Waveguide Activities and Demonstrations

This lesson addendum was created to provide a method to do the lessons as stations in the classroom or as demonstrations. They could also be used during Family Science Nights or public Science Outreach events.

This addendum includes a series of "cards" with information that can be placed at each of the stations. The author recommends laminating each card so that they can be reused. The materials needed for each station can be found in the lessons but include:

- laser lights (including red and green)
- flashlight
- refraction tank
- protractor
- fiber optic light wand
- water gel beads
- clear cups
- Lucite optical path demonstrator
- clear gelatin blocks
- sandpaper
- plastic knife
- sugar

Developed by Marilyn Garza
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Refraction Tank Station

Play with the refraction laser tank. Find out all you can about how the entering laser beam relates with the exiting laser beam. Prepare to share at least one insight with the rest of the group.

Challenge #1

How does the entering light beam (*angle of incidence*) relate with the leaving light beam (*angle of refraction*) as light travels **from water into air?**

(Hint: Write down the angles)

Challenge #2

How does the entering light beam (*angle of incidence*) relate with the leaving light beam (*angle of refraction*) as light travels **from air into water?**

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Glass of Water

1. Hold the cup of water and look through it.
2. Pour the water into another cup while holding the paper clip.
3. What happens?
4. Add water to the cup again. What happens?

Why is it invisible?

(**Hint**: What happened to the beam in the refraction tank?)

If you figure this out on your own, you may get a prize!

Lucite (optical path demonstrator)

Point one end of the Lucite upward. Keep it in this position for all steps.

1. Shine a flashlight through the Lucite.
2. Shine a **red** laser beam through one end of the Lucite.
3. Shine a **green** laser beam through one end of the Lucite.

How does the light stay inside?

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Fiber Optic Light Wand

1. Turn on the light wand. Where do you see the light?
2. Cut one of the fibers. Does it stop working? What happens to the light?

How does this happen?

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Gelatin Waveguide

Play with how light can bend and stay inside the gelatin block. Prepare to share at least one insight with the rest of the group.

Challenge #1

Can you guide the light beam inside the gelatin so that the beam turns 45^{o}?

Challenge #2

Can you guide the light beam inside the gelatin so that the bean turns 90^{o}?

Challenge #3

What happens to the light beam if you make the side rough instead of smooth?

Challenge #4

Can you guide the light beam inside the gelatin so that the beam turns 90^{o} **without losing light out the sides?**

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Gelatin Waveguide: Advanced Challenge

For these challenges:

The beam cannot reflect off the sidewalls.

The beam must stay inside the gelatin at some point.

Challenge # 1

Design a gelatin waveguide that will guide the light beam inside the gelatin and turn the beam 180^o.

Challenge #2

Design a gelatin waveguide that will guide the light beam inside the gelatin and turn the beam 180^o **and not lose light out the sidewalls.**

Challenge #3

Design a gelatin waveguide that will guide the light beam inside the gelatin and turn the beam 180^o and occupy the smallest footprint (surface area) possible.

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Fiber Optic Cable Signals

Use the Morse Code table to send a message down the cable. **Do this with a metronome**.

Challenge #1 Send/decipher one word.

Challenge #2 Send/decipher a short phrase.

Between letters = light of 3 metronome ticks
_____ = light of 3 metronome ticks
● = light of 3 metronome ticks

International Morse Code

1. A dash is equal to 3 dots
2. The space between parts of the same letter is equal to 1 dot.
3. The space between 2 letters is equal to 3 dots.
4. The space between two words is equal to 7 dots.

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International Morse Code

A	• —	U	• • —
B	— • • •	V	• • • —
C	— • — •	W	• — —
D	— • •	X	— • • —
E	•	Y	— • — —
F	• • — •	Z	— — • •
G	— — •		
H	• • • •		
I	• •		
J	• — — —		
K	— • —	1	• — — — —
L	• — • •	2	• • — — —
M	— —	3	• • • — —
N	— •	4	• • • • —
O	— — —	5	• • • • •
P	• — — •	6	— • • • •
Q	— — • —	7	— — • • •
R	• — •	8	— — — • •
S	• • •	9	— — — — •
T	—	0	— — — — —

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Refraction Tank

Explore the different ways the laser beam can bend using the refraction laser tank. Find out all you can about the relationship between the entering laser beam going in and the exiting laser beam. Prepare to share at least one insight with the rest of the class.
Students may notice that the ray bends and goes through at angles up to 40^o. At greater angles, students may notice that the laser beam bends and reflects back into the water.

Challenge #1

Find the relationship between the incoming light beam (angle of incidence) and the outgoing light beam (angle of refraction) as light travels **from water into air.**
Students may notice that the angle of incidence is smaller than the angle of refraction when the laser bean leaves the water. Once internal reflection occurs, the angles of incidence and the angles of reflection are the same.

Challenge #2

Find the relationship between the incoming light beam (angle of incidence) and the outgoing light beam (angle of refraction) as light travels **from air into water.**
Students may notice that the angle of incidence is larger than the angle of refraction when the beam travels into the water. The students will also notice that total internal reflection is never reached.

Phantom Crystals Demonstration (Glass of Water)

These crystals are often called water gel beads or growing spheres. Hook a paper clip through several of the crystals to keep them together. Place them in a glass of water. Let them stay in water to expand. Hold up the glass of water with phantom crystals in it. The students should clearly see the paper clip in the water but will have difficulty seeing the crystals themselves. Then dramatically lift the paper clip and the crystals from the water. The crystals should now be easily seen by the students. Ask the students to explain why the crystals can be seen in air but not seen so easily in water. Have them discuss answers in table groups for a few minutes then ask for volunteers to give answers. *The crystals have absorbed so much water that their index of refraction is similar to that of water. This makes it difficult to distinguish between the crystals and water when the crystals are immersed. However, when the crystals are lifted out of the water, the index of refraction is greater than air and light is bent as it travels through the crystals causing it to be easily distinguished from the surrounding air*.

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Optical Path Demonstrator (Lucite)

Hold up the optical path demonstrator, dim the lights, and shine a laser pointer through one end of the optical path. Ask the students to explain using vocabulary terms *index of refraction* and *total internal reflection*. *The index of refraction of the plastic material (Lucite) is much greater than that of air so that total internal reflection is achieved easily and the light beam stays within the curved path with little loss of light.*

Gelatin Waveguide

Procedure:

Using a laser pointer, gelatin square, and graph paper describe how light is refracted as it passes into the gelatin. Explore how light behaves as it travels in the gelatin and when it encounters corners of walls of the gelatin. Prepare to share at least one insight with the rest of the class.

Students may notice that the light ray bends towards the normal as it travels into the gelatin. This indicates that the gelatin has a greater index of refraction that air. Students may also notice that the light ray can be internally reflected off of the walls of the gelatin and hence stay within the gelatin.

Challenge #1

Examine the effects of sidewall roughness on the internal reflection of your light ray. You may use the materials available (sandpaper, plastic knife, and sugar) to damage or roughen the sidewalls and/or use material of your own. Create a table describing the type of damage and the effect it has on the internal reflection of the light ray.

Students may notice that sidewall roughness dramatically decreases internal reflection of the light ray. Roughness due to damage from the sandpaper or the grooves produced by the plastic knife serve to provide surfaces from which light escapes. Particles such as the sugar granules also serve as exit points for the light ray.

Challenge #2

Design a waveguide made of gelatin that will turn a beam of light 180^{o} and occupy the smallest footprint (surface area) possible.

Students will produce a variety of designs. Students may even cut various pieces and set them end on end to produce a curved waveguide. Recognize innovative designs. However, the most efficient will be the design with the smallest surface area.

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