

## INSTRUCTIONAL GUIDE

## Contents

- Color Mixing Projector
- Power Supply
- Instructional Guide

## Recommended for Activities:

- Construction Paper
- Food coloring



## Introduction

The spectrum of visible light consists of a broad swatch of wavelengths and frequencies along the electromagnetic spectrum. On the other hand, our perception of light is not based on a continuum so much as it is the result of the mixing of only a few colors that represent a much narrower selection of light wavelengths. Indeed, this color mixing is a bit more complex than the traditional color wheel that historically (and incorrectly) identifies red, yellow, and blue as the primary colors that mix to create orange, green, and purple.

The compact size and elegant simplicity of the Color Mixing Projector makes exploring and experimenting with additive color mixing accessible for everyone. Use a white sheet of paper as a small screen for individual or small group work, or project onto a white wall or larger screen to demonstrate concepts for the entire class. Address physics concepts such as wavelengths and the electromagnetic spectrum and connect the learning to concepts in biology such as sensory perception, anatomy and physiology of the eye and nervous system, and variation between individuals and species.

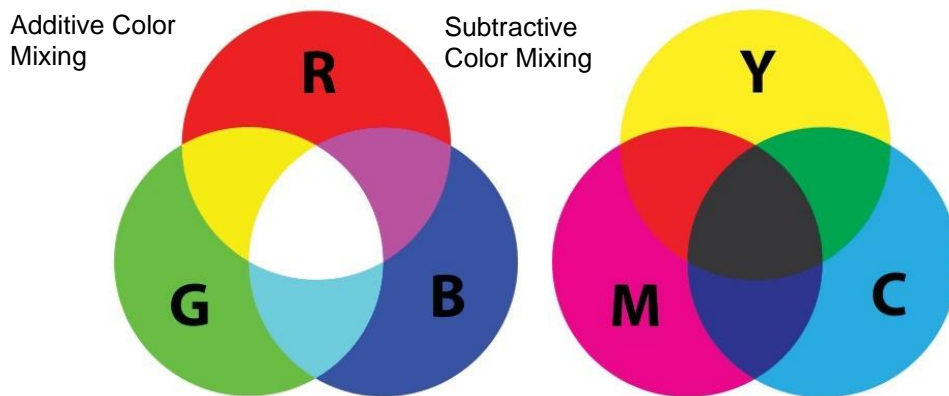
## Background

The human nervous system senses light as it hits the retina at the back of eye. The retina is made up of light receptor cells (photoreceptors) called rods and cones. Rods do not recognize colors and send messages to the brain regarding shape, lines, light, and shadows. Cones are capable of distinguishing colored light. There are three kinds of cones. Each is activated by a narrow range of light wavelengths in either the red, green, or blue range. Different colors along the visible light spectrum activate the different cones in varying amounts sending combinations of messages to the brain such that humans can detect and distinguish between a very broad range and variety of colors.

The Color Mixing Projector models the properties of additive color mixing that can be detected by the human eye. By mixing the three primary colors of red, green, and blue light, the projector can be used to create cyan light (green and blue), magenta light (blue and red), yellow light (red and green) and white light (red, green, and blue). By varying the intensity of each of the light sources, a broad range of additional colors can be created.

This particular Color Mixing Projector works well in conjunction with the human eye, because it uses the primary colors that activate cone photoreceptors. Other species, with different combinations of photoreceptors, would recognize the broadest mixing of colors with lights that matched their own photoreceptors. For example, some insect species would recognize additional color combinations if an ultraviolet light source was added.

Mixing different colors of light is known as additive color mixing. In contrast, subtractive color mixing creates different colors when additional colors of the spectrum are subtracted or absorbed by a medium, allowing a limited range of light to reflect off of the medium. The light that is reflected is the color detected by the eye. Primary colors for subtractive color mixing are cyan, magenta, and yellow. With the addition of black—or key—the CMYK color model is typically used for inks, paints and printing, including photographic printing.



## Set-Up

For younger students, focus on science practice skills such as predicting, making observations, and explaining at an age-appropriate level. More complex physics, anatomy, and physiological concepts can be addressed using the same activities with middle school students and higher.

Use a sheet of white paper as a small screen for small groups or a larger screen or white wall for classroom demos. Dimming the lights is advised.

### Getting Started:

To begin color mixing exploration, allow students to see the colors on their own before overlapping the beams of light on the screen. Then demonstrate what happens when two colors are combined. Be sure to explore all three combinations of two colors. Use the knobs to adjust the intensity of each color LED such that the Projector projects white light. Play a little with the intensity of the LEDs to create different mixtures. Have students share their observations and any explanations for what they observe. Introduce terms such as primary colors, secondary colors, and complementary colors.

### Shadows:

Adjust the intensity of the LEDs to create a white light. Use a pencil or other narrow object to create a shadow on the screen. Vary the distance of the pencil from the screen. Have students share their observations and any explanations. You may also choose to turn off one color beam at a time and make observations of the shadows with only two colors of lights. Have students discuss the explanations for their observations.

## Activities

Have students explore color perception and light by experimenting and playing with additional concepts. Be sure to discuss observations and possible explanations.

- **Color Absorption:** Project the colored light beams onto different colors of construction paper or butcher paper.
- **Color Absorption II:** Project the colored beams through different colors of plastic filters to a white screen behind.
- **Pinhole:** Project the lights through a hole in a piece of paper. Vary the distance of the hole from the light sources and the screen. Pay attention to the positions of the colors on the screen. Which one is on top? Bottom? Right? Left? Can the students explain their observations?
- **Color Fatigue/After Images:** Choose just one of the LEDs to turn on. Stare at the center of the white patch for 30-60 seconds. Be sure not to look away from the light! Turn off the light beam and continue looking at the screen. What do you see? Try it with another primary color. Then try again with a secondary color (a mix of two LEDs). What do you think would eventually happen to your vision if you were exposed to an environment with only blue light? Green? Red?
- **Subtractive Color Mixing:** Use ink, paint, or food coloring (or other liquids with pigments that selectively absorb different wavelengths of visible light) to experiment with subtractive color mixing. Compare the results to additive color mixing with colored lights.

## NGS Standards

**Students who demonstrate understanding can:**

- 1-PS4-2:** Make observations to construct an evidence-based account that objects can be seen only when illuminated.
- 1-PS4-3:** Plan and conduct an investigation to determine the effect of placing objects made with different materials in the path of a beam of light.
- 4-PS3-2:** Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.
- 4-PS4-2:** Develop a model to describe that light reflecting from objects and entering the eye allows objects to be seen.
- 4-LS1-2:** Use a model to describe that animals receive different types of information through their senses, process the information in their brain, and respond to the information in different ways.
- MS-PS4-2:** Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.
- MS-LS1-8:** Gather and synthesize information that sensory receptors respond to stimuli by sending messages to the brain for immediate behavior or storage as memories.

## Related Products

**Light Box and Optical Set 2.0 (P2-9580)** This affordable Light Box and Optical Set makes it easy to perform experiments involving the optics of lenses, mirrors, and prisms, as well as providing a versatile way to display primary and secondary colors; and both additive and subtractive color mixing.

**Subtractive Color Theory Demonstration (P2-9565)** Students manipulate transparent tiles on a backlit board to see how color mixing with light produces different results than mixing pigments.

**Color Filters Set of 7 (33-0195)** This low-cost filter kit includes seven 175mm x 200mm filters of primary and secondary colors, complete with spectrum graphs and teacher's guide with experiments. Cut to any shape with scissors.