

**Lesson Plan:**  
**The Physics of Color**  
Kevin Hugo  
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## **Introduction**

Although educational research on the physics of color is far less advanced than other aspects of physics education, several student misconceptions have been reported. In particular, students perceive color as a property of objects, rather than the light that reflects from those objects (Anderson, 1986). Color filters are believed to add color to light, rather than remove it (Arons, 1997). Students are also often taught at earlier grade levels that red, yellow, and blue are the primary colors. Finally, particular names of colors such as brown or gray can be applied to a range of possible primary color combinations, causing further student confusion (Martinez-Anton, 1995).

The purpose of this lesson is to convey the effects of light sources, filters, and objects on color. It is intended for high-school students in a first or second year physics course. Although it assumes knowledge of how light intensity is measured, it is not dependent on other aspects of optics.

## **Standards**

Wisconsin A.12.6 Identify and, using evidence learned or discovered, replace inaccurate personal models and explanations of science-related events.

Wisconsin C.12.5 Use the explanations and models found in the earth and space, life and environmental, and physical sciences to develop likely explanations for the results of their investigations.

Wisconsin C.12.6 Present the results of investigations to groups concerned with the issues, explaining the meaning and implications of the results, and answering questions in terms the audience can understand.

Wisconsin D.12.9 Describe models of light, heat, and sound and through investigations describe similarities and differences in the way these energy forms behave.

## **Objectives**

Students will be able to

1. Identify the three primary colors and predict their combinations.
2. Explain how black, white, and gray shades are produced.
3. Apply the theory of primary colors to produce other colors on a computer screen.
4. Determine the relationship of a filter between the intensity of incident light, intensity of transmitted light, and the number of filters.
5. Determine the relationship between the amount (or concentration) of a pigment, the intensity of incident light, and the intensity

of transmitted light.

6. Predict and explain how colored light sources and/or filters change the appearance of a colored object.

### **Process**

The lesson is designed to be taught over a period of three to five days. The class should be divided into five small groups, each rotating among the five stations described below. The teacher should explain each of the stations to the students on the first day. It should take two to three days (15 to 20 minutes per station) for the students to complete the lab procedures. When all groups have completed each station, the teacher should assign each group one station to present on a whiteboard, paying particular attention to the "For Discussion" sections below. Preparing and presenting the whiteboards should take two to three days.

### **References**

Anderson, C.W. and E.L. Smith. *Children's Conceptions of Light and Color: Understanding the Role of Unseen Rays*. Michigan State University Institute for Research on Teaching. Technical report number 166.

Arons, A.B. "Novice conceptions of the nature of light." Section I-9.19 in *Teaching Introductory Physics*. New York: John Wiley and Sons, 1997.

Martinez-Anton, J.C. *et al.* "A Simple Colorimeter." *Physics Teacher*. 33(6): pp. 372–374. Sep. 1995.

## **Station 1: Combining light**

### **Materials**

3 light boxes

Red, green, and blue color filters

Sheet of white paper

### **Procedure**

Insert a red color filter on the end of one of the light boxes. Turn on the box. What is the color of the light coming from the box? What color do you see when the light is projected on a piece of white paper? Repeat with each of the remaining filters and light boxes.

Suppose you shine a red light and a green light on the same spot. What color would you expect to see? Try it with the red and green light boxes. How many possible combinations of colors can you make with the three light boxes? Try them and record the colors produced.

### **For Discussion**

- Make a diagram of the color combinations you made.
- Why does mixing red and green result in a color that appears neither red nor green?
- What color results from mixing yellow and blue light?
- What do we see when we see the color white?
- What do we see when we see the color black?

## Station 2: More combining light

### Materials

Macintosh computer  
"Color Sliders" program

### Procedure

Double-click the "Color Sliders" computer program to launch it. This program combines red, green, and blue light, just as is done with the light boxes at Station #1; however, this program also allows you to adjust the intensity of each of the red, green, and blue components by clicking on the sliders. Practice moving the sliders for a few minutes to familiarize yourself with the program.

Determine the slider settings that produce each of the following "crayon colors": red, orange, yellow, green, blue, purple, black, white, and gray. Do people always agree on the settings for each color? For an extra challenge, find the settings for pink, brown, and flesh.

### For Discussion

- Make a table of the red, green, and blue components of each color.
- Consider the colors of the rainbow. As you move from red to violet, what happens to the red component? The green component? The blue component?
- How do we produce gray tones?
- Are there any colors that "Color Sliders" cannot generate? Why?

### Station 3: A series of filters

#### Materials

Light box  
Flashlight  
4 smoked glass filters  
Meterstick  
Light sensor  
Computer with LabPro interface

#### Procedure

Turn on the light box and shine it at the light sensor, at a distance of 20 cm. Record the reading of the light sensor.

Place one of the glass filters between the light source and the sensor. Record the reading of the light sensor. Repeat with up to 4 filters between the light source and the sensor.

Repeat all of the above with the flashlight as the light source.

#### For Discussion

- Draw a diagram of your setup and a graph of light intensity versus number of filters for each of your light sources.
- What is the relationship between light intensity and the number of filters?
- Suppose you had a set of filters that each reduces the light to  $1/3$  of the intensity put into it. How much light would you get by combining two of these filters? Three filters?
- Suppose you had one filter that reduces the light to  $1/3$  of the intensity put into it and another filter that reduces the light by  $1/2$ . What is the effect of combining these two filters?
- Suppose you had a filter that reduces the light to  $1/4$  of the intensity put into it. What is the effect of doubling the thickness of the filter? Of halving the thickness?
- Does the order of the filters matter?
- Would reflecting the light off of a mirror in between the filters change the intensity of the light?

## Station 4: Pigments

### Materials

Green food coloring  
100 ml beaker  
5 or 10 mL graduated cylinder  
Colorimeter with cuvettes  
Computer with LabPro interface

### Procedure

Because there will only be enough time for each group to analyze one wavelength (color) or light, your teacher will assign each group one wavelength to examine. When the lab is finished, share your results with the other groups and analyze data from all three wavelengths for discussion.

Set the colorimeter to your assigned wavelength. It will take 5 minutes for the colorimeter to stabilize to this wavelength. It is not necessary to calibrate the colorimeter. While you are waiting, prepare a "pigment" of one drop of food coloring in 100 mL of water. Let's call the concentration of this solution 4 mM. Prepare 5 cuvettes with 0, 1, 2, 3, and 4 mL of pigment each. Add water to fill each cuvette to 4 mL. Cap each cuvette and mix gently.

Run the "Pigment.cmb1" LoggerPro program. Insert each cuvette into the colorimeter, close the lid, and click the "Keep" button on the LoggerPro toolbar.

### For Discussion

- For each wavelength, graph the light intensity versus concentration of pigment. What is the relationship?
- How is this effect similar to station #3? Why?
- How is the effect at the red wavelength similar to the green and blue wavelengths? How is it different?
- Why does the pigment look green when held up to a white light?

## Station 5: Combining colors and filters

### Materials

Flashlight

Red, green, and blue filters

White, red, yellow, green, and blue paper

### Procedure

Place the red filter over one group member's eye and close both eyes. Shuffle the pieces of colored paper. When you are ready, have the tester look at one of the pieces of paper through the red filter. Illuminate the paper with the white beam of the flashlight. Does the paper appear bright or dark? Repeat with the other colors of paper and record your results. Can you tell the difference between the white, red, and yellow papers when looking through the red filter? Repeat with the green and blue filters, again recording whether the paper appears bright or dark.

Now place the red filter over the flashlight, and illuminate each piece of paper with the red beam of the flashlight. Record whether the paper appears bright or dark. Repeat with the other color filters.

### For Discussion

- Use both pictures and words to explain your results.
- Does it matter whether the filter is placed in front of your eye rather than the light source? Explain.