Mysterious Glowing Ball

OPT-500 / OPT-505

This unique ball is a fun way to demonstrate and discuss **persistence of vision**. It can also be used to begin a unit on light, color and vision.

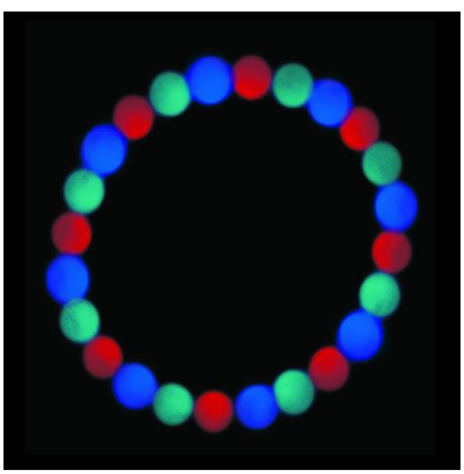
When the ball is stationary, your students will observe a white light but when the ball is in motion (in a darkened room), they will see alternating red, blue, and green lights.

What's going on?

The three oscillating lights effectively demonstrate that white light is composed of colors blending. Your students will be intrigued and eager to find out more.

Explanation

Why do we see three distinct colors when the Mysterious Glowing Ball is in motion? Because of **persistence of vision**—the brief retention of an image on the retina after an object has moved. (To quickly demonstrate this concept to your students, see the *Do-It-Yourself Persistence of Vision Test* on page 5.)



Inside the ball are three colored LEDs that rapidly cycle between red, blue and green light. When the ball is stationary, the eye focuses all three colors on the same part of the retina. As a result, our brain interprets this as white light.

This is due to the persistence of vision that occurs inside the brain. The brain remembers each of the different colored lights for about 1/10 of a second. (This also indicates that the color cycling of the LEDs is faster than 1/10 of a second.) If the light is focused on different parts of the retina, individual colors are seen.

When the glowing ball is tossed, the natural tendency is for the eye to follow the ball. In this case, the viewer will see white light. But if the viewer is staring at the background when the ball is tossed across the field of vision, alternating colored lights are seen.

NGSS Correlations

Our Mysterious Glowing Ball and these lesson ideas will support your students' understanding of these Next Generation Science Standards (NGSS):

Elementary

1-PS4-2
Students can use the Mysterious Glowing Ball to make observations to construct an evidence-based account that objects can be seen only when illuminated.

K-2-ETS1-3
Students can use the Mysterious Glowing Ball in an investigation to develop a simple sketch, drawing, or physical model to illustrate how the shape of an object helps it function as needed to solve a given problem.

4-PS4-1
Students can use the Mysterious Glowing Ball in an investigation to develop a model to describe that light reflecting from objects and entering the eye allows objects to be seen.

Middle School

MS-PS4-2
Students can use the Mysterious Glowing Ball to develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.

High School

HS-PS4-1
Students can use the Mysterious Glowing Ball to conduct investigations and use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.

HS-PS4-5
Students can use the Mysterious Glowing Ball to conduct investigations about technological devices use the principles of wave behavior and wave interactions with matter to transmit.

Suggested Science Idea(s)

1-PS4-2 • 2-PS1-1 • K-2-ETS1-3 • 4-PS4-1 • MS-PS4-2 • HS-PS4-1 • HS-PS4-5
When held stationary, the Mysterious Glowing Ball appears to glow with white light. When spun in a circle by the cord, one can see the white light separate into blinking red, blue and green lights.

Using Your Mysterious Glowing Ball

The Mysterious Glowing Ball works best in a darkened room.

1. Turn the battery plug counterclockwise until the cover comes off.
2. Insert three button batteries with the "+" symbol facing upward.
3. Reinsert the battery plug and turn clockwise until it is secure.
4. Turn on the ball by twisting the battery plug even further clockwise.
5. Stand at a distance from students.
6. Hold the ball stationary and allow students to observe its white light.
7. Next, quickly move the ball back and forth—even just a waving it a few centimeters should be enough—so that students can observe the alternating slivers of red, blue and green light.
8. Hold the end of the string and spin the ball in a large circle. Make sure that students observe the alternating colors with dark spaces in between.

Let's Play Catch!

Remove the string and toss the ball back and forth to someone several meters away. If your students watch the ball's path, they will observe a white ball being tossed. However, if they focus away from the ball (i.e., at a wall), they will see an alternating red, blue and green ball being tossed.

NOTE: To replace the batteries, turn the battery plug counter clockwise until the battery compartment is open. Insert three *L1154 batteries* (BAT-55), positive side up.

Try These Variations!

- Let your students try the ball at different speeds or with different movements. How does the effect change at different speeds?

- What happens if you hold the ball stationary behind a variable-speed fan and view it while switching fan speeds?

- Encourage students to experiment with different variables. For example, have them view the ball through colored filters such as our *Color Filter Paddles* (FIL-100) or *Magic Filter Kit* (FIL-200). What happens to the colors?

- The Mysterious Glowing Ball is a perfect introduction to the concept of persistence of vision. Challenge your students to relate this concept to what happens when we watch a movie or TV. How do our eyes and brain translate the series of images on the screen into motion? Can they discover a way to measure the persistence of vision time? Is it the same for everyone?

- For more advanced classes, use the ball to discuss the three different retinal color receptors in the back of the human eye. How does this ball relate to our ability to perceive colors? "Color blindness" is an inability to see certain colors. How might color blindness change a person's ability to see the colors in the ball?

- In a darkened room, use two Mysterious Glowing Balls on strings to demonstrate poi. (If you know how to juggle, try using three balls!) Invite students to sketch some of the glowing geometrical patterns that emerge. How are they formed? What makes them change?

photograph by Hendrik Kueck

WHAT IS POI?

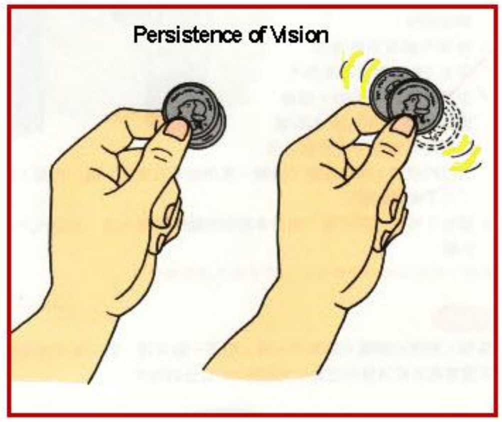
Poi is a type of performance art that originated with the Māori people of New Zealand, and now is practiced in many countries. It usually involves swinging tethered weights or balls to create beautiful geometric patterns. The Mysterious Glowing Ball is a favorite of poi spinners.

Do-It-Yourself Persistence of Vision Test

To help your students understand the concept of persistence of vision, try this simple experiment:

1. *Hold two identical coins together between your thumb and index finger so that one coin is on top of the other.*

2. *Quickly rub the coins against each other so that they slide back and forth. Observe the coins and count the number of coins that you see. If done properly, you will appear to have an extra coin.*



Explanation:

When you look at an object, an image of the object is projected on the **retina** (back inner wall) of your eyes. Even if the object is moved or removed, its image its image remains on the retina for a fraction of a second. This is called **persistence of vision.** Thus an extra coin seems to appear.

NOTE: This experiment can be done successfully even without coins! Try rapidly rubbing your thumb and forefinger back and forth. You will see that you've suddenly "gained" a few extra fingers!

Source: www.scienceprojectideasforkids.com/2010/persistence-of-vision-coins

The Science of Color

Color is created by utilizing two properties of light, energy and frequency of vibration or wavelength. How our brain separates these two properties of light, energy and wavelength, and then recombines them into color perception is a mystery that has intrigued scientists through the ages.

For more information on color perception, consider these useful reference materials:

Encyclopedia.com (color)
www.encyclopedia.com/topic/color.aspx

Encyclopædia Britannica (Visible Spectrum):
www.britannica.com/EBchecked/topic/126658/colour/21838/The-visible-spectrum

Many uses for the "Mysterious Glowing Ball"

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One popular new demonstration in physics classrooms is the "Mysterious Glowing Ball," available from Educational Innovations, Inc.[1] The ball is marketed as a device for illustrating the phenomenon of persistence of vision, an effect due to an afterimage remaining on the retina for a fraction of a second.

The ball is made of a rubbery translucent material. It has an attached cord and loops for holding the ball. Inside the ball is a small light emitting diode (LED), which rapidly flashes from red to blue to green. The flash rate is fast enough that the human eye cannot perceive the individual colors, and the colors combine together to appear essentially white when the ball is stationary.

When the ball is moved, for example by swinging it with the cord, the individual colors can be observed as the speed of the ball increases. The distributor of the ball has posted a video of this demonstration on YouTube at tinyurl.com/glowball.

Although the single demonstration for which this ball is marketed is a dramatic illustration of color mixing, it is not the only use for the ball. This device is ripe for use in explorations of various physical phenomena.

Secondary colors

With a little practice, it is easy to swing the ball at a speed such that the successive flashes occur before the ball has moved a complete diameter. In this situation, one color flash will overlap with the next color flash. The colors will mix and students will be able to see the secondary colors: cyan, magenta, and yellow. It is likely that at least one of the secondary colors will be significantly more difficult to see than the others. Observation of this brightness discrepancy provides a wonderful opportunity to discuss a few things, the eye's sensitivity to different colors and the differences between variously colored LEDs, for example.

A camera with selectable shutter speed can be used to take photos of the ball as it is swinging. Some example photos are shown in Fig. 1. Both photos were taken with the Glowing Ball suspended by the included cord. The ball was given an initial angular velocity by holding the cord taut and throwing

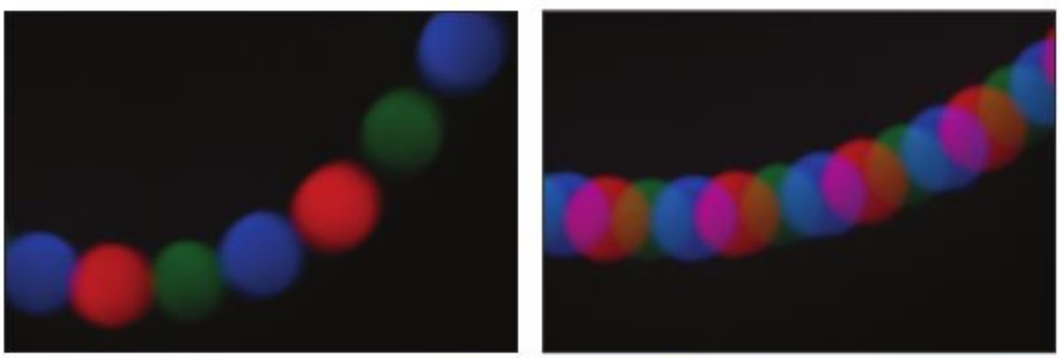

Fig. 1. Photos of a swinging Mysterious Glowing Ball. The ball was suspended by the included cord. The photo on the left shows the swinging ball with a velocity large enough to show separate colors between flashes. The photo on the right shows the swinging ball with a smaller velocity, illustrating color mixing.

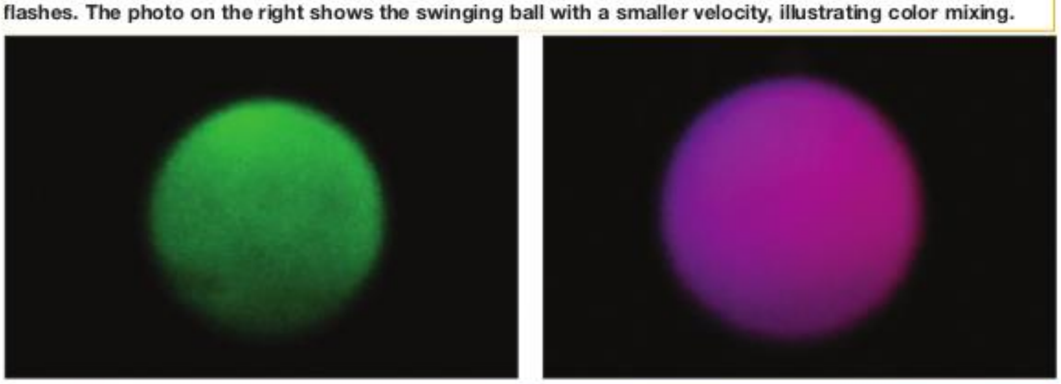

Fig. 2. Photos of a stationary ball showing single LED flash (left, exposure time was 1/124 s) and two LED flashes showing secondary color mixing (right, exposure time was 1/49 s).

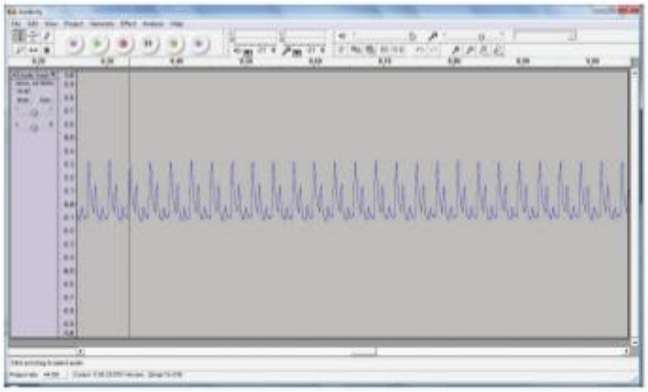

Fig. 3. Signal captured in Audacity of Glowing Ball flashing.

the ball by hand. The shutter speed was set so that the shutter would be open long enough to capture a single pass of the ball in front of the camera.

The first photo was taken with the ball moving with a velocity large enough to show the separation of the colors between subsequent flashes. The second photo was taken with the ball moving at a slower velocity in order to show the secondary colors due to color mixing.

The camera used for Fig. 1 was a digital single-lens reflex (DSLR) camera mounted on a tripod and triggered with a remote. The advantage of using a DSLR is that the shutter can be left open long enough for a student to trigger the camera and then set the ball into motion in the image plane. Some models of point-and-shoot cameras also have the ability to choose a shutter speed, although many cameras of this type will automatically select the shutter speed.

Extended uses

If the flash rate of the LED is known, then the ball can be used for a variety of kinematic experiments. The flash rate is not given by the manufacturer, but measuring the flash rate could become an inquiry-based laboratory activity. Students could be asked to find ways to measure the flash rate without the use of prewritten instructions.

One possible way to estimate the flash rate of the LED is to successively increase the shutter speed (decreasing time that camera shutter is open) for photos taken of a stationary ball. It is easy to find a shutter speed that captures two flashes and will show one of the secondary colors. Students should find a narrow window of shutter speeds that show either a single primary color or single secondary color. The method provides a decent estimate of the flash rate and is also a way for students to learn about the operation and physics of cameras.

A second way of measuring the flash rate is by using a cadmium-sulfide photocell connected to an oscilloscope or the microphone input of a computer's sound card. Figure 3 is a screenshot of the signal from a photocell exposed to the ball as recorded by the free software package Audacity.[2] Note that the signal shows a cycle of three peaks of different amplitudes. The photocell is least sensitive to blue wavelengths. Since the order of the flashes is known, each peak can be matched with the color of the LED that flashed. Analysis of the photocell signal is a good way to show students the dependence of instrumentation on sensitivity to wavelengths. Additionally, students may be encouraged to explore advanced signal analysis by looking at the Fourier transform of the time signal they acquire.

There are surely other methods of measuring the flash rate. Your students should be challenged to come up with their own ways. After the flash rate is known, see how many experiments can be conducted using the ball and the camera. Be aware of the issue of parallax when taking length measurements from photos. It is best to set the camera as far away from an experiment and use the zoom to frame the photo.

An example of an inquiry-based challenge is to ask how good of an approximation it is to neglect air resistance when dropping an object such as the Glowing Ball. This should lead to more student questions: What is the maximum height from which we can drop the ball and still observe an acceleration of 9.8 m/s^2? Can we drop it from a height that allows us to observe it reach terminal velocity? Does the cross-sectional area of the ball make a difference? What if we were to tape the ball to a book and drop it? Some ideas students come up with may be untestable with the Glowing Ball and camera, but many of them are easily investigated in the classroom or on school grounds.

With access to a relatively dark space and a camera with controllable shutter speed, the Mysterious Glowing Ball can be used for more than showing persistence of vision and color mixing. Students can explore many topics, from kinematics and electronics to signal analysis and the physics of cameras.

1. www.teachersource.com/LightAndColor/ColorMixing/MysteriousGlowingBall.aspx.
2. audacity.sourceforge.net.

A PDF of this article is available online at:

http://cdn.teachersource.com/downloads/lesson_pdf/GlowingBall.pdf

Take Your Lesson Further

As science teachers ourselves, we know how much effort goes into preparing lessons.
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www.TeacherSource.com

Check our blog for classroom-tested teaching plans on dozens of topics:

http://blog.TeacherSource.com

To extend your lesson, consider these Educational Innovations products:

Persistance of Vision Double Fan (OPT-370)

This two-headed fan does more than cool you off—it delivers a dazzling lesson in persistence of vision! Each fan blade contains five colorful LEDs that flicker at different speeds, giving the illusion of streams of light instead of individual dots. (This is the same principle that turns a sequence of still images into a motion picture.) Turn it on and enjoy a double light show in red, green, yellow, and blue. Better still, give the blades an extra spin to increase the speed of the rotating arm so that the two individual fan patterns merge into a larger, ever-changing geometric design: triangles, loops, spirals, and more! We guarantee you haven't seen a persistence of vision device like this before!

Color Filter Paddles (FIL-100)

Mix Primary (Red, Blue & Green) and Secondary (Cyan, Yellow & Magenta) filters to study additive and subtractive color mixing, color transmission, and absorption of different wavelengths of light. Polarizing filters can be used to show birefringence, light scattering, and light reflection. Diffraction gratings can be used for direct viewing and analysis of spectra from light sources. Included are 13,500 line/inch double axis and the 500 line/mm single axis gratings. Filters are 5.5 cm (2.16") x 6.7 cm (2.63").

Subtractive Color Theory Demonstration (LGT-330)

The Subtractive Color Theory Demonstration can be used to promote memory retention, encourage logical thinking, and teach the optics and physics of color mixing. As you are challenged to create specific color designs on the back-lit board, you must predict how colors of the filter tiles will mix either by experimentation or previous understanding—then you must strategically slide the squares into the correct configurations. An extensive guide to lead you through a variety of activities is included! This Color Theory Demonstration has a game-like quality and is elegantly simple. It makes exploring and experimenting with color mixing accessible (and fun!) for curious minds of all ages.