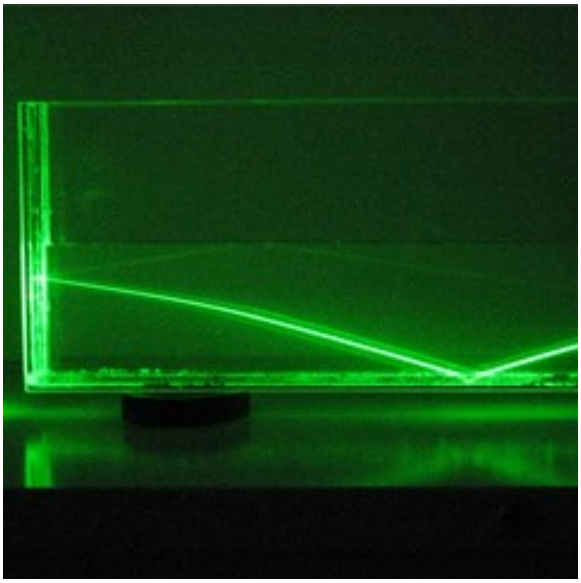
Variable Index of Refraction

Demonstration

Corn syrup and water are used to create a liquid with a variable index of refraction. Participants learn about solutions, gradients, and refraction.



Oberlin College

Number of Participants: 2-30

Audience: Elementary (ages 5-10) and up

Duration: 10-20 minutes

Difficulty: Level 2

Materials Required:

- 2.5 gallon fish tank (or larger)
- 1 gallon corn syrup
- 1.5 gallons of water
- Laser pointer (green 5 mw preferred)
- Mirror(s) cut to fit footprint of the tank

Setup:

1. Place the tank on top of the mirror. Optional: permanently attach the mirror to the bottom of the tank with epoxy or caulk.
2. Add the corn syrup to the bottom of the tank.
3. Carefully add the water. Pour near the bottom and try not to disturb the corn syrup.
4. Let sit for at least 24 hours, if not 48 hours. Times will vary with exact mixture and temperature. The syrup should entirely dissolve. Do not disturb during this process! Mixing the liquid destroys the gradient.

Presenter Brief:

This demonstration must be prepared 24 hours in advance and should not be moved once set up. You can put in on a cart but move **very** gently. Any water mixing destroys the effect. Familiarity with introductory optics topics such as reflection, refraction, and angle of incidence is recommended.

Vocabulary:

- Refraction – Bending of a wave when encountering a change in refractive index of the medium.
- Index of Refraction – A characteristic of transparent materials which describes how light propagates through the medium in relation to space. Light moves slower in higher index of refraction materials.
- Gradient – A change or variation in the magnitude of some property from one point to another.

Physics & Explanation:

Middle (ages 11-13) and general public:

Light undergoes a change in (phase) velocity when travelling between two transparent media. The change in velocity results in a change in direction (or bending of the light path) and a change in the wavelength of the light.

For example, a pencil looks “broken” or bent when sitting in a glass of water as in Figure 1.

Figure 1

Explain that on a microscopic level, the light wave interacts with the atoms of the material through which it is travelling – when light moves through matter it slow down. The speed of light is fastest in a vacuum when no atoms to interfere with it.

Describe examples of refraction, such as looking at an object through a glass of water on in a swimming pool. Additionally, recreate the example in Figure 1 if desired.

🔑 The speed of a light wave is affected by atomic interactions with the medium that it travels through. When encountering a change in medium (with a different speed of light), a light beam’s path will bend. This bending called refraction.

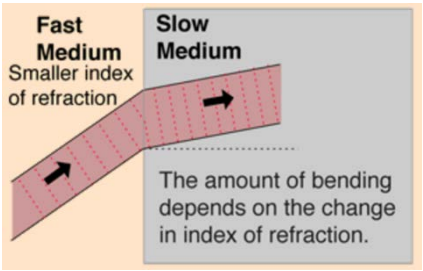


Figure 2: HyperPhysics (©C.R. Nave, 2017)

The index of refraction describes how the speed of light changes for a given medium (see Figure 2). For example, air and water have different indices of refraction and light will bend when passing through a boundary between the two.

Begin with the laser beam shining near the top of the tank, parallel to the bottom, as seen in Figure 3a. Slowly move the beam toward the bottom of the tank, keeping the laser parallel with the surface, as in Figures 3b and 3c. The index of refraction of the liquid is variable – it increases with depth.

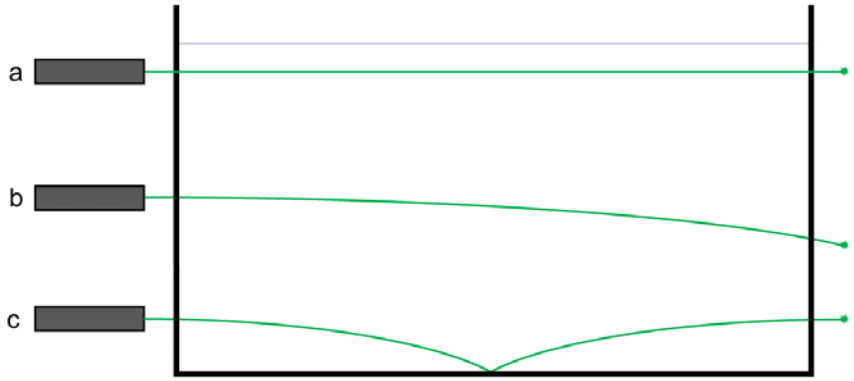


Figure 3

Dissolving the corn syrup in water creates a syrup-water solution, which has a higher index of refraction than just pure water. The more concentrated the solution of syrup water, the higher the index of refraction. Note that the solution was *not* created by stirring; since the corn syrup was placed evenly at the bottom of the tank then the water was slowly added on top, the solution should have a greater concentration of syrup at the bottom of the tank. Thus, there should be a gradient in the index of refraction with depth.

Use Figure 4 to illustrate the idea of a gradient and variable index of refraction.

Figure 4

🔑 Since the index of refraction increases with depth, the light bends in an arc as it moves through the tank. The mirror at the bottom of the tank reflects the beam if struck. Thus, if the index of refraction varies enough, a cycloid pattern can be formed. This

pattern is similar to the path a dot on a circular wheel would trace out as the wheel rolls along a flat surface.

Additional Resources:

- Pedrotti, S.J., and Pedrotti, Leno S. *Introduction to Optics*, 1993. 38-40.
- Video from UC Berkeley: https://www.youtube.com/watch?v=r441tRBmajw&feature=youtu.be