of a beaker. When water is put in the beaker, the penny will vanish. This is best seen at an edge on level. A digital projector was used to show the classroom.
- Fill a beaker halfway with water and halfway with a cooking oil on top. An object can be placed in the beaker and will appear broken. It can also be moved at different angles to see how the effect changes.
- A laser pointer can be pointed into a large aquarium full of water to see how the light itself is actually bending. It can help to use chalk dust or similar to better see the light before it enters the water.

Assessment

Assessment will be achieved by evaluating the work completed in the student's worksheets as well as a weekly quiz and unit test. In addition, five minutes can be reserved at the end of the activity to assess what the students achieved during the lesson.

Additional Information

The NetLogo activity is available currently online in a browser (JAVA required) at: <https://www.googledrive.com/host/0B9OE1qp3UUMATnREUk15b1ppRVU/refraction.html>. The source code is also available. It could easily be modified to include reflection for a more complete model if utilized in a physics course.

Attached below is the worksheet used in the classroom.

Refraction Activity

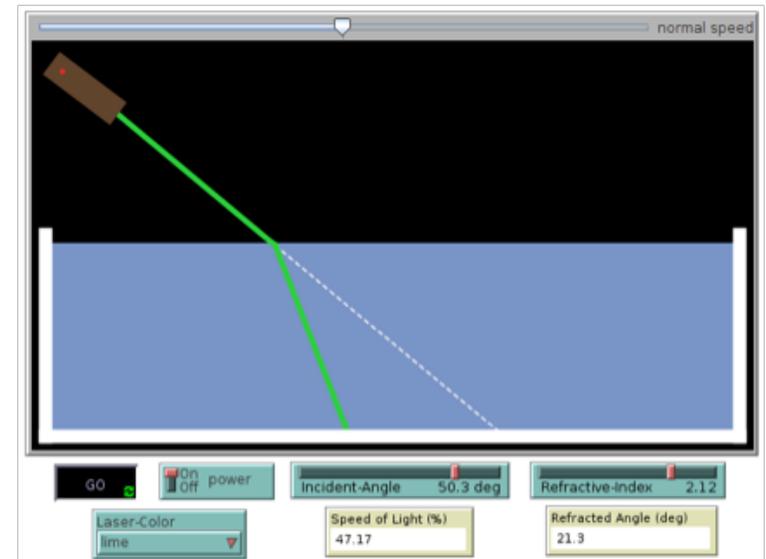
Introduction

In this module, you will investigate refraction of light in different mediums. All questions should be answered in your notebook unless otherwise noted.

Refraction Applet

To run this applet, go to the astronomy webpage and click on the link associated with today's date. It should open a Java program and should look like the image below:

This side gets
pasted into your
Composition
Notebook on
the LEFT side



You can begin the applet by hitting the 'GO' button. The power button will toggle the laser pointer on and off. You can change the angle of the pointer by sliding the 'Incident-Angle' slider. The 'Refractive-Index' slider will change the substance of the medium that appears in the 'aquarium'. In addition, you can change the color of the laser pointer, although this does not affect the results.

Question 1

Experiment with the applet in any way you choose and write down in your notebook any observations.

Refractive-Index

The refractive index or index of refraction of a substance quickly describes the way light will interact with the medium when it moves through it. Although not exactly, the refractive index varies with the density of a material. Here is a table of some materials and their refractive index.

Material	Index of Refraction
Air	1.00
Water	1.33
Sugar	1.40
Salt	1.54
Flint Glass	1.65
Sapphire	1.77
Diamond	2.42

Question 2

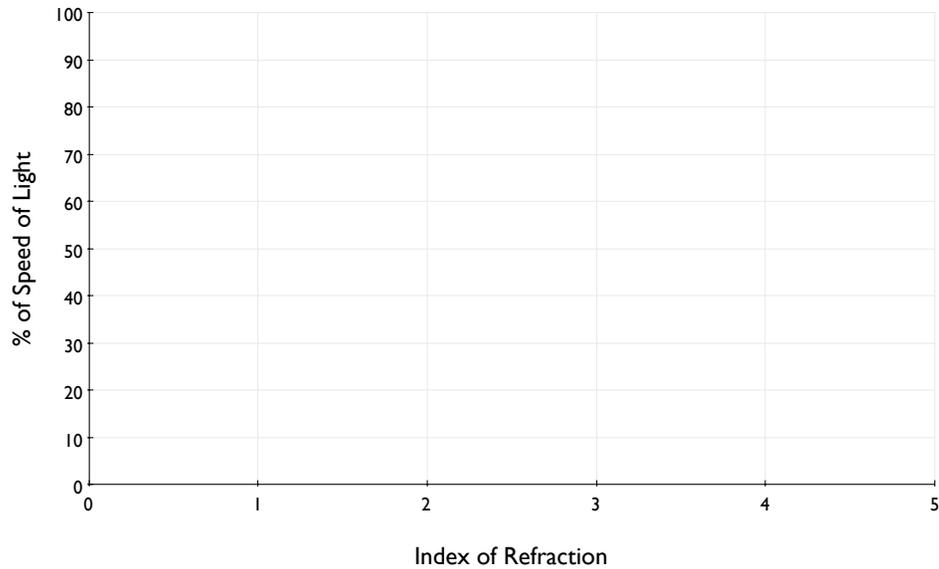
Look at the table again, write down how you think the index of refraction varies with density. That is, does a higher index of refraction typically mean a larger or smaller density? What materials in the table made you think this?

Question 3

By adjusting the parameters of the applet, take note of when the speed of light changes. Which parameters change it? Which parameters don't? Describe what this means in the context of question 2.

Question 4

Complete the plot below by using the applet to find the speed of light for various index of refractions. Then, use your plot to predict the speed of light in silicon, which has an index of refraction of 4.00.



Incident-Angle

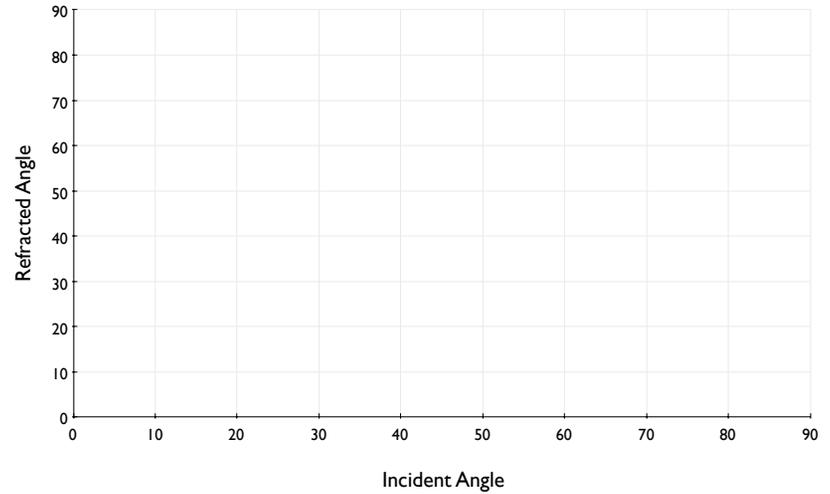
Complete the next two questions with the Refractive-Index set to water:

Question 5

Which incident angle results in a refracted angle of zero? What is the obvious conclusion to be made because of this? That is, what does the incident angle need to be in order to get a non-zero refracted angle ?

Question 6

Complete the plot below by using the applet to find the refracted angle for various incident angles. Does a larger incident angle result in a bigger or smaller refracted angle?



Question 7: Target Practice

For the next question, turn on the 'target' in the applet and complete the table by finding the incident angle that hits the target for each material.

Material	Incident Angle	Refracted Angle
Air		
Water		
Sugar		
Salt		
Flint Glass		
Sapphire		
Diamond		

Question 8

What happens when the refractive index is 1.00? What does this imply about the index of refraction of the medium the laser pointer is in?

Question 9

What combination of incident angle and refractive index produces the largest refracted angle? Is there only one combination? What about the smallest refracted angle? How many combinations get you the smallest?

Question 10

In reality, the index of refraction varies with the color of the light. Because of this, what would happen to a beam of white light after it was refracted? Can you think of any real-world examples of this phenomenon?