Laser Reflection & Refraction

Demonstration

Participants will learn about light, lasers, reflections, and refractions in a medium. Made by Holly Fortener, Din Pasic, and Noah Johnson.

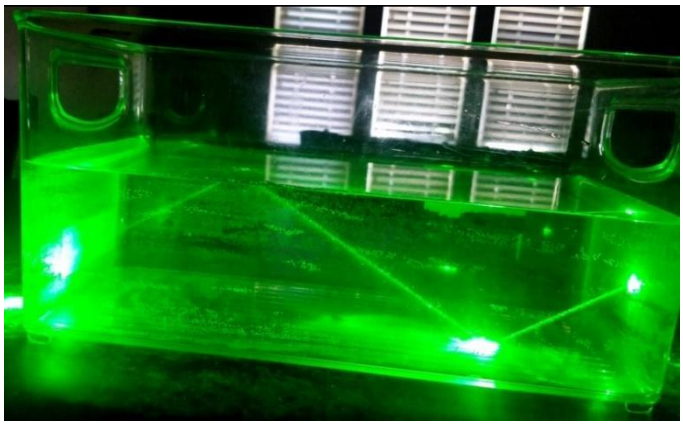

Figure 1: laser reflection (photo courtesy of Din Pasic).

Number of Participants: 2-100
Audience: Middle (ages 11-13) and up
Duration: 5-10 Minutes
Difficulty: Level 3

Materials Required:

- Large rectangular tub with flat and clear sides (glass works best, such as a fish tank)
- Clear water
- Sugar (to act as a scattering agent)
- Laser pointer of any color ~5mW (using
- A spray bottle or flour
- Pencil or Straw

Setup:

1. Fill a large rectangular tub most of the way with water. If your container is plastic, you might need to add a mirror to the bottom surface.
2. Dissolve 1 cup (200g) of sugar in the tank for every 2 liters of water.
    a. The objective is to dissolve the sugar in the water, creating an opaque solution thus allowing the viewing of the laser reflecting and refracting.
    b. Note: if the sugar does not dissolve easily, use warmer water.
3. Dim the lights. In the dark environment, point the laser at an angle through one side of the container so that the laser strikes the air/water interface. The laser should bounce off this interface and produce the pattern seen in *Figure 1*. Experiment with what angle works best so that there is a zig-zag pattern in the container made by the laser. Note: take particular care to avoid striking participants with the laser.

4. Position the laser above the water/sugar solution and angle the beam into the water
5. Observe the laser refracting when it hits the water and shines into the air
6. Use a spray bottle to spray in the area the beam is shining through to better see the refraction of the beam. Note: Smoke machines or humidifiers can help as well.

Presenter Brief:

Be familiar with what a laser is and what LASER stands for (see vocabulary below). Be able to explain that this effect is not limited to lasers, but all light. Understand how light can reflect and refract through mediums such as water and how introducing impurities may change the behavior of light in that medium.

Vocabulary:

- L.A.S.E.R. (laser): Laser is an acronym for “Light Amplification by Stimulated Emission of Radiation” and is a device that emits light through a process of optical amplification based on the stimulated emission of electromagnetic radiation.

- Reflection: Reflection is the change in direction of a wavefront (light) at an interface between two different media so that the wavefront (light) returns into the medium from which it originated.

- Refraction: Refraction, in physics, is the change in direction of a wave (light or sound) passing from one medium to another caused by its change in speed. For example, waves (light or sound) in deep water travel faster than in shallow water. The speed of sound waves is greater in warm air than in cold.

- Scattering: When certain forms of energy pass through air. The path may sometimes shift in unexpected ways.

- Medium: A material through which waves propagate.

Physics and Explanation:

Middle School (ages 11-13) and General Public:

What is a laser and what is the difference between a lightbulb and a laser? First, let's consider a lightbulb. A lightbulb gives off light in all directions - this is why they are used to light up rooms. Now, let’s change to a laser. A laser is a light beam that is one

color and travels in one direction (whereas a lightbulb emits light that travels in all directions). So, you can only see a laser if the beam is in your view, or when the beam is reflected to shine into your view.

Unimpeded light behaves in such a way that it follows a straight line. Imagine that you are throwing a ball against a wall in a straight line. The tennis ball will bounce right back at you in a straight line. However, if you are playing basketball, you can bounce the ball to your teammate by throwing the ball at an angle to the floor. Light behaves in the same way and this is called reflection. A reflection is when light bounces off a surface and goes off onto a different path (see *Figure 2*).

The sugar in the solution allows us to view the laser refraction within the water. Reflection from the mirror refracts the laser beam within the solution. As the laser travels through the water, it reflects off of the sugar in the solution. These small sugar molecules reflect small amounts of the laser in many directions allowing you to see the beam. When the beam hits the bottom of the container it reflects off the shiny plastic and bounces to the top of the container. When it gets to the top, it bounces back down to make a “zig-zag” pattern.

Have the students explain what is happening when the laser bounces from the top of the water to the bottom, what examples can they give?

There is one thing you’ll notice. The laser slowly dims out! To put it in perspective, let’s say that you drop a basketball on the ground. Would you expect the ball to bounce to the same height every time? No, you wouldn’t, and the ball eventually comes to a stop. This is also what happens with light, but instead of stopping the light dims until you can’t see it anymore.

Refraction is when light bends because the light enters another medium (air to water, as an example). A very common example is putting a pencil or a straw in a glass of water and seeing how it doesn’t stay in a straight line. The refraction part of this demo is optional, but recommended as it is a cool and common phenomenon that students may see in their day to day lives. See figure 3 at the end of this document.

Highschool (ages 14+):

The objective of this experiment is to understand scattering of the laser through the visualization in the tub. When light passes through a medium, it encounters particulates (dust, water droplets, etc). These particulates cause the light to scatter. The scattering of the light causes the light to dim as it hits the particulates and is sent in many directions. This phenomenon is why headlights don’t go on infinitely, but also why we can see a laser beam in a fog or sugary water. You can do this with other agents such as detergent as well.

Another interesting light phenomenon is how lasers “bounce” off of reflective surfaces.The reason we want to angle the laser when we shoot it through the tank is to demonstrate the Laws of Reflection.

The Laws of Reflection are as follows:

1. The incident ray, the reflected ray, and the normal to the reflection surface at the point of the incidence lie in the same plane.
2. The angle which the incident ray makes with the normal is equal to the angle which the reflected ray makes to the same normal.
3. The reflected ray and the incident ray are on the opposite sides of the normal.

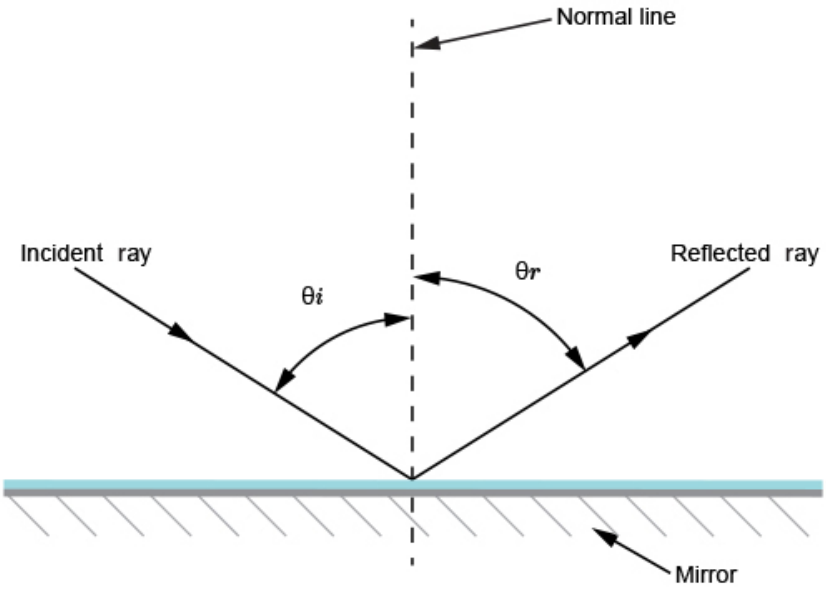

Figure 2: a diagram of an incident ray and reflected ray (Source: Mammoth Memory[1])

This can also be expressed by the equation (1) below. Where is the angle and the notations *i* and *r* are referencing *incident* and *reflected* respectively.

$$\theta_i = \theta_r \quad (1)$$

Have the laser at a fixed angle and have the students count how many times the laser bounces. Turn off the laser and increase the angle and have the students make predictions about whether the laser will bounce more or less times.

As light reflects in the water it loses energy. However, an important thing you must know is that light will never slow down when it loses energy. The loss in energy amounts to a drop in frequency or intensity. When you shine a laser at a high angle, more of the light will be absorbed by the material you are shining it at, and therefore there will be less of a reflection. An interesting thing you can do is place a mirror on the bottom of the container to create better means of reflection.

Refraction is when light bends because the light enters another medium (air to water, as an example). A very common example is putting a pencil or a straw in a glass of water and seeing how the pencil seems to be cut in half (see Figure 3 below). This is because light bends at a different angle in water than it does in air. Refraction is a cool and common phenomenon that students may see in their day to day lives.

Figure 3: Light refracting as demonstrated by a pencil in a cup of water (Source: Canada Science and Technology Museum[2])

References:

OpenStax. “The Law of Reflection.” *Lumen Learning*, courses.lumenlearning.com/physics/chapter/25-2-the-law-of-reflection/.

"What is Scattering? - Definition & Examples." Study.com, 27 March 2016, study.com/academy/lesson/what-is-scattering-definition-examples.html

The Editors of Encyclopaedia Britannica. “Scattering.” *Encyclopædia Britannica*, Encyclopædia Britannica, Inc., 22 Sept. 2008, www.britannica.com/science/scattering.

1. “The 3 Laws of Reflection.” *Mammoth Memory*, Figure 2, https://mammothmemory.net/physics/mirrors/flat-mirrors/the-three-laws-of-reflection.html

2.“Broken Pencil Illusion: *Canada Science and Technology Museum*, Figure 3,

https://ingeniumcanada.org/scitech/education/try-this-out/broken-pencil-illusion

Additional Resources:

Video | Reflection explanation video for kids:
https://www.youtube.com/watch?v=9PRRUgoTSro

Video | Scattering explanation video:
https://study.com/academy/lesson/what-is-scattering-definition-examples.html

Video | Why does light slow down in water?
https://www.youtube.com/watch?v=CUjt36SD3h8

Video | Refraction in Water

https://www.khanacademy.org/science/physics/geometric-optics/reflection-refraction/v/refraction-in-water

Article | Total Internal Reflection Article:
http://www.excelatphysics.com/total-internal-reflection.html

Article | How does a laser work:
https://ehs.oregonstate.edu/laser/training/how-laser-works

Article | Reflection of light article:
https://www.sciencelearn.org.nz/images/45-types-of-reflection