Teacher's Guide

ACTIVITY 1:

Disappearing crystals

Intro

In this activity students will use crystals to determine the concentration of Splenda® in 4 different cups of water. Dry water gel crystals are put into water where they will quickly absorb hundreds of times their weight in water. They will be invisible in plain water but if Splend® a is added they will begin to appear. Students will use this property to determine how much Splenda® is in 4 different cups of water.

Key Question

How does adding Splenda® to water change the index of refraction?

Key Terms

Refraction: When light travels from one material to another it changes direction, or refracts.

Index of refraction: A number that describes how the speed of light in a material compares to the speed of light in vacuum. It also tells how much light changes direction when it moves from one material to another, as well as how much light will be reflected when light hits the surface.

Transparent: Most light is transmitted, a little bit is reflected

Translucent: Some light is transmitted, some will be reflected

Opaque: All light it reflected or absorbed, none is transmitted.

Materials

- **Water gel grystals**
- **21 Splenda® Brand Sweetner packets**
- Water
- 4 clear plastic or glass cups labeled A, B, C, D
- 1 clear plastic or glass cups, unlabeled.
- Spoon

NOTE TO TEACHERS: This activity must be set up beforehand. It takes several hours to grow the water gel crystals. The students will be guessing the contents of 4 "mystery cups" so cups must be prepared by the instructor before the students begin the activity.

Fill all cups with ½ cups of water. Then add Splenda® as follows:

Cup A: 3 packets
Cup B: 12 packets
Cup C: 0 packets
Cup D: 6 packets

Make sure all of the Splenda® has dissolved completely before starting the activity.

The unlabeled cup will be used to grow the crystals. Fill the cup with water and place about 10 water gel crystals in the cup and wait several hours. The cup will be full of gel crystals but you will not be able to see them when they are still in the cup of water.

Before the activity students should know that …

Light travels in a straight line

When light goes from one material to another it changes its path

After the activity students should be able to …

Explain why we can see materials that are transparent even though light passes through them.

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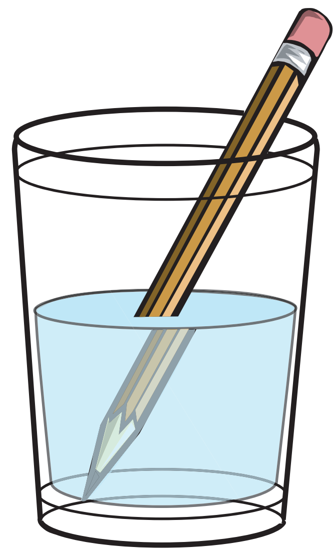
Explain why we cannot see the water gel crystals when they are submerged in water but we can see them when they are in air.

Explain "index of refraction" and understand that larger indices of refraction make light change direction more.



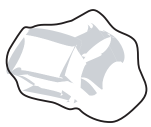
The science behind refraction

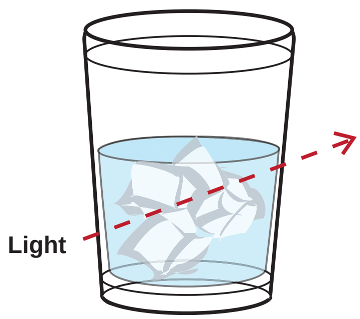
Light travels in a straight line. If it weren't for this property of light there wouldn't be shadows or laser pointers. This rule however isn't completely true. When light moves from one material to another it changes its path. Some of the light changes it direction by reflecting and some changes direction by refracting. When a light ray goes from one transparent or translucent material to another it continues to move through the material but not in the same direction. This change in direction is called refraction.

In the year 984 Ibn Sahl noticed that light did this when it moved through a lens and he wondered if there was a rule that said how much light changed direction. He found that as light moved from air to the glass of the lens that the amount it refracted depended on the angle at which the light hit as well as the type of glass he used. He realized that the light was also changing speed. In 1621 Willebrord Snellius and Renee Decartes both found an equation that tells how much of a light ray will reflect and how much will refract when the light hits a surface. Both of these depend on a number called the index of refraction, or "n". The larger the index of refraction of a material the more light it will reflect and the more it will bend the light that is transmitted. The index of refraction also tells how fast light travels in the new material.

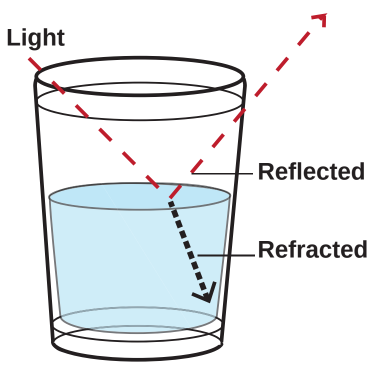
Light is fastest when it is moving in a vacuum. No, not a Hoover, in this case "moving in a vacuum" means that light is moving through nothing, no matter at all, not even air. Outer space is an example of a vacuum. In a vacuum light travels at 300,000,000 meters per second but that's as fast as it can go. If it travels in any type of matter, even air, it slows down a little bit. As it slows down it changes directions. Because the index of refraction tells how fast light goes in a particular material it can also say how much light changes direction as it moves from one material to another. It can also tell us how much light will be reflected. The speed of light in a material is related to the index of refraction by the formula: $n=c/v$ where c is the speed of light in a vacuum and v is the speed of light in a material.

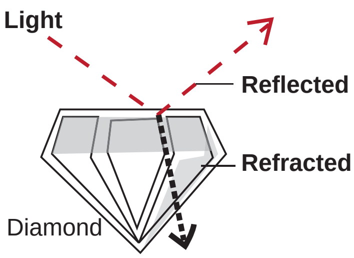
The index of refraction depends on many things. Mostly it depends on the type of material. Water has an index of refraction of 1.3 while diamond has an index of refraction of 2.4. This means that diamond reflects more light than water and that light goes 2.4 times slower in diamond than it does in a vacuum. Index of refraction can also depend on temperature. The index of refraction of cooler air is 1.0003 but when the air is heated by 100 degrees C it changes to 1.0002. This may not seem like much but it bends light enough to cause the wavy appearance seen on top of roads and the hood of your car on hot days.





Light is not bent or reflected going from water to crystal





When we look at an object through a transparent material, such as water, we can see that the light is bending because it looks like the object has shifted a bit. Try this with a glass of water and a pencil. When you put the pencil in the water it looks like the part that is in the water is disjointed from the part that is still in air. This is because of refraction. But what happens when two different materials have the same index of refraction? Could we see them?

We can see transparent materials because of the reflections and in some cases because objects seen through these materials seem distorted by refraction. The index of refraction is different from that of air. But what would happen if two objects had the same index of refraction? Would we be able to distinguish between the two? Would one seem to disappear? That is what the students will be investigating with this experiment. The gel crystals are grown in water and because the final crystal is 99% water it has the same index of refraction as water. While in water, it seems to disappear but in air it is clearly visible. But is it possible to change the index of refraction of water to make the crystals visible? Yes, by adding Splenda®. Water with Splenda® in it has a different index of refraction than plain water. The more Splenda® dissolved in the water, the greater the difference in the index of refraction. When you place a crystal that is grown in water in Splenda® water, it will be visible. The more Splenda® in the water, the easier it will be to see the crystal. There are machines that cost hundreds of thousands of dollars that use this fact to determine the amount of sugar in a liquid, but your students can do the same thing for pennies with the amazing water gel crystals.

Safety

For water gel crystal safety see the Material Safety Data Sheet on page 48.

Corresponding extension activities

1. **Jello lensing:** Watch as light bends on its way through Jell-o.
2. **Spear fishing:** Learn how light bends in water by trying to spear Swedish Fish.
3. **Tabletop sunset:** Create a beautiful sunset using milk and a flashlight.

Bibliography/suggested resources

The Arizona Collaborative for Excellence in Preparation of Teachers. *The Refraction of Light. http://acept.asu.edu/PiN/rdg/refraction/refraction.shtml*

Robin Wood. *Refraction Index of Various Substances for 3D modelers. http://www.robinwood.com/Catalog/Technical/Gen3DTuts/Gen3DPages/RefractionIndexList.html*

Kwan, A., Dudley, J., and Lantz, E. (2002). “Who really discovered Snell’s law?”. *Physics World* **15** (4): 64

Cobb, Vicki, and Cobb, Josh, *Light Action!*. New York: Harper Collins, 1993

Student's Guide

ACTIVITY 1: Disappearing crystals

Intro

You have been cast in the role of Nikola Tesla's sidekick, or "hero support," as he battles Edison and lights the Chicago World's Fair. After each activity you will have to track a pigeon throughout the comic book pages you read. The pigeons have stolen Tesla's tools and it's up to you to get them all back. Before you begin this epic quest, you must first learn about light itself. Then you will begin to learn about exactly how Tesla used magnets and electricity to power the light bulbs he used to illuminate the fair.

Key Question

How does adding Splenda® to water change the index of refraction?

Getting Started

Why can we see clear objects such as glass or clear plastic?

What happens to light when it moves from air to water?

Does light always travel in straight lines?

How might you change the direction in which light travels?

When light interacts with an object it is absorbed, reflected or refracted. If the object is opaque all of the light will be reflected or absorbed. If the material is transparent, such as glass or water, some of the light is reflected but much of the light goes through the material and is refracted or bent. Both the amount of light that is reflected and the amount the light is bent depends on a number called the index of refraction. Most of the time different materials will have different indices of refraction which is why we can see them. This activity will show you what happens when two materials have the same index of refraction. You will then use the fact that Splenda® Brand Sweetener can change the index of refraction of water to determine the concentration of Splenda® in a glass of water.

Materials

- **Water gel crystal**s
- 4 clear plastic or glass cups labeled A, B, C, D
- 1 unlabeled cup full of what looks like water

Setting up the experiment

Before you began, your teacher mixed different amounts of Splenda® into 4 cups. Unfortunately your teacher promptly forgot how much Splenda® was in each cup (Note to Teacher: just play along). Your job is to figure out how much Splenda® is in each cup, but remember, just like all good scientists, you cannot taste anything in the lab. To accomplish your task you will have to use your knowledge of light and its properties.

ACTIVITY 1: Disappearing crystals

Please write in your answers

Your water gel crystals are in a cup filled with water.

Are you able to see them in the water?

Are you able to see them in the air?

How do you think the index of refraction of the crystals compares to that of water? Air?

Collecting data

1. Place three large crystals in each of the four cups.
2. Have each person in the group arrange the cups so that the cup in which the crystals are least visible is ranked "1" and the most visible is ranked "4."
3. Record your results.
4. As a group determine an order for the cups.

Why do the crystals disappear some times, but not at other times?

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Analyzing your results

In the box below, draw an illustration of your 4 cups in order.

Why do you think you can see the crystals in some cups but not others?

How does the index of refraction of the water depend on the amount of Splenda® dissolved in the water?

Which cup do you think has the most Splenda®?

What are some practical ways you might use what you just learned about how index of refraction depends on what is dissolved in water?

Lets say you wanted to make an invisibility cloak just like Harry Potter's. How might you use what you learned about index of refraction to do that? Write your answers below:

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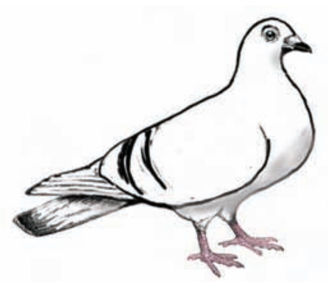
You can use the relationship between index of refraction and speed of light to find the speed of light in a particular material. N = c/v where c is the speed of light (300,000,000) and v is the speed of light in the material. Here is a list of the index of refraction of some other materials. What is the speed of light in these materials?

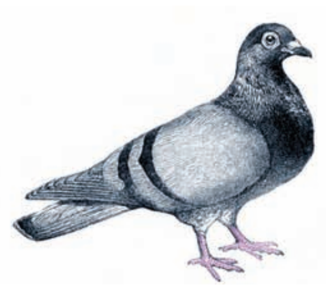
Material	Index of refraction	Speed of light
Water	1.33	____________________
Window glass	1.52	____________________
Diamond	2.42	____________________
Pyrex	1.47	____________________
Cubic zirconia	2.17	____________________
Cranberry juice	1.35	____________________

Using your results to help Tesla light the Chicago's World Fair

It's time to chase your first pigeon! Hurry, they can be fast and Nikola Tesla needs your assistance to accomplish his goal. Rank the cups from most amount of Splenda® to the least amount of Splenda® Where did you put cup D?

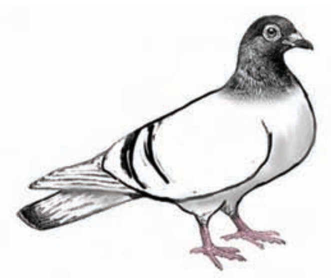


First
Chase the white pigeon



Second
Chase the gray pigeon

Third
Chase the pigeon with stripes



Fourth
Chase the pigeon with the gray head and white body

ACTIVITY 1: Disappearing crystals