Invisible Glass WIP

Keywords: 2017, Cloaking, How Can You Make Stuff Invisible, Invisible Glass, Optics, Physics, Reflection, Refraction, Refractive Index

Meta Description

Understand the fascinating science of refractive indices by making glass disappear in a transparent liquid. This easy experiment will leave you speechless.

Learning Objectives

Understand the concept of refraction of light waves.

Understand the concept of refractive index.

Appreciate the underlying principles of invisibility cloaks.

Key Terms

Cloaking
A technique used to hide or partially hide an object by manipulating light waves.

Electromagnetic Wave
A family of waves which are formed by cyclical patterns in the electrical and magnetic fields in an environment. Electromagnetic waves include x-ray waves, visible light waves from the sun or an electrical light, and microwaves.

Fresnel's Equations
A set of equations describing the behavior of light when it moves between media that have different refractive indices.

Metamaterials
A material constructed in such a way that it has special properties not found in nature.

Optical Medium
A material through which a light wave can pass, for example water or glass.

Refractive Index
A property of an optical medium which determines by how much light is bent when it passes through the optical medium. This bending occurs because the refractive index affects the propagation of light through the medium.

Reflection
Occurs when there is a change in the direction of a wavefront at a boundary such that wave returns into the medium from which the wave originated, such as when light bounces off a mirror on a wall and back into a room.

Refraction
Occurs when there is a change in direction of a wavefront at a boundary due to a change in the medium through which it is travelling. Wave Propagation Describes the way in which electromagnetic waves travel.

Method

Step 1
Prior to the demonstration, fill the aquarium with vegetable oil and the bowl with water. For the experiment to work well, the glassware should be clean, clear and without scratches since blemishes on the glassware may still show when it is submerged in the oil.

Step 2
Place some pyrex glassware in the aquarium. Make sure that the glassware is completely full and that there are no trapped air bubbles within the glassware. This glassware will be ‘hidden’ throughout the demonstration and will be revealed at the end. Wear long rubber gloves when dipping the glassware in the vegetable oil.

Step 3
Start the demonstration by dipping a pyrex test tube in water and emphasise the fact that when the test tube is filled with water it can be seen less but it is still visible.

Step 4
Take another test tube and submerge it in the aquarium filled with vegetable oil. Ensure the test tube has been filled with oil and ensure that there are no air bubbles trapped inside. Ask the audience whether the pyrex glassware is still visible.

Step 5
Explain the physics behind this phenomenon and then, at the end of the demonstration, remove the remaining “invisible” glassware from the aquarium in a big-reveal moment which will catch the audience by surprise.

Precautions

1. Handle all glassware with care. If the glassware breaks it can pose a cutting hazard. If the glass breaks into small pieces on bare flesh this is a significant hazard and medical attention may need to be sought.
2. Be careful of spilled oil, which can cause a slipping hazard. Oil can also stain textiles, and care should be taken to remove or thoroughly cover anything which could be damaged were oil to be spilled on it.

Narrative

Before the demonstration, take two identical beakers and submerge one of them in vegetable oil, making sure it is completely invisible. Start the demonstration by wrapping the second beaker in a newspaper and carefully breaking the glass. You should be wearing thick gloves as an extra precaution against cuts. Next, pour the the broken glass in the oil container and after a while pull the intact beaker out of the vegetable oil as if it was repaired by magic. Lead the audience to believe that the vegetable oil is a special liquid with the ability to repair glass. Of course, at the end of the demonstration detailed in the method, explain that the liquid is not special at all, and that it is simply vegetable oil. Explain the physics behind this phenomenon, using the information in the ‘How it Works’ section.

Questions

Why does pyrex become invisible in the vegetable oil?
Because pyrex has exactly the same refractive index as the vegetable oil.

What is the refractive index?
The refractive index is a property of a material that determines by how much light is bent as it passes through the material.

How is the refractive index of a material calculated?
It is the ratio of the velocity of light through a vacuum to the velocity of light through the particular material.

Why does light bend as it passes from one medium to another?
Because it travels with a different speed through different media.

Hows is refractive index linked to the speed of the light waves travelling in a medium?
Light passes more slowly through a material with a larger refractive index when compared to a material with a smaller refractive index.

Brief Explanation

The propagation of light depends on the medium through which the light travels. At a boundary, that is when light travels from one medium to another, for example from air to glass, the speed of light changes and this causes the light to bend. The amount of bending depends on the refractive indices of the two media.

When the test tube was dipped into the water, it was still clearly visible. This is because pyrex and water have different refractive indices and thus at the boundary, light is reflected back into the eye of the observer, effectively making the test tube visible. However, the pyrex completely disappears in the vegetable oil because both materials have nearly the same refractive index, and thus no light is reflected back into the eye of the observer. Neither is the light refracted or absorbed – it simply passes straight through both the pyrex and the oil as though they were the same material.

Detailed Explanation

The refractive index (*n*) of a material is a dimensionless number describing the propagation of light through a particular material and is given by:

$$n = c/v \qquad (1)$$

where*c*is the speed of light in free space and*v*is the velocity of light as it travels through the medium.

The concept of the refractive index was first described by Snell’s law, which relates the ratio of sines of the angles of incidence and reflection with the ratio of indices of refraction at the boundary of any two media:

$$\sin ?_1 / \sin ?_2 = n2n1 \qquad (2)$$

More commonly it is known as:

$$n1 \sin ?1 = n2 \sin ?2 \qquad (3)$$

A more detailed description of light waves at a boundary is given by Fresnel's equations. The amount of light reflected and refracted depends on the indices of refraction of the media and the angle of incidence. Fresnel's equations suggest that when the indices of refraction are the same there is no reflection and all the incident light is transmitted. This explains why the test tubebecomes invisible when placed in the vegetable oil.

Applications and Research

Applications

Refractive index is a unique property of a material and has many applications in industry. Several techniques were developed to measure the concentration of a solution or determining concentrations of chemicals in particular drugs, by measuring their refractive index. The refractive index is also measured in order to determine the composition and thermophysical properties of chemicals known as hydrocarbons.

Refractive indices are also of importance in laser physics. This well defined parameter of a material is crucial to determine the properties of light sources such as the wavelength, velocity and frequency. http://pubs.acs.org/doi/abs/10.1021/ie000419y

The concepts of optical wave theory, like reflection and refraction, have also been successfully applied to acoustics, which deal with sound waves. These concepts are used to investigate how sound waves travel and can be controlled.

Research

Cloaking devices are used to manipulate electromagnetic rays and make an object invisible when waves of certain frequencies are shone on it. If this range of frequencies corresponds to the frequency of light which is seen by the human eye, this can result in invisibility of the material. Research is being carried out on metamaterials, which can be used to make cloaking devices. These materials can bend light around an object, thus making the object invisible to the naked eye.

Investigation

Experiment with fluids having different refractive indices and analyse how well the glassware can disappear in them. For example, baby oil or washing up liquid could be used.

Subject

Physics

Education

Primary
Secondary
Post Secondary
University
Informal

Time Required

~1 hour
Preparation: 20 minutes
Conducting: 15 minutes
Clean Up: 20 minutes

Cost

25 – 50 €

Recommended Age

6 – 9
10 – 12
13 – 16
>16

Number of People

2 participants

Supervision

Not Required

Location

Indoors
Outdoors
Festivals
Laboratory

Materials

Aquarium or large container

Black paper

Pyrex glassware (such as a clear pyrex kitchen bowl without any markings, a 500ml or 250ml pyrex beaker or a pyrex test tube)

Transparent bowl of water

Vegetable oil

Contributors

Ryan Vella
Author
Natasha Padfield
Editor

Sources

Fresnel's Equations for Reflection and Transmission

Refractive Index

Refraction of light

The Invisible Bowl

Additional Content

Disappearing Glass Rods (Beginner)

How to make glass completely invisible | Live Experiments (Ep 33) (Beginner)

Optical Fibres (Beginner)

The Invisible Bowl (Intermediate)

Is the Arm Testing an Invisible Tank? (Intermediate)

Now You See Me: True Invisibility Cloak Impossible to Build (Intermediate)

Invisibility exposed: Physical bounds on passive cloaking (Advanced)

This is in for Invisibility Cloaks (Advanced)

Omnifocal Glasses Could Focus On Whatever You’re Looking At Automatically (Advanced)

Cite this Experiment

Vella, R., & Padfield, N. (2018, March 10). Invisible Glass. Retrieved from http://steamexperiments.com/experiment/invisible-glass/

First published: **March 10, 2018**
Last modified: **March 10, 2018**