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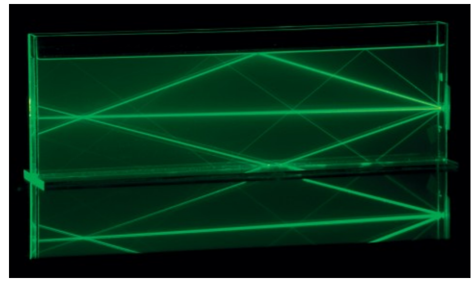


Laser Viewing Tank

P2-7690

BACKGROUND:

Exploring basic optical phenomena with lasers is highly engaging and more cost-effective than ever before. But laser beams, themselves, are invisible. Classroom demonstrations involving airborne scattering agents can be messy. And with highly sensitive smoke detectors becoming common in today's classrooms, the use of some scattering agents could result in an unscheduled fire drill! Some instructors get around this by using an aquarium filled with water and a scattering agent. But aquaria are made of glass and are quite heavy when filled with water. Furthermore, large-scale demonstrations (in water or in air) are controlled by the instructor rather than by students, so active participation is limited.

The Laser Viewing Tank resolves these issues. The tank is designed for lab group use and uses a waterborne scattering agent. It allows students to see and manipulate laser beams as they explore a variety of optical phenomena. And there are interesting applications *beyond* the viewing of laser beams.

PRODUCT DESCRIPTION AND OPERATION:

The tank is long and narrow. It's easy to fill with a relatively small amount of water, and easy to move once it's filled. Students working in a lab group can easily see what's going on from both sides of the tank, and a laser beam can be directed into the tank from above, below, or from the side.

The scattering agent will make them beam highly visible in the otherwise transparent water.

Use the dropper to add a small amount of scattering agent to the water in the tank.

Use the stirring rod to rapidly disperse the scattering agent. Because the rod is cylindrical and transparent, it can also be used as a lens to spread a laser beam laterally.

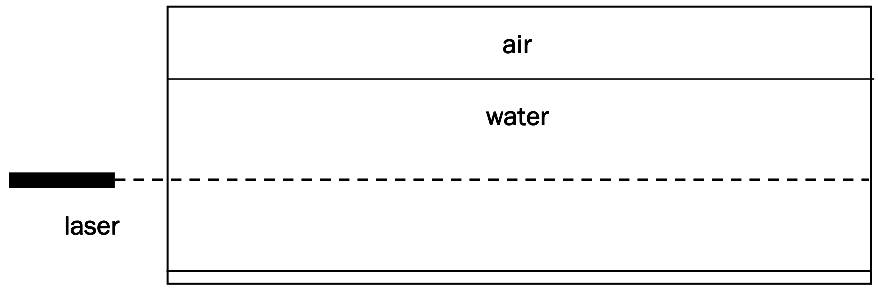
The opaque background can be used to see the refraction of the laser beam as it passes from air to water or water to air.

The diffraction gratings can be attached to the end of the tank. A laser beam directed into the tank through the grating will be split into multiple, highly visible maxima.

OBSERVABLE PHENOMENA:

1. Effect of the Scattering Agent

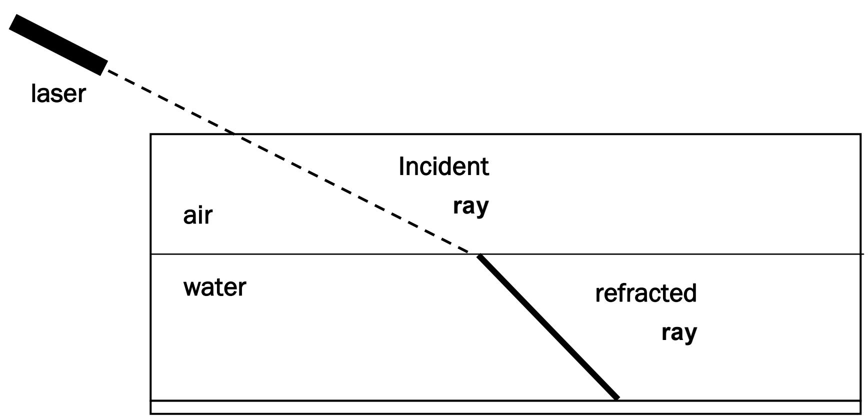
Fill the tank with pure tap water as shown in the diagram.



Direct the laser into the water from one end of the tank. The beam may be visible, but it will not be bright. Add a small amount of scattering agent to the tank and stir it in gently. Now shine the laser beam through the tank. Though the water still appears transparent, the beam is highly scattered and bright.

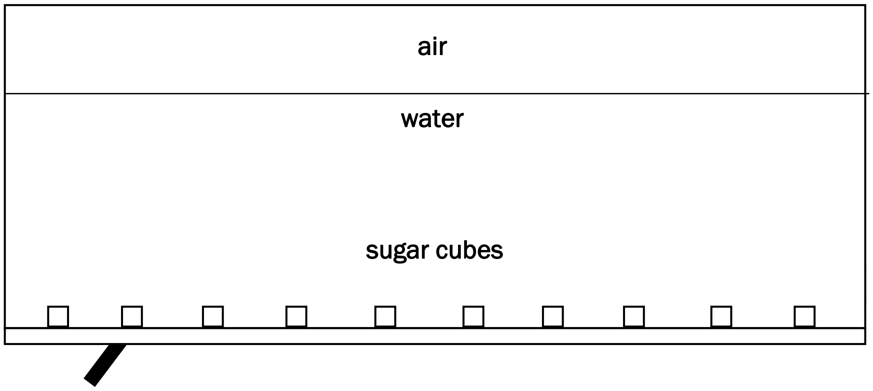
2. Refraction

Fill the tank only about half way and stir in scattering agent as usual. Direct the laser beam into the water at an oblique angle from above. Notice the difference between the angle of incidence and the angle of refraction as the beam passes from the air into the water.



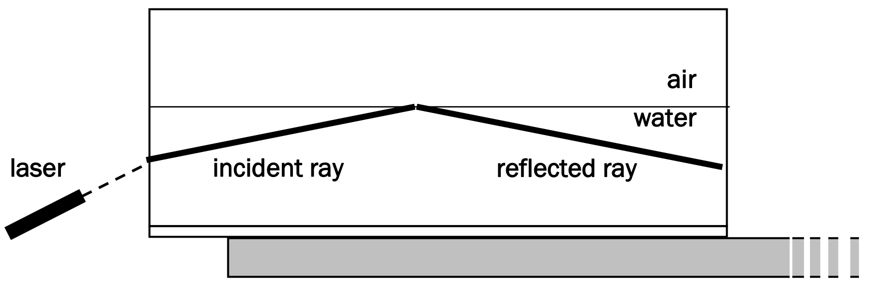
To see the difference more clearly, use the opaque, white backdrop. And use the stirring rod as a lens the spread the laser beam laterally. Aim carefully so that the laser beam can be seen on the white backdrop before and after it passes into the water.

Move the tank so that one end is a few centimeters beyond the edge of the table. Now direct the laser beam upward from below the tank. Use the backdrop and stirring rod as described above to see the beam passing from water into air.



3. Total Internal Reflection

Fill the tank and stir in the scattering agent as usual. Direct the laser beam through one end of the tank at an upward angle.



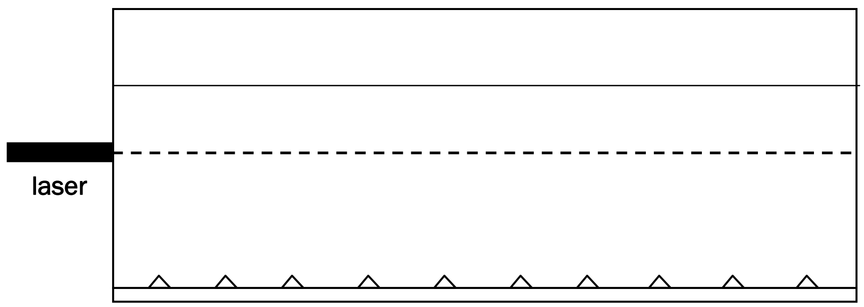
The beam will undergo total internal reflection. Vary the angle of incidence. Careful investigation will reveal the *critical angle*. If the angle of incidence from the water to the air is less than the critical angle, some fraction of the beam will emerge from the water into the air. If the angle of incidence is greater than the critical angle, total internal reflection will occur.

Conceptual Physics online lab activity: "Trapping the Light Fantastic"

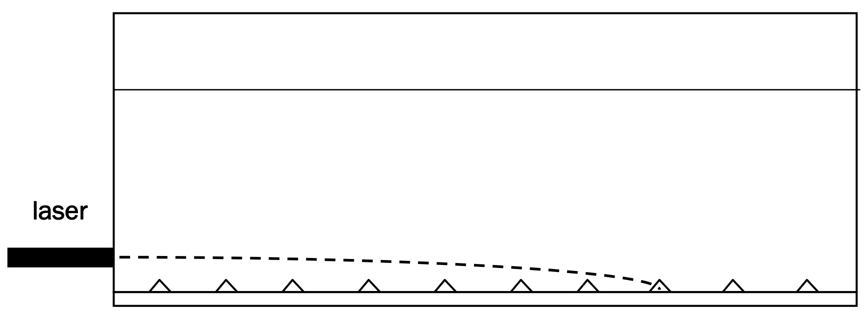
4. Gradual Refraction (Optics of the Mirage)

Use <u>hot</u> tap water to fill the tank this time. Stir in the usual amount of scattering agent, and allow the water to settle. When the water is once again still, carefully drop about 10 sugar cubes into the warm water, spacing them as evenly as possible along the bottom of the tank. Don't worry if the spacing is a little uneven.

Allow 10-20 minutes for the cubes to dissolve in the undisturbed water. **Do not stir the water during this time.** The cubes will not dissolve completely, but the result will be a sugar solution concentration *gradient* from the bottom to the top of the tank. Direct the laser horizontally through the water near the top of the tank. It should be unaffected and pass through as expected.



Maintain the horizontal aim as you lower the beam to deeper and deeper depths of water. As you get close to the bottom of the tank, the beam will appear to arc downward into the sugar.



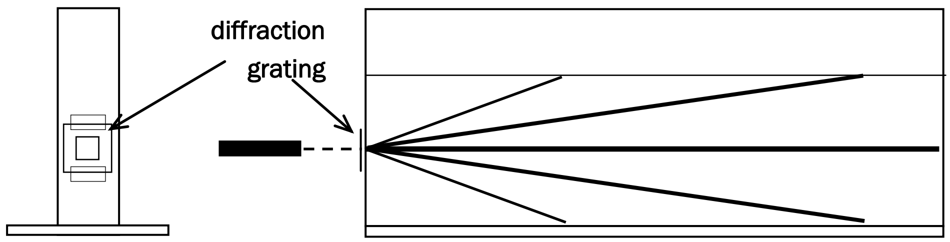
This gradual refraction results from a gradient in the index of refraction. The gradient in the index of refraction arises from the gradient in the concentration of the sugar solution.

Gradual refraction is the optics behind *mirages*, where the index of refraction gradient coincides with the temperature gradient of the air above the surface of the ground.

Finally, stir the water thoroughly. Once the sugar is distributed uniformly, the gradient no longer exists and gradual refraction no longer occurs.

5. Diffraction

Fill the tank and add some scattering agent as usual. Select a diffraction grating and orient it so that its lines are horizontal. When you look at a light source through the grating, colors should spread out vertically. Now attach the grating to the end of the tank about halfway up. Use tape that's easy to work with and be careful to preserve the horizontal orientation of the grating lines. Direct the laser horizontally through the grating.

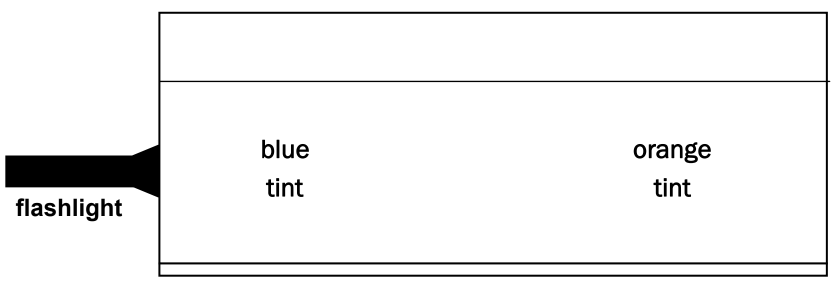


Observe the well-defined maxima as they diverge from one another in the water. By trying different gratings, you can see the effect of line spacing on the diffraction pattern. By using different-color lasers, you can see the effect of wavelength on the diffraction pattern.

Conceptual Physics online lab activity: "Laser Tree"

6. Why the Daytime Sky is Blue and Sunsets are Red

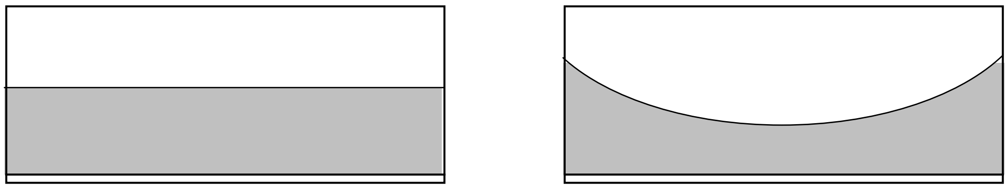
Prepare the tank with water and scattering agent as usual. But this time, **add significantly more scattering agent.** The water *should* appear somewhat cloudy for this activity. Instead of a laser, use a compact, bright flashlight as a light source. Direct the light into the water from one end of the tank.



View the tank from the side or (even better) from above. Notice the bluish color of the beam in the water close to the flashlight. The scattering agent scatters the shorter wavelengths of light more effectively than the longer wavelengths. As a result, the color of the beam becomes redder as it passes through the water. Look back toward the flashlight from the far end of the tank to see this effect more dramatically. The longer wavelengths are scattered less and get through a greater distance in the water.

7. Centripetal Acceleration

Fill the tank to about half its depth. Stir in several drops of food coloring to make the water more visible. Carefully set the tank on a rotating platform such as Arbor's **Rotating Platform** (P3-3510) so that it is well balanced. Gently spin the platform to increasing angular speeds.



Observe as the surface of the water changes shape from a straight, horizontal line to a parabola.

OBSERVABLE PHENOMENA:

1. Avoid scratching the surfaces of the tank. Use only the provided stirring rod or other rounded, non-scratching items to stir the water in the tank. Set the tank only on clean surfaces, taking particular care when moving the tank along a lab table.

2. Rinse the tank thoroughly after using to clear out residual scattering agent and/or sugar. Wipe off excess water with a soft cloth and allow to air dry before storing. Clean with a mild liquid dishwashing detergent as needed.