Shadow and Color in Light

Equipment

1	Color Mixer	OS - 8496
1	Color Mixer Accessory Kit	OS - 8495
1	Viewing Screen	OS - 8460
1	Optics Bench	OS-8508

Introduction

When lights of two different colors are arranged so they shine on the same location on a white surface, the human eye perceives the reflection of that light as an additive mixture, because the reflected light contains wavelengths from both of the colors. Students will use the Color Mixer to learn how three colors of light - red, blue, and green - add together to create a full range of colors.

Setup

Attach the color mixer to the optics bench. Attach the viewing screen to the optics bench so it faces the color mixer. Turn up the red LED and adjust the position of the viewing screen as necessary to see the circle of red light as large as possible on the screen. The circle of red light will not be centered on the screen.
Turn the knob on the red LED fully counter-clockwise to turn off the color, and turn the knob fully clockwise to make the color as bright as possible.

Caution: The Color Mixer light-emitting diodes (LEDs) produce intense light. Do not look directly into the Color Mixer when it is turned on.

Figure 1: Adjusting the viewing screen position

Procedure: Additive Color Mixing

1. Turn the red LED fully on with the blue and green LEDs off. What do you predict will happen as the intensity of the green LED is gradually increased?

2. Gradually increase the green LED and note the range of colors that is formed where the green and red circles of light overlap. Were your predictions accurate?

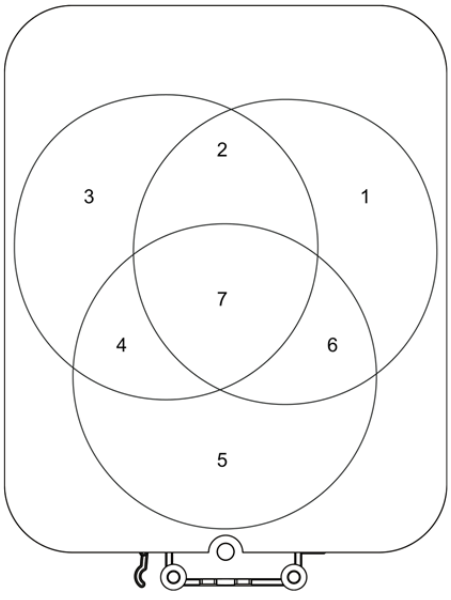
3. Now turn off the red and turn the green fully on. What do you predict will happen as the red is gradually increased in intensity?

4. Gradually increase the intensity of the red and note the colors that are formed in the overlapping segment. Were your predictions accurate?

5. Repeat the steps above for both green and red with the blue source. For each of the colors listed below, describe which colors of light were mixed to create that color. For some you will need to describe the relative intensity (low, medium, high) of each color.

Color of Light Produced	**Light Color(s) Mixed**
Red	
Blue	
Green	
Pink	
Yellow	
Orange	
White	
Turquoise	

6. For each of the 7 regions of overlapping circles shown in the diagram below, list the resulting colors produced by mixing the colors of light.



Region	**Color of Light Produced**
1	
2	
3	
4	
5	
6	
7	

Figure 2: The regions formed by overlapping circles of light

LED Emission and Filter Transmission Curves

The Color Mixer LEDs emit light whose wavelengths fall within a certain range. Although the individual color wavelengths will vary from unit to unit due to minor variations in the LEDs, the peak wavelength ranges for each color are as follows:

Color	Peak Wavelength Range
Red	620 to 630 nm
Green	520 to 535 nm
Blue	450 to 465 nm

These peak wavelength ranges are illustrated in the graph below, which is intended to give a general idea of the emission curves for each color LED in the Color Mixer.

Each filter card allows some light to pass through it. If you hold a filter card up to the sunlight and look through it, the transmitted light will reach your eye. You perceive the color corresponding to the wavelengths of light that are transmitted by the filter. For example, if you hold up filter card 1 and look through it, light between about 600 nm and 700 nm passes though the filter material and reaches the receptors in your eye, so you see red. Light of shorter wavelengths does not pass through the filter, so you do not see blue or green.

Each filter card has the characteristic transmission curve printed on the card, as show below. The transmission curve information will be used for analysis of the behavior of the filters.

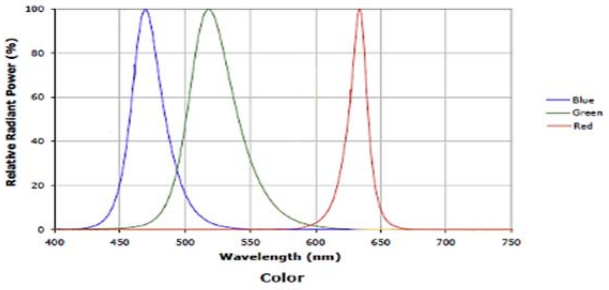


Figure 3: Emission Curves of the Color Mixer

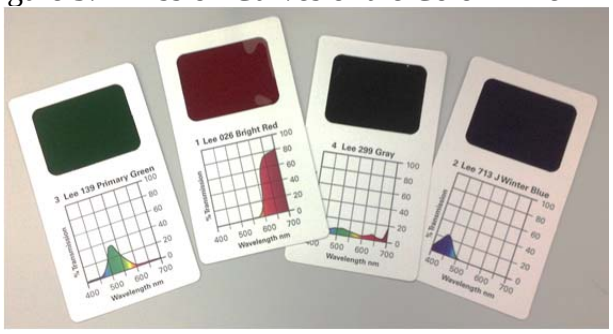


Figure 4: Filter cards, Imprinted with Transmission Curves

Procedure: Using Filters

1. Look at each of the filters that you have been given and predict what will happen to the red light from the Color Mixer when the filters 1 through 4 are placed between the red LED and the viewing screen. List your predictions in the table below.

2. Turn on only the red source and look at the screen as each of the filters is placed between the screen and the mixer. Record your observations in the table.

3. Based on what you saw with the filters and their interaction with the red light, predict what will be observed when the filters are placed in front of the blue source. Turn on the blue source and record your observations.

4. Perform the same prediction and observation activity with the green source and filters.

Filter	**Predictions for Red Light**	**Observed Results**
Card 1 – Bright Red		
Card 2 – Winter Blue		
Card 3 – Primary Green		
Card 4 – Gray		

Filter	**Predictions for Blue Light**	**Observed Results**
Card 1 – Bright Red		
Card 2 – Winter Blue		
Card 3 – Primary Green		
Card 4 – Gray		

Filter	**Predictions for Green Light**	**Observed Results**
Card 1 – Bright Red		
Card 2 – Winter Blue		
Card 3 – Primary Green		
Card 4 – Gray		

Analysis: Filters

1. Compare your observed results with your predictions for each color light. Briefly discuss any differences between predictions and observations.

2. Review the emission curves for the Color Mixer and the filter transmission curves for the red, blue and green cards. Create a graph which overlays the transmission and emission curves. Explain why the blue filter allows some of the green led light to show on the screen using the overlay graph in your explanation.

3. Explain the difference between the action of the #4 filter and the rest of the filters. How does it differ and why?

4. Based on your analysis of filters 1 through 4, which of filters 5 through 7 would behave

the most like filter 4 (gray) if it were placed between the viewing screen and the red LED?

Procedure: Absorption vs. Transmission

Using printed cards 8–11, the Color Mixer, and filter cards, students will explore the meaning of absorption and reflection of light.

Note: Ambient light in the room will make observation of some things difficult. Decrease room lighting as low as possible to enhance this lab.

1. Predict what each of the cards will look like when illuminated only by the red source.

2. Place each card (red, blue, green and white) in front of the red source and note your observations.

3. Based on what you observed with the red source, predict how the same cards will appear when illuminated by the blue and green sources.

Color Card	**Predictions for Red Light**	**Observed Results**
Card 8 – Red		
Card 9 – Blue		
Card 10 – Green		
Card 11 – White		

Color Card	**Predictions for Blue Light**	**Observed Results**
Card 8 – Red		
Card 9 – Blue		
Card 10 – Green		
Card 11 – White		

Color Card	**Predictions for Green Light**	**Observed Results**
Card 8 – Red		
Card 9 – Blue		
Card 10 – Green		
Card 11 – White		

Analysis: Absorption vs. Transmission

1. Compare your observed results with your predictions for each color light. Briefly discuss any differences between predictions and observations.
2. Did any of the cards exhibit the same brightness for all three sources? If so, which card? The relative intensity of reflection vs. wavelength is printed on the card. Create an overlay of this card's relative intensity curve with the spectral emission curves for the LEDs used in the Color Mixer. Suggest a possible explanation based on your overlay graph.

3. Discuss the difference between a filter's interaction with light and an ink's interaction with light.

Procedure: Casting Shadows

1. Turn on the red, green, and blue LEDs, and adjust the intensities of the lights until the whitest light possible appears on the viewing screen at the central region of overlap.

2. Place a pen or a pencil as close to the screen as possible. Describe the shadow cast by the object on the viewing screen in each region of the overlapping circles on which the shadow falls.


Figure 5: Pencil near Screen

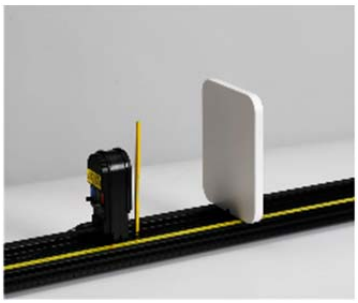


Figure 6: Pencil in Front of Color Mixer

3. Turn off each LED on the Color Mixer.

4. Adjust the distance of the object so that it is now about 2 cm in front of the Color Mixer.

5. Turn on first the red light, then the green light, then the blue light. Observe the shadow that falls on each region of the overlapping circles.

6. What color light must be blocked by the object in order to form a blue shadow? What color light must be blocked to form a red shadow?

7. Develop a rule for blocking one or more colors of light to form each of the following seven colors of shadows:

Color of Shadow Produced	**Light Color(s) Blocked**
Red	
Blue	
Green	
Black	
Cyan	
Magenta	
Yellow	