Reflection and Refraction of Light and Polarization

In today's laboratory several properties of light, including the laws of reflection, refraction, total internal reflection and polarization, will be examined.

Experiment 1: The Law of Reflection

![Reflection and incidence angles diagram]

**Figure 1: Optics table setup for the law of reflection experiment.**

**Introduction:**

The shape and location of the image created by reflection from a mirror of any shape is determined by just a few simple principles. One of these principles you already know: light propagates in a straight line. You will have an opportunity to learn the remaining principles in this experiment.

To determine the basic principles underlying any phenomenon, it is best to observe that phenomenon in its simplest possible form. In this experiment, you will observe the reflection of a single ray of light from a plane mirror. The principles you discover will be applied, in later experiments, to more complicated examples of reflection.

**Procedure:**

1. Set up the mirror on the optics table on your optics bench. Adjust the components so a single ray of light is aligned with the bold arrow labeled "Normal" on the Ray Table Degree Scale. Carefully align the flat reflecting surface of the mirror with the bold line labeled "Component" on the Ray Table. With the mirror properly aligned, the bold arrow on the Ray Table is normal (at right angles) to the plane of the reflecting surface.

2. Rotate the Ray Table and observe the light ray. The angles of incidence and reflection are measured with respect to the normal to the reflecting surface, as shown in Figure 1.

3. By rotating the Ray Table, set the angle of incidence to each of the settings shown in Figure 1. For each angle of incidence, record the angle of reflection (Reflection1). Repeat your measurements with the incident ray coming from the
opposite side of the normal (Reflection2).

4. Are the results for the two trials the same? If not, to what do you attribute the differences?

5. What relationship holds between the angle of incidence and the angle of reflection?

Table 8.1: Data

<table>
<thead>
<tr>
<th>Angle of Incidence</th>
<th>Reflection1</th>
<th>Reflection 2</th>
<th>% Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>0°</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30°</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>60°</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>90°</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Experiment 2: The Law of Refraction

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; they depend on the two media through which the light is passing. The angles \( \theta_1 \) and \( \theta_2 \) are the angles that the ray of light makes with the normal to the boundary between the two media (see the inset in Figure 2). In this experiment, you will test the validity of this law, and measure the index of refraction for acrylic.
Procedure:

Set up the equipment as shown in Figure 2. 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 2 on the following page. For each angle of incidence, measure the angle of refraction (Refraction1). Repeat the measurement with the incident ray striking from the opposite side of the normal (Refraction2).

1. Are your results for the two sets of measurements the same? If not, to what do you attribute the differences?
2. Solve for the index of refraction, $n$, for the acrylic material. (Assume that the index of refraction for air is equal to 1.0).

\[ n = \text{________________________} \]

Additional Questions:

1. Was all the light of the ray refracted? Was some reflected?
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?

<table>
<thead>
<tr>
<th>Angle of Incidence</th>
<th>Refraction1</th>
<th>Refraction2</th>
<th>n of acrylic</th>
</tr>
</thead>
<tbody>
<tr>
<td>0°</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20°</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40°</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>60°</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>80°</td>
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</tbody>
</table>

**Experiment 3: Total Internal Reflection**

**Introduction**

In this experiment, you will look at Total Internal Reflection. In Total Internal Reflection, it is found that in certain circumstances, light striking an interface between two transparent media cannot pass through the interface.

**Procedure**

Rotate the cylindrical lens so a single light ray is incident on the curved surface of the Cylindrical Lens. 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? You need to look for light emerging from the lens. To do this you may have to hold up paper so that the light shines on it since this ray will be faint.
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. At what angle of incidence is all the light reflected (no refracted ray)?
Experiment 4: Polarization

Introduction

Light is a transverse wave; that is, the electromagnetic disturbances that compose light occur in a direction perpendicular to the direction of propagation (see (a) 8.3). Polarization, for light, refers to the orientation of the electric field in the electromagnetic disturbance. The magnetic field is always perpendicular to the electric field. 8.3 (b) and (c) show vertical and horizontal polarization, respectively. Figure 3 (d) depicts random polarization, which occurs when the direction of polarization changes rapidly with time, as it does in the light from most incandescent light sources.

Your optics equipment includes two Polarizers, which transmit only light that is plane polarized along the plane defined by the 0 and 180 degree marks on the Polarizer scales. Light that is polarized along any other plane is absorbed by the polaroid material. Therefore, if randomly polarized light enters the Polarizer, the light that passes through is plane polarized. In this experiment, you will use the Polarizers to investigate the phenomena of polarized light.

Procedure

Replace the optics table with two polarizers in holders. Turn the light source so that it is showing a point of light (on its side) and view the light with both polarizers removed. Replace the first polarizer on the component holder bench. Rotate the polarizer while viewing the target.

1. Does the target seem as bright when looking through the polarizers as when looking directly at the target? Why?
2. Is the light from the Light Source plane polarized? How can you tell?
3. Align the polarizer on the bench so it transmits only vertically polarized light. Add the second polarizer. Looking through both Polarizers, rotate the second polarizer, call it B.
4. For what angles of Polarizer B is a maximum of light transmitted? For what angles is a minimum of light transmitted?