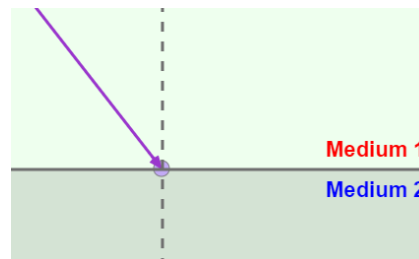


Name: \_\_\_\_\_ Date: \_\_\_\_\_

## Student Exploration: Refraction

### Gizmo Warm-up

Light can travel through many materials, or **media**. As with a runner on pavement or sand, the speed of light can change when it moves into a different medium. The *Refraction Gizmo™* allows you to observe what happens to a beam of light as it travels from one medium to another.



Turn off **View wave fronts**. Set **Index of refraction 2** to 3.0.

1. Click **Play** (▶). Observe the ray of light as it passes from **Medium 1** to **Medium 2**.

A. What happens to the speed of the light wave? \_\_\_\_\_  
 \_\_\_\_\_

B. What happens to the direction of the light wave? \_\_\_\_\_

2. Click **Reset** (↺) and turn on **View wave fronts**. A **wave front** is an imaginary line that connects the crests or troughs of a wave. The **wavelength** of a wave is the distance between wave fronts.

Click **Play**. What happens to the wavelength of the wave as it passes into **Medium 2**?

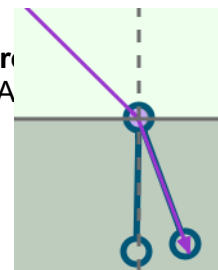
\_\_\_\_\_

<p><b>Activity A:</b> <b>Angle of refraction</b></p>	<p><u>Get the Gizmo ready:</u></p> <ul style="list-style-type: none"> <li>• Click <b>Reset</b>. Turn off <b>View wave fronts</b>.</li> <li>• Make sure <b>View normal</b> is selected.</li> <li>• Make sure <b>Index of refraction 1</b> is 1.0 and <b>Angle of incidence</b> is 45°.</li> <li>• Set <b>Index of refraction 2</b> to 2.0.</li> </ul>	
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### Question: What affects how much light waves refract?

1. **Measure:** Click **Play**. To measure the angle of refraction, turn on **Click to measure angles**. Drag the protractor's vertex to the intersection of the ray and the normal. A the protractor's legs to the ray and the normal in **Medium 2**.

What is the angle of refraction? \_\_\_\_\_



2. **Gather data:** For each angle of incidence listed in the table below, use the Gizmo to find the angle of refraction. Then, fill in the “Change of direction” column by subtracting the angle of refraction from the angle of incidence.

Angle of incidence	Angle of refraction	Change in direction
20°		
40°		
60°		
80°		

3. **Analyze:** What patterns do you notice? \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

4. **Explain:** Do you think refraction would occur if the angle of incidence is 0°? Explain.  
 \_\_\_\_\_  
 \_\_\_\_\_

5. **Predict:** The **index of refraction** indicates how fast light can travel through a medium. The higher the index is for a medium, the slower light will travel through that medium. How do you think increasing a medium’s index of refraction might affect the angle of refraction?  
 \_\_\_\_\_

6. **Gather data:** Keep the **Index of refraction 1** set to 1.0. Set the **Angle of incidence** to 60°. For each **Index of refraction 2** listed in the table below, use the Gizmo to find the angle of refraction and the change in direction.

Index of refraction 2	Angle of refraction	Change in direction
1.0		
2.0		
3.0		

7. **Analyze:** What patterns do you notice? \_\_\_\_\_  
 \_\_\_\_\_

8. **Explain:** Why does no refraction occur when the media have the same index of refraction?  
 \_\_\_\_\_



9. **Explore:** Set the **Index of refraction 2** to 1.0. Set the **Angle of incidence** to  $25^\circ$ . Collect data for each **Index of refraction 1** listed in the table below.

Index of refraction 1	Angle of refraction	Change in direction
1.5		
2.0		
3.0		

10. What happened in the third trial? \_\_\_\_\_

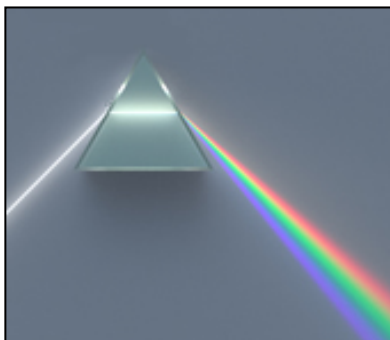
When the angle of refraction is greater than  $90^\circ$ , the beam of light will reflect off of the surface instead of refracting through the surface. This is called **total internal reflection**.

## Student Exploration: Basic Prism

**Vocabulary:** angle of incidence, angle of refraction, critical angle, dispersion, index of refraction, medium, prism, refract, Snell's law, total internal reflection, visible spectrum, wavelength

**Prior Knowledge Questions** (Do these BEFORE using the Gizmo.)

A **prism** is a transparent object that can be used to bend, or **refract**, light. The photo below shows what happens when sunlight passes through a prism.



1. What do you see? \_\_\_\_\_

\_\_\_\_\_

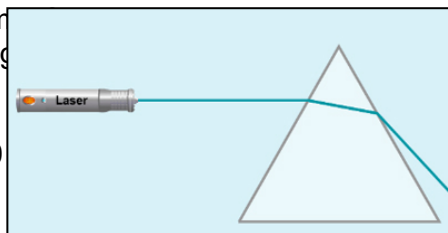
2. What does this indicate about the composition of sunlight?

\_\_\_\_\_

\_\_\_\_\_

### Gizmo Warm-up

The *Basic Prism* Gizmo allows you to investigate how a prism refracts light. The Gizmo shows a laser emitting a beam of light through a triangular prism.



To begin, check that **Single color beam** is selected,  $\lambda$  is 500 nm,  $w$  is 2.0, and the angle ( $\theta$ ) is  $0^\circ$ .

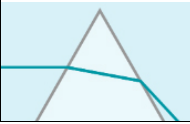
1. What do you notice about the path of light when it passes through the prism? \_\_\_\_\_

\_\_\_\_\_

2. Move the  $\lambda$  slider to increase and then to decrease the **wavelength** of the beam of light.

A. How does this affect the color of the light ray? \_\_\_\_\_

B. How does this affect the direction of the light ray? \_\_\_\_\_

<b>Activity A:</b> <b>Refraction and dispersion</b>	<u>Get the Gizmo ready:</u> <ul style="list-style-type: none"><li>• Set <math>\lambda</math> to 500 nm and <math>n</math> to 1.00.</li><li>• Check that <math>w</math> is 2.0 and <math>\theta</math> is <math>0^\circ</math>.</li></ul>	
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**Introduction:** When light passes from a vacuum into a **medium** such as glass, it slows down. The **index of refraction** ( $n$ ) is equal to the ratio of the speed of light in a vacuum to the speed of light in a medium. The index of refraction of air is very close to 1.00.

**Question: What factors affect the refraction of light through a prism?**

1. Observe: What do you notice about the beam of light when the  $n$  is 1.00? \_\_\_\_\_

\_\_\_\_\_

2. Predict: How do you think increasing the index of refraction will change the path of the light?

\_\_\_\_\_

3. Observe: Slowly increase  $n$  to 1.50, close to the value for glass. What happens? \_\_\_\_\_

\_\_\_\_\_

4. Observe: Increase  $n$  to 1.53. What happens now? \_\_\_\_\_

\_\_\_\_\_

In this situation, the light cannot move from the prism into the air. Instead, it reflects off the surface, a phenomenon called **total internal reflection**.

5. Gather data: Set  $n$  to 1.50. The Gizmo also allows you to change the width of the prism ( $w$ ), the angle of the prism ( $\theta$ ), and the wavelength of the light ( $\lambda$ ). Describe the effect of each action listed below. Return the Gizmo to its starting conditions after each trial.

Action	Effect on path of light ray exiting the prism
Decrease $w$ to 1.0.	
Increase $w$ to 3.0.	
Decrease $\theta$ to $-30^\circ$ .	
Increase $\theta$ to $30^\circ$ .	
Decrease $\lambda$ to 400 nm.	
Increase $\lambda$ to 700 nm.	



6. Summarize: Which actions caused the amount of refraction to increase? \_\_\_\_\_

\_\_\_\_\_

Which actions caused the amount of refraction to decrease? \_\_\_\_\_

\_\_\_\_\_

7. Think and discuss: Why does widening the prism cause the beam to bend more? If possible, discuss your answer with your classmates and teacher.

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

8. Observe: Return the Gizmo to its initial settings ( $n = 1.50$ ,  $w = 2.0$ ,  $\theta = 0^\circ$ ). Select **White light** from the menu at upper left. What happens when white light goes through a prism?

\_\_\_\_\_

\_\_\_\_\_

The band of colors you see is called a **visible spectrum**. The ability of a prism to separate white light into a spectrum is called **dispersion**. (Note: The Gizmo shows the spectrum as a collection of individual colored beams rather than a continuous band of color that would be produced by a real prism.)

9. Explain: Why is a spectrum of colors produced when white light passes through a prism? (Hint: Think about the effect of the wavelength of light on how much it refracts.)

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