REFRACTION

Purpose: To study refraction of light at plane surfaces.

Apparatus: Pentagonal Lucite plate; scale; protractor; water refraction apparatus; pins; pin board.

References:

Discussion:

When a ray of light passes from one medium into another one of different optical density, it undergoes a change of velocity. The ratio of the velocity of light in vacuum to the velocity of light in any medium is a constant for that particular medium, and is called the absolute index of refraction, n. It can be shown that if i is the angle of incidence, i.e., the angle which the incident ray makes with the normal to the boundary surface, and if r is the angle of refraction, i.e., the angle which the refracted ray makes with the normal; then

$$n = \frac{c}{v(medium)} = \frac{\sin i}{\sin r} \qquad (1)$$

Since the velocity of light in air is very nearly equal to that in free space, the absolute index of refraction is defined, for most practical purposes, as the ratio between the velocity of light in air to that in the medium, i.e., c = v(air) to a very good approximation.

When a ray of light passes through a prism of angle A, it is deviated from its original direction by an angle D which has a minimum value D_m when the angle of incidence is equal to the angle of emergence. When the angles A and D_m are known the following equation may be used to determine n for the material of the prism:

$$n = \frac{\sin((D_m + A)/2)}{\sin(A/2)} \qquad (2)$$

If one of the media is not air, then the constant ratio of the velocities in the two media is called the relative index of refraction, which can be found from the relation:

$$(\text{relative}) \; n_{1,2} = \frac{V_1}{V_2} = \frac{n_2 \, (\text{absolute})}{n_1 \, (\text{absolute})}$$

Procedure:

The method of sighting in Parts 1-4 is similar to that used in Experiment # 8. Clean the glass plate, especially the five lateral surfaces.

1. Place the pentagon approximately in the center of a sheet of unlined paper and carefully trace its outline with a sharp pencil. As shown in Fig 10-1, place two pins about 8 cm apart so that the incident ray, represented by the line connecting the two pins, makes an angle of approximately 45E with the normal and the first pin is near the right angle of the parallel-sided portion of the plate 1/2 cm from the corner. While looking through the opposite *parallel* surface place two sighting pins in line with your eye and the *images* of pins (1) and (2). Pin (4) should then hide from view the other three pins. Remove the plate and carefully trace the lines indicated by the first two (object)   pins and the two sighting pins. Measure *both* angles of incidence and *both* angles of refraction.
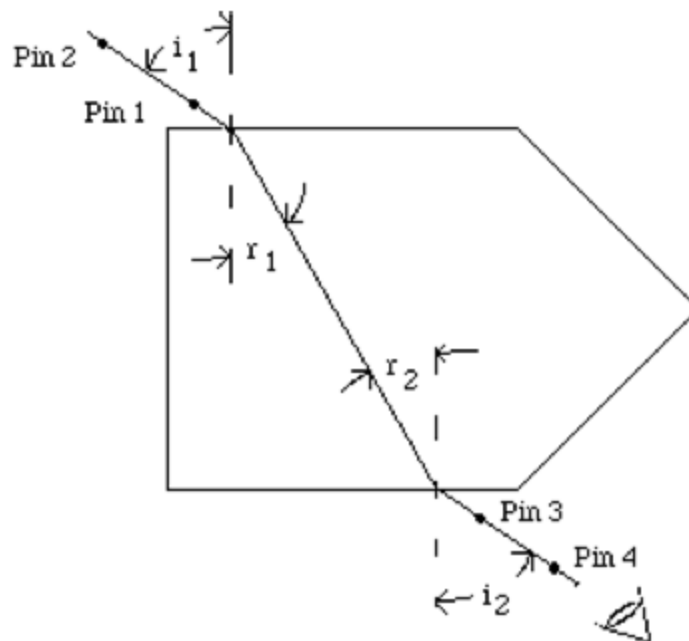

Fig 10-1

2. On another sheet of paper, as indicated in Fig. 10-2, place two pins at exactly 4 cm from the apex of the triangular part of the plate, one on each side of the refracting angle A. These pins should be just outside of the traced lines and in contact with the lateral surface of the prism. As in (1), use two pins (3 and 4) for sighting. Without removing any of the pins place a pin (5) about 10 cm from the far pin (1) in such position that it will be exactly in line with the other four pins when viewed in the direction of the

line of sight. Remove the glass plate and draw lines connecting the pins showing the direction of the bent ray. Also extend the incident and emergent rays to find the angle of deviation. This is the angle D_m inasmuch as the condition for minimum deviation is obtained when the ray in the prism is perpendicular to the bisector of the angle A.

      With a protractor measure the angles A,D_m,i_1 and i_2 (the angle of emergence).
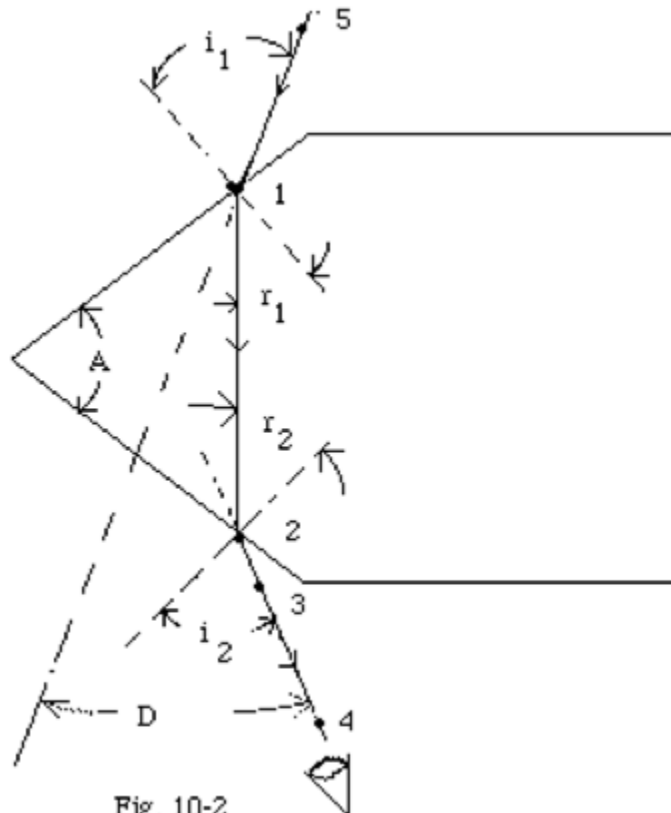

Fig. 10-2

      3. To prove that the angle D_m measured in (2) is the angle of minimum deviation, on another sheet place two pins on the far side of the prism about 10 cm apart so the line joining them makes an angle of 75E with the normal. Trace the direction of two sighting pins and of the ray in the prism. Extend the incident and emergent rays to find the angle of deviation D. Repeat, on another sheet of paper, using the angle of incidence of 60E .

      4. Using the *vertical edge* of apex angle A in place of a pin, sight at it through the opposite side of the pentagon from two widely different directions. Prolong the two emergent rays until they meet. Measure the angle of incidence and the angle of refraction for each ray and also the perpendicular distance of the apex A from the refracting surface, and the point of intersection of the emergent rays from the refracting surface.
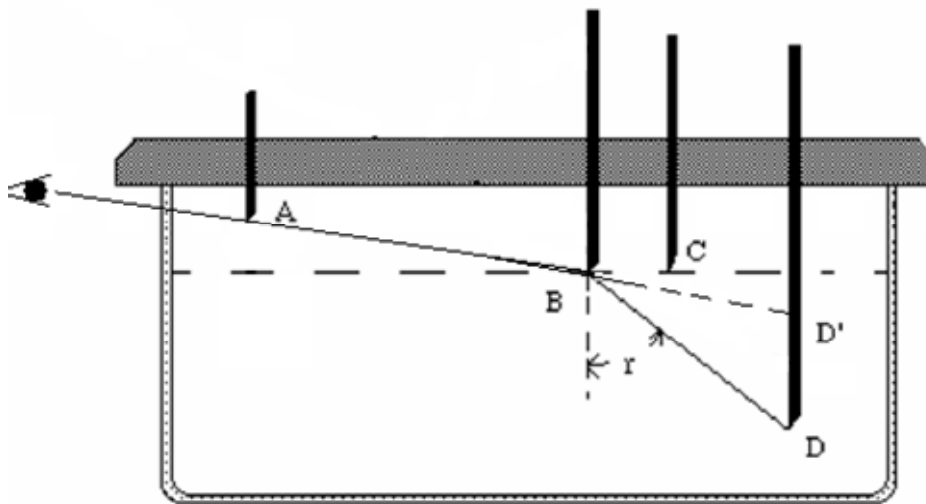
Fig. 10-3

5. The apparatus for determining the index of refraction of water (Fig. 10-3 and 10-4) is a metal frame carrying four brass sliders 1,2,3 and 4. Set the sliders in the slots of the frame with the arrows pointing upwards and with the corresponding numbers opposite each other.(Fig. 10-4).The jar should be set on a sheet of white paper.Mount the metal frame on the jar as shown (Fig. 10-3); push 4 as far down as possible; push sliders 2 and 3 as close to the surface of the water as possible without touching the water. Finally adjust 1 so that the point A *appears* to be in line with B and D (See Fig. 10-3).
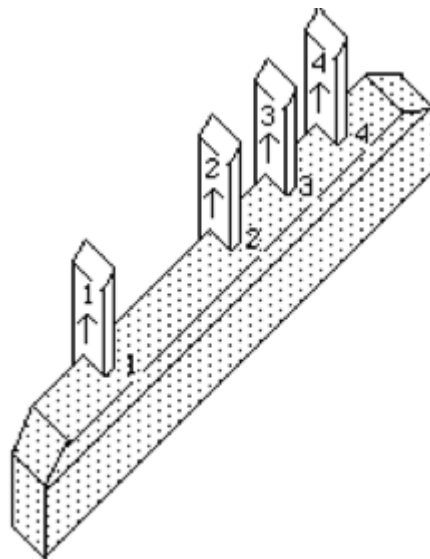

Fig. 10-4

Remove the frame from the water and lay it on a sheet of paper without disturbing the sliders. Mark the positions of points A, B, C and D on the paper. Draw the line BC (the

water level); with the protractor erect a perpendicular to BC at B; draw DB and AB, and finally, measure the angles of incidence and refraction with the protractor.

Computations:
      1. Compute 5 values of n for glass and one for water.
         Two from data of procedure (1) using equation (1); One from data of procedure (2) using equation (2); Two from data of procedure (4) using equation (1); One from data of procedure (5) using equation (1).
      2. From the data of procedure (3) show that these deviation angles are greater than D_m obtained from procedure (2).
      3. Compute the ratio of the actual depth of the prism to the apparent depth from procedure (4).
      4. Compute the velocity of light in water and in glass.
      5. Compute the index of refraction of the glass plate relative to water.

Questions to be Answered in the Report:

1. What cause, other than experimental error, will make the emergent ray not parallel to the incident ray, in Part (1)?

2. In which part of the experiment were the images of the pins colored? Explain.

3. Show by a geometrical proof that for small angles of incidence the ratio of computation 3 should equal n. Show also in which direction this ratio should deviate from n for large angles of incidence.

4. If a hunter desired to shoot a fish whose image could be seen in clear water, should he aim above or below the fish? Explain by the aid of a diagram.

6. Compute the displacement of the incident ray in Part (1).