SECTION 10

Color

Section Overview

To investigate color addition, students project the light of colored bulbs on a screen and investigate the shadows that remain. First they shine the light from two bulbs (red and green) on a screen and record what they see. They then place a puppet between the light bulbs, project the image on the screen, and record the colors of the various shadows formed that they see. Students see what happens to the colors of the shadow when they turn off one light bulb. Students continue to record their observations of how the puppet's shadow changes each time they use different colored bulb combinations while all the bulbs are on and when one is turned off.

In *Section 5* they made a drawing to show the size of the shadow and the relationship of size to the positions of bulb, object, and screen. Here they progress to combinations of colored lights, and for each combination they make a drawing to record the color patterns of the shadows that are formed.

Background Information

Color is a perception produced by the eye and the brain. The corresponding physical property of light is the wavelength (or frequency). Visible wavelengths range from about 0.4×10^{-6} m to 0.7×10^{-6} m. Light with a narrow range of wavelengths in this range stimulates the eye and brain to produce the sensation of a spectral color, as shown by the spectral colors of sunlight formed by a prism (the index of refraction of the prism glass depends on the wavelength of light). You can also see these spectral colors when white light reflects from the grooves of a CD or DVD. The color spreading here occurs due to light wave diffraction and interference. (Note that the interference of light is not discussed in this chapter.)

In addition to the spectral colors, the perception of color can also be produced by combinations of lights with different wavelengths. Red light plus green light produces light seen as yellow. This effect is called color addition or additive color mixing. Mixing a wide range of wavelengths usually gives the perception of an unsaturated, pastel color. Such a combination might be a red, green, and blue light. If the blue light is more intense than the red and green lights, the light mixture would be seen as a pale blue. In a saturated color, there is a narrow range of wavelengths. Saturated colors are often called "strong" or "intense." As different colored lights are progressively turned on to illuminate a screen, more and more light falls on the screen, which looks brighter and brighter. In the drawing of the three overlapping disks at the bottom of the first page of the *Physics Talk*, the central area, illuminated by light of all three colors, would be the brightest area and would be (almost) white.

Overlapping colored filters gives quite different results. As more and more filters are overlapped, the light transmitted is less and less, so the stack of filters looks dark. Typically, a filter passes a range of wavelengths, which correspond to a range of colors and absorbs light of wavelengths not in this range. So two overlapped filters pass only those wavelengths that both pass in common.

Crucial Physics

- Your eyes (and brain) interpret different frequencies of light as different colors. Each frequency has a corresponding wavelength.
- When light from different colored light sources enters your eyes, you interpret the result as yet another color. This is called additive color mixing.
- When an object is illuminated by light from different colored light sources in different locations, the object can produce colored shadows. By tracing light rays from the different sources, you can understand the colors that appear in different parts of the shadows.

Learning Outcomes	Location in the Section	Evidence of Understanding
Observe combinations of colored lights.	***Investigate*** Step 3	Students light up bulbs of different colors to observe the colors they see on a screen.
Predict patterns of colored shadows.	***Investigate*** Steps 3-6	Students predict the patterns of colored shadows by illuminating them with light bulbs of different colors.

Section 10 Materials, Preparation, and Safety

Materials and Equipment

PLAN A		
Materials and Equipment	**Group (4 students)**	**Class**
Lamp, clip-on with shade		4 per class
Stand for clip-on lamp		4 per class
Cardboard, 14” x 14”	2 per group	
Bulb - 25W White		1 per class
Bulb - 25W Green		1 per class
Bulb - 25W Blue		1 per class
Bulb - 25W Red		1 per class
Access to an electrical outlet*	1 per group	
Large white screen*		1 per class
Acrylic or water-color paints (different colors)*	6 per group	
Paper to paint on*	2 per group	
Paint brush*	1 per group	

*Additional items needed not supplied

Time Requirement

- Allow 30 minutes for students to complete the *Investigate* portion of this section.

Teacher Preparation

- Assemble the required material. Test the quality of the colored light sources to ensure they give approximately the correct colors when combined.
- If colored light sources are not available, white light sources covered with filters are an acceptable alternative. The best filters are known as theatrical gels. Ask a member of your school’s theater production group if they have any or where to purchase the appropriate red, green, and blue gels to yield white.
- If colored bulbs and light shield reflectors are not available, obtain light shield reflectors from Earth science teachers, if possible.
- For each group’s setup, it is best to use a large cardboard box to provide a shaded space in which they can observe the colored light.
- Although not as effective, the light bulbs can be low-voltage Christmas lights, which are both easier to handle and safer than 120-volt bulbs.

Safety Requirements

- If 110-volt light sources are used, review light-bulb safety from *Section 5*.

Materials and Equipment

PLAN B		
Materials and Equipment	**Group (4 students)**	**Class**
Lamp, clip-on with shade		4 per class
Stand for clip-on lamp		4 per class
Cardboard, 14" x 14"		2 per class
Bulb - 25W White		1 per class
Bulb - 25W Green		1 per class
Bulb - 25W Blue		1 per class
Bulb - 25W Red		1 per class
Access to an electrical outlet*		1 per class
Large white screen*		1 per class
Acrylic or water-color paints (different colors)*	6 per group	
Paper to paint on*	2 per group	
Paint brush*	1 per group	

*Additional items needed not supplied

Time Requirement

- Allow 30 minutes for students to complete the *Investigate* portion of this section.

Teacher Preparation

- Assemble the required material. Test the quality of the colored light sources to ensure they give approximately the correct colors when combined.
- If colored light sources are not available, white light sources covered with filters are an acceptable alternative. The best filters are known as theatrical gels. Ask a member of your school's theater production group if they have any or where to purchase the appropriate red, green and blue gels to yield white.
- If colored bulbs and light shield reflectors are not available, obtain light shield reflectors from Earth science teachers, if possible.
- For each group's setup, it is best to use a large cardboard box to provide a shaded space in which they can observe the colored light.
- Although not as effective, the light bulbs can be low-voltage Christmas lights, which are both easier to handle and safer than 120-volt bulbs.

Safety Requirements

- If 110-volt light sources are used, review light-bulb safety from *Section 5*.

Meeting the Needs of All Students

Differentiated Instruction: Augmentation and Accommodations

Learning Issue	Reference	Augmentation and Accommodations
Repeating steps without new directions Reading comprehension	***Investigate*** Steps 4-6	**Augmentation** • Repeating the directions in *Step 3* may be difficult for students who are struggling with reading comprehension and focus. Pair students strategically to include someone who could follow the directions more easily and also substitute the color changes independently. • Instruct students to use colored pencils or crayons to visually represent their observations, instead of just using words. This visual cue will help students who struggle with reading. • Model *Step 3* and record observations as a class. Then ask students to complete *Steps 4-6* in groups. **Accommodation** • Provide typed directions for *Steps 4-6*.
Understanding vocabulary	***Investigate*** Step 7.b)	**Augmentation** • Ask students what color "cyan" is similar to. Show students the cyan paint.
Understanding essential concepts	***Physics to Go*** Question 1	***Augmentation*** • Students are required to use their reading comprehension skills and the *Investigate* to answer this question; however, some students have a difficult time summarizing and applying information to answer comprehension questions. Remind students that the *Investigate* and *Physics Talk* sections provide information to help them answer this question. • Allow students with more severe reading comprehension struggles to use a red, green, and blue light to experiment and describe their results to answer this question. Experimenting more with lighting effects is also a worthwhile strategy because being able to use the lights to produce a certain effect is the ultimate goal to show understanding of the *Chapter Challenge.*

Strategies for Students with Limited English-Language Proficiency

Learning Issue	Reference	Augmentation
Understanding concepts	***Investigate*** Step 3	Be sure ELL students keep track of their predictions and results pertaining to their shadow studies. Suggest that they write their interpretations of what might be causing what they see as well.
Vocabulary comprehension	***Physics Talk***	Students need to know that "pigments" are substances that give color to paints as well as to other substances. Students may know from biology class that "chlorophyll" is the pigment that gives plants their green color.
Understanding concepts Vocabulary comprehension	***Physics Talk***	Encourage ELL students to participate in a class discussion on why an object looks a certain color. Students need to understand that objects of different colors absorb or reflect different colors of light. When they can grasp that information, they can begin to understand subtractive color mixing. "Subtractive color mixing" happens when you mix pigments. Help students remember how this works. Tell them that by absorbing some colors, a paint subtracts, or removes, these colors from your view. You see only the color that the paint reflects. Continue the discussion to help students understand how light affects color. They need to know that white light is made up of red, blue, and green light combined. "Additive color mixing" happens when you mix colors of light. When only red light enters your eye, an object looks red. When both red light and green light enter your eye, you see both colors, which add together to look yellow. Different combinations of red, blue, and green light make different colors. And different amounts of red, blue, and green light in different combinations add together to make even more colors. When you shine colored lights on colored objects, you get even more color effects.
Understanding concepts	***Physics Talk***	Have ELL students refer back to their notes on shadow formation. Encourage them to think about what they just learned about additive color mixing and ask them what might have caused the colors of shadows they saw in the penumbra area. Use this discussion as a transition to the predictions students will make during the *Active Physics Plus* experiment.
Using parts of speech	***Physics to Go*** Step 1	Explain to ELL students that when they use "bright," "brighter," and "brightest" they are using different forms of an adjective (a word that describes nouns). "Bright" is the basic adjective, "brighter" is the comparative form, and "brightest" is the superlative.

SECTION 10

Teaching Suggestions and Sample Answers

What Do You See?

The colorful display of the *What Do You See?* illustration is designed to capture students' attention and draw their comments. The colored shadows on the wall of a person dancing indicate a theatre performance. Ask the students about the relative orientation of the light bulbs and the location of the colored images, and if they think what is drawn can actually be accomplished. Encourage students to look at each image carefully and think of its significance to the section. You might wish to return to this illustration later, so that students can review the purpose of the illustration and recognize how much they have progressed in their understanding of color.

What Do You Think?

A Physicist's Response

The answer to these questions lies in the field of both physiology and physics. The human eye and brain respond to the wavelength of light by producing the sensation of color, and each wavelength produces a distinct color, as seen in the spectrum of sunlight formed by a prism. (Recall that the index of refraction of the prism is a function of the wavelength of light, so different colors will refract at slightly different angles, forming the familiar spectrum.) The nature of the light-sensitive cells in the eye, together with the structure of the brain, determine in a complex way the color you see. Mixing paints produces color by subtraction, because only light that can be reflected by both paints is seen (the other colors are subtracted out and absorbed in the paint). Overlapping lights in a theater produce color addition, since more light is reflected from a white surface. The colors that are reflected then both stimulate the eye. The eye and brain do the rest to produce the colors you see.

What Do You Think?

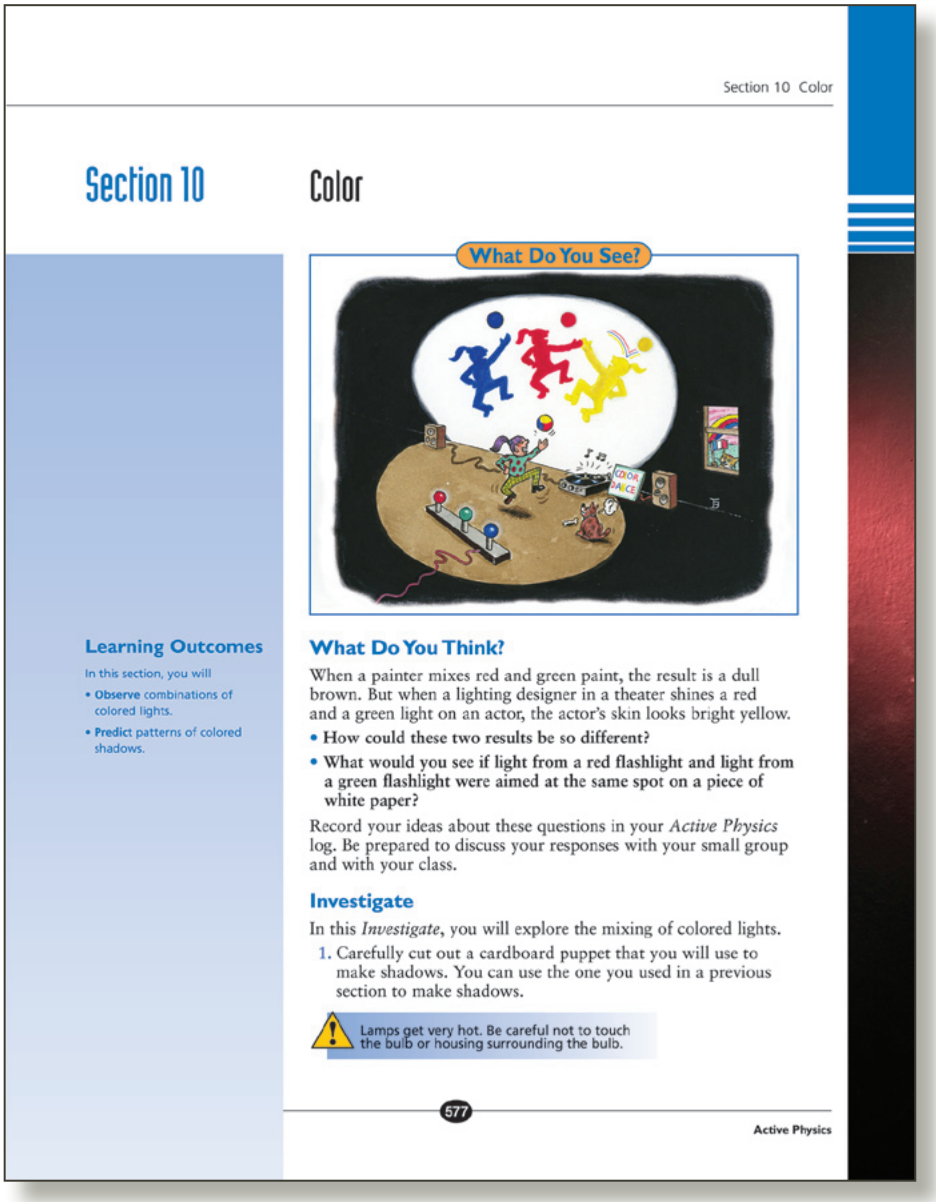
Students are most likely going to come up with a wide range of answers to the *What Do You Think?* questions. Accept all answers and record a few on the board to generate a brief discussion. You may want to prompt them with questions that relate to their observation of color. Remind students to record their responses in their *Active Physics* logs. These responses might provide clues about prior conceptions that students have about color.

Students' Prior Conceptions

Students' conceptions about color mainly stem from their life experiences with art and paints, with finger painting and even with mixing food dyes in the kitchen. You need to compare and contrast the transmission and absorption of light through filters, with translucent and opaque materials, and with the mixing of paint pigments to form 'colors.' Although students cannot 'see' the matter interactions that occur between molecules of substances and light, they can experience and observe results. You may elect to extend student experiences to what happens between molecules of different materials and light to create the transmission and/or absorption of different energies associated with colors of light.

1. **The primary prior student conception that needs to be addressed in this section is that color is the property of objects rather than of reflected light.** The creation of colored shadows with different combinations of red, green or blue light helps to modify student thinking. Looking at differently patterned wrapping paper with differently colored lights also shows students that the same material can create different effects that depend upon the nature of the reflected light and the interaction between the matter of the paper and the incident light.

2. **Students believe that objects have colored components that change the color of the incident light.** Student explanations of the investigations in this section should lead them to identify distinct patterns that encourage them to accept



Section 10 Color

Section 10 Color

What Do You See?

Learning Outcomes

In this section, you will

- **Observe** combinations of colored lights.
- **Predict** patterns of colored shadows.

What Do You Think?

When a painter mixes red and green paint, the result is a dull brown. But when a lighting designer in a theater shines a red and a green light on an actor, the actor's skin looks bright yellow.

- How could these two results be so different?
- What would you see if light from a red flashlight and light from a green flashlight were aimed at the same spot on a piece of white paper?

Record your ideas about these questions in your *Active Physics* log. Be prepared to discuss your responses with your small group and with your class.

Investigate

In this *Investigate*, you will explore the mixing of colored lights.

1. Carefully cut out a cardboard puppet that you will use to make shadows. You can use the one you used in a previous section to make shadows.

Lamps get very hot. Be careful not to touch the bulb or housing surrounding the bulb.

577

Active Physics

Investigate

1.

Students can cut out a cardboard puppet of any shape.

CHAPTER 5

the idea that objects absorb or emit light and even perhaps refract light to create changes in the patterns and colors of the incident light when they are reflected or transmitted.

3. **Students have naïve conceptions about how filters work; they believe that filters change the color of the transmitted light.** You may ensure students correctly explain how filters work by ensuring the availability of many different gels for their exploration. Evaluate what students are saying about what they observe when light is transmitted through these gels onto a variety of objects with different textures and designs. You may review and stress the concepts of absorption and transmission as a function of the wavelength of light (the color of the light) and the characteristics of the gels.

4. **Students believe white is a color or white is the absence of color since white is a primary color.** Students will say that black is the combination of all colors. This concept about light often emerges from life experiences and how students explain these experiences with their naïve view of how things work. The root of this confusion originates in art experiences. Demonstrate what happens when paints are mixed and what happens with lights, such as when you mix red, blue, and green. This section also presents opportunities to correlate physics principles with art. You may choose to explore this option by inviting an art teacher to demonstrate color addition and to talk about the physics of color in art.

2.

If you are using the light bulbs and reflectors provided with *Active Physics* kits, use the metallic reflectors that hold the light bulbs to direct the light toward the screen.

3.a)

With red and green together on the screen, students will see yellow. Where both lights strike the screen, students will see yellow (but it may appear almost white depending on the colored lights you are using).

3.b)

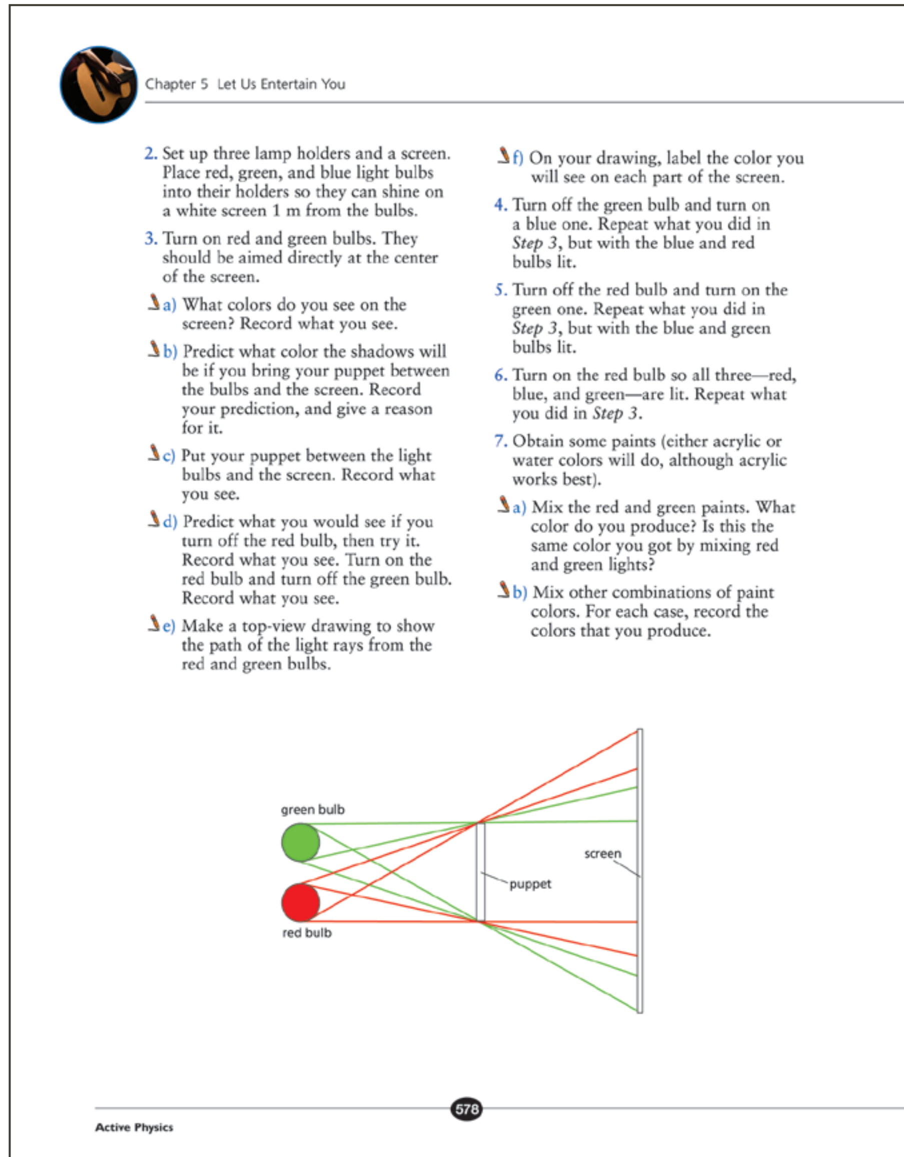
Where the red light is blocked but the green is not, students will see a green shadow. Where the green light is blocked but the red is not, students will see a red shadow.

3.c)

See the diagram at the end of the *Investigate*. Between the two red lines at the top of the diagram, students will see where light from both bulbs hits the screen. Moving toward the center of the screen, the yellow gradually changes to green between the two green lines where the red light is blocked and then where the green is also blocked will be the shadow with no light. Moving out of the shadow of the puppet toward the bottom of the page, students will see red light between the two red lines. The red light gradually changes to yellow in the region between the green lines, where light from both bulbs again strikes the screen.

3.d)

When the red bulb is turned off, students will see a dark shadow behind the puppet with green on the other side. The shadow will have an umbra where no


Chapter 5 Let Us Entertain You

2. Set up three lamp holders and a screen. Place red, green, and blue light bulbs into their holders so they can shine on a white screen 1 m from the bulbs.

3. Turn on red and green bulbs. They should be aimed directly at the center of the screen.

a) What colors do you see on the screen? Record what you see.

b) Predict what color the shadows will be if you bring your puppet between the bulbs and the screen. Record your prediction, and give a reason for it.

c) Put your puppet between the light bulbs and the screen. Record what you see.

d) Predict what you would see if you turn off the red bulb, then try it. Record what you see. Turn on the red bulb and turn off the green bulb. Record what you see.

e) Make a top-view drawing to show the path of the light rays from the red and green bulbs.

f) On your drawing, label the color you will see on each part of the screen.

4. Turn off the green bulb and turn on a blue one. Repeat what you did in *Step 3*, but with the blue and red bulbs lit.

5. Turn off the red bulb and turn on the green one. Repeat what you did in *Step 3*, but with the blue and green bulbs lit.

6. Turn on the red bulb so all three—red, blue, and green—are lit. Repeat what you did in *Step 3*.

7. Obtain some paints (either acrylic or water colors will do, although acrylic works best).

a) Mix the red and green paints. What color do you produce? Is this the same color you got by mixing red and green lights?

b) Mix other combinations of paint colors. For each case, record the colors that you produce.

578

Active Physics

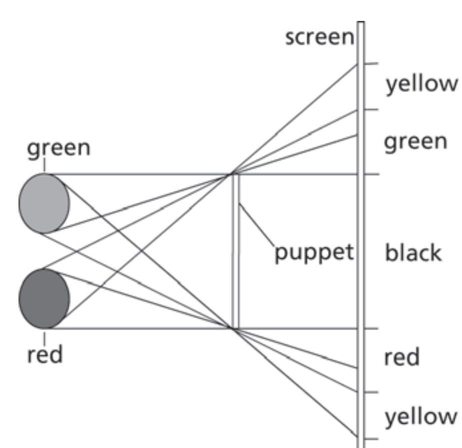
light strikes the screen, and a penumbra, where the light gradually goes from the dark shadow to the green color of the screen where the light strikes.

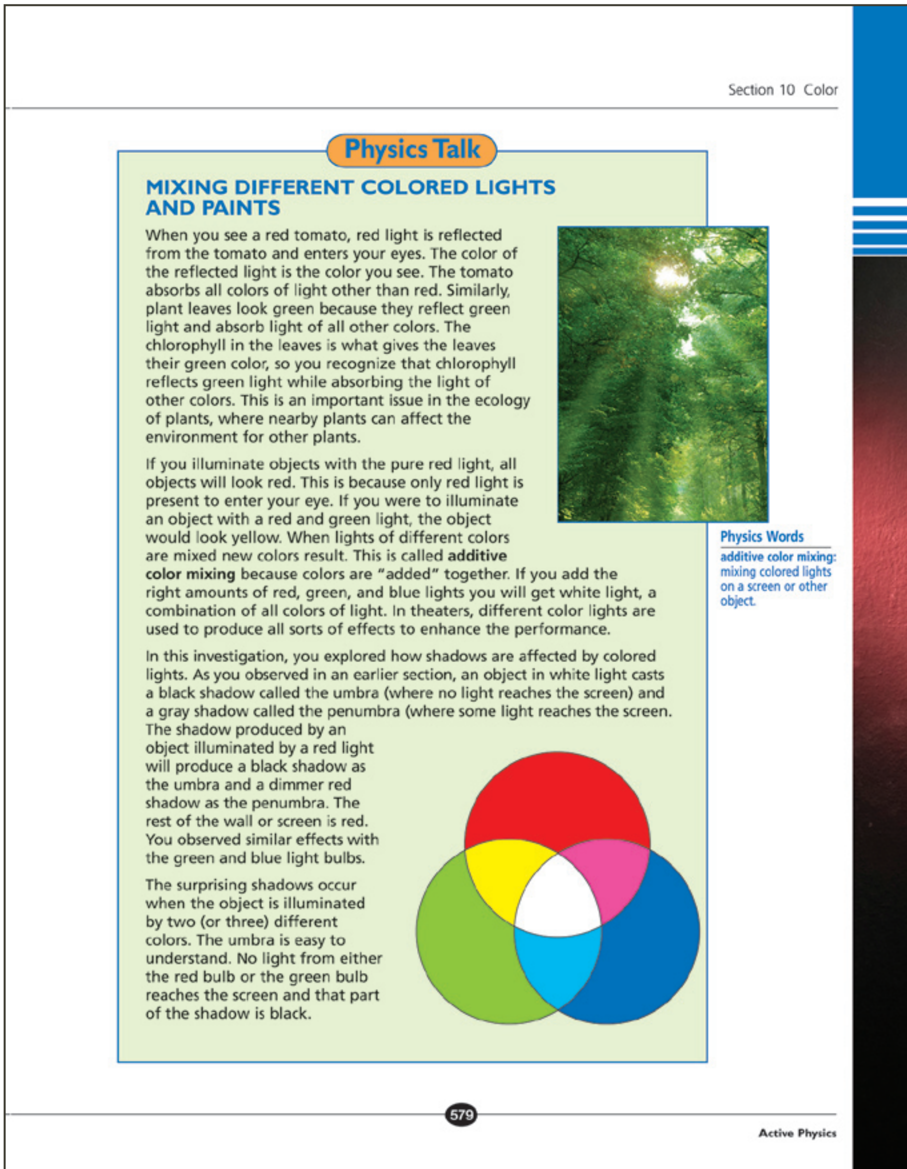
3.e)

Student's drawings should be the same as the one in the *Investigate* below *Step 3.f)*.

3.f)

From the top, the colors will be yellow, green, black, red, and yellow.





Physics Talk

MIXING DIFFERENT COLORED LIGHTS AND PAINTS

When you see a red tomato, red light is reflected from the tomato and enters your eyes. The color of the reflected light is the color you see. The tomato absorbs all colors of light other than red. Similarly, plant leaves look green because they reflect green light and absorb light of all other colors. The chlorophyll in the leaves is what gives the leaves their green color, so you recognize that chlorophyll reflects green light while absorbing the light of other colors. This is an important issue in the ecology of plants, where nearby plants can affect the environment for other plants.

If you illuminate objects with the pure red light, all objects will look red. This is because only red light is present to enter your eye. If you were to illuminate an object with a red and green light, the object would look yellow. When lights of different colors are mixed new colors result. This is called **additive color mixing** because colors are "added" together. If you add the right amounts of red, green, and blue lights you will get white light, a combination of all colors of light. In theaters, different color lights are used to produce all sorts of effects to enhance the performance.

Physics Words

additive color mixing: mixing colored lights on a screen or other object.

In this investigation, you explored how shadows are affected by colored lights. As you observed in an earlier section, an object in white light casts a black shadow called the umbra (where no light reaches the screen) and a gray shadow called the penumbra (where some light reaches the screen. The shadow produced by an object illuminated by a red light will produce a black shadow as the umbra and a dimmer red shadow as the penumbra. The rest of the wall or screen is red. You observed similar effects with the green and blue light bulbs.

The surprising shadows occur when the object is illuminated by two (or three) different colors. The umbra is easy to understand. No light from either the red bulb or the green bulb reaches the screen and that part of the shadow is black.

4.

Students should substitute the green bulb with a blue one. For red and blue bulbs lit together, students will see purple (magenta).

5.

For green and blue bulbs together, students will see cyan.

6.

When all three lights strike the screen, students will see white. When one light is blocked, students will see a shadow with the color of the combination of the other lights. See *Steps 2-4* for these colors. When two lights are blocked, students will see a shadow with the color of the unblocked light.

Where all three lights overlap, in the center, students see white. Students will see yellow where red and green overlap. Students will see magenta where red and blue overlap and students will see blue-green (cyan) where blue and green overlap.

7.a)

This is an exercise in subtractive color mixing. Mixing red and green paints usually results (depending on the exact pigments used) in a darkish brown color. Mixing red and green lights, results in a bright yellow color.

7.b)

Students try different combination of paints and record their results. The results will vary with the colors chosen.

Physics Talk

This *Physics Talk* builds on the *Investigate* to distinguish between additive and subtractive color mixing. Students read that a tomato appears red because a tomato reflects red light, while green plants appear green because they reflect green light. The red tomato only reflects the red while absorbing all other colors and the green plant behaves in similar way. This phenomenon is related to the process that occurs in subtractive color mixing.

To show how subtractive color mixing works, consider asking students to bring their paint boxes to class or supply them with a paint box. Have them mix different colors and ask them to note the new colors that they see after mixing. Point out that paints absorb light of certain colors but reflect the light that is visible.

In contrast, students should understand that additive color mixing works on the principle of color addition. Colors are combined to produce different light effects. To highlight how different colors are produced

CHAPTER 5

in the penumbra, refer to the experiments with puppets. Ask students how these experiments demonstrate additive color mixing.

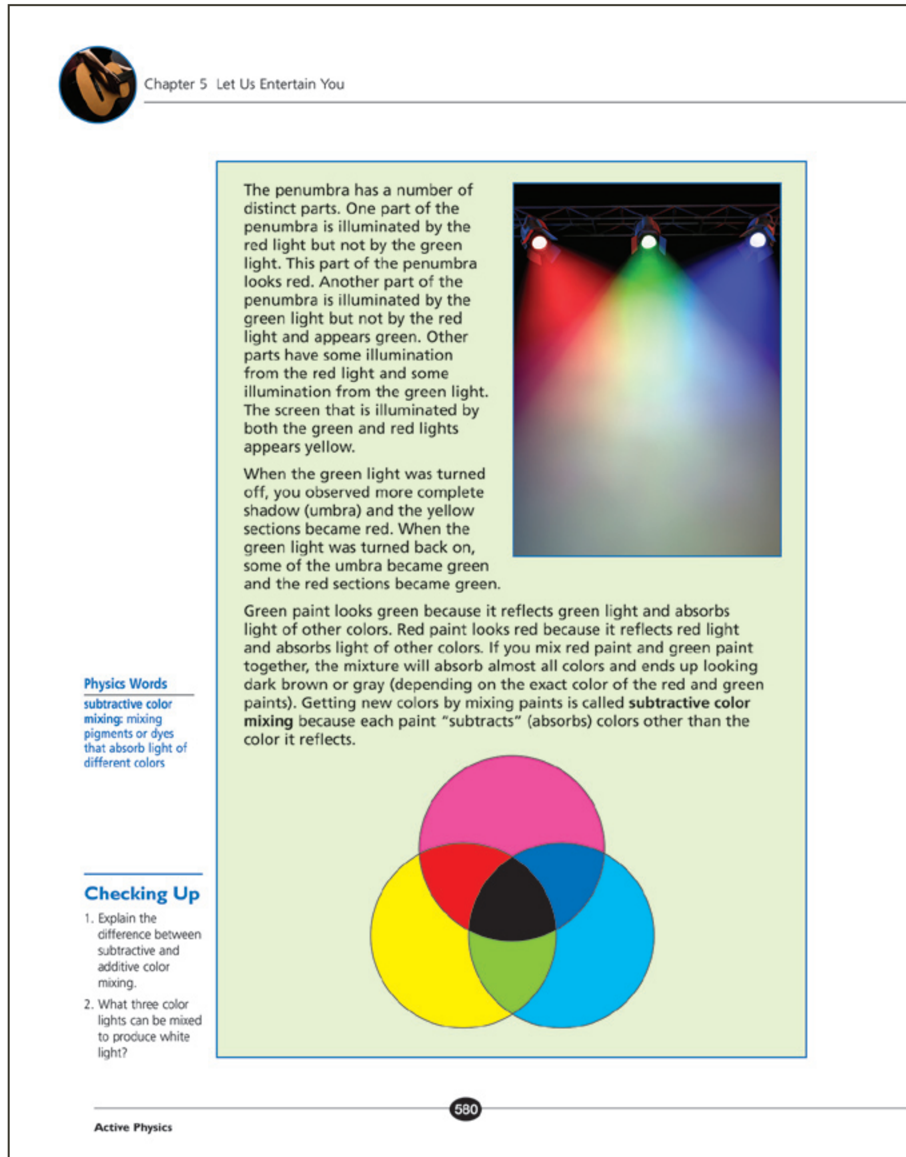
Checking Up

1.

In subtractive color mixing, paints of different colors are mixed to produce a new color. Each paint absorbs all colors other than the color it reflects. In additive color mixing, lights of different colors are mixed to produce light effects on a screen or any other object.

2.

The three colors that can be mixed to produce white light are red, green, and blue.



Chapter 5 Let Us Entertain You

The penumbra has a number of distinct parts. One part of the penumbra is illuminated by the red light but not by the green light. This part of the penumbra looks red. Another part of the penumbra is illuminated by the green light but not by the red light and appears green. Other parts have some illumination from the red light and some illumination from the green light. The screen that is illuminated by both the green and red lights appears yellow.

When the green light was turned off, you observed more complete shadow (umbra) and the yellow sections became red. When the green light was turned back on, some of the umbra became green and the red sections became green.

Green paint looks green because it reflects green light and absorbs light of other colors. Red paint looks red because it reflects red light and absorbs light of other colors. If you mix red paint and green paint together, the mixture will absorb almost all colors and ends up looking dark brown or gray (depending on the exact color of the red and green paints). Getting new colors by mixing paints is called **subtractive color mixing** because each paint "subtracts" (absorbs) colors other than the color it reflects.

Physics Words

subtractive color mixing: mixing pigments or dyes that absorb light of different colors

Checking Up

1. Explain the difference between subtractive and additive color mixing.
2. What three color lights can be mixed to produce white light?

580

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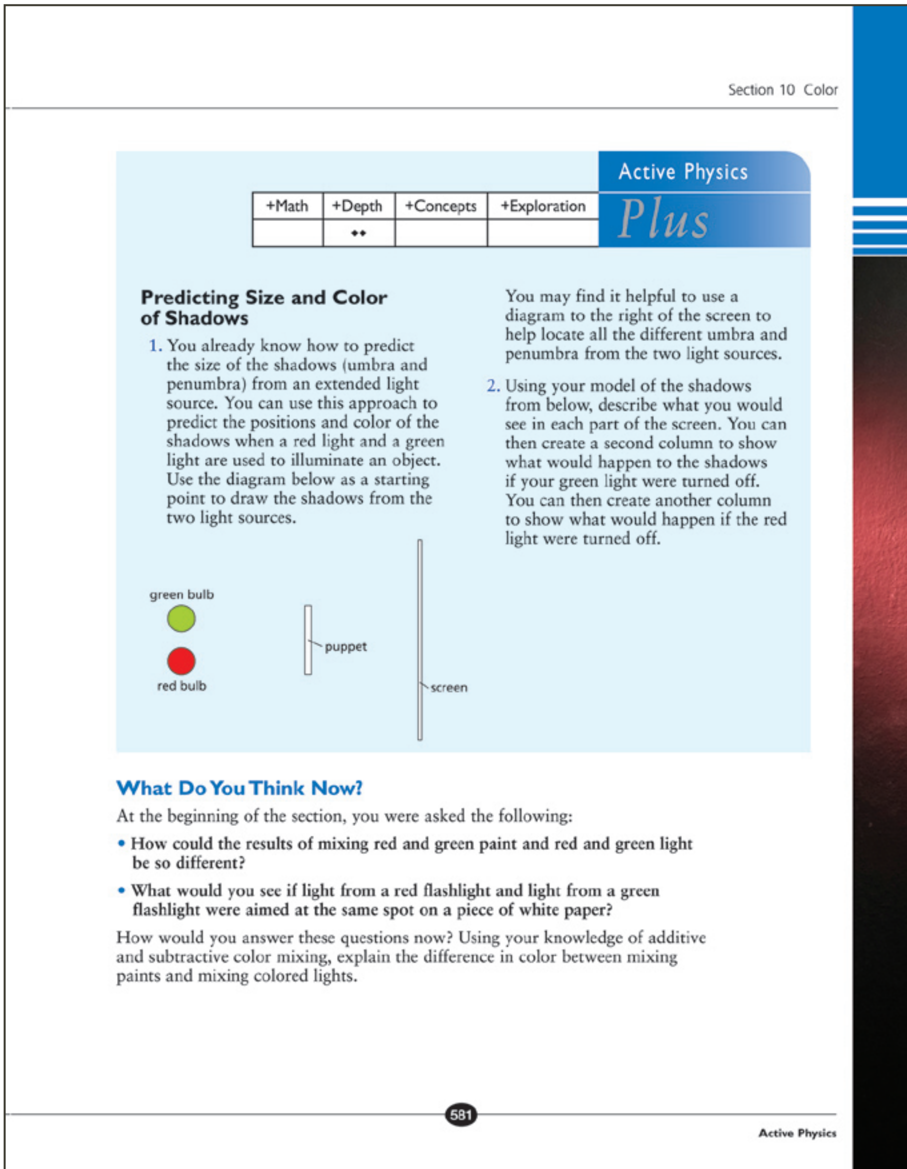

Active Physics *Plus*

+Math	+Depth	+Concepts	+Exploration
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Predicting Size and Color of Shadows

1. You already know how to predict the size of the shadows (umbra and penumbra) from an extended light source. You can use this approach to predict the positions and color of the shadows when a red light and a green light are used to illuminate an object. Use the diagram below as a starting point to draw the shadows from the two light sources.

You may find it helpful to use a diagram to the right of the screen to help locate all the different umbra and penumbra from the two light sources.

2. Using your model of the shadows from below, describe what you would see in each part of the screen. You can then create a second column to show what would happen to the shadows if your green light were turned off. You can then create another column to show what would happen if the red light were turned off.

What Do You Think Now?

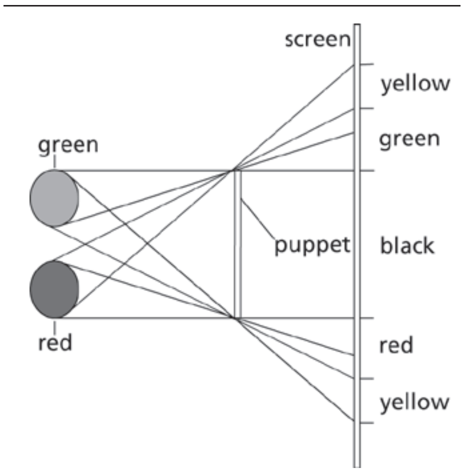
At the beginning of the section, you were asked the following:

- How could the results of mixing red and green paint and red and green light be so different?
- What would you see if light from a red flashlight and light from a green flashlight were aimed at the same spot on a piece of white paper?

How would you answer these questions now? Using your knowledge of additive and subtractive color mixing, explain the difference in color between mixing paints and mixing colored lights.

Active Physics Plus

1.

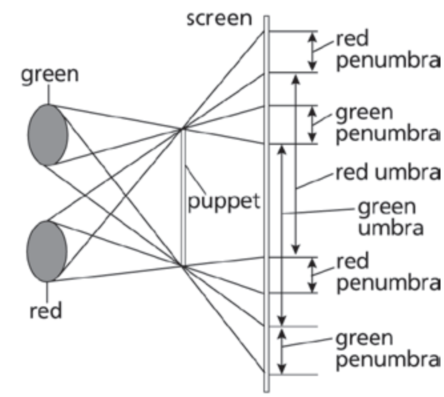


2.

If the red light is turned off, red penumbra areas will disappear. The lower red penumbra in the diagram above will be part of the green umbra (no light), while the upper red penumbra will be in pure green light.

If the green light is turned off, the green penumbra areas will disappear. The upper green penumbra will become part of the red umbra, and the lower green penumbra will be in pure red light.

The colors on the screen with both lights on will be as shown in the diagram below.



What Do You Think Now?

Students now have the opportunity to update their previous answers to the *What Do You Think*? questions. Emphasize that they need to answer the questions based on additive and subtractive color mixing. Read aloud *A Physicist's Response* and discuss with the students how much they have progressed in their understanding of the physics of color. Ask students to review their responses to the *What Do You See?* illustration and refer to their findings in the *Investigate*.

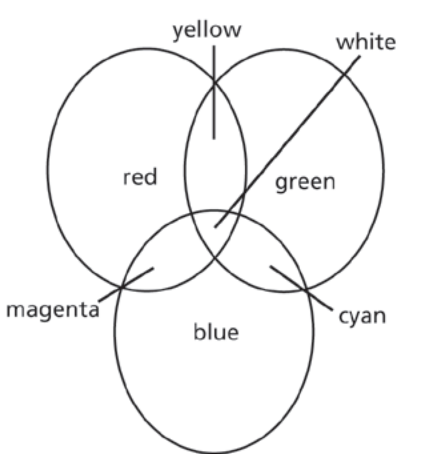
CHAPTER 5

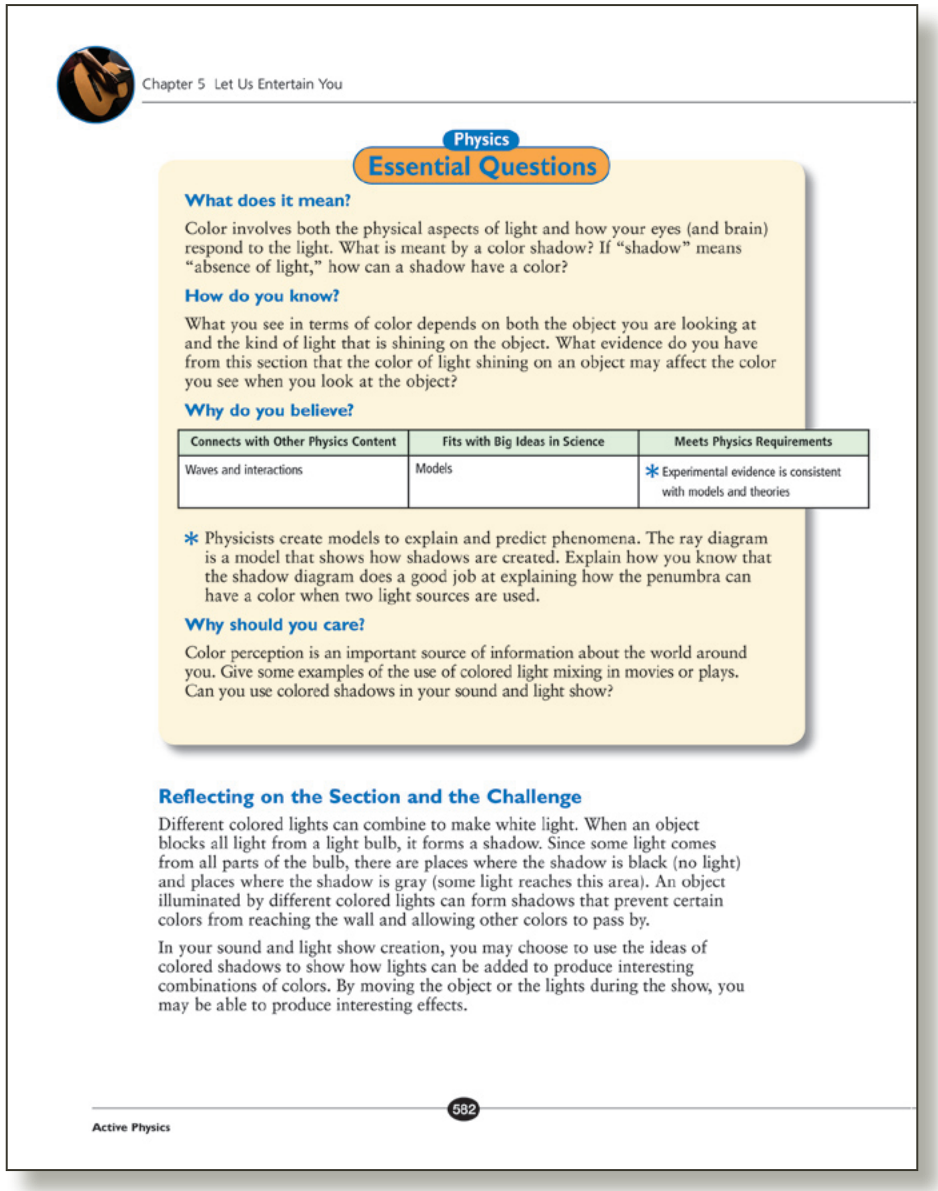
Reflecting on the Section and the Challenge

Encourage students to read this passage slowly. Have them consider the different ways in which they can use what they have learned in this section to develop the light effects of their show. Discuss how much they now know about shadows and how they can produce colored shadows to enhance the quality of light effects in their challenge. Review their experiment with the puppet in the *Investigate* to promote the idea of using colored shadows.

Physics to Go

1.a)





Chapter 5 Let Us Entertain You

Physics

Essential Questions

What does it mean?

Color involves both the physical aspects of light and how your eyes (and brain) respond to the light. What is meant by a color shadow? If "shadow" means "absence of light," how can a shadow have a color?

How do you know?

What you see in terms of color depends on both the object you are looking at and the kind of light that is shining on the object. What evidence do you have from this section that the color of light shining on an object may affect the color you see when you look at the object?

Why do you believe?

Connects with Other Physics Content	Fits with Big Ideas in Science	Meets Physics Requirements
Waves and interactions	Models	* Experimental evidence is consistent with models and theories

* Physicists create models to explain and predict phenomena. The ray diagram is a model that shows how shadows are created. Explain how you know that the shadow diagram does a good job at explaining how the penumbra can have a color when two light sources are used.

Why should you care?

Color perception is an important source of information about the world around you. Give some examples of the use of colored light mixing in movies or plays. Can you use colored shadows in your sound and light show?

Reflecting on the Section and the Challenge

Different colored lights can combine to make white light. When an object blocks all light from a light bulb, it forms a shadow. Since some light comes from all parts of the bulb, there are places where the shadow is black (no light) and places where the shadow is gray (some light reaches this area). An object illuminated by different colored lights can form shadows that prevent certain colors from reaching the wall and allowing other colors to pass by.

In your sound and light show creation, you may choose to use the ideas of colored shadows to show how lights can be added to produce interesting combinations of colors. By moving the object or the lights during the show, you may be able to produce interesting effects.

Active Physics 582

Physics Essential Questions

What does it mean?

A colored shadow is a shadow that gives the perception of some color. Colored shadows usually occur when an object is illuminated by two or more differently colored lights.

How do you know?

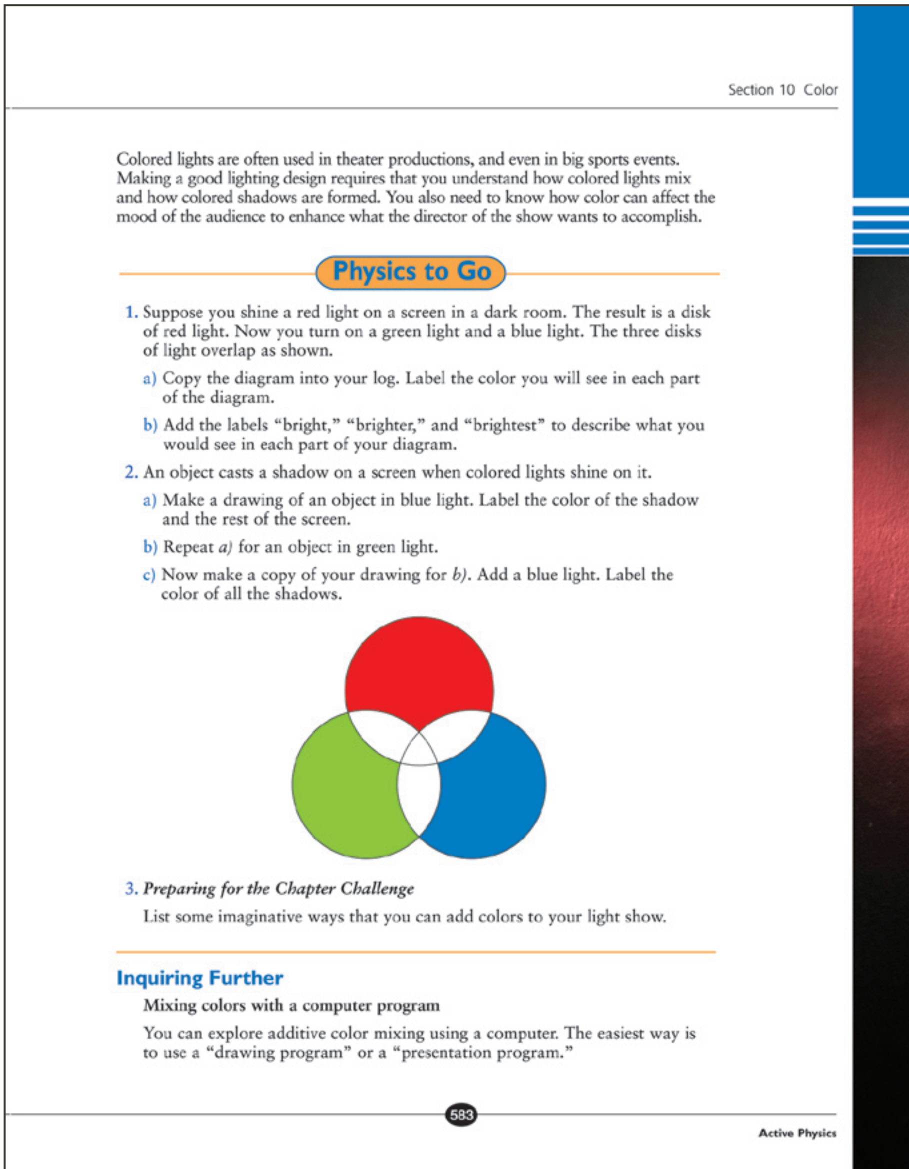
When blue light illuminates a blue object, the object appears blue. When blue light illuminates a red object, it appears black. This is because none of the blue light is reflected.

Why do you believe?

The ray model of light can show how some of the colored light from one source and some of the colored light from another source can both illuminate the penumbra and create a colored shadow that is a combination of the two colors.

Why should you care?

Colored lights are used in theatre productions to convey mood. Lighting designers for movie and theatre sets use color mixing to create different moods and "atmospheres" to enhance the emotional impact of the movie or play. They often use colored filters over spotlights to create colored lights and then mix those different lights in a scene to create specific effects.


Section 10 Color

Colored lights are often used in theater productions, and even in big sports events. Making a good lighting design requires that you understand how colored lights mix and how colored shadows are formed. You also need to know how color can affect the mood of the audience to enhance what the director of the show wants to accomplish.

Physics to Go

1. Suppose you shine a red light on a screen in a dark room. The result is a disk of red light. Now you turn on a green light and a blue light. The three disks of light overlap as shown.
   a) Copy the diagram into your log. Label the color you will see in each part of the diagram.
   b) Add the labels "bright," "brighter," and "brightest" to describe what you would see in each part of your diagram.
2. An object casts a shadow on a screen when colored lights shine on it.
   a) Make a drawing of an object in blue light. Label the color of the shadow and the rest of the screen.
   b) Repeat *a)* for an object in green light.
   c) Now make a copy of your drawing for *b)*. Add a blue light. Label the color of all the shadows.
3. *Preparing for the Chapter Challenge*
   List some imaginative ways that you can add colors to your light show.

Inquiring Further

Mixing colors with a computer program

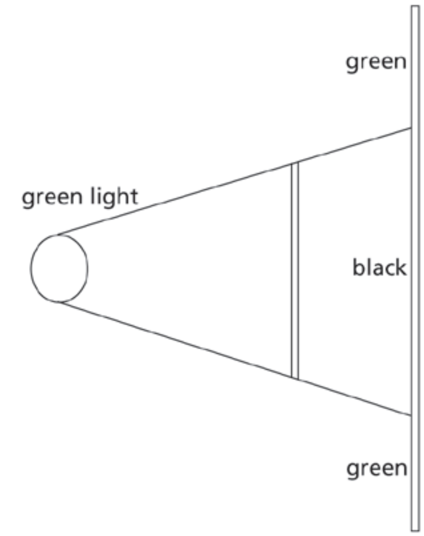
You can explore additive color mixing using a computer. The easiest way is to use a "drawing program" or a "presentation program."

583

Active Physics

2.b)

The diagram for green light would appear the same except where there is blue. In the diagram below, the color would be green.



2.c)

The diagram for the green and blue bulb would look like the diagram above. The right part of the shadow will be blue, part will be green, part will be dark (where neither light source illuminates the screen), and part will be cyan where both the green and the blue overlap.

3.

Preparing for the Chapter Challenge

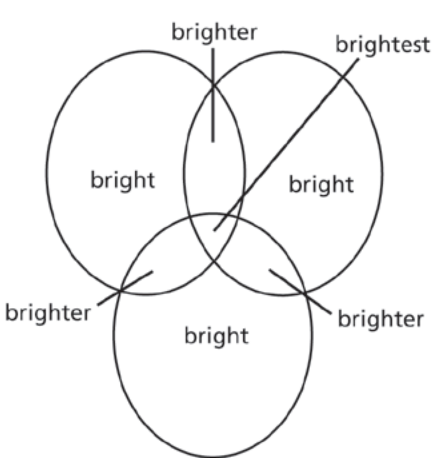
Students' answers will vary. Many will want to use colored shadows.

Inquiring Further

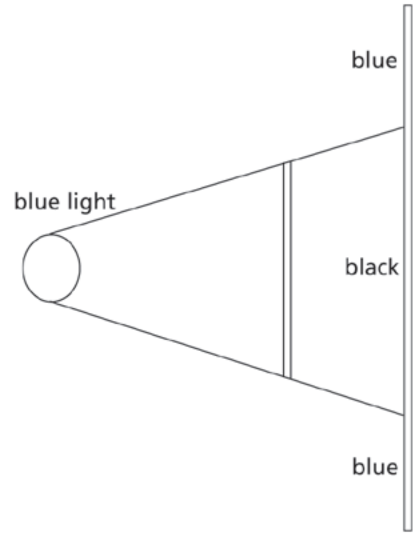
Mixing colors with a computer program

Students explore additive color mixing using a computer.

1.b)



2.a)

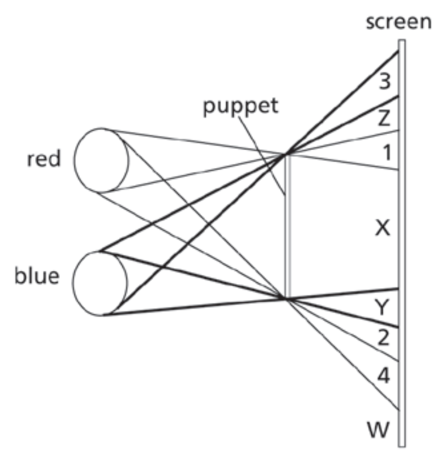


CHAPTER 5

SECTION 10 QUIZ

5-10a Blackline Master

1. The diagram below shows a screen illuminated by a red and a blue light bulb with a puppet between the light bulbs and the screen. What color would be seen in position 1?



a) Red. b) Blue.

c) Magenta. d) Black.

2. In *Question 1*, what color should be observed at position X?

a) Red. b) Blue.

c) Magenta. d) Black.

3. In *Question 1*, what region should a combination of blue and red be seen?

a) X. b) Y.

c) 1. d) 4.

4. A red apple is illuminated by a blue light. The apple will appear

a) red. b) blue.

c) black. d) white.

5. A red apple is viewed through a blue filter. The apple will appear

a) red. b) blue.

c) black. d) white.

SECTION 10 QUIZ ANSWERS

1. a) At position 1, only red light can strike the screen, so the region must be red. Because light from the red bulb can hit this position, it cannot be black, and no blue light can reach the screen, so it cannot be blue or magenta.

2. d) At position X, no light from any bulb is able to reach the screen, so the screen must be black.

3. d) A position where light from both the red and blue bulbs can strike the screen would be position 4. Positions Y and 1—choices *b)* and *c)*—would only receive light from one bulb, and position X is the umbra, which is black.

4. c) The apple will appear black.

5. c) The apple will appear black.