Sugar–Water Fiber Optics

Introduction

Demonstrate a graded refraction column using sugar and a clear container. Refraction gradients are important to the "Information Superhighway." Graded fiber-optic wires help to prevent light pulses, carrying enormous amounts of information, from fading and diminishing as they travel hundreds of miles.

Concepts

- Refraction
- Reflection
- Fiber optics

Materials

Clear glass or plastic container with flat sides*

Laser pointer

Table sugar (sucrose), 100–200 g

Water, enough to fill the container

See Tips for suggestions.

Safety Precautions

Do not look directly at the laser beam. Do not shine the laser into anyone's eyes. Wear chemical splash goggles. Please review current Material Safety Data Sheets for additional safety, handling, and disposal information.

Preparation

1. Obtain a large, clear container with flat sides, such as a 600-mL microchemistry solution bottle, clear plastic trough or clean 10-gallon aquarium.
2. Cover the bottom of the container with enough sugar so that the sugar layer is approximately 1 cm high.
3. Slowly and carefully add hot water (about 70 °C) to the container so as not to disturb the sugar layer significantly. Pour evenly over the sugar pile until it is completely covered by water.
4. Continue to add water until the container is approximately ¾ full.
5. Allow the container to sit undisturbed overnight, allowing the sugar to slowly dissolve in the water. A concentration (density) gradient will develop in the container from the bottom to the surface.
6. After the first day, test the density distribution by shining the laser into the water at a slight upward angle. Shine the laser near the bottom of the container where the density will be greatest. If a density gradient has been established, the laser beam will bend down toward the bottom of the container (see Figure 1).
7. If the density gradient has not extended up high enough, allow the solution to sit for another day.

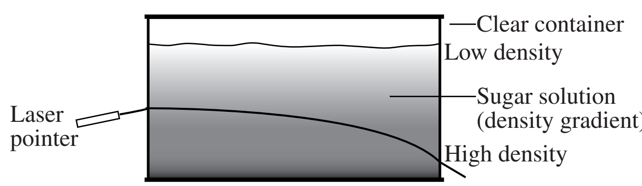

Figure 1.

Procedure

1. Once a significant density gradient is established, demonstrate the effect to the students.
2. "Bounce" the laser beam across the bottom of the container via reflections. The laser beam will reflect off the bottom of the glass tank and the reflected light will then bend again towards the bottom as it passes through the density gradient (see Figure 2). *Note:* The sugar must be completely dissolved from the bottom of the container for the light to reflect off the bottom.

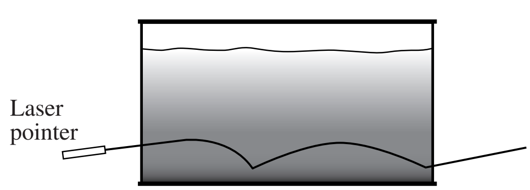

Figure 2.

Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures, and review all federal, state and local regulations that may apply, before proceeding. The sugar–water solution may be disposed of according to Flinn Suggested Disposal Method #26b.

Tips

- The *Density Box Demonstration*, Catalog No. AP4784, is an excellent clear container for this demonstration. This apparatus is available from Flinn Scientific. Other recommended clear containers include microchemistry solution bot tles, small aquarium tanks, and clear plastic or glass troughs. For best results, the containers need to be clear, long and have flat sides.
- Various laser pointer experiments and demonstrations can also be found in the *Laser Pointer Education Kit*, Catalog No. AP4507, available from Flinn Scientific.
- The *Disappearing Beaker*, Catalog No. AP6264, is a great refraction demonstration and is also available from Flinn Scientific.
- The density column will slowly disappear over time as the sugar–water solution slowly becomes uni form (in about a week).
- Please refer to your physical science or physics textbooks for more information on the topics of refraction and total internal reflection.

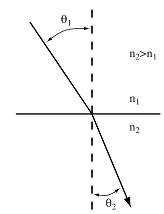

Figure 3.

Discussion

Refraction of light is the phenomenon observed when light bends as it travels from one medium to another, such as from air into water. A familiar example of refraction is the apparent bending of a pencil when it is placed at an angle in a glass of water. The amount of refraction is determined by Snell's law (Equation 1 and Figure 3).

$$n_1 \sin \theta_1 = n_2 \sin \theta_2 \qquad \textit{Equation 1}$$

Where n_1 is the index of refraction of incident medium, θ_1 is the incident angle of light beam (with respect to the vertical) at the media boundary, n_2 is the index of refraction of exiting medium, and θ_2 is the exiting angle of light beam (with respect to the vertical) at the media boundary.

In this demonstration, as the light travels through more and more dense sugar–water solution, the light bends downward as it enters higher density sugar–water, which has a higher index of refraction compared to the lower-density sugar–water (see Figure 4).

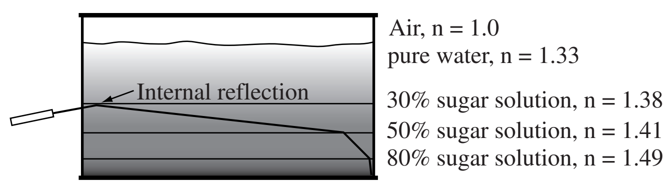

Figure 4. Refraction not to scale and simplified

When light travels between any two media, some light is always reflected back into the incident medium. *Total internal reflection* can occur when light travels from a medium with a high index of reflection to a medium with a low index of refraction. If the light strikes the media boundary (such as between sugar and water solution, or sugar and air) at the proper angle, all the light will completely reflect back into the container. Any reflected light will once again curve back towards the bottom of the container as it travels through the sugar–water density gradient.

Materials for *Sugar–Water Fiber Optics* are available from Flinn Scientific, Inc.

Catalog No.	Description
AP8934	Laser Pointer
AP1450	Microchemistry Solution Bottles, Graduated, 600-mL
S0135	Sucrose, 1 kg

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.