Experiment 4: The Law of Refraction

EQUIPMENT NEEDED:

-Optics Bench
-Ray Table and Base
-Slit Plate
-Cylindrical Lens.
-Light Source
-Component Holder
-Slit Mask

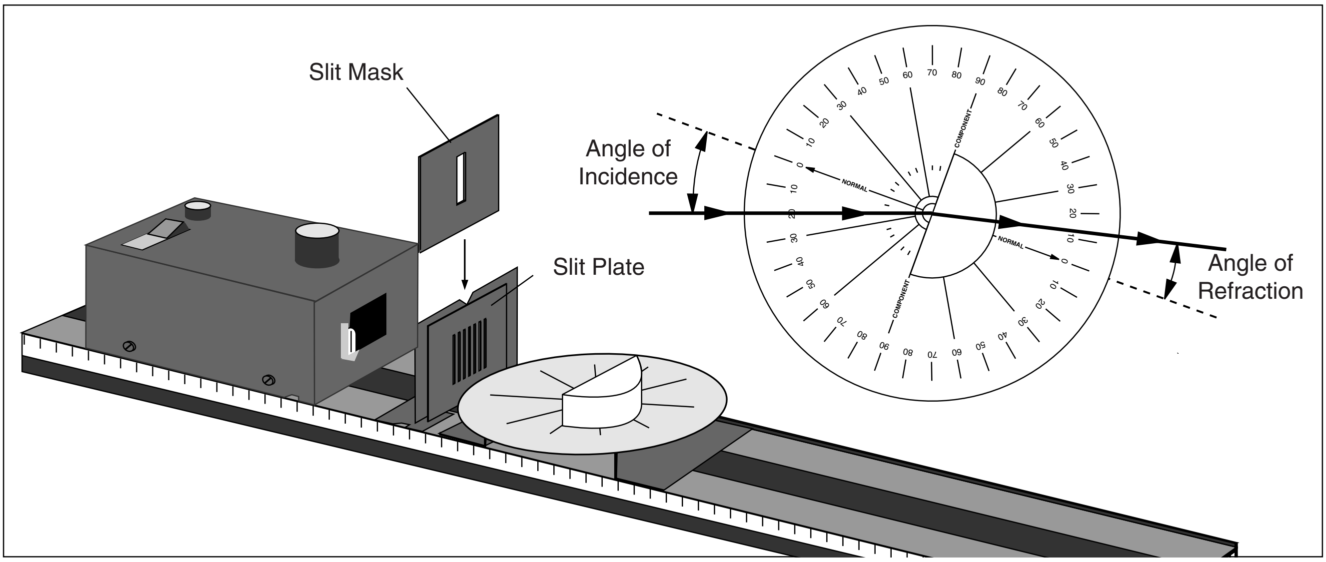

Figure 4.1 Equipment Setup

Introduction

As you have seen, the direction of light propagation changes abruptly when light encounters a reflective surface. The direction also changes abruptly when light passes across a boundary between two different media of propagation, such as between air and acrylic, or between glass and water. In this case, the change of direction is called Refraction.

As for reflection, a simple law characterizes the behavior of a refracted ray of light. According to the Law of Refraction, also known as Snell's Law:

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

The quantities n_1 and n_2 are constants, called indices of refraction, that depend on the two media through which the light is passing. The angles θ_1 and θ_2 are the angles that the ray of light makes with the normal to the boundary between the two media (see the inset in Figure 4.1). In this experiment you will test the validity of this law, and also measure the index of refraction for acrylic.

Procedure

Set up the equipment as shown in Figure 4.1. Adjust the components so a single ray of light passes directly through the center of the Ray Table Degree Scale. Align the flat surface of the Cylindrical Lens with the line labeled "Component". With the lens properly aligned, the radial lines extending from the center of the Degree Scale will all be perpendicular to the circular surface of the lens.

Without disturbing the alignment of the Lens, rotate the Ray Table and observe the refracted ray for various angles of incidence.

① Is the ray bent when it passes into the lens perpendicular to the flat surface of the lens?

____

_______________________________________.

② Is the ray bent when it passes out of the lens perpendicular to the curved surface of the lens?

____

_______________________________________.

By rotating the Ray Table, set the angle of incidence to each of the settings shown in Table 4.1 on the following page. For each angle of incidence, measure the angle of refraction (Refraction_1). Repeat the measurement with the incident ray striking from the opposite side of the normal (Refraction_2).

Angle of:	**Incidence**	**Refraction$_1$**	**Refraction$_2$**
	0°		
	10°		
	20°		
	30°		
	40°		
	50°		
	60°		
	70°		
	80°		
	90°		

Table 4.1 Data

③ Are your results for the two sets of measurements the same? If not, to what do you attribute the differences?

____

____.

On a separate sheet of paper, construct a graph with sin(angle of refraction) on the x-axis and sin(angle of incidence) on the y-axis. Draw the best fit straight line for each of your two sets of data.

④ Is your graph consistent with the Law of Refraction? Explain.

____.

⑤ Measure the slope of your best fit lines. Take the average of your results to determine the index of refraction for acrylic (assume that the index of refraction for air is equal to 1.0).

n = ____________________________________.

Additional Questions

① In performing the experiment, what difficulties did you encounter in measuring the angle of refraction for large angles of incidence?

② Was all the light of the ray refracted? Was some reflected? How might you have used the Law of Reflection to test the alignment of the Cylindrical Lens?

③ How does averaging the results of measurements taken with the incident ray striking from either side of the normal improve the accuracy of the results?

Experiment 5: Reversibility

Equipment Needed:

- -Optics Bench
- -Ray Table and Base
- -Slit Plate
- -Cylindrical Lens.
- -Light Source
- -Component Holder
- -Slit Mask

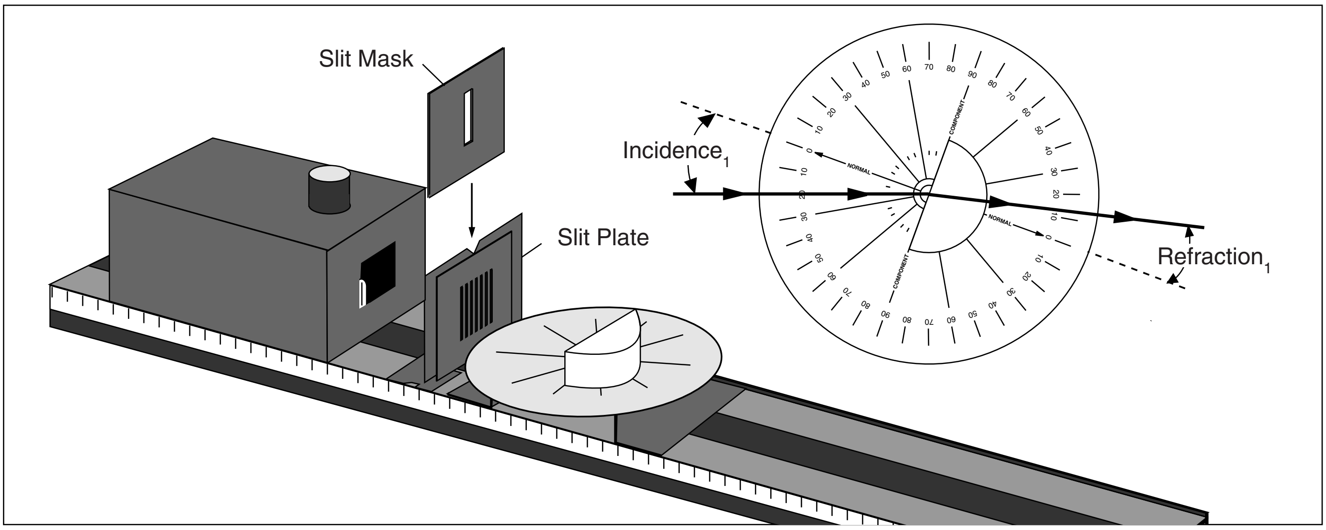

Figure 5.1 Equipment Setup

Introduction

In Experiment 4, you determined the relationship that exists between the angle of incidence and the angle of refraction for light passing from air into a more optically dense medium (the Cylindrical Lens). An important question remains. Does the same relationship hold between the angles of incidence and refraction for light passing out of a more optically dense medium back into air? That is to say, if the light is traveling in the opposite direction, is the law of refraction the same or different? In this experiment, you will find the answer to this question.

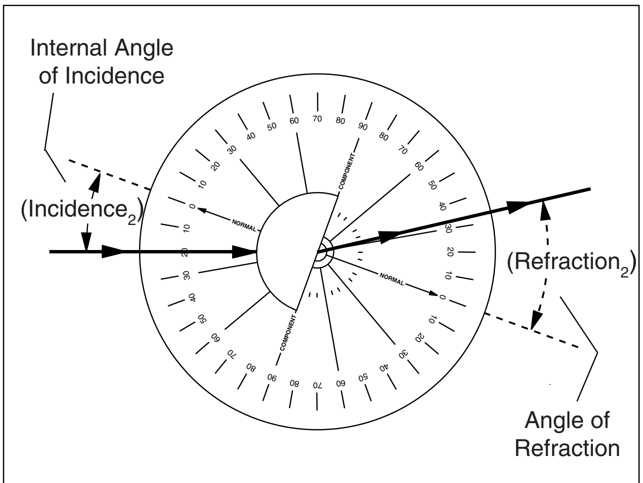

Figure 5.2 Internal Angle of Incidence

Procedure

Set up the equipment as shown in Figure 5.1. Adjust the components so a single ray of light passes directly through the center of the Ray Table Degree Scale. Align the flat surface of the Cylindrical Lens with the line labeled "Component". With the lens properly aligned, the radial lines extending from the center of the Degree Scale will all be perpendicular to the circular surface of the lens.

Without disturbing the alignment of the lens, rotate the Ray Table and set the angle of incidence to the values listed in Table 5.1 on the following page. Enter the corresponding angles of Refraction in the table in two columns: Refraction$_1$ and Incidence$_2$. (Let Incidence$_2$ = Refraction$_1$).

Table 5.1 Data

Ray Incident on:	**Flat Surface**		**Curved Surface**	
Angle of:	**Incidence$_1$**	**Refraction$_1$**	**Incidence$_2$**	**Refraction$_2$**
	0°			
	10°			
	20°			
	30°			
	40°			
	50°			
	60°			
	70°			
	80°			
	90°			

Now let the incident ray strike the curved surface of the lens. (Just rotate the Ray Table 180°.) The internal angle of incidence for the flat surface of the Cylindrical Lens is shown in Figure 5.2. Set this angle of incidence to the values you have already listed in the table (Incidence$_2$). Record the corresponding angles of refraction (Refraction$_2$).

① Using your collected values for Incidence$_1$ and Refraction$_1$, determine the index of refraction for the acrylic from which the Cylindrical Lens is made. (As in experiment 4, assume that the index of refraction for air is equal to 1.0.)

n_1 = ____.

② Using your collected values for Incidence$_2$ and Refraction$_2$, redetermine the index of refraction for the acrylic from which the Cylindrical Lens is made.

n_2 = ____.

③ Is the Law of Refraction the same for light rays going in either direction between the two media? ____.

④ On a separate sheet of paper, make a diagram showing a light ray passing into and out of the Cylindrical Lens. Show the correct angles of incidence and refraction at both surfaces traversed by the ray. Use arrow heads to indicate the direction of propagation of the ray. Now reverse the arrows on the light ray. Show that the new angles of incidence and refraction are still consistent with the Law of Refraction. This is the principle of optical reversibility.

⑤ Does the principle of optical reversibility hold for Reflection as well as Refraction? Explain.
____.

Experiment 6: Dispersion and Total Internal Reflection

EQUIPMENT NEEDED:

- -Optics Bench
- -Ray Plate and Base
- -Slit Plate
- -Cylindrical Lens
- -Viewing Screen.
- -Light Source
- -Component Holder
- -Slit Mask
- -Ray Table Component Holder

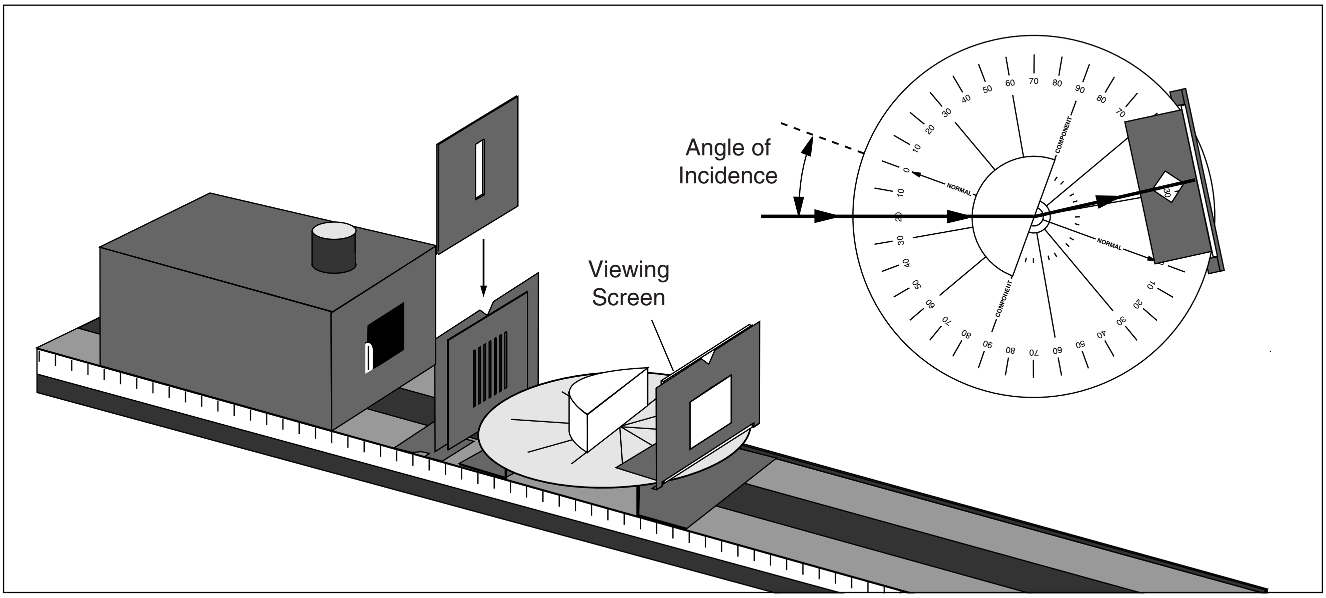

Figure 6.1 Equipment Setup

Introduction

In this experiment you will look at two phenomena related to refraction: Dispersion and Total Internal Reflection. Dispersion introduces a complication to the Law of Refraction, which is that most materials have different indexes of refraction for different colors of light. In Total Internal Reflection, it is found that in certain circumstances, light striking an interface between two transparent media can not pass through the interface.

Procedure

Set up the equipment as shown in Figure 6.1, so a single light ray is incident on the curved surface of the Cylindrical Lens.

Dispersion

Set the Ray Table so the angle of incidence of the ray striking the flat surface of the lens (from inside the lens) is zero-degrees. Adjust the Ray Table Component Holder so the refracted ray is visible on the Viewing Screen.

Slowly increase the angle of incidence. As you do, watch the refracted ray on the Viewing Screen.

① At what angle of refraction do you begin to notice color separation in the refracted ray?

② At what angle of refraction is the color separation a maximum? ____________________

____.

③ What colors are present in the refracted ray? (Write them in the order of minimum to maximum angle of refraction.)
____

____.

④ Measure the index of refraction of acrylic for red and blue light
($n_{acrylic} \sin \theta_{acrylic} = n_{air} \sin \theta_{air}$).

> ➤**NOTE:** In Experiment 4 we said that the index of refraction of a given material is a constant. That statement was almost accurate, but not quite. As you can see, different colors of light refract to slightly different angles, and therefore have slightly different indexes of refraction.

n_{red} = _______________________________________.

n_{blue} = ____.

Total Internal Reflection

Without moving the Ray Table or the Cylindrical Lens, notice that not all of the light in the incident ray is refracted. Part of the light is also reflected.

① From which surface of the lens does reflection primarily occur? ___________________

____.

② Is there a reflected ray for all angles of incidence? (Use the Viewing Screen to detect faint rays.)
____

____.

③ Are the angles for the reflected ray consistent with the Law of Reflection? __________

____.

④ Is there a refracted ray for all angles of incidence?____________________________

____.

⑤ How do the intensity of the reflected and refracted rays vary with the angle of incidence?
____.

⑥ At what angle of refraction is all the light reflected (no refracted ray)? ______________

____.