

OPTICS MAGIC

with Judy & Nancy

#OpticsAtHome
#SeeTheLight

WHAT ELSE CAN YOU DO WITH A LASER POINTER?

This webinar is a collection of some of our favorite outreach activities using a laser pointer
LASER SAFETY: Before allowing children to use the laser discuss rules for laser safety and the reason it is important to use the laser safely:

- Keep lasers flat on the table or mounting blocks when used
- Only turn laser on for the duration of the measurement
- Be aware of other people in the area and don't shine the beam on them
- Make sure your beam doesn't go beyond the edge of your work space
- No high sticking with the laser beam.

ACTIVITY 1: SEE YOUR PULSE!

MATERIALS

- Laser pointer
- Small (about 1 cm x 1 cm) mirror. A piece of shiny plastic, like a chip from a CD jewel case or plastic packaging, will work too

PARENT AND TEACHER NOTES

Using a small mirror to visualize your pulse relies on the “optical lever” principle: a very small angular motion is magnified through the law of reflection. (We talked about Law of Reflection in a Spring 2020 webinar. See Resources) In Figure 1, the laser initially strikes the mirror head-on (0° angle of incidence). When the mirror rotates by an angle A , the beam of light now strikes at angle A and also reflects at angle A (Law of reflection: angle of reflection = angle of incidence). So rotating the mirror by an angle A results in the beam rotating by $2A$.

You can use any (preferably flat) shiny reflector- a chip of mirror if you have one or a small piece of shiny plastic like a piece cut from a CD jewel case or plastic packaging. The hardest part is to find your pulse and place the mirror above that point. It does take some practice and it may not work on every person (look for a thin wrist). It's easiest to keep your arm flat with the mirror facing up but if you need to project onto a wall a bit of moisture on your wrist will help.

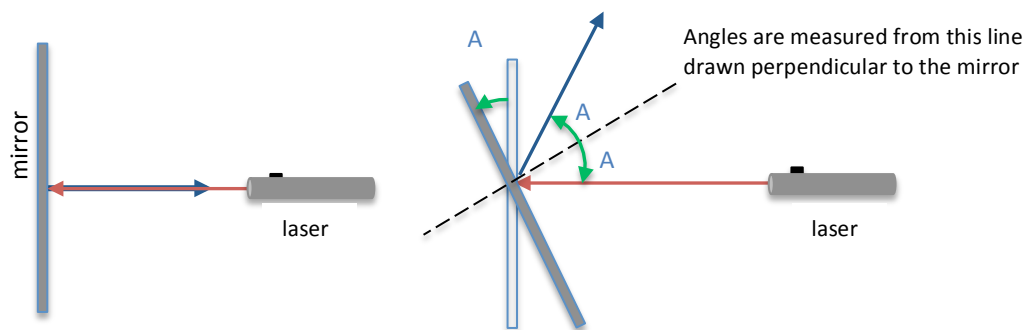


Figure 1 – On the left, the laser light (red) strikes the mirror head on, and reflects back (blue) toward the laser. On the right, the mirror rotates counterclockwise by an angle A . Now the laser is incident at an angle A and by the law of reflection it reflects at an angle A . This means the rotation angle A of the mirror is doubled to $2A$.

ACTIVITY 2: LASER TARGET SHOOT

MATERIALS

- CD jewel cases lined with black paper to serve as stand-up mirrors
- A printed target mounted on blocks or books to stand vertical
- Protractor, string
- Laser pointer

PARENT AND TEACHER NOTES

This law-of-reflection game was presented in the Spring 2020 webinar on Reflection and the notes can be found in the References below. The CD jewel cases, front surface lined with black paper, serve as mirrors to deflect a beam from the stationary laser onto the target. The laser may be mounted on blocks to raise it to the height needed to strike the mirrors and target. This activity is a good application of the law of reflection, angle of incidence=angle of reflection.

ACTIVITY 3: OBSERVE REFRACTION (optional math activity: Measure the Index of Refraction)

MATERIALS

- Stiff blocks of gelatin, about 1 – 1.5 cm thick
- Round cookie cutter; strips cut from a plastic folder, a ruler or toothpick for cutting
- Laser pointer

Note on gelatin: A very stiff gel is needed- use a little less than half the usual amount of water for each packet of gelatin (U.S. measurements: $\frac{3}{4}$ cup per package). Use hot (boiling) water only and stir very well. Pour into pans so that the gelatin is about 1.5 cm thick. Place in the refrigerator. (However, it will usually gel at room temperature if the room is not too warm.)

PARENT AND TEACHER NOTES

The bending of waves as they change speed going from one medium to another is called *refraction*. Refraction of light explains many things you see around you every day, such as the apparent bending of a spoon when it is partially submerged in water and how lenses work. (There is a more complete refraction lesson including background information in the Dumpster Optics lessons. See Resources)

When scientists talk about refraction, they speak of *incident* light, the light that strikes the surface, and *refracted* light, the light enters the second *medium* (or substance). The angles of incidence and refraction are measured from the *normal line*, a line drawn at 90° to the surface (Figure 2).

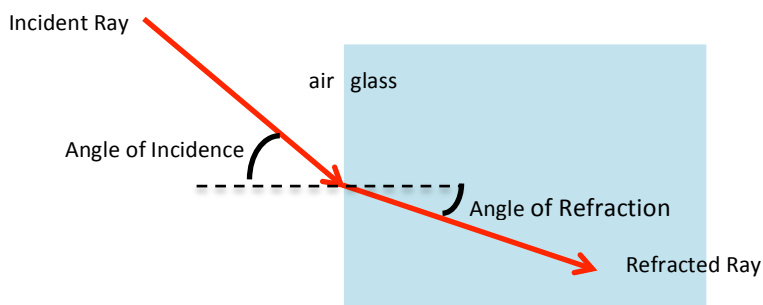


Figure 2 - Incident and refracted rays and angles of incidence and refraction. Note the way the light bends when it goes from air on the left to glass on the right. Light travels slower in the glass.

Observing Refraction

Cut a gelatin rectangle about 3 cm x 4 cm. The size is not important, but the edges must be very straight and smooth. You can cut it with a toothpick held vertically or slice it with a plastic strip. On a piece of paper draw two lines that meet at right angles. Place the smoothest edge of the block along one of the straight lines (Figure 2). Shine the laser directly into the edge of the gelatin block along the horizontal line, so it strikes the edge of the block at 90° .

Observation: Does the beam of light bend when it goes from the air straight into the gelatin? When it goes from the gelatin back into the air on the other side?

Now shine the beam into the block at a different angle. Which way does the beam bend

Observation : Does the beam bend toward the horizontal line or away from the horizontal line when it enters the gelatin block? As the angle of incidence increases, does the beam bend more, less, or the same amount?

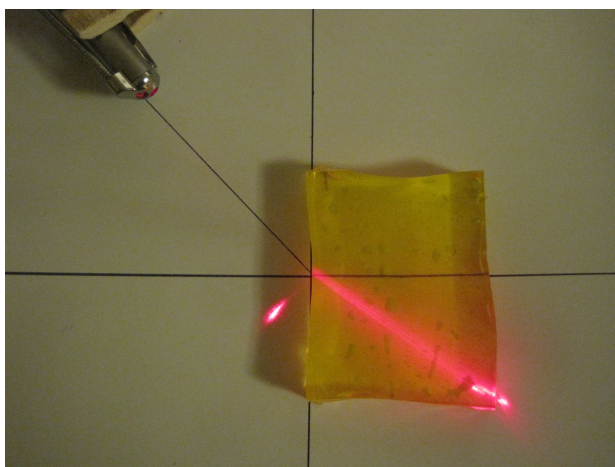


Figure 3 - Photograph of the gelatin block and laser. The beam isn't visible in air, but there's a bit of reflection showing where it strikes the paper at the edge of the block.

You can also use a round cookie or biscuit cutter to make curved surfaces like lens shapes and see how light can be directed using refraction. Try a long thin rectangle to model an optical fiber!



Figure 4 – Gelatin “optical fiber”. Note the total internal reflection where the laser beam strikes the gelatin-air boundary.

Optional- Measure the index of refraction of gelatin

The speed of light in a material is usually stated not in meters/second but as the *index of refraction* given by

$$n = \frac{c}{v}$$

Where n is the index of refraction, c is the speed of light in a vacuum, and v is the speed of light in the material. Since light never travels faster than c , the index of refraction is always 1 (for vacuum) or greater. n varies with wavelength (why a prism can separate colors of white light) so the wavelength at which n is measured is stated in tables of measurement.

Sample Values of Index of Refraction measured at 590 nm (yellow light)

Dry air, atmospheric pressure	$n = 1.0003$
Water (at 20 degrees C)	$n = 1.33$
Glass* (depends on type)	$n = 1.45 - 1.75$
Diamond	$n = 2.42$

Snell’s law relates the angles of incidence and refraction and the indices of refraction of the two materials. In this equation the subscript 1 refers to the material from which light is incident (on the left in Figure 2) and the subscript 2 is the material light is entering (the gelatin).

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

This equation can be solved for n_2 and using $n_1 = 1.00$ for air. Student-measured values for the index of refraction of gelatin have varied from 1.35-1.45. It actually varies with the exact composition of the gelatin mix, and can be increased by adding sugar.

ACTIVITY 4: LIGHT PAINTING

MATERIALS

- Camera with controllable shutter speed (need long exposure time) or a camera app such as LightPainting (Wow!Stuff)
- Laser pointer- or other light source, like LED indicator of holiday lights

PARENT AND TEACHER NOTES

The Wikipedia definition of light painting is:

“Light painting, painting with light, light drawing, or light art performance photography are terms that describe photographic techniques of moving a light source while taking a long exposure photograph, either to illuminate a subject or space, or to shine light at the camera to 'draw', or by moving the camera itself during exposure of light sources.”

Light painting can take many forms, from moving a camera with open shutter in front of a string of holiday lights to mounting a camera on a tripod and taking a long-exposure photograph while manipulating the light in front of it, including selectively illuminating parts of a scene.

To begin, mount the camera (or phone) steady and pointed at a wall. With the shutter open, “paint” the wall with light using a laser pointer. It usually takes a few tries to get what you are looking for. Alternatively, use a still source like a string of small lights and move the camera (Figure 5).

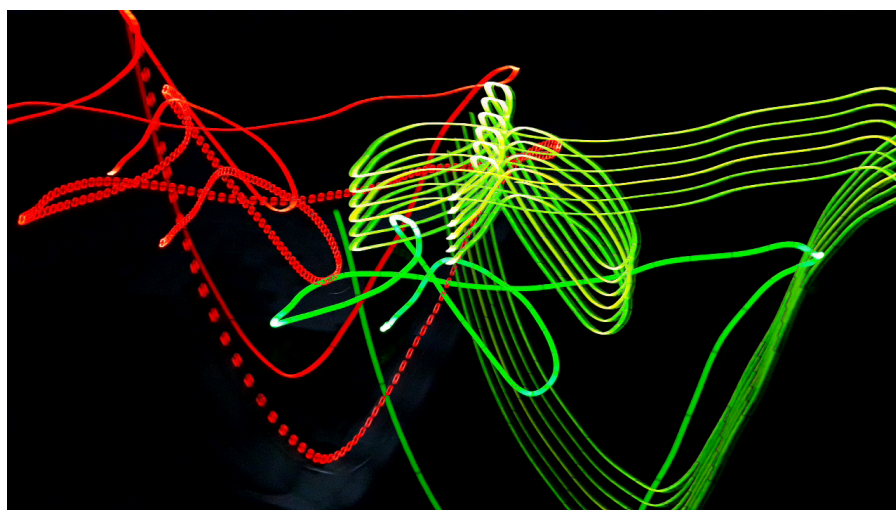


Figure 5 – 5 second exposure of the LED indicator lights on a modem, router and phone.

Resources

Reflection webinar from Spring 2020 [https://www.osa.org/en-us/meetings/webinar/2020/may/optics_magic_at_home_with_judy_nancy_colors_of_\(1\)/](https://www.osa.org/en-us/meetings/webinar/2020/may/optics_magic_at_home_with_judy_nancy_colors_of_(1)/)
Laser target game video <https://youtu.be/izD40kfNAfM>

Refraction lesson from Dumpster Optics is linked here <https://www.pblprojects.org/teaching-and-learning-optics-with-inexpensive-materials/>

Exploring refraction video <https://youtu.be/SKmlP6UKUDU>

Beginners guide to light painting <https://digital-photography-school.com/beginners-guide-to-light-painting/>

A YouTube search for “light painting photography tutorial” brings up dozens of videos for beginner and advanced light painters including light painted spheres, spirals and more.