

## 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.<sup>1</sup> 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 vid-

eo of this demonstration on YouTube at [tinyurl.com/glowball](http://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

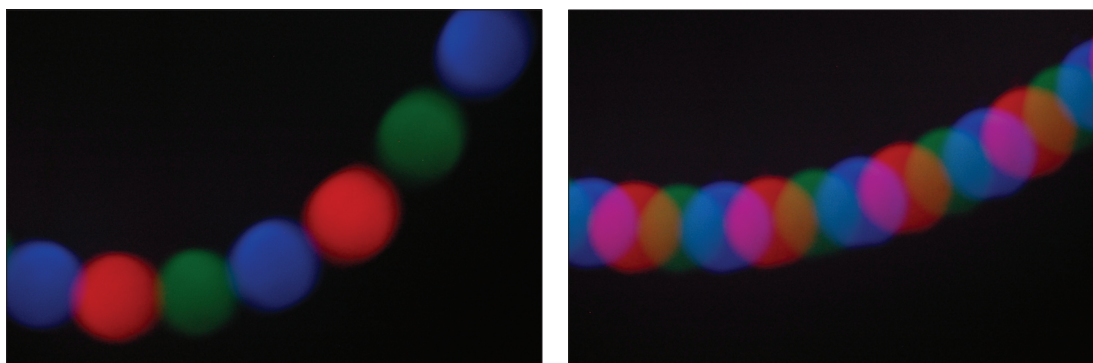


Fig. 1. Photos of a swinging Mysterious Glowing Ball. The ball was suspended by the included cord. The photo on the left shows the swinging ball with a velocity large enough to show separate colors between flashes. The photo on the right shows the swinging ball with a smaller velocity, illustrating color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

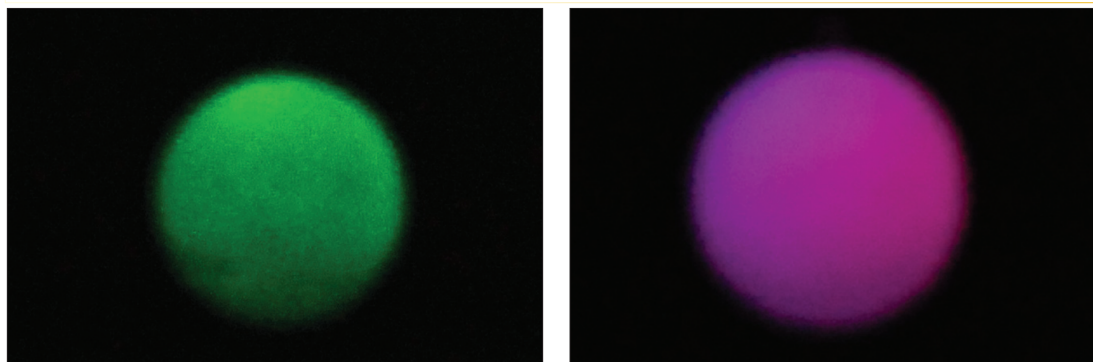
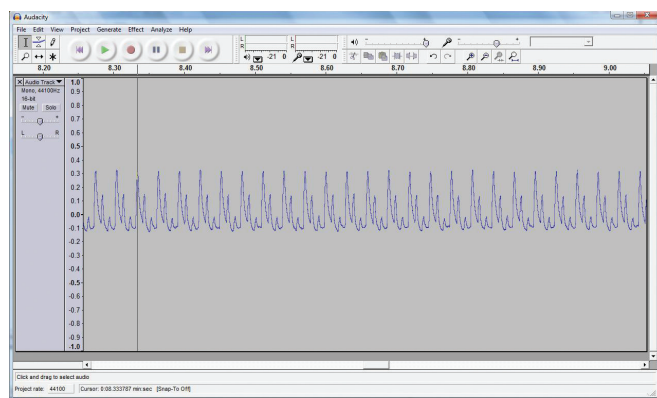


Fig. 2. Photos of a stationary ball showing single LED flash (left, exposure time was 1/124 s) and two LED flashes showing secondary color mixing (right, exposure time was 1/49 s).



**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 pri-

mary 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.<sup>2</sup> 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  $9.8 \text{ m/s}^2$ ? 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](http://www.teachersource.com/LightAndColor/ColorMixing/MysteriousGlowingBall.aspx).
2. [audacity.sourceforge.net](http://audacity.sourceforge.net).