Apparatus Competition
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Invisible Spheres

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Abstract

Making a transparent object "disappear" by immersing it in a fluid with the same index of refraction has always been a pain in the glass. Oils are messy, and polyacrylate "grow" spheres with the same index as water are slippery, fragile, and hard to work with. This new demonstration contains polyacrylate spheres water in a sealed cylinder, separated into two halves. Tipping the container one way immerses the spheres in water, rendering them invisible. Tipping it the other way moves the water into the other half of the cylinder and makes the spheres appear. A laser shining into the cylinder shows how refraction at the surface of the spheres causes the effect.

Construction of Apparatus:

The "Invisible Spheres" demonstration is made using a transparent plastic cylinder sealed with a pair of end caps – these are available as "Tenite" tubing and polyethylene end caps from US Plastic. A flat piece of plastic made of the same Tenite material was made by cutting off a 2" length from one of the tubes, slitting it along the side, then flattening it by hand. Once it was flat (a heat gun helps to soften it), it was cut to the same size as the inner diameter of the tube.

A number of small holes were then drilled into the flat piece of Tenite, and it was pushed into the center of a long piece of the tubing. A long piece of stiff wire was used to run a bead of cement along the edges of the flat plastic and allowed to dry, firmly cementing the flat plastic "sieve" in place at the center of the tube.

At the same time, a number of polyacrylate spheres (available from Arbor Scientific as "Grow Lenses Spheres" were prepared by soaking them in water for a day or two. As they absorb water, the spheres increase greatly in size. At full size, they are mostly water and thus have an index of refraction that is nearly identical to that of water.

When the cylinder was finished and the spheres were fully expanded, a number of the spheres were gently rolled into one half the cylinder, and a polyethylene end cap was placed over that end. The cylinder was inverted, and enough water to cover the spheres was poured into the other end of the cylinder. Then another end cap was placed on that end of the cylinder, and the "Invisible Spheres" demo was ready for use.

A readily available laser pointer is also useful for this demonstration, as outlined below.

Use of Apparatus:

Even transparent objects such as glass or water-filled polyacrylate spheres are easily visible in air, because refraction at the surface/air interface changes the direction of the light. Snell's Law says that light entering an interface between two different indices of refraction must changes direction if it enters at an angle. Our brains recognize that the light coming to our eyes from the object is not what it would be if no object were present, and the object is easily visible, even if it is perfectly clear.

But if the object is surrounded by a fluid with the same index of refraction as the object, Snell's Law predicts that no change of direction will take place. When that is the case, the object "disappears". This has often been demonstrated in the past by immersing a glass object in an oil with a similar index of refraction (approximately 1.4 for many common glasses). But oil is messy to work with, and there is no glass available that works with water.

Polyacrylate is a polymer material that absorbs water and expands nearly 1000 times in volume. When the expansion is finished, the jelly-like solid that remains is 99.9% water, and its index of refraction is so similar to water that is nearly invisible underwater. Because it has an index of refraction that is much higher than air, it is easily visible in air. It makes a good alternative to the standard glass/oil demonstration, but the expanded material is slippery and fragile, making it hard to use effectively in a demonstration.

The "Invisible Spheres" demonstration combines the spheres and water in a sealed cylinder that allows the spheres to be alternately submerged and removed from water with no mess, fuss or muss. Tipping the cylinder slowly in one direction submerges the spheres in water (tip slowly to avoid air bubbles!), while tipping the other direction lets the water flow into the other half of the cylinder. The spheres first disappear, and then reappear as the surrounding water is removed.

A standard laser pointer can also be used to show the reason for the effect. When the spheres are fully submerged in water, a laser beam shining through the combined water/spheres is not significantly deflected. Drain the water from the spheres and shine the laser through them, and the difference in refraction of the beam is obvious.

If tipped carefully, it is possible to have three different conditions in the cylinder – spheres out of water, spheres in water, and water alone (see diagram). Tip the cylinder slowly until about half the water runs out, then tip it suddenly to vertical. Surface tension in the "sieve" keeps the other half of the water in the upper half of the cylinder.

You now have three different areas to explore with the laser. Shine the laser through the spheres out of water, and the beam refracts crazily at all angles. Shine it through the spheres in water, and the beam passes straight through. Shine it through the water alone, and it passes through in the same manner as the spheres in water.

The laser *can* be made to visibly refract by aiming it at a very low grazing angle at a water/sphere interface. At a very low angle of incidence, even the tiny difference in index of refraction is enough to strongly refract the beam.