REFRACTION OF LIGHT

EXPERIMENT PROCEDURE

- **Verify Snell’s law of refraction.**
- **Determine the refractive index and the critical angle for total internal reflection for transparent acrylic plastic.**
- **Observe and measure how a beam deviates along a different parallel path when refracted by a rectangular block.**
- **Observe the path of light inside a prism which merely deflects a beam and in one which reverses it.**
- **Observe the path of light inside a convex lens and in a concave lens and determine their focal lengths.**

You can find technical information about the equipment at 3bscientific.com

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OBJECTIVE

Investigate refraction of light by various optical components

SUMMARY

Light propagates at different speeds in different media. If a medium has low optical depth, the speed of propagation is higher than it would be in a medium of greater optical depth. A change in direction therefore takes place when a beam of light passes through a boundary between two media at any non-zero angle of incidence. The degree of deflection is dependent on the ratio of the refractive indices of these two media, as described by Snell’s law of refraction. This refractive behaviour will now be investigated using optical components made of transparent acrylic (perspex).

REQUIRED APPARATUS

Quantity	Description	Number
1	Optical Bench U, 1200 mm	**1003039**
3	Optical Rider U, 75 mm	**1003041**
1	Optical Rider U, 35 mm	**1003042**
1	Optical Lamp with LED	**1020630**
1	Iris on Stem	**1003017**
1	Object Holder on Stem	**1000855**
1	Optical Disc with Accessories	**1003036**
1	Set of 5 Slit and Hole Diaphragms	**1000607**

BASIC PRINCIPLES

Light propagates at different speeds *c* in different media. If a medium has low optical depth, the speed of propagation is higher than it would be in a medium of greater optical depth.

The ratio of the speed of light in a vacuum c_0 to the speed within the medium is called the absolute refractive index n. If the speed of light in the medium is c, then the following is true:

$$c = \frac{c_0}{n}. \tag{1}$$

When a beam of light passes from one medium of refractive index n_1 to another one of refractive index n_2, the beam changes direction at the boundary. This is described by Snell’s law of refraction:

$$\frac{\sin\alpha}{\sin\beta} = \frac{n_1}{n_2} = \frac{c_2}{c_1} \tag{2}$$

α, n_1, c_1: angle of incidence, refractive index and speed of propagation in medium 1

β, n_2, c_2: angle of refraction, refractive index and speed of propagation in medium 2

A beam of light passing from a medium of relatively low optical depth into one of higher optical depth will be refracted towards a normal to the boundary surface and a beam passing from a medium of higher optical depth into one of lower optical depth would be refracted away from the normal. In the latter case, there is also a critical angle α_T, at which the beam is actually refracted along the boundary surface. At greater angles of incidence than this, refraction does not take place at all and the beam is totally reflected.

This refractive behaviour is investigated in this experiment using a semi-circular body, a rectangular block with parallel sides, a prism, a converging lens and a dispersing lens, all made of transparent acrylic. The semicircular body is particularly well suited to demonstrating the law of refraction since no refraction takes place at the semicircular perimeter if the beam strikes the flat surface precisely at the centre of the circle. The flat side forms the boundary between media and will be aligned at various angles to the optical axis (see Fig. 1).

As a beam of light is refracted on entering and on exiting a rectangular block, it is deflected along a line parallel to its original direction but a distance *d* away from that line. The deflected distance is dependent on the angle of incidence α. The following applies (see Fig. 1):

$$d = h \cdot \frac{\sin(\alpha-\beta)}{\cos\beta},\ h\text{: thickness of block.} \tag{3}$$

A 90° prism will act in such a way as to deflect a beam of light if light beams strike it perpendicular to one of the short sides. The beam is then reflected at the hypotenuse and exits the prism having been deflected by 90°. If, however the beam strikes perpendicular to the hypotenuse, it is reflected by both the other sides and emerges from the prism travelling parallel to its original direction but going the opposite way. (see Fig. 1).

A convex lens causes parallel rays of light to be bunched together or converged by refraction, whereas a concave lens cause such rays to diverge (see Fig. 1). The rays then meet on the other side of the lens at a focal point F or can be traced back to what appears to be a virtual focal point F‘ in front of the lens.

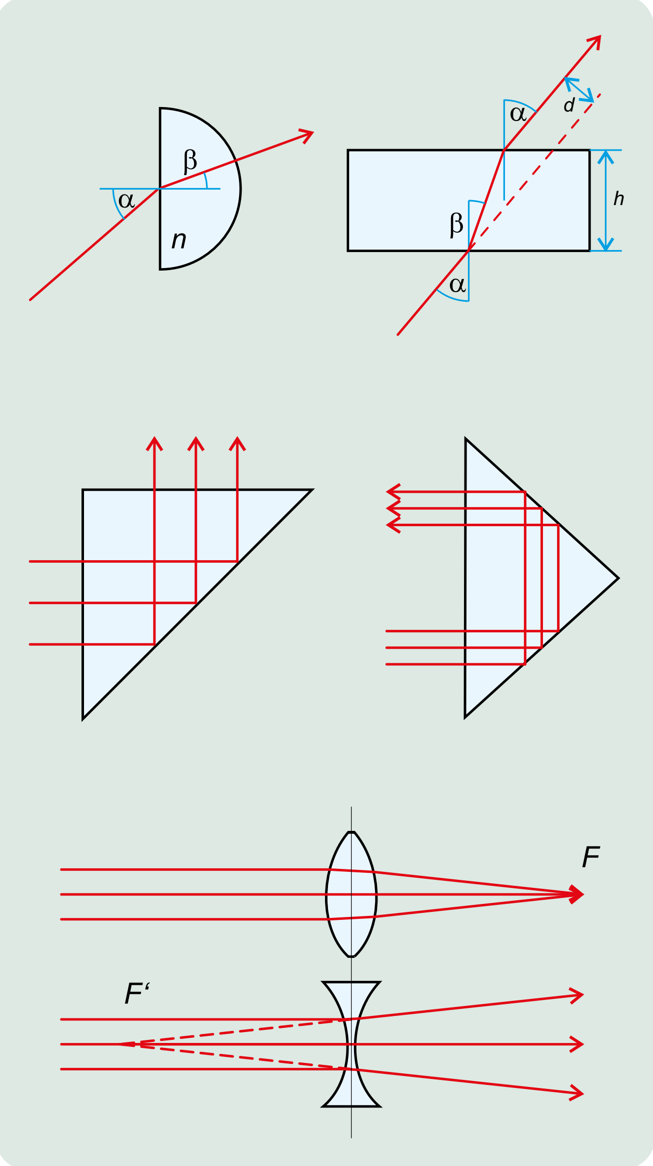

Fig. 1: Refraction by a semi-circular body, path of light through a rectangular block, deflecting and reversing prisms, path of light through a rectangular convex lens and through a concave lens

EVALUATION

If the original medium is air, for the purposes of this experiment it will be sufficiently accurate to assume that its refractive index $n_1 = 1$.

If the angle of incidence is equal to the critical angle for total internal reflection α_T, the angle of refraction $\beta = 90°$. From equation (2) it therefore follows that if n is the refractive index for transparent acrylic, then:

$$\sin\alpha_T = \frac{1}{n}$$

For refraction by a rectangular block, equations (2) and (3) imply the following:

$$d = h \cdot (\sin\alpha \cdot - \cos\alpha \cdot \tan\beta) = h \cdot \sin\alpha \left(1 - \frac{\cos\alpha}{\sqrt{n^2 - \sin^2\alpha}}\right)$$

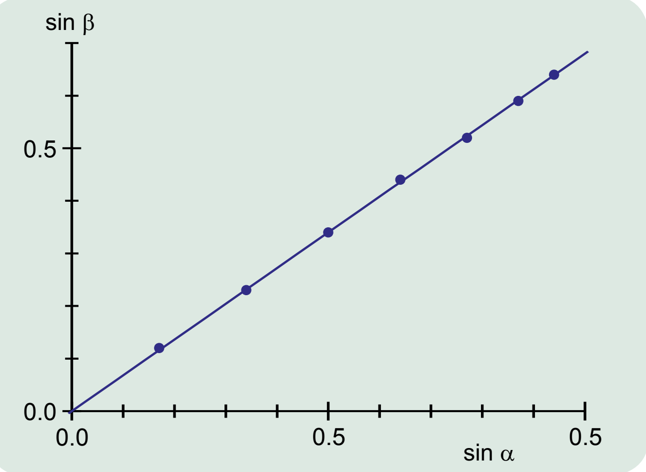

Fig. 2: Diagram for determination of refractive index *n*