## **Refraction Lab (Teacher Guide)**

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### **Purpose**

The purpose of this investigation is to determine **how much a light ray will be refracted** at the interface between media with different indices of refraction. It also helps the students **recognise that the behaviour of the refracted ray** is dependent on the value of the index of refraction of the second medium, compared to the first one.

### **When To Do This Investigation?**

This lab is designed to be completed after students have been introduced to the idea that a light ray going from one transparent medium to another will not necessarily go through it at the same speed. A simple demonstration with a straw in a glass of water could be used to introduce students to the idea that light travels at different speeds according to the specific transparent/translucent medium it goes through.

This lab activity should be preceded by the presentation of some concepts related to refraction:

* Snell’s Law of refraction
* Conditions and significance of a critical angle
* Conditions and significance of total internal reflection

### **Materials**

This investigation is done using a free virtual simulation on the **Intro** option of the PhET simulation called [Bending Light](https://phet.colorado.edu/sims/html/bending-light/latest/bending-light_en.html) (produced by the University of Colorado Boulder). No hands-on materials are required other than a scientific calculator.

### **Results & Sources of Error**

This is an investigation where the data collected from the simulation is consistent; therefore, all of the students' data tables and graphs would be identical. It is recommended that the focus be on interpreting and analyzing the data. The teacher could ask students to collect data with their choice of medium to see if they compare with the others given.

The students may need reminders about how to use the protractor to measure the angle of incidence and refraction (with respect to the normal) correctly.

### **Safety Considerations**

There are no safety considerations for this investigation since it is purely virtual.

### **Evaluation**

There is a provided rubric for this investigation that teachers can use or modify as needed. Note that the spreadsheet has two tabs, including one with instructions for the teacher on how it works.

**Physics – Refraction Lab**

**(ANSWER KEY for Student Guide)**

**Purpose**

The purpose of this investigation is to determine how much a light ray will be refracted at the interface between media with different indices of refraction.

**Hypothesis -** Please write 2 hypotheses

Example: If the first medium is \_\_\_\_ (less, more) \_\_\_\_refractive than the second medium, the angle of refraction will be \_\_\_\_ (smaller, greater) \_\_\_\_than the angle of incidence.

**Hypothesis 1:**

|  |
| --- |
| If the first medium is less refractive than the second medium, the angle of refraction will be smaller than the angle of incidence, making the refracted ray move closer to the normal. |
| **Hypothesis 2:**  If the first medium is more refractive than the second medium, the angle of refraction will be greater than the angle of incidence, making the refracted ray move further to the normal. |

**Material**

Bending light interactive simulation found at:[PhET Bending light](https://phet.colorado.edu/sims/html/bending-light/latest/bending-light_en.html). Select the **Intro** option.

**Procedure**

**Scenario 1** - Going from a low index of refraction to a high index of refraction

1. Use the slider on the application to set n2 and n1 to the values given in Table A. The index n1 is the control variable and should not be changed.

2. Using the protractor, set Θ1 to the value specified in the table.

3. Use the protractor to measure and record the angle of refraction Θ2 generated for each n1 and Θ1 in Table A.

4. For each set of values in the table, calculate the ratio of sin Θ1/sin Θ2.

**Scenario 2** - Going from a high index of refraction to a low index of refraction

1. Use the slider on the application to set n2 and n1 to the values given in Table A. The index n1 is the control variable and should not be changed.

2. Using the protractor, set Θ1 to the value specified in the table.

3. Use the protractor to measure and record the angle of refraction Θ2 generated for each n1 and Θ1 in Table A.

4. For each set of values in the table, calculate the ratio of sin Θ1/sin Θ2.

**Observations**

**Table A:** **Scenario 1** – Going from a low index of refraction to a high index of refraction

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Air | | Glass | |  |
| Angle of incidence Θ1 (degrees) | Index of refraction n1 | Angle of refraction Θ2 (degrees) | Index of refraction n2 | Calculations of sinΘ1/sinΘ2 |
| 15 | 1.00 | 12 | 1.25 | 1.24 |
| 30 | 1.00 | 24 | 1.25 | 1.23 |
| 45 | 1.00 | 34 | 1.25 | 1.26 |
| 60 | 1.00 | 44 | 1.25 | 1.25 |
| 75 | 1.00 | 51 | 1.25 | 1.24 |
| 15 | 1.00 | 10 | 1.50 | 1.49 |
| 30 | 1.00 | 19 | 1.50 | 1.53 |
| 45 | 1.00 | 28 | 1.50 | 1.50 |
| 60 | 1.00 | 35 | 1.50 | 1.51 |
| 75 | 1.00 | 40 | 1.50 | 1.50 |
| 15 | 1.00 | 9 | 1.75 | 1.65 |
| 30 | 1.00 | 17 | 1.75 | 1.71 |
| 45 | 1.00 | 24 | 1.75 | 1.74 |
| 60 | 1.00 | 30 | 1.75 | 1.73 |
| 75 | 1.00 | 34 | 1.75 | 1.73 |

**Table B:** **Scenario 2** – Going from a high index of refraction to a low index of refraction

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Glass | | Air | |  |
| Angle of incidence Θ1 (degrees) | Index of refraction n1 | Angle of refraction Θ2 (degrees) | Index of refraction n2 | Calculations of  sin Θ1/sin Θ2 |
| 15 | 1.25 | 19 | 1.00 | 0.79 |
| 30 | 1.25 | 39 | 1.00 | 0.79 |
| 45 | 1.25 | 62 | 1.00 | 0.80 |
| 60 | 1.25 | ≠ refraction | 1.00 | Total Internal Reflection (TIR) |
| 75 | 1.25 | ≠ refraction | 1.00 | TIR |
| 15 | 1.50 | 23 | 1.00 | 0.66 |
| 30 | 1.50 | 49 | 1.00 | 0.66 |
| 45 | 1.50 | ≠ refraction | 1.00 | TIR |
| 60 | 1.50 | ≠ refraction | 1.00 | TIR |
| 75 | 1.50 | ≠ refraction | 1.00 | TIR |
| 15 | 1.75 | 27 | 1.00 | 0.57 |
| 30 | 1.75 | 61 | 1.00 | 0.57 |
| 45 | 1.75 | ≠ refraction | 1.00 | TIR |
| 60 | 1.75 | ≠ refraction | 1.00 | TIR |
| 75 | 1.75 | ≠ refraction | 1.00 | TIR |

**Analysis**

1. What trends did you notice in Table A of your Observations?

As n2 increases while n1 remains the same, the angle of refraction becomes smaller which will have the refracted ray move closer to the normal.

2. Do you notice any mathematical relationships between sin Θ1/sin Θ2, n1 and n2 in Table A?

The result of sin Θ1/sin Θ2 is equivalent to n2 divided by n1 which is Snell’s law.

\*\*Many students will respond: The result of sin Θ1/sin Θ2 is equivalent to n2 which is a misconception. To help students understand this better, it may be helpful to have them investigate a situation where both n1 and n2 1.

3. What trends did you notice in Table B of your Observations?

As n1 increases while n2 remains the same, the angle of refraction becomes larger which will have the refracted ray move farther from the normal. At one point, when the angle of incidence reaches the critical angle, the refracted ray disappears and Total Internal Reflection (TIR) occurs.

4. What is the critical angle for each value of n1 in scenario 2? Use the application to determine the exact value for each case.

|  |  |
| --- | --- |
| When n1 = | Critical angle value |
| 1.25 | 53.0 |
| 1.50 | 41.8 |
| 1.75 | 34.8 |

5. What happens to the refracted ray when Θ1 is greater than the critical angle?

We can observe the phenomenon of Total Internal Reflection.

6. As the value of n1 increases, what happens to the critical angle? Why?

As the value of n1 increases, the critical angle decreases because the greater the refractive index of the first medium is, the greater the relative speed of the refracted ray will be through the second medium, which will make it further away from the normal.

7. Does the same mathematical relationship you found in question #2 work when Θ1 is **less than the critical angle** for the data you collected in Table B? If not, can you suggest a new mathematical relationship between sin Θ1/sin Θ2, n1 and n2 for angles less than the critical angle?

The result of sin Θ1/sin Θ2 is equivalent to n2 divided by n1 which is Snell’s law.

\*\*Many students will respond: No, which is a misconception as they haven’t made the connection between the parameters of Snell’s law and cannot suggest a new mathematical relationship.

**Conclusion**

What did you learn in this investigation? What can you conclude from this investigation? Were your hypotheses correct?

Please make use of these optic terms you now know the meaning: incident ray, reflected ray, angle of incidence, angle of refraction, smaller than, larger than, index of refraction, medium, behavior of refracted ray, normal, closer to, farther from…

Answers will vary, but here is a sample answer:

When the index of refraction of the first medium is less than that of the second medium, the refracted ray moves closer to the normal which makes the angle of incidence larger than the angle of refraction.

When the index of refraction of the first medium is more than that of the second medium, the refracted ray moves further from the normal which makes the angle of incidence smaller than the angle of refraction. In this case, it is possible to see that a critical angle of incidence would produce an angle of refraction of 90 degrees. If the angle of incidence is greater than or equal to the critical angle, no refraction occurs, rather we can observe the phenomenon of total internal reflection (TIR).