# Total Internal Reflection

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**Aim:** To determine the refractive index $\mu$ of glass using total internal reflection.

**Introduction**: This is an experiment to expose students to the possibilities beyond the standard book experiments. There are different ways the light can react after being incident on one side of a glass block. The text book experiment talks about light refracting from one surface and emerging from the opposite side (shown in Figure 1). But there is another option when light undergoes total internal reflection and is emergent from the other side in an entirely different direction.

**Equipment:** drawing pins, drawing board, plain paper and glass block .

This experiment is designed to motivate students to try different approaches when given standard equipment. In a standard class room experiment, two pins are kept in front of the face AB and face CD such that all four pins are along a straight line. The light bends closer to the normal after entering the optically denser material (glass). The standard experiment can be seen in Figure 1. However there are different ways by which the concept of refraction can be explored. One option is to use the concept of total internal reflection. [Note: teachers can be their own judge on what information is to be provided to the students depending on their existing knowledge base. Hence the ray diagrams may or may not be given to the students right at the beginning of the experiment.]

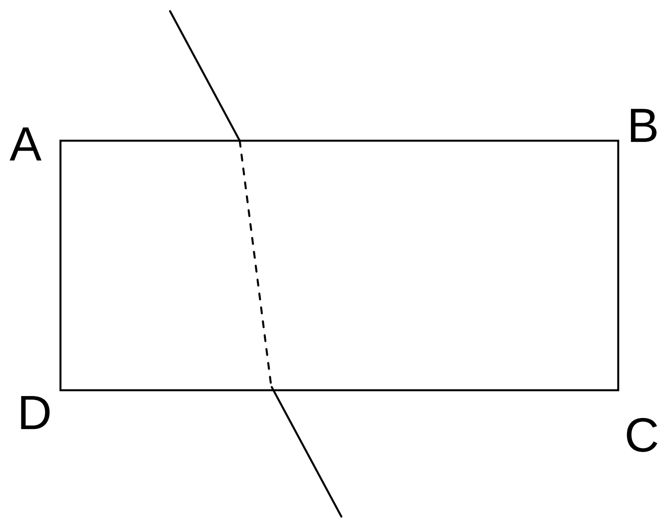



*Fig1. The standard text book experiment.*

If one places pins in front of faces AD and BC of the glass block, total internal reflection can be studied.

**Procedure:**

1) Lay a plain paper on the drawing board and anchor it with boarding pins. Place the glass block on the paper and draw a border around the block with a pencil. Label the corners ABCD as given below. (Long sides being AB and CD) as shown in Figure 2.

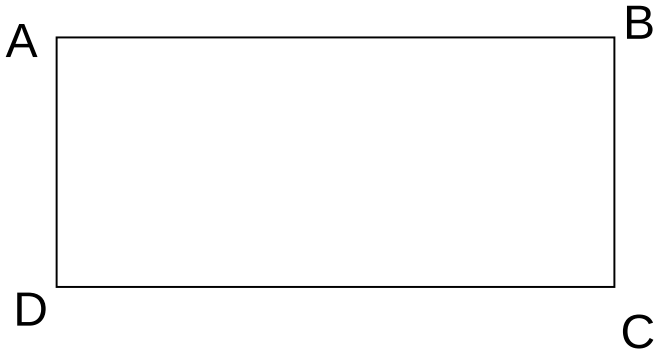



*Fig 2. The glass block.*

2) Place two pins 1 and 2 along the side AD such that a line drawn by this pin makes an angle less than $90^0$ with the normal to the side AD and inclined towards DC.
3) View these two pins from the side BC and place pins 3 and 4 in such a way that they are in line with images of pins 1 and 2.

   [Note: Teachers can note that students do not place the pins in such a way that the lines drawn by pins 1-2 and pins 3-4 are not parallel, but in a way that the lines meet when extended. The ray of light from 1-2 pins reflects from the surface AB and then touches pins 3-4. However students should **NOT** be given this hint well in advance…just let the students explore.

   After placing pins 1 and 2, students should be encouraged to look at those pins from all the different sides possible to get a feeling of how light reflects and refracts at various surfaces.]
4) Measure the angle i (with respect to normal to the surface AD).

   [Note: The angle is to be measured using the trigonometric principles and not protrectors.]
5) Trace the two lines passing through pins 1 and 2 and passing through 3 and 4. Let them meet in the absence of the glass block and let θ be the angle between them. [With glass block in place the light undergoes total internal reflection at point P. But when the glass block is removed, the rays meet at point O, when extended. Angle θ is to be calculated/measured at point O.]
6) Repeat the procedure for 2 more angles and obtain the values of corresponding q.
7) Let M be the point of incidence on AD, N be the point of emergence from

BC. Then let $l$ be AB, $l_1$ be AM and $l_2$ be BN

8) Obtain an expression for $\mu$ in terms of the measured quantities and write it in the Text Box in the answer sheet.

[Note: Students should be given the opportunity to calculate the equation for m and only if they do not succeed should the equation be provided to them.]

9) Determine its value of $\mu$ in each case and enter in Table 2.

**Answer Sheet**

**Table 1:** **(12 marks)**

| Sr. No | Angle $i$ | Angle $\theta$ | $\theta$ /(90-i) |
|---|---|---|---|
| 1 | | | |
| 2 | | | |
| 3 | | | |

**Text Box**

| **Expression for μ** **(4 marks)** |
|---|
| |

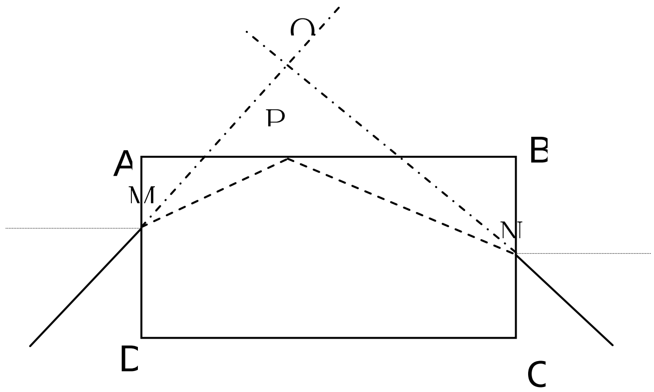
**Table 2:** **(9marks)**

Length $l$(AB) = …………… cm

| Obs No | Angle i | Angle θ | Ratio θ/(90-i) | $l_1$ | $l_2$ | | $\mu$ |
|---|---|---|---|---|---|---|---|
| 1 | $45^0$ | | | | | | |
| 2 | | | | | | | |

| 3 | | | | | | | |
|---|---|---|---|---|---|---|---|

The ratio of the two angles $\theta$ /(90-i) is always close to 2. Hence if the student has carefully carried out the experiment, the ratio will be very close to the value of 2.0.




let $l$ be AB, $l_1$ be AM and $l_2$ be BN

Let angle AMP be r then sin(r) = AM/MP

By Geometry

$$\frac{AM}{AM+BN} = \frac{AP}{AP+PB} = \frac{AP}{l}$$

$$\therefore AP = l\,\frac{AM}{AM+BN} = l\frac{l_1}{l_1+l_2}$$

$$\tan(r) = \frac{AM}{AP} = \frac{l_1}{AP} = l_1\,\frac{l_1+l_2}{l l_1} = \frac{l_1+l_2}{l}$$

$$sin^2(r) = \frac{tan^2(r)}{1+\ tan^2(r)}$$

$$= \frac{\left(\frac{l_1+l_2}{l}\right)^2}{1+\left(\frac{l_1+l_2}{l}\right)^2}$$

$$= \frac{(l_1 + l_2)^2}{l^2 + \ (l_1 + l_2)^2}$$

$$\sin(r) = \sqrt{\frac{(l_1 + l_2)^2}{l^2 + \ (l_1 + l_2)^2}}$$

$$\mu = \sin(i) \frac{\left(\sqrt{l^2 + \ (l_1 + l_2)^2}\right)}{l_1 + l_2}$$

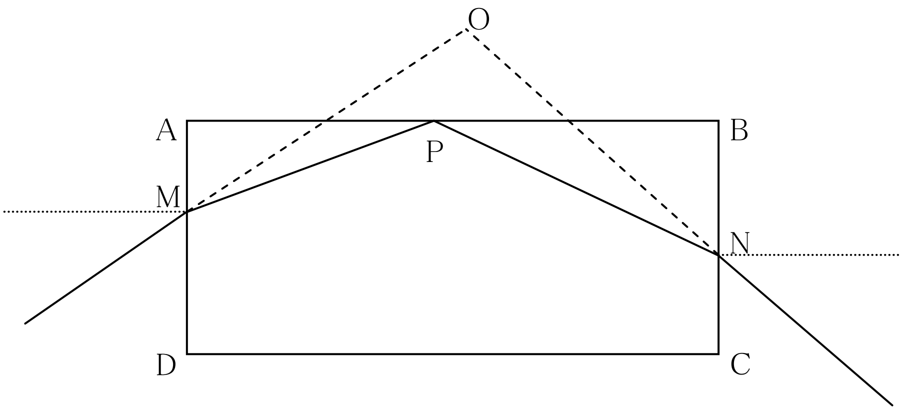



*Fig 3. The ray diagram of light incident on glass block.*

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