Refractive index- using adjacent sides

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We are all familiar with a glass slab experiment conducted in the schools, shown in Figure 1. But what happens if the light ray is incident on surface AD with angle of incidence i and emerges from side CD with angle of emergence e?

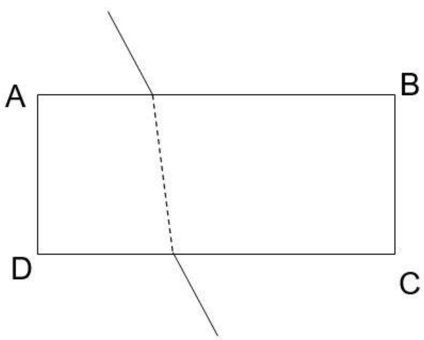


Figure 1. Standard textbook experiment.

This is shown in Figure 2. When the ray is emergent from the adjacent side, the equation for calculation of refractive index has to be reformulated.

On side AD (first surface)

$\sin(i_1)/\sin(r_1) = \mu$. ....(1)

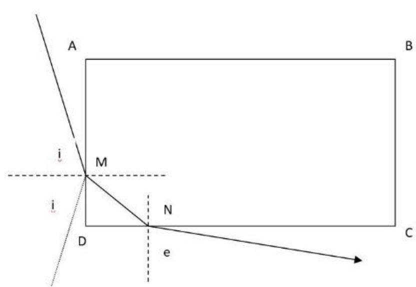


Figure 2.Incident and emergent rays on adjacent sides.

But the angle r_1 after first refraction is same as 90-i_2. Thus for surface 2 the equation becomes

$\mu = \sin(r_2)/\sin(i_2)$ ....(2).

But $i_2 = e$ and $i_1 = i$. So replacing the values in equation 1 we get

$\sin(i)/\sin(90-i_2) = \sin(i)/\cos(i_2) = \mu$........(3)

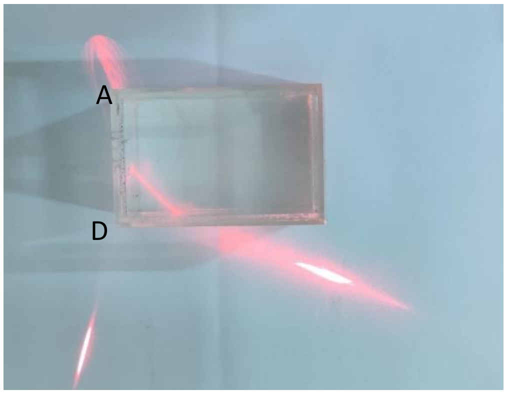
And equation 2 becomes $\mu = \sin(e)/\sin(i_2)$...4

Equation 4 can be written as $\sin(i_2) = \sin(e)/\mu$.

Equation 3 can be written as $\mu = \frac{\sin(i)}{\sqrt{1-\left(\frac{\sin e}{\mu}\right)^2}}$.

This can be rewritten as $\mu^2 - \sin^2 e = \sin^2 i$.

Thus the final equation is $\mu^2 = \sin^2 e + \sin^2 i$. The maximum value i and e can each take are 90, leading to value of $\mu^2 = 2$. Which implies that this experiment cannot work when the value of μ is less than 1.44.



So this experiment can be carried out only in water, which can be placed in a rectangular acrylic container as can be seen in Figure 3. A red laser light (use a simple laser pointer) is incident on the side AD. Since the light is given a slight angle with respect to the horizontal table, its image on the floor can be seen after it is emergent from the side CD (of figure 2.).

The setup is placed on a white sheet of paper. A line is drawn along the edge DC and extended to a length of 1 m from the edge C. A wooden scale is placed perpendicular to this line. Using trigonometry, the angle e can be measured. Similarly angle i is measured.

It is observed that the angle of emergence is very sensitive to very small changes in values of refractive index. Hence this method is suitable for use in measuring tiny changes in refractive index brought about when solutes (or impurities) are added to water in small concentrations.

Aim: to measure the refractive index of water upon addition of different concentrations of Lemon juice.

Material provided: A rectangular piece of acrylic, water, laser source, measuring tape, measuring scale, a screen, 500 ml lemon juice. Syringes.

Procedure. (marks for the observations, skill, calculations, etc can be decided by the teacher as per their convenience)

1) Figure 2, gives the top view of the experimental layout. Keep the source around 25 cm from point M.

2) Lay the acrylic piece on the graph paper in such a way that corner D is on one cross edge of a graph paper. Fill it with 250 ml of distilled water. Shine a laser on the smaller side AD at point M of the acrylic piece so that the light is incident on the surface AD with angle i and emergent from the longer surface CD from point N, with angle e.

The lines should be so planned that one can extend the line AD and CD on the graph paper conveniently. [Teachers have to note how the students draw the lines parallel to the edge of the container and as close to container as possible, to reduce the errors.]

3) Extend the line MA sufficiently long on the graph paper so that a perpendicular can be drawn/established from source to the line MA (extended). Using this perpendicular distance calculate tan (i) and hence the angle i.

Similarly extend the side DC line to calculate angle tan(e) and angle e.

4) For the ray incident at angle i on the first surface, it will also reflect with the same angle. This rule can also be used to measure the angle i. Measure the emergent angle e and calculate μ.

5) Repeat the same with two different values of incident angle i.

6) calculate the value of μ.

7) Stir the lemon juice and remove 50 ml of water and add 50 ml of lemon juice provided. Calculate the concentration of lemon juice in water and repeat steps 4-6, to calculate new value of μ. [Teachers should observe that when concentrations are being changed, the container does not get disturbed.]

8) Plot a graph of μ vs concentration.

No.	Concentration	Angle i	Angle e	μ

(X1 marks)

[Teachers should be alert to the fact that there is no established relationship between the refractive index and concentrations of the solution. Physical density of the solution is different from the optical densities. This concept should be conveyed to the students at the appropriate time.]

The average value of μ is

Plot a graph of μ vs concentration of lemon juice (X marks)

Q) Can this experiment be carried out by a glass slab? Y/N. Explain with reason in 1 sentence. (Y marks)

Q) What is the lower limit of angle I for which the experiment will give an emergent ray in distilled water.? (Y1 Marks)