Refraction B2—When is Light Reflected Internally?
Teacher's Notes

The Light and Color Teachers Guide includes dozens of activities to teach about Reflection, Refraction, Color, Polarization, and Diffraction. Each lab has teacher background information, reproducible student worksheets, an equipment chart and an answer key.

This activity is written for use by high school or college physics students. Computational questions are included, and students are expected to have an understanding of basic geometry and trigonometry. The Teachers Guide also includes activities for middle school students (or any student with lower math skills), including one on this topic.

Educational Objectives

- Students will recognize that refraction occurs at the boundary (interface) between two transparent materials.
- Students will be able to discover that the angle of refraction when light passes from plastic to air is larger than the angle of incidence.
- Students will discover that there is an angle of incidence (when the light ray is passing from plastic to air) is not refracted but is reflected totally internally. This phenomenon is called total internal reflection.

Key Question

- As the path of light moves from plastic (angle of incidence) to air (angle of refraction) are all angles of light refracted or is there a limiting angle of incidence in this case?
  - If incident light for all angles are not refracted what is the smallest angle that is not refracted?
  - What happens to the incident light?

Concept Overview

Light is refracted as it moves from plastic to air. However, the angle of refraction (the light in the air) is larger than the angle of incidence (the light in the plastic). The angle of refraction will increase in size faster than the angle of incidence increases in size. The refracted angle will reach 90° before the angle of incidence does. This incident angle is called the critical angle when the refracted angle is 90°. If the incident angle is greater than the critical angle, all the light will be reflected at the plastic/air interface. Your students will observe that some light is reflected and some is refracted when the incident angle is less than the critical angle. But, all light will be reflected when the incident angle is greater than the critical angle.

Techniques

The plastic half round has been set up on the student page so that light enters the plastic half round block from the round side of the plastic block. In this configuration, the light is always entering the plastic block along a normal to the surface (a radius) thus there is no bending at this point. The light will follow a radius through the block to point "O" where it exits the plastic block into air and is refracted.

Name: _____

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Goal

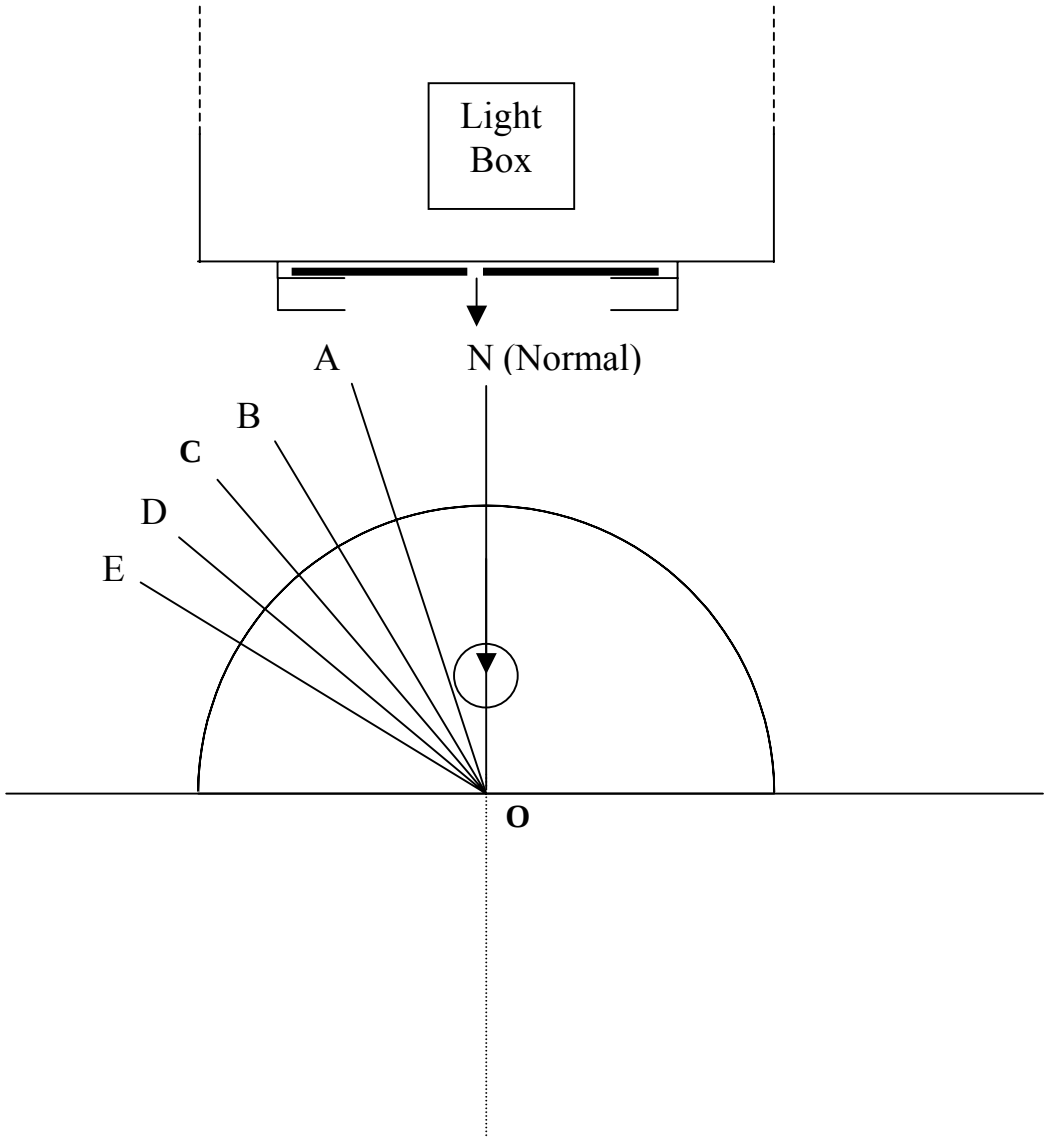
- To learn how light is refracted when it passes from Plexiglas to air.

Materials

Light box
Semicircular Plexiglas optical element
mask with single slit opening
Protractor

Procedure

1. Use a single slit mask on the light box. Position semicircular Plexiglas block on the diagram.
2. Aim the ray at the center point on the semi-circular slab of plastic.
3. Start at the normal. The light should pass through the semi-circular slab of plastic with no change in its direction.
4. Move the light box so the ray is along line AO. Use your pencil to mark the ray path of light that comes out of the Plexiglas.
5. Adjust the light box so that the light ray enters the slab along the indicated lines. Mark the path each ray takes as it leaves the slab.



6. Remove the plastic slab. Draw a line from point O for each refracted ray.
7. Where does the bending of the light ray take place?

_____

_____

8. For which ray (A, B, C, D, E) does the refracted ray disappear? _____
9. Measure each angle of incidence and the corresponding angle of refraction for each ray. Record your measurements in the data table below.

Ray	**Angle of Incidence θ_i**	**Angle of Refraction θ_r**	**Sine of the angle of Incidence**	**Sine of the angle of Refraction**	**Ratio of Sin θ_i/Sin θ_r**
AO					
BO					
CO					
DO					
EO					

10. Use the data above to make a general statement about refraction of light as it moves from Plexiglas to air.

_____

_____

_____

11. What do you notice about the ratio of sin θ_1 / sinθ_r?

_____

_____

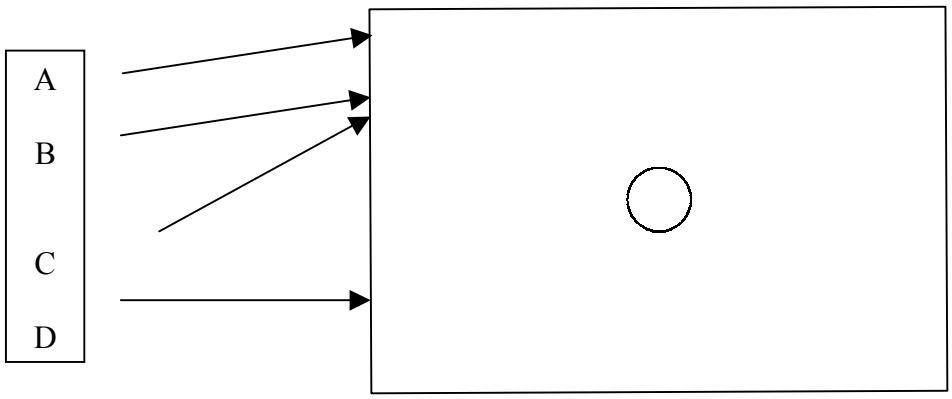
12. As you moved the light box, you observed that the angle of the refracted ray (light leaving flat side of Plexiglas) was greater than the incident ray. For what incident angle did the refracted angle equal 90°? Incident angle = _____. What happened when the incident angle exceeds this angle?

_____

_____

13. Find this special angle (where the refracted angle disappears) mathematically.

14. When all of the light bounces off the boundary of a material and none of the light escapes from the material, the light is totally reflected. Sketch the path that light takes in traveling through a large Plexiglas block when the light enters on one of the paths below.



Name: *Answer Key*

When is Light Reflected Internally?

7. Where does the bending of the light ray take place?

   The bending occurs at the boundary between Plexiglas and air. There is no bending for the light entering the Plexiglas since it is moving on a radius that is a normal line.

8. For which ray (A, B, C, D, E) does the refracted ray disappear?

   The light along line D or E do not exit the Plexiglas through refraction. It is reflected at the Plexiglas – air boundary. None escapes through refraction.

9. Measure each angle of incidence and the corresponding angle of refraction for each ray. Record your measurements in the data table below.

Ray	Angle of Incidence θ_i	Angle of Refraction θ_r	Sine of the angle of Incidence	Sine of the angle of Refraction	Ratio of Sin θ_i/Sin θ_r
AO	*18.0*	*28.2*	*.312*	*.473*	*1.53*
BO	*31.0*	*50.0*	*.515*	*.766*	*1.49*
CO	*40.0*	*78.3*	*.643*	*.979*	*1.52*
DO	*50.1*	*Reflected*			
EO	*58.8*	*Reflected*			

10. Use the data above to make a general statement about refraction of light as it moves from Plexiglas to air.

    The refracted angle is greater than the incident angle when air travels from Plexiglas to air. If the incident angle is too large, the light is no longer refracted.

11. What do you notice about the ratio of sin θ_I / sinθ_r?

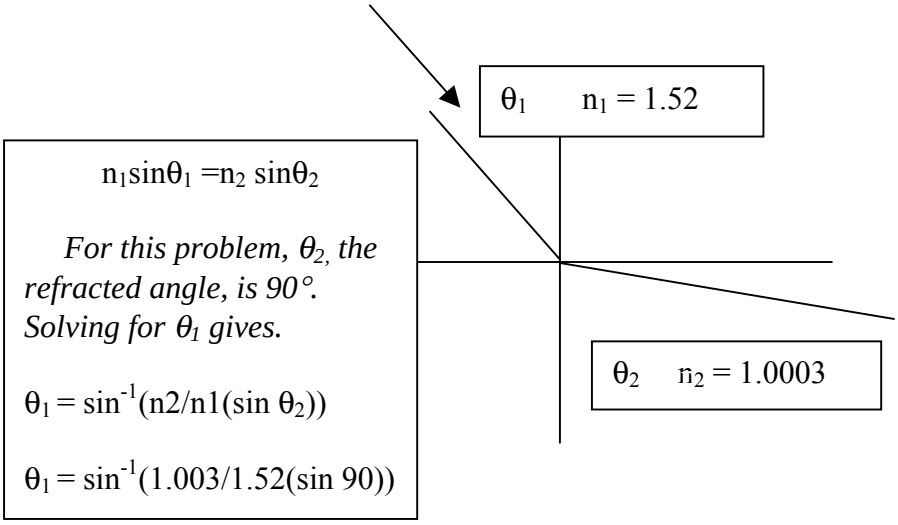
    The ratio is nearly the same for each of the three trials.

12. As you moved the light box, you observed that the angle of the refracted ray (light leaving flat side of Plexiglas) was greater than the incident ray. For what incident angle did the refracted angle equal 90°? Incident angle = *41°*. What happened when the incident angle exceeds this angle?

    When this angle is exceeded, no light is refracted. It is reflected at the Plexiglas – air boundary.

13. Find this special angle (where the refracted angle disappears) mathematically.

The index of refraction for this Plexiglas is about 1.52. The index of refraction for air, 1.003, may be found in a reference text.



$n_1 \sin\theta_1 = n_2 \sin\theta_2$

For this problem, θ_2, the refracted angle, is 90°. Solving for θ_1 gives.

$\theta_1 = \sin^{-1}(n2/n1(\sin\theta_2))$

$\theta_1 = \sin^{-1}(1.003/1.52(\sin 90))$

14. When all of the light bounces off the boundary of a material and none of the light escapes from the material, the light is totally reflected. Sketch the path that light takes in traveling through a large Plexiglas block when the light enters on one of the paths below.