614-0285 (30-060) Disappearing Cube

Warranty:

We replace all defective or missing parts free of charge. Additional replacement parts may be ordered toll-free. We accept MasterCard, Visa, checks and School P.O.s. All products warranted to be free from defect for 90 days. Does not apply to accident, misuse or normal wear and tear. Intended for children 13 years of age and up. This item is not a toy. It may contain small parts that can be choking hazards. Adult supervision is required.

Description:

This acrylic cube can be used for Index of Refraction and Total Internal Reflection experiments.

Faces are 5 cm square and are transparent and highly polished to aid in the reflection of light.

Index of refraction is about 1.5, meaning that light travels 50% faster in air than it does upon entering the acrylic plastic.

How to Use:

1. Pour sea (salt) water in the beaker.
2. Immerse cube in the beaker.
3. Note that the object becomes more difficult to see until only a ghostly image remains.
4. Experiment with other acrylic objects such as: clear marbles, lenses, small cylinders. Some will disappear more completely than others.
5. [Optional] A similar experiment can be done with a Pyrex™ glass and regular vegetable oil such as Wesson oil (not light oil). Pour a small amount of oil into the beaker and immerse a glass object. The glass object becomes very difficult to see. Experiment with other glass objects.

- You can make a glass eye dropper "disappear" by immersing it and then sucking up oil into the dropper.
- You can immerse a glass magnifying lens and then note it no longer magnifies.

The refractive index of Wesson oil does not exactly match most Pyrex™ glass because glass can have internal strains which vary its index of refraction at different locations. Even if the index of one part of a Pyrex™ stirring rod is matched with the oil, another part of the rod may not. For this reason, a ghostly image of the stirring rod remains.

Theory:

When light hits an acrylic surface at an angle some of the light is reflected. The rest of the light keeps traveling but it bends or refracts as it encounters the acrylic surface. You see a clear acrylic object because it both reflects and refracts the light.

Refraction is the bending of the path of a light wave as it passes the boundary separating two materials. Refraction is caused by the change in speed experienced by a light wave when it changes medium.

The light slows down as it passes into the acrylic plastic. It is this change in speed that causes the light to reflect and refract as it moves from one clear material (air) to the clear acrylic. Every material has an **index of refraction** connected to the speed of light inside the material. The higher the index of refraction, the slower the light travels inside the material. The index of refraction of air is 1.0; the index of refraction of our acrylic cube is 1.5.

The smaller the difference in speed between two clear materials, the less reflection occurs at the boundary between the two. The transmitted light will therefore have little refraction. If a transparent object (acrylic cube) is surrounded by another material that has the same index of refraction (water), the speed of light does not change as it enters the object. Because no reflection or refraction take place, the object appears invisible.

Sea water has almost the same index of refraction (n) as acrylic (where $n = 1.50$). Different plastics have different indices of refraction. Although the acrylic cube disappears in salt water, other types of clear plastic can remain visible.

This same principle can apply in aquariums with underwater viewing stations. Their large windows can be up to 30 cm thick. But because the windows are made of acrylic, the view they afford is very clear.

The relation between the incident angle and the refracted angle is given by Snell's Law:

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

Here light is considered to be passing from material 1 into material 2. The index of refraction for the medium in question is n. At θ = zero, the light is travelling perpendicular to the boundary and is not bent.

The fact that no intensity loss occurs in total internal reflection is the basis for *fiber optics*, for which there are several medical applications, including instruments used in urinary bladder examinations and in studying the bronchi.

Indices of refraction of representative materials, using approximate values n = 1 for air and n = 4/3 for water.

Air	1.00029
Carbon dioxide	1.00045
Water	1.333
Ethyl alcohol	1.362
Benzene	1.501
Carbon disulfide	1.628
Glass, light crown	1.517
glass, heavy flint	1.647
Fluorite	1.434
Diamond	2.417

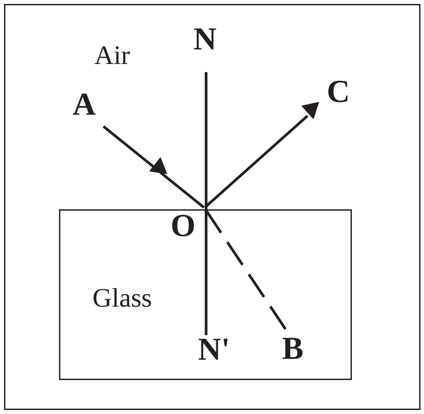

Figure 1: *How a ray of light is reflected and refracted at the surface of a glass plate. AO = single ray of light. N' ON is the normal (perpendicular) to the surface at O. When a light ray strikes the surface, some is reflected as OC. The angle of reflection NOC is always equal to the angle of incidence, AON. The remaining portion of energy of the incident ray passes into the glass along the refracted ray OB. The angle formed by the normal and the refracted ray is called the angle of refraction.*

A ray of light passing obliquely from air into a denser medium is bent toward the normal.

Snell's Law relates the angle of incidence to the angle of refraction.

Experiment 2:

Part 1: Refraction and Total Internal Reflection

You need:

- Multiple slit mask
- Magnetic mask mount
- Light source
- Ray table and optics bench
- Single slit mask

1. Adjust the light source to yield a single beam of light along the optical bench using the single ray mask placed over the multiple ray attachment.
2. Position the beam by adjusting the filament position so that the beam travels along the zero degree axis of the ray table.
3. Place the acrylic cube on the ray table. Allow the ray to strike a flat surface.
4. Rotate the ray table and observe the refracted ray for 6 angles between 0 and 90°. Measure and record the angle of refraction for each case.
5. Find the index of refraction of the cube by plotting sin q_1 versus sin q_2. If you have access to a computer, pass a linear regression line through the points and compare the slope of the line with the actual indix of refraction.
6. Record the slop and the uncertainty in the slope. Round the result.
7. How does your result compare to the expected value of around 1.5? What are the sources of error?

Part 2: Total Internal Reflection

1. Using an index of refraction of 1.5, predict the theoretical value for total internal reflection.
2. Reverse the position of the acrylic cube so that the light enters the acrylic always at 90°. Now the bending occurs when the light exits the flat surface of the lens. Investigate the light travelling from the higher indix medium (acrylic) into the lower index medium (air).

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