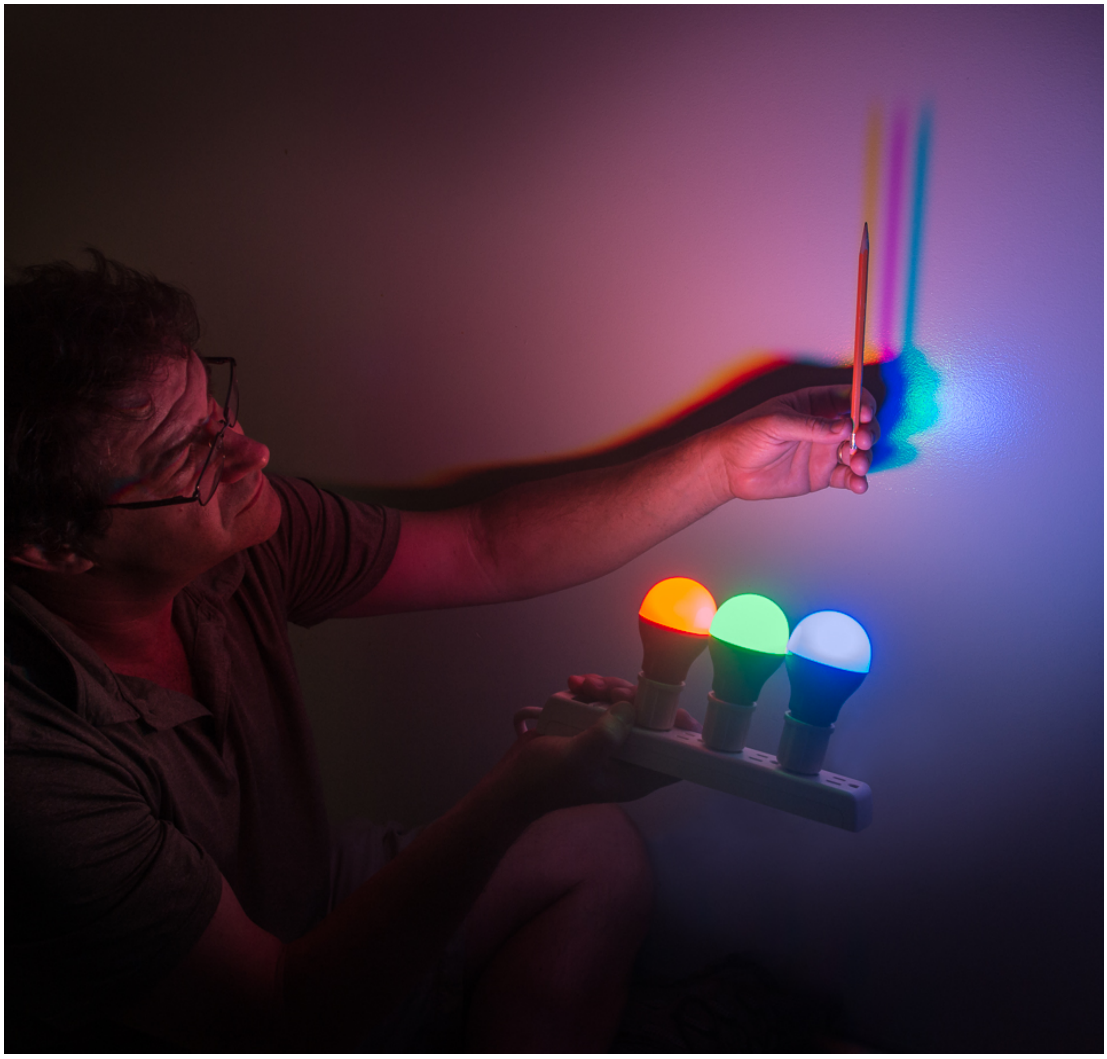
Science Snack

Colored Shadows

Not all shadows are black.



Grade Band: 3-5, 6-8, 9-12, K-2

Subject **Physics:** Light **Perception:** Light Color and Seeing

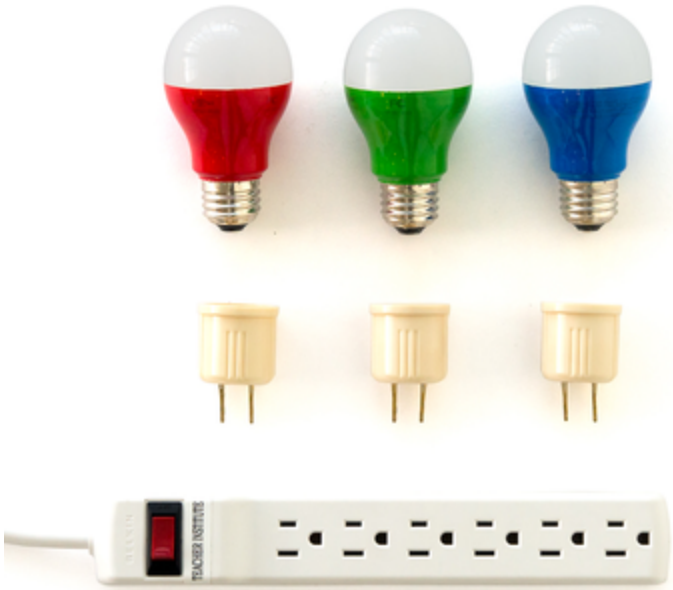
Activity Tags: color, shadows, RGB, CMY, video, exhibit-based

Next Generation Science Standards **CCCs:** Patterns

Cause and Effect Scale, Proportion, and Quantity Structure and Function

LS: LS1 **PS:** PS4 **ETS:** ETS1

When lights of different colors shine on the same spot on a white surface, the light reflecting from that spot to your eyes is called an additive mixture because it is the sum of all the light. We can learn about human color perception by using colored lights to make additive color mixtures.



Tools and Materials

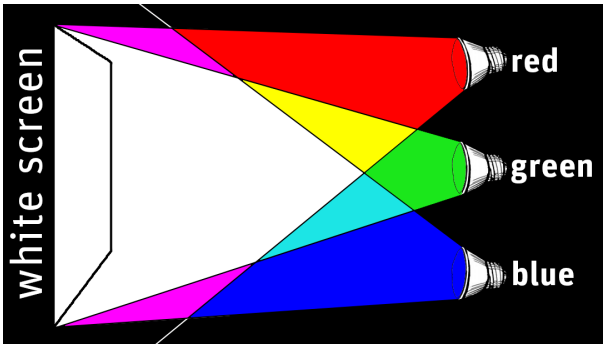
- Red, green, and blue lightbulbs
- A way to plug in all three lightbulbs at the same time and simultaneously direct their light onto the same white surface
- A white surface, such as a wall or a piece of white poster board (white paper taped to stiff cardboard also works well)
- Any narrow solid object such as a pencil or ruler (not pictured)

Assembly

1. Set up the bulbs and the white surface, which will be your screen, in such a way that the light from all three bulbs falls on the same

area of the screen and all bulbs are approximately the same distance from the screen.

2. For best results, put the green bulb between the red and blue bulbs.



To Do and Notice

Make the room as dark as possible. Then turn on the three colored lights, aim them all at your white screen, and adjust the positions of the bulbs until you obtain the “whitest” light you can make on the screen.

Place a narrow opaque object, such as a pencil, fairly close to the screen. Adjust the distance until you see three distinct colored shadows on the screen.

Remove the object, turn off one of the colored lights, and notice how the color on the screen changes. Put the object in front of the screen again and notice the colors of the shadows. Move the object close to the screen until the shadows overlap. Notice the color of the combined shadows.

Repeat the preceding step with a different bulb turned off while the other two remain on, and then a third time until you’ve tried all the possible combinations. Repeat again with only one color turned on at a time, and then with all three on. Vary the size of the object and the distance from the screen. Try using your hand as an object.

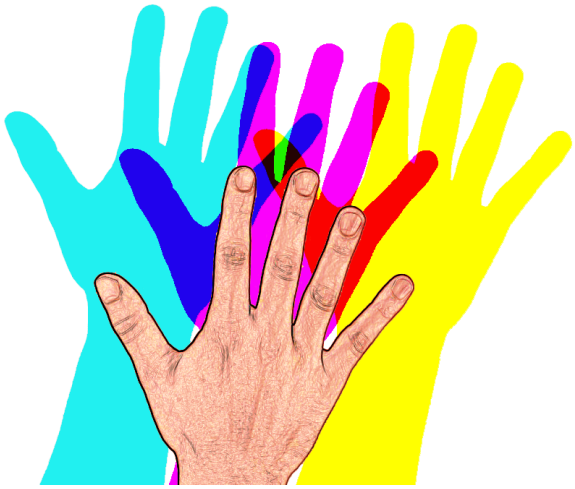
What's Going On?

Your retina, which covers the back of the eye, contains light receptors called rods and cones. Rods are used for night vision and they only let you see in shades of gray. You have only one type of rod but three types of cones. Cones let you see in color as long as it's not very dark.

All three types of cones respond to a wide range of wavelengths, but one type is the most sensitive to long wavelengths (the red end of the spectrum), one to medium wavelengths, and one to short wavelengths (the blue end of the spectrum). With just these three types of cones, we are able to perceive more than a million different colors.

When a red light, a blue light, and a green light are all shining on the screen, the screen looks white because these three colored lights stimulate all three types of cones in your eyes approximately equally, creating the sensation of white. Red, green, and blue are therefore called additive primaries of light.

With these three lights you can make shadows of seven different colors —blue, red, green, black, cyan, magenta, and yellow—by blocking different combinations of lights (click to enlarge diagram below). When you block two lights, you see a shadow of the third color—for example, block the red and green lights and you get a blue shadow. If you block only one of the lights, you get a shadow whose color is a mixture of the other two. Block the red light and the blue and green light mix to create cyan; block the green light and the red and blue light make magenta; block the blue light and red and green make yellow. If you block all three lights, you get a black shadow.



You can achieve a similar effect by turning off different lightbulbs. If you turn off the red light, leaving on only the blue and green lights, the entire screen will appear cyan. And when you hold an object in front of the screen, you will see two shadows, one blue and one green. In one place, the object blocks the light coming from the green bulb, leaving a blue shadow; in the other location it blocks the light from the blue bulb, leaving a green shadow.

When you move the object close to the screen, the shadows overlap, leaving a very dark (black) shadow where the object blocks both lights. When you turn off the green light, leaving on the red and blue lights, the screen will appear to be magenta, a mixture of red and blue. The shadows will be red and blue. When you turn off the blue light, leaving on the red and green lights, the screen will appear to be yellow. The shadows will be red and green.

It may seem strange that a red light and a green light mix to make yellow light on a white screen. It just so happens that a particular mixture of red and green light stimulates the cones in your eyes exactly as much as they're stimulated by yellow light—that is, by light from the yellow portion of the rainbow—so your eye can't tell the difference. Whether a mixture of red and green light or yellow light alone—whenever the cones in your eye are stimulated in just these proportions, you'll see the color yellow.

Going Further

If you let light from the three bulbs shine through a hole in a card that is held an appropriate distance from the screen, you will see three separate patches of colored light on the screen, one from each lamp. (Make the hole large enough to get a patch of color you can really see.) If you move the card closer to the screen, the patches of light will eventually overlap and you will see the mixtures of each pair of colors.

If you want to experiment further, find out what happens when you use different colors of paper or poster board for the screen. Try yellow, green, blue, red, or purple paper, and so on.

Resources

Watch this video to see Teacher Institute staff present this activity in a workshop designed to help teachers bring Science Snacks into the classroom.