Experiment 6

Index of Refraction

Equipment: Simulation (phet.colorado.edu) “Bending Light”

In this experiment you will determine the index of refraction for various materials (including an unknown material). This is done using the simulation stated above. In the simulation you will be able to direct a beam of light originating in one transparent material, and striking a second transparent material of a different index of refraction. The beam of light will refract through the second material at a different angle than the incident beam of light. The Snell’s Law equation models this refraction angle.

Ɵ1

Ɵ2

Material 1

Material 2

Where n1 is the index of refraction for Material 1, and n2 is the index of refraction for Material 2.

A virtual protractor will allow you to measure these angles.

The index of refraction of a material relates to the velocity at which the light travels through the material. For a material with an index of refraction equal to 1 the velocity of the light equals c (≈3x108 m/s), the velocity of light. The ratio of the velocity of light c, to the velocity of light in a material v, is also equal to the index of refraction of the material.

The velocity of light in a material with an index of refraction n can then be determined.

**Part 1**

**Index of Refraction of Water**

Open the Bending Light simulation and click on the “Intro” button. Once you have opened the “Intro” simulation you will see a virtual laser pointer suspended in the air. Click on the red button to turn it on. The beam of light strikes the surface of the second material at the point where the dashed Normal line is drawn. As you can see the angle as measured from the normal line incident to the interface between the two materials is a different angle from the refracted angle of the light beam in the second material. The two materials should already be set to Air for the material of the incident light beam, and to Water for the other material of the refracted light beam.

Place your cursor near the back end of the laser pointer and two green arrows should appear. This indicates that you can click and drag the laser pointer about an arc, changing the angle of incidence.

Click and drag the image of the protractor located in the lower left-hand corner of the simulation over to the point where the light beam enters the water, aligning the zero degree marks (top of protractor, and bottom of protractor) with the Normal line. Make sure that both 90 degree marks align with the surface of the water.

Now you are able to set the incident angle to those angles that will be given out by your lab instructor during lab. Record these incident angles onto the Excel worksheet for this part (Ɵ1 on the worksheet). For each of the incident angles given, measure the refracted angle (Ɵ2 on the worksheet) to the nearest degree. The light beam has a little bit of thickness to it, so you will have to estimate the angle for the middle of the beam.

Using Snell’s Law determine the index of refraction for each of the indicated incident angles and resulting refracting angles (calculate this on the worksheet). Determine the average index of refraction and its associated uncertainty (calculate these on the worksheet). Compare your experimentally found index of refraction for water with the accepted value shown in the simulation.

Using the experimentally determined index of refraction for this material determine the velocity at which the light travels in the material (calculate this on the worksheet).

**Part 2**

**Index of Refraction of Glass**

This procedure is exactly the same as in Part 1 except that you will change the refracting material to Glass. Click on the black triangle just to the right of “Water” and choose “Glass”.

**Part 3**

**Index of Refraction of Mystery Material A**

This procedure is again exactly like Part 1 with one difference. Once you have determined the average index of refraction for this mystery material**, look up online** for a list of materials and their associated indices of refraction and determine of what material mystery material A is made. State the materials name, index of refraction, and how well it agrees with your experimentally determined value.

**Part 4**

**Determining the Index of Refraction using the Critical Angle**

The Critical Angle (ƟC) is the angle of incidence of a ray of light from a material of higher index of refraction such that the refracted angle of the light beam (in a lower index of refraction material) just becomes equal to 90 degrees. Any incident angle greater than the Critical Angle results in total internal reflection (no refracted light beam leaves the material).

This allows us to determine the index of refraction of the material that the laser pointer is in.

ƟC

Material 1

Material 2

In this part of the experiment you will change the lower material of the simulation to Air (n2 = 1), and the upper material (with the laser pointer) to each of Water, Glass, and the Mystery A material. Determine the critical angle for each material. Use these Critical Angles to determine the index of refraction for each of the materials of Water, Glass, and Mystery A material. Compare these values with those determined in Parts 1 through 3.

**Questions for Discussion**

1. For each of the materials (Water and Glass) state whether the index of refraction is in agreement with the accepted value’s index of refraction given in the simulation. Use the range of values for each material’s index of refraction that you calculated in your discussion.
2. Mystery A material’s index of refraction is not given in the simulation (else, it would not be a mystery). Look up online for a list of indices of refraction of various materials to determine what material Mystery A is made. Justify your answer using the range of values for the experimentally determined index of refraction for Mystery A. Are there any other materials that have an index of refractions that are close to the material you chose from the online list? If so, list these as possible choices. Discuss why you chose a particular material over other materials that may be close.
3. The following is a graph of the Index of Refraction for Water as a function of the wavelength of the light beam used.

In the simulation a “red” laser light is used. Look up what the wavelength of red light is (it is really a range of values, so choose an average value) and compare the index of refraction that you found experimentally for Water to this graph. How well does your value agree with the graph? If you were using a green laser pointer what approximate expected index of refraction would you have?

1. Visible light ranges from approximately 400 nanometers to 700 nanometers. Using the graph in question 3 and Snell’s Law, determine the angular spread (largest angle to smallest angle) that an incident white light source (starting in Air) being refracted by Water would have.