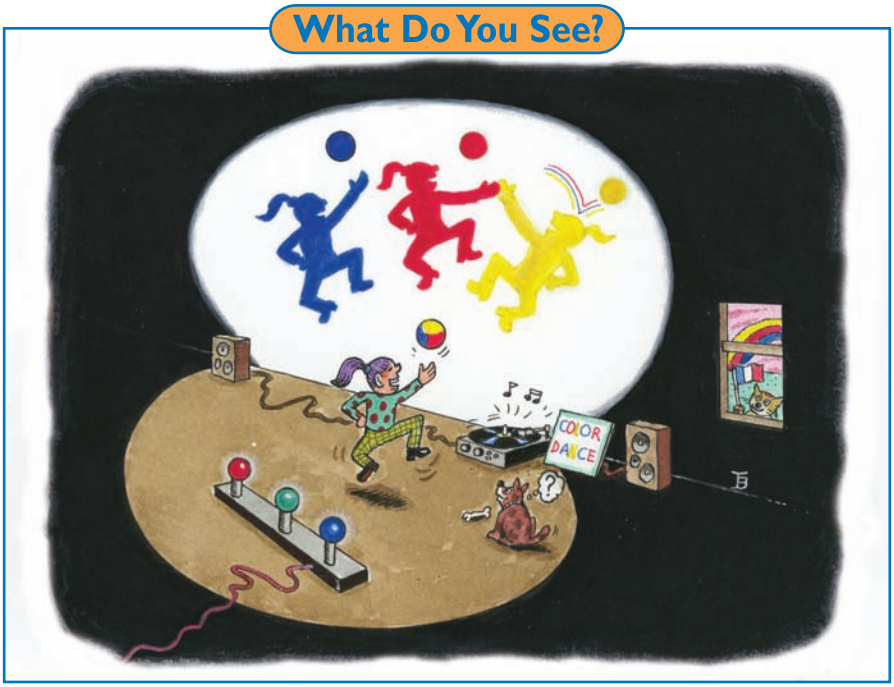
Section 10 Color

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.

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.

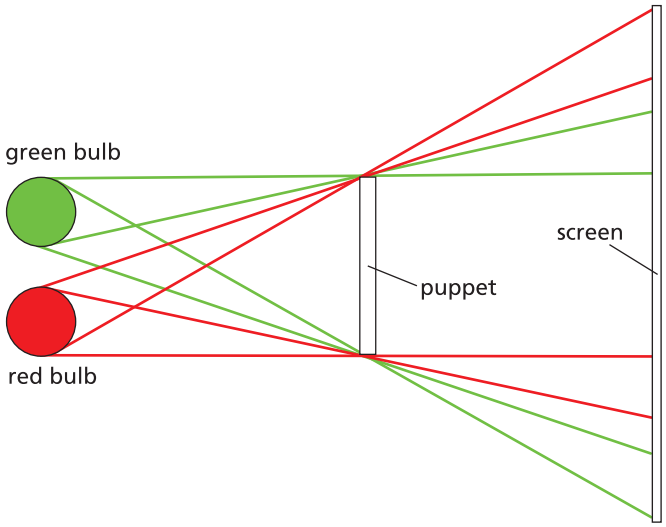
5. Turn off the red bulb and turn on the green one. Repeat what you did in *Step 3*, but with the blue and green bulbs lit.

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.



Physics Talk

MIXING DIFFERENT COLORED LIGHTS AND PAINTS

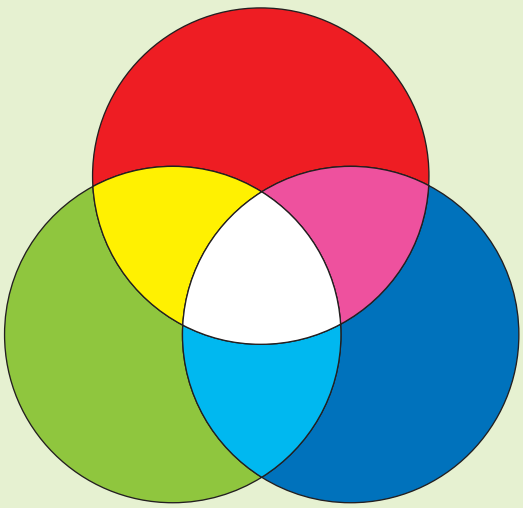
When you see a red tomato, red light is reflected from the tomato and enters your eyes. The color of the reflected light is the color you see. The tomato absorbs all colors of light other than red. Similarly, plant leaves look green because they reflect green light and absorb light of all other colors. 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.

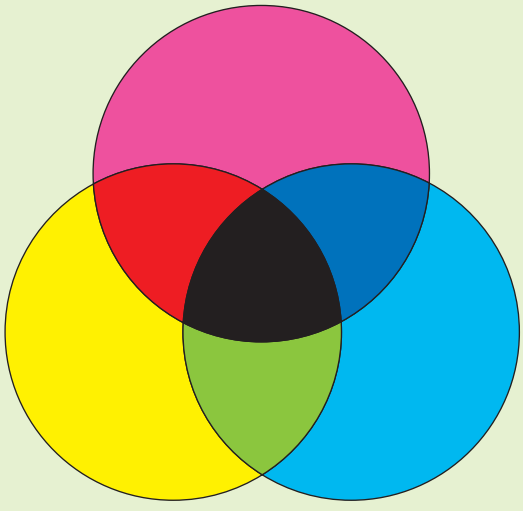
The penumbra has a number of distinct parts. One part of the penumbra is illuminated by the red light but not by the green light. This part of the penumbra looks red. Another part of the penumbra is illuminated by the green light but not by the red light and appears green. Other parts have some illumination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

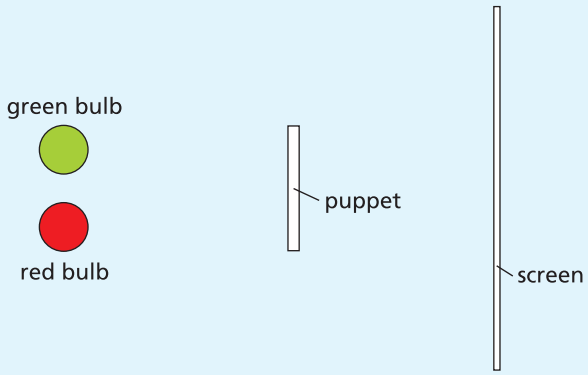
1. Explain the difference between subtractive and additive color mixing.
2. What three color lights can be mixed to produce white light?

Active Physics Plus

+Math	+Depth	+Concepts	+Exploration
	◆◆		

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.

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 colored 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.

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.

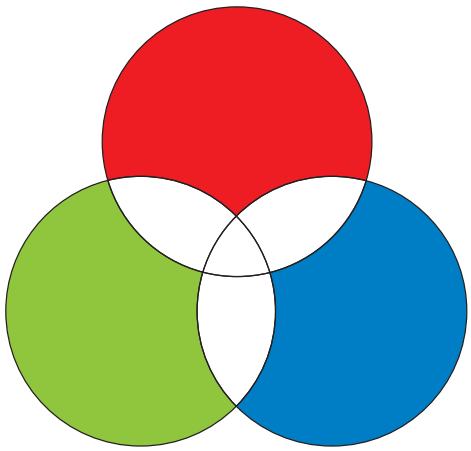
   b) Add the labels "bright," "brighter," and "brightest" to describe what you would see in each part of your diagram.

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."