UNIVERSITY PHYSICS

EXPERIMENT 11

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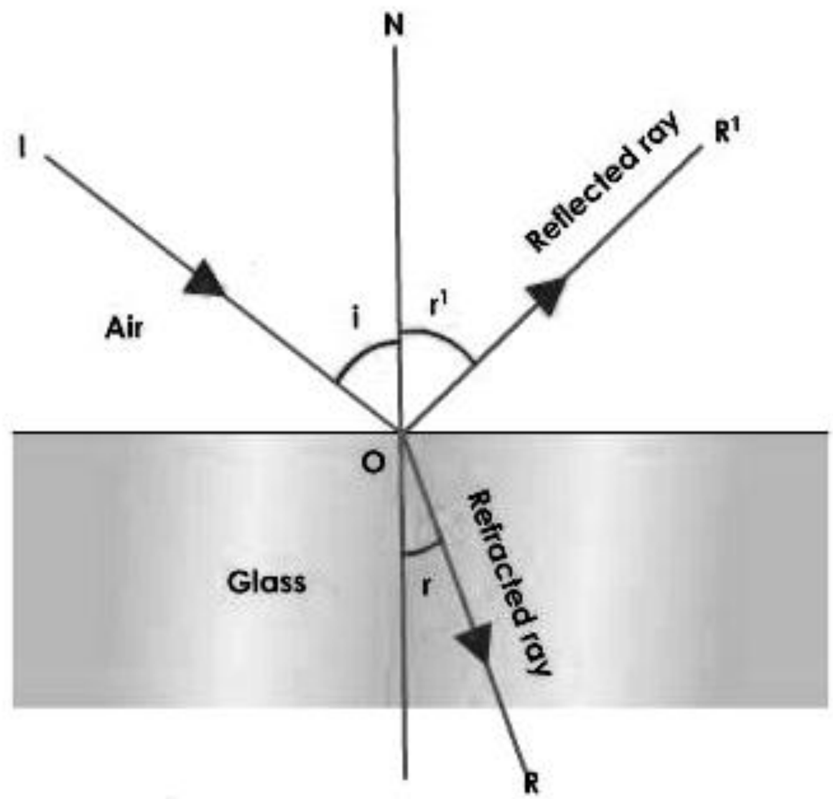
COLLIN COLLEGE

Reflection and Refraction



Produced by the Physics Staff at Collin College

Purpose

In this experiment, you will study and verify the laws of reflection and refraction using a plane mirror and a glass block.

Equipment

- Pins
- Pin Board
- Sheets of white paper
- Ruler and protractor
- Short candle or similar light source
- Rectangular mirror
- Thick glass plate

Introduction

Reflection and refraction are two commonly observed optical properties of light. Whenever a light strikes the surface of some material at an angle, part of the wave is reflected and part is transmitted (or absorbed). Due to refraction, the velocity of transmitted light is less than the velocity before it entered the medium. The denser the medium, the more the light is slowed down. This is due to interaction between the light and the orbiting electrons in the atoms comprising the material.

The reflection of light rays from a plane surface such as a glass plate or a plane mirror is described by the **law of reflection**:

The angle of incidence (θ_i) is equal to the angle of reflection (θ_r).

These angles are measured from a line perpendicular or *normal* to the reflecting surface (Figure 11.1). Furthermore, the reflected ray is always in the same plane as the incident ray, and this plane is perpendicular to the surface. The rays from an object reflected by a smooth place surface appear to come from an image located behind the surface.

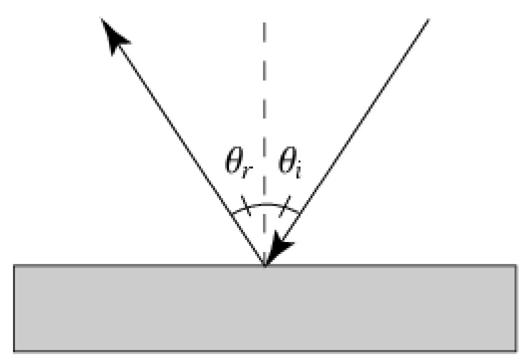


Figure 11.1

For rough surfaces, the law of reflection remains valid. It predicts that rays incident at slightly different points on the surface are reflected in completely different directions, because the normal to a rough surface varies in direction very strongly from point to point on the surface. This type of reflection is called *diffuse reflection*, and is what enables us to see non-shiny objects.

When light travels from one medium to another, it generally bends, or *refracts* as it slows down in the new medium. ***Snell's law*** (Figure 11.2) states the relationship between the indices of refraction (*n*) of the two materials, and the light's angle of incidence and angle of refraction:

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

Here n is a measure of the speed of light in a transparent material and is given by the ratio c/v, where c is the speed of light in a vacuum and v is the speed of light in the material.

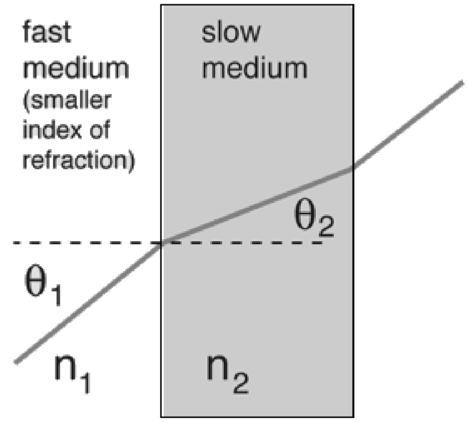


Figure 11.2

In terms of the indices of refraction and Snell's law, the following relationships hold true for refraction:

- If the second medium is <u>more</u> optically dense than the first medium ($n_2 > n_1$), the refracted ray will bend *toward* the normal ($\theta_2 < \theta_1$).
- If the second medium is <u>less</u> optically dense than the first medium ($n_2 < n_1$), the refracted ray will bend *away from* the normal ($\theta_2 > \theta_1$).

<u>Procedure</u>

<u>A. Reflection</u>

Glass Plate as a Mirror

1. Place a sheet of white paper on the pin board. Draw a center line and place the glass plate and candle as shown. Draw the candle line and place a pin in the pin board where it touches the glass plate.
2. Move your eye to the observing position so that you see a reflection of the candle in the glass plate aligned with the pin you placed. The glass plate partially reflects the light and serves as a mirror. You will see a double image, can you explain why?
3. With your eye still in the observing position, place another pin in the pin board closer to you so that it is aligned with the nearer reflected image and first pin. Repeat this procedure, viewing from a position on the other side of the candle.
4. Remove the equipment from the paper. Draw straight lines through the pair of pin points to create two image lines (extend through the glass plate). The place where the image lines

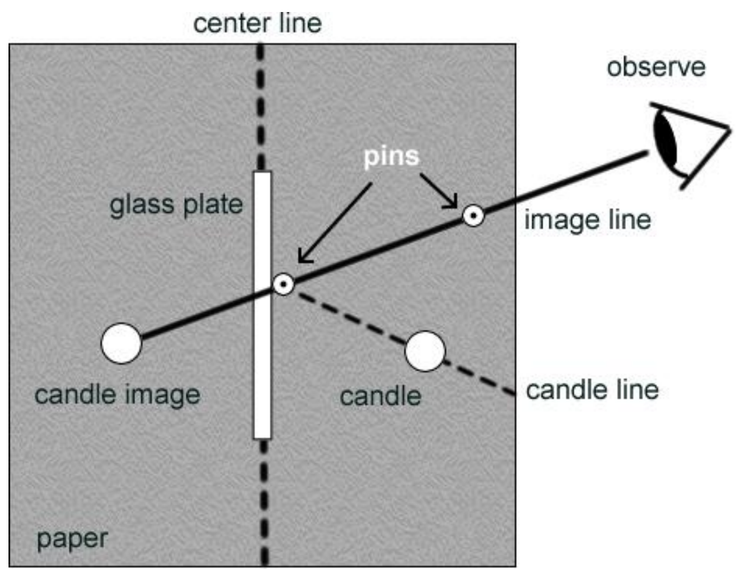


Figure 11.3

cross marks the image position. The place where the candle lines cross should be where the candle was located and mark the candle object position.

5. Draw normal lines to the glass plate line at the points of intersection of the ray lines. Label and measure the angles of incidence and reflection. Record the data in Table 11.1.
6. Measure the perpendicular distances from the glass plate line to the candle mark (the object distance d_o) and to the candle image position (the image distance d_i). Calculate the percent difference in the quantities and record in Table 11.1.

Plane Mirror

1. Place the mirror near the center of a sheet of paper as with the glass plate used previously. Prop the mirror up or use a holder so that its sits vertically. Draw a line along the reflective silver side of the mirror. Then lay an object pin about 10 cm in front of the mirror and parallel to its length Figure 11.4)
2. Stick a reference pin *R* in the board to one side of the object pin and near the edge of the paper, as illustrated, and mark its location.
3. Place another pin nearer the mirror so that it is visually aligned with the reference pin and the head of the object pin's image in the mirror. Mark the position of this pin, and label it with an *H*. Then move this pin over so that it aligns with the reference pin and the "tail" of the image pin. Mark this location and label it with a *T*.
4. Repeat this procedure on the opposite side of the object pin with another reference pin.
5. Remove the equipment from the paper and draw straight lines from the reference points through each of the *H* and *T* locations and the mirror line. The *H* lines and *T* lines will intersect and define the locations of the head and tail of the pin image, respectively. Draw a line between the line intersections (the length of the pin image). Measure the length of this line and the length of the object pin, and record in Table 11.2. Also measure the object distance d_o and the image distance d_i from the mirror line, and record. Calculate the percent difference of the respective measured values and record in Table 11.2.

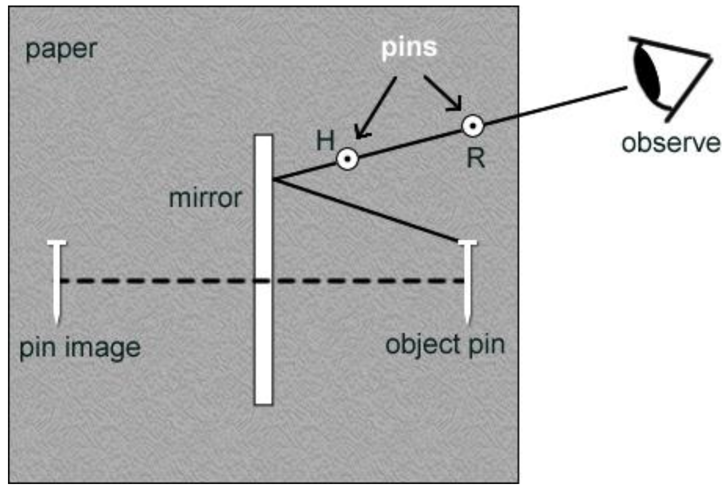


Figure 11.4

Rotation of a Mirror

1. Place the mirror near the center of a sheet of paper and draw a line along the reflective silver side of the mirror. Find the center of the line and mark that location.
2. Stick two pins (*A* and *B*) in the board to one side and in front of and in line with the center of the mirror as in Figure 11.5. Viewing the aligned images of these pins from the other side of the paper, place two more pins (*C* and *D*) in alignment. Label the locations of the pins.

3. Leaving pins *A* and *B* in place, rotate the mirror a small but measurable angle θ about its center point, and draw a line along the silvered side of the mirror. Align two pins (*E* and *F*) with the aligned images of *A* and *B*, and mark and label the locations of *E* and *F*.

4. Remove the equipment from the paper and draw the incident ray and two reflected rays. Measure the angle of rotation θ of the mirror and the angle of deflection ϕ between the two reflected rays, and record in Table 11.3.

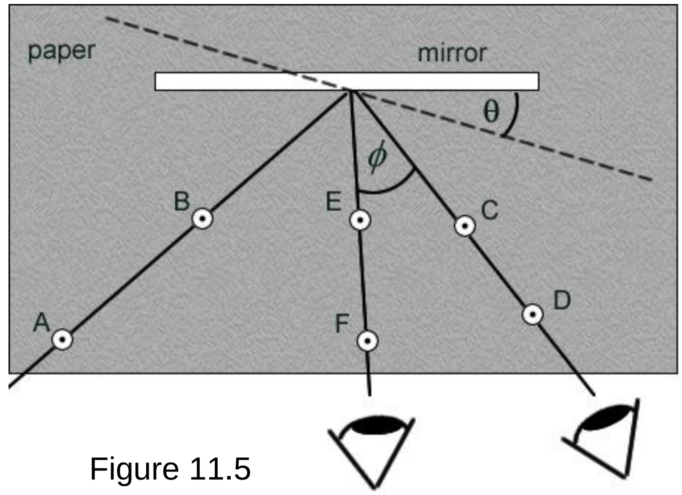


Figure 11.5

5. Double θ and compute the percent difference between 2θ and ϕ and record. Make a conclusion about the relationship between the angle of rotation of a mirror and the angle of deflection of a ray.

B. Refraction

Index of Refraction of a Glass Plate

1. Lay the glass plate in the center of a sheet if a paper and outline its shape with a pencil. Draw a line normal to one of the sides of the plate, and place a pin (*R*) at the intersection of this line and the face of the plate. Measure an angle of 15° relative to this line, and place a pin (*A*) about 6 to 8 cm from the plate at this angle.

2. Looking through the edge of the plate from the eye positions shown in Figure 11.6, place a pin (*A*') adjacent to the face of the plate so that it is aligned with *R* and *A*. Mark and label the locations of the pins.

3. Repeat with pins *B* and *C* at angles of 30° and 45°, respectively. For the 45° angle case, align an additional pin (*C*').

4. Trace the various rays, and measure and record in Table 11.4 the values of θ_1 and θ_2 for each case. Also measure and record the displacement *d* of ray *C*'*C*" from the normal and the thickness of the plate. Use *Snell's law* to calculate the index of refraction of the glass (*n*). Compare your calculated value of *n* with the general range of *n* for glass (1.5 – 1.7 depending on type).

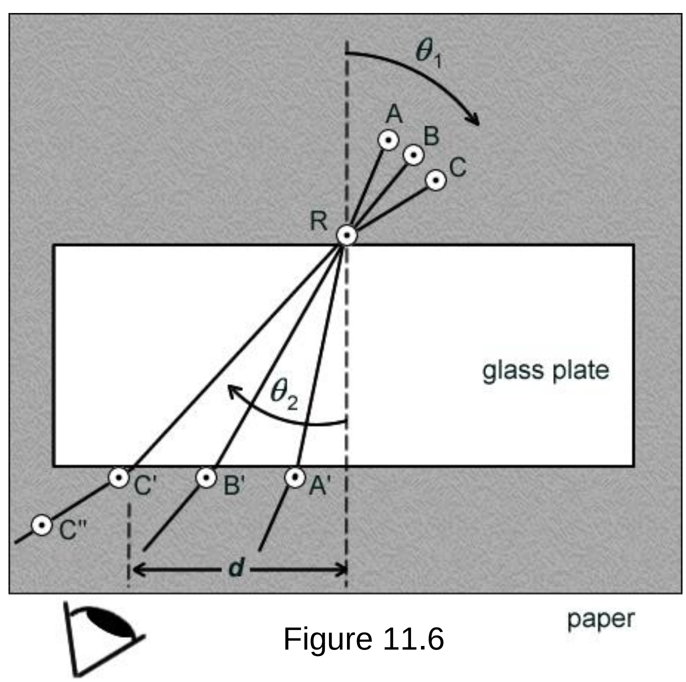


Figure 11.6