Reflection and Refraction

Safety and Equipment

- Ruler
- Ray Box
- VWR Optics Kit (Small flat mirror and 2-D Lenses)
- Rectangular Acrylic Prism
- Triangular Glass Prism
- Red Reflective Flat Mirror
- Two identical objects (soda cans or weights)
- White paper and pencil

Introduction

Light is an electromagnetic wave that consists of the oscillations of an electric field accompanied by the oscillations of a magnetic field. When light waves arrive at the interface between two media, from medium A to medium B, part of the wave energy is reflected back into A or reflects, and the remainder is transmitted into B. As an electromagnetic wave, light travels at different speeds in different media. Light travels fastest in a vacuum, where it has a speed, \( c = 3.00 \times 10^8 \) m/s. When electromagnetic wave propagates from a medium A where its speed is \( v_1 \) to medium B where its speed is \( v_2 \), it will change the direction of motion. This phenomenon is called refraction. Refractive property of a medium is described by a refractive index, \( n = \frac{c}{v} \).

This experiment will study the phenomena of reflection and refraction of light. To simplify the study we will overlook the electromagnetic nature of light and use a “light rays” model; such an approach is called “Geometrical Optics”. A light ray is a line directed along propagation of electromagnetic energy. Propagating energy forms a front (line of points that just being reached) and rays of light are always perpendicular to the frontline.

The Law of Reflection of light states that the angle of incidence is equal to the angle of reflection.

The Law of Reflection of light also states that the incident ray, the reflected ray and the normal to the media boundary all lie in the same plane. This is illustrated by Figure 1. Pay attention that both, the angle of incidents and angle of reflection, are measured with the normal of the media boundary not with the boundary itself.

![Figure 1](image-url)
The Law of Refraction of light also known as Snell's Law gives the relationship between the angles and index of refractions: \( n_i \sin \theta_i = n_r \sin \theta_r \)

1) When a ray of light enters a medium where its speed is decreased \((n_i < n_r)\), it is bent toward the normal.

2) When a ray of light enters a medium where its speed is increased \((n_i > n_r)\), it is bent away from the normal.

In Figure 2, the speed of light in upper medium is greater than in the speed of light in medium below.

![Diagram of light ray](image)

**Figure 2.** Trace of the light ray for \( n_i < n_r \)

**Objective**

- *To verify the law of reflection.*
- *To verify the Snell’s Law*

**Part #1. Ray Reflection from a Small Flat Mirror**

1. Install one-slit diaphragm into a ray box. Place the ray box and a flat mirror on a sheet of white paper.
2. Draw a line along the edge of the mirror to trace the surface of the mirror.
3. Direct the light ray to the surface of the mirror at a certain angle to observe a reflected ray.
4. Mark two dots inside both, incident and reflected, rays.
5. Remove the ray box and the mirror from the paper. For each ray, connect the corresponding dots for and extend the connecting line towards the surface of the mirror to retrace the light rays.
6. Draw a normal to the surface of the mirror at the point of reflection (where the connecting lines get together).
7. Use a protractor to measure the angle between the incident ray and the normal. Record it as an incident angle.
8. Use a protractor to measure the angle between the reflected ray and the normal. Record it as a reflected angle.
9. Repeat the experiment two more times for different angles.
10. Comment on the agreement between the angles by calculating a % difference \(\frac{\text{ABS}(\theta_i - \theta_r)}{\text{AVERAGE}(\theta_i, \theta_r)}\).

<table>
<thead>
<tr>
<th>trial</th>
<th>incident angle</th>
<th>reflected angle</th>
<th>% Diff</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>3</td>
<td></td>
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</tbody>
</table>

**Table 1:** Angles measured for rays reflecting from a flat mirror.
Part #2. Ray Refraction through a Rectangular Acrylic Prism

1. Keep one-slit diaphragm in a ray box. Place the ray box and a prism on a sheet of white paper.
2. Direct the light ray to a surface of the prism at a shallow angle to the surface (lower than 45°).
3. Observe the ray exiting the prism into the air out of parallel (not perpendicular) surface.
   If not, adjust the ray box.
4. Trace the edges of the prism.
5. Mark one point where the ray enters the prism and another where the ray comes out.
6. Mark two more points: one along the entering ray and another along the exiting ray.
7. Remove the ray box and the prism from the paper, and then connect the dots to retrace the light path.
8. Make sure to connect the point of entrance with the point of exit to trace the path inside the prism.
9. Draw one normal to the surface of the prism at the point of entrance and another normal at the point of exit. See Figure 3.
10. Using a protractor, measure two sets of angles (each between the normal and the ray):
    - Incident Ray from Air to Acryl and Refracted Ray in Acryl
    - Incident Ray from Acryl to Air and Refracted Ray in Air
11. Conclude about where the speed of light in Air is large than speed of light in Acryl. Include the statement in the abstract.
12. Using Snell’s Law, calculate refractive index of Acryl. Use the value of 1.0 as refractive index of air.
13. Average the results and compare it with the value that could be found on the Net by calculating % Diff.

<table>
<thead>
<tr>
<th>Medium</th>
<th>Incident angle, Θi (deg)</th>
<th>Refracted angle, Θr (deg)</th>
<th>n</th>
<th>( n_{\text{average}} )</th>
<th>( n_{\text{theor}} )</th>
<th>% Diff</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air to Acryl</td>
<td></td>
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<tr>
<td>Acryl to Air</td>
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</tbody>
</table>

Table 2: Angles measured for rays refracting in an acrylic prism and calculation of refractive index of acryl.

Figure 2. Refraction of light in an acrylic prism
Part #3. Ray Refraction through a Triangular Glass Prism

1. Keep one-slit diaphragm into a ray box. Place the ray box and a prism on a sheet of white paper.
2. Direct the light ray to a surface of the prism at very low angle.
3. Adjust the prism or the ray until you see that exiting ray splits into different colors
4. Using a pencil, trace the edges of the prism.
5. Mark points where light enters and exits the prism; and then mark light ray of each color with a dot.
6. Connect the point of entrance with the point of exit to trace the path inside the prism.
7. Remove the prism and trace the path of each color.
8. List the colors in order from least diverted from the original path to most.
9. Conclude the order of refractive indexes in glass for light of different color.

<table>
<thead>
<tr>
<th></th>
<th>Light of different colors in order from least to most deflected</th>
<th>Light of different colors in order from least to most refractive index in glass</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<td>1</td>
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<tr>
<td>2</td>
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<td>5</td>
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<tr>
<td>6</td>
<td></td>
<td>6</td>
</tr>
</tbody>
</table>

Table 3: Sorting out light of different colors

Figure 3. Refraction of light in a glass prism
Part #4. Ray Refraction through a Lens

1. Install five-slit diaphragm into a ray box and place it on a sheet of white paper.
2. Adjust the ray box so that the five light ray are parallel.

Convex Lens:
3. Place a *convex lens from VWR kit* in the middle of the paper.
4. Direct the parallel light rays through the *convex lens*.
5. Observe the refracted rays and record the observation in Table 4.
6. Use a pencil to trace the edges of the lens, mark the focal point, and measure the focal length.

Concave Lens:
7. Set up the ray box on another sheet of white paper.
8. Place a *concave lens from VWR kit* in the middle of the paper.
9. Direct the parallel light rays through the *concave lens*.
10. Observe the refracted rays and record the observation in Table 4.
11. Find the focal distance:
   - Trace the edges of the lens and the light rays *refracted* (ignore reflected rays) by the lens
   - Remove the ray box and the lens from the paper
   - With dashed line, extend each trace towards the light source until they intercept.
   - Measure the focal length of the lens.

Note: Because not the actual rays but the extensions form the focal point, the focal length is negative

<table>
<thead>
<tr>
<th>Type of lens</th>
<th>Manner of Refraction (converging/diverging)</th>
<th>Focal Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Convex</td>
<td></td>
<td></td>
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<tr>
<td>Concave</td>
<td></td>
<td></td>
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</tbody>
</table>

*Table 4. Comparison of refractive properties of different types of lens*

Part #5. Image Formed from a Red Reflective Flat Mirror

1. Put an object in front of the red reflective plane mirror.
2. Place another identical object behind the mirror exactly where you see the image of the first one.
3. Use a ruler to measure the distance from the mirror to the object in front of the mirror.
4. Measure the distance from the mirror to the object placed where the image of the first one appears. Be consistent with the measurements: measure the nearest distance between the mirror and an object.
5. Comment on the relationship between measured distance to the object and measured distance to the image.

<table>
<thead>
<tr>
<th>Distance to the object, $d_o$ (m)</th>
<th>Distance to the image, $d_i$ (m)</th>
<th>% Match</th>
</tr>
</thead>
</table>

*Table 5. Measure values of distances for the flat mirror reflection*