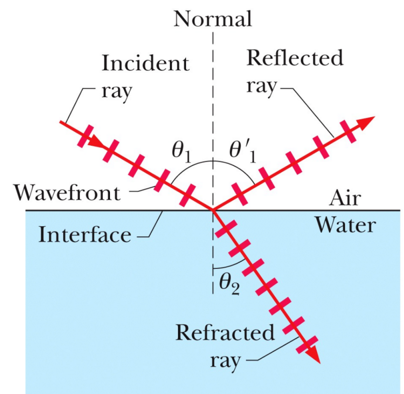
Online Lab: Snell's Law

Name: Date:

Instructor: Section:

Background:

When light travels between two different medium, the velocity and wavelength changes. The result is the "bending" of the light. The "bending" of light is referred to as refraction. The "bending" follows a convenient mathematical relationship called Snell's law, named after Dutch astronomer Willebrord Snellius (1580-1626).



Law of Reflection:

A reflected ray lies in the plane of incidence and has an angle of reflection equal to the angle of incidence (both relative to the normal). $\theta_1 = \theta_1'$

Law of Refraction

A refracted ray lies in the plane of incidence and has an angle of refraction θ_2 that is related to the angle of incidence θ_1 by:

$$n_2 \; sin \; \theta_2 \; = \; n_1 \; sin \; \theta_1 \tag{1}$$

where n_1 is the refractive index of medium 1, θ_1 is the incident angle, n_2 is the refractive index of medium 1 and θ_2 is the refraction angle. This equation is known as Snell's Law.

Chromatic Dispersion

While light appears white, it is made up of colors of the rainbow. These colors can be separated by shining a white light through a prism (a triangular glass object). This separation is called dispersion and is more commonly observed in a rainbow when sunlight is refracted by droplets of water. Chromatic dispersion occurs in some materials because different wavelengths of light have differing indices of refraction and are reflected at different angles.

Total Internal Reflection

When the incident angle equals the critical angle ($\theta_1 = \theta_c$), the angle of refraction is 90° ($\theta_2 = 90°$). Noting that sin 90° = 1, Snell's law in this case becomes $n_1 \sin \theta_1 = n_2$.

The critical angle θ_c for a given combination of materials is thus for $n_1 > n_2$:

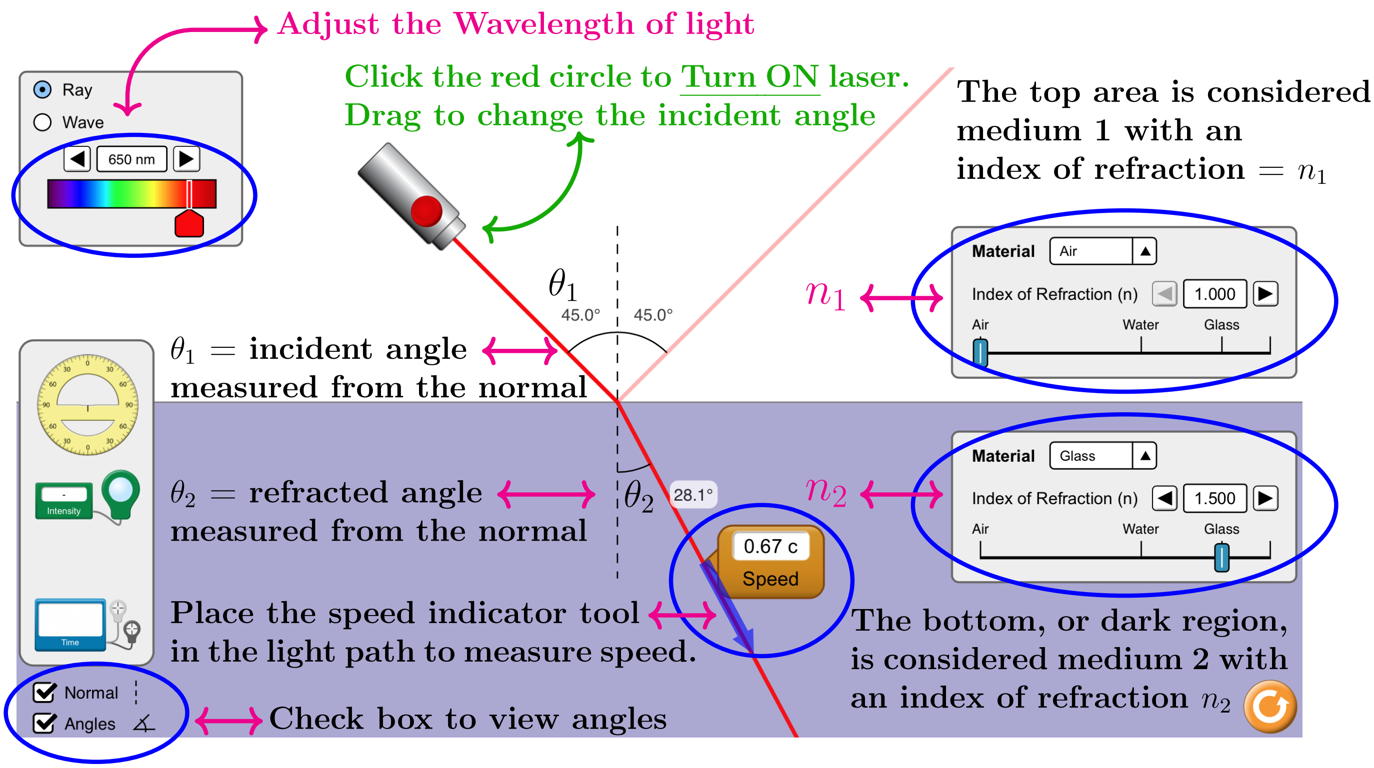
$$\theta_c \; = \; sin^{-1} \left(\frac{n_2}{n_1} \right) \tag{2}$$

Total internal reflection occurs for any incident angle greater than the critical angle θ_c, and it can only occur when the second medium has an index of refraction less than the first.

Online Experiment Setup Instructions

1. Go to the following website:
   https://phet.colorado.edu/sims/html/bending-light/latest/bending-light_en.html

2. Click the **More Tools** tab on the PHeT simulation.



3. The index of refraction, n, is the ratio of the speed of light in a vacuum, (c), to the speed of light in a medium, (ν): $n = \frac{c}{\nu}$. As light travels into different substances, the velocity of light is lower. For our purposes the speed of light in a vacuum will be the same as that of air. Using the initial parameters, use the speed tool to measure the velocity of light in the glass.

   Write the velocity in terms of c.

4. The relationship between the velocity (ν), frequency (f), and wavelength (λ) of a wave is given by: $\nu = f\lambda$. Since the frequency remains constant when light travels between different media, an expression can be written to solve for λ_2. For medium 1, $\nu_1 = f\lambda_1$ and for medium 2, $\nu_2 = f\lambda_2$. By making an appropriate substitution, write a mathematical expression for λ_2, in terms of ν_1, ν_2 and λ_1. **Show all your work**.

Snell's Law

1. Click on the Reset button to clear the previous settings.
2. Turn ON the laser and Check the box to view Angles.
3. For each Data Set, setup using the initial data parameters and complete the table below.

Data Set 1	Data Set 2	Data Set 3	Data Set 4
λ_1 = 650 nm	λ_1 = 532 nm	λ_1 = 440 nm	λ_1 = 395 nm
n_1 = 1.000	n_1 = 1.000	n_1 = 1.333	n_1 = 1.500
n_2 = 1.333	n_2 = 1.500	n_2 = 1.500	n_2 = 1.000
θ_1 = 30°	θ_1 = 45°	θ_1 = 60°	θ_1 = 30°

4. Record the resulting θ_2.
5. Measure ν_1 and ν_2 using the speed measurement tool.
6. Calculate Sin θ_1 and Sin θ_2.
7. Calculate λ_2 using the expression you wrote on page 2.
8. Repeat Steps 3-6 for Data Sets 2, 3 & 4.

***************** **NOTE** *****************

Record your velocities ν_1 and ν_2 in terms of the speed of light, c.
Record your values for Sin θ_1 and Sin θ_2 to three significant figures.
Record your values for λ_2 in nanometers (nm).

Table 1: Data Results: Snell's Law

Set #	θ_2	ν_1	ν_2	**Sin** θ_1	**Sin** θ_2	λ_2
1						
2						
3						
4						

Data Analysis: Snell's Law

Table 2: Data Analysis: Snell's Law

Set #	$\frac{sin\ \theta_1}{sin\ \theta_2}$	$\frac{n_2}{n_1}$	$\frac{\nu_1}{\nu_2}$	$\frac{\lambda_1}{\lambda_2}$
1				
2				
3				
4				

Observations and Analysis

1. Using your data from Table 1, Calculate and Record each of the ratios in the Table above. **Record your results to 3 significant digits**.

2. What is the relationship between the angles of incidence, θ_1 and refraction, θ_2?

3. What is the relationship between wave speed and the index of refraction?

4. Based upon the pattern you see above for the ratios across different data sets, write a complete mathematical expression for Snell's Law. Verify your expression by looking up Snell's Law in your textbook or the internet.

Chromatic Dispersion

1. Click on the Reset button to clear the previous settings.
2. Turn on the laser and check the box to turn on Angles.
3. Set n_1 to air and n_2 to glass. Adjust the incident angle, θ_1 to 30°.
4. **Adjust the Color** of the light beam to Red.
5. Record the wavelength and its associated refracted angle in the table below.
6. Repeat Steps 4 & 5 for each of the colors given in Column 1.

Table 3: Data Results: Chromatic Dispersion

Color	**Wavelength, λ (nm)**	**Refracted Angle, θ_r (°)**
Red		
Orange		
Yellow		
Green		
Blue		
Purple		

Observations

1. Describe the relationship between refracted angle and wavelength.

2. Which wavelength of light bends more blue or red? Explain your reasoning.

Total Internal Reflection

1. Reset the simulation. Turn ON the laser and Check the box to view Angles.
2. Set the following initial data parameters given in **Column 1 of the table below**.
3. Calculate and Record the critical angle $\theta_{critical}$, for the water-air interface.
4. Set θ_2 to 15° and complete the table below. Repeat for angles 30°, 45° and 60°.

Table 4: Data Results and Analysis: Total Internal Reflection

Data Parameters	θ_1 (°)	θ_2 (°)	**Reflected,** θ_r (°)
$\lambda_1 = 650$ nm	15°		
$n_1 = 1.333$	30°		
$n_2 = 1.000$	45°		
	60°		

Observations and Analysis

1. What happens when the refracted angle, θ_2, approaches 90 degrees?

Reset the Simulation and Choose Mystery A for Material 2.
Turn ON Laser and Check box to view Angles.

2. When air is the medium of incidence of light, Snell's Law can be simplified to

$$n_2 = \frac{sin\ \theta_1}{sin\ \theta_2}$$

Use this to determine the index of refraction of the Mystery A material.

Record your answer here.

3. Use the table to the right to determine what the mystery material might be:

Record your answer here.

Media	Index of Refraction
Vacuum	1.00
Air	1.0003
Carbon dioxide gas	1.0005
Ice	1.31
Pure water	1.33
Ethyl alcohol	1.36
Quartz	1.46
Vegetable oil	1.47
Olive oil	1.48
Acrylic	1.49
Table salt	1.51
Glass	1.52
Sapphire	1.77
Zircon	1.92
Cubic zirconia	2.16
Diamond	2.42
Gallium phosphide	3.50