Section 1

# Light and Color

## Objectives

After this lesson, students will be able to

**O.4.1.1** State what happens to the light that strikes an object.

**O.4.1.2** Describe what determines the color of an opaque, transparent, or translucent object.

**O.4.1.3** Explain how mixing pigments is different from mixing colors of light.

## Target Reading Skill

**Building Vocabulary** Explain that knowing the definition of key-concept words helps students understand what they read.

### Answers

As students read each passage that contains a Key Term, remind them to write a sentence in their own words about the term. Encourage students to write one or two descriptive phrases to help them remember the Key Term. Invite students to share their sentences and phrases.

## Preteach

### Build Background Knowledge

L2

*Introducing Color*

Ask: **What color would you get if you combined blue and yellow paint?** *(Most students will say green.)* Then ask: **What color would you get if you combined blue and yellow light?** *(Students may say green.)* Reply that the correct answer is white. Tell students that, in this section, they will learn why blue and yellow light combine to make white light.

Section 1

# Light and Color

### Reading Preview

**Key Concepts**

- What happens to the light that strikes an object?
- What determines the color of an opaque, transparent, or translucent object?
- How is mixing pigments different from mixing colors of light?

**Key Terms**

- transparent material
- translucent material
- opaque material
- primary colors
- secondary color
- complementary colors
- pigment

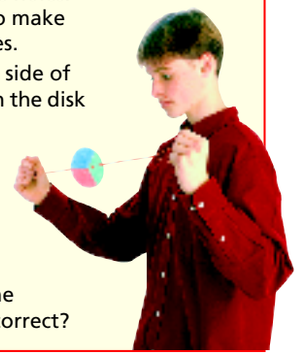
### Target Reading Skill

**Building Vocabulary** Using a word in a sentence helps you think about how to best explain the word. As you read, carefully note the definition of each Key Term. Also note other details in the paragraph that contains the definition. Use all this information to write a sentence using the Key Term.

### Lab zone Discover Activity

**How Do Colors Mix?**

1. Cut a disk with a diameter of 10 cm out of white cardboard. Divide the disk into three equal-sized segments. Color one segment red, the next green, and the third blue.
2. Carefully punch two holes, 2 cm apart, on opposite sides of the center of the disk.
3. Thread a 1-m long string through the holes. Tie the ends of the string together to make a loop that passes through both holes.
4. With equal lengths of string on each side of the disk, tape the string in place. Turn the disk to wind up the string. Predict what color(s) you will see if the disk spins fast.
5. Spin the disk by pulling the loops to unwind the string.

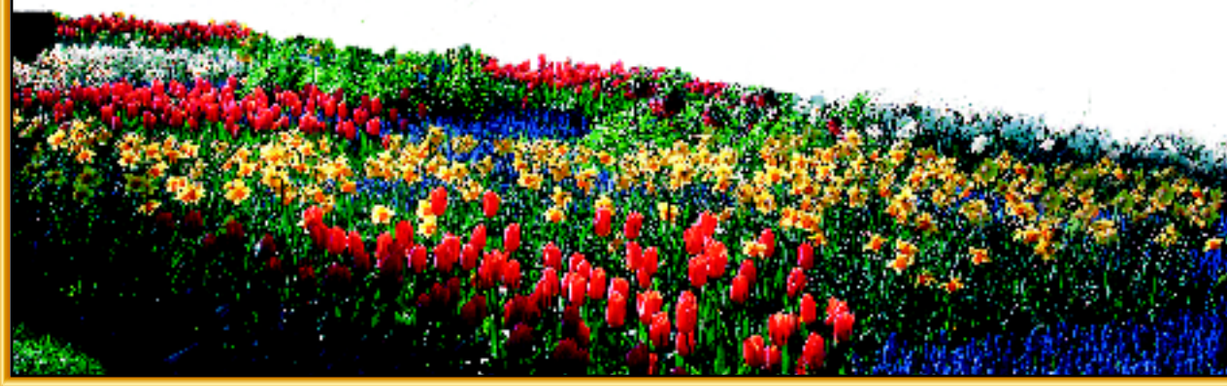


**Think It Over**

**Observing** What color do you see as the wheel spins fast? Was your prediction correct?

It was hard work, but you are finally finished. You stand back to admire your work. Color is everywhere! The bright green grass rolls right up to the flower garden you just weeded. In the bright sunlight, you see patches of yellow daffodils, purple hyacinths, and red tulips. The sun's light allows you to see each color. But sunlight is white light. What makes each flower appear to be a different color?

Flowers in sunlight ▼



### Lab zone Discover Activity

**Skills Focus** Observing L2

**Materials** white cardboard, metric ruler, scissors, markers (red, green, and blue), 1 m of string

**Time** 15 minutes

**Tips** Students can punch holes in the disk with the tip of a ballpoint pen. Taping the disk to the strings helps the disk to stay perpendicular to the strings. Demonstrate how to make the disk spin if students are having difficulty.

**Expected Outcome** When the disk spins rapidly, it appears almost white.

**Think It Over** The disk looks grayish white when it spins fast. Some students may have predicted this outcome.

## When Light Strikes an Object

To understand why objects have different colors, you need to know how light can interact with an object. **When light strikes an object, the light can be reflected, transmitted, or absorbed.** Think about a pair of sunglasses. If you hold the sunglasses in your hand, you can see light that reflects off the lenses. If you put the sunglasses on, you see light that is transmitted by the lenses. The lenses also absorb some light. That is why objects appear darker when seen through the lenses.

Lenses, like all objects, are made of one or more materials. Most materials can be classified as transparent, translucent, or opaque based on what happens to light that strikes the material.

**Transparent Materials** A **transparent material** transmits most of the light that strikes it. The light passes right through without being scattered. This allows you to see clearly what is on the other side. Clear glass, water, and air all are transparent materials. In Figure 1, you can clearly see the straw through the glass on the left.

**Translucent Materials** A **translucent material** (trans LOO sunt) scatters light as it passes through. You can usually see something behind a translucent object, but the details are blurred. Wax paper and a frosted glass like the middle glass in Figure 1 are translucent materials.

**Opaque Materials** An **opaque material** (oh PAYK) reflects or absorbs all of the light that strikes it. You cannot see through opaque materials because light cannot pass through them. Wood, metal, and tightly woven fabric all are opaque materials. You cannot see the straw through the white glass in Figure 1 because the glass is opaque.

Reading Checkpoint **What happens when light strikes an opaque material?**

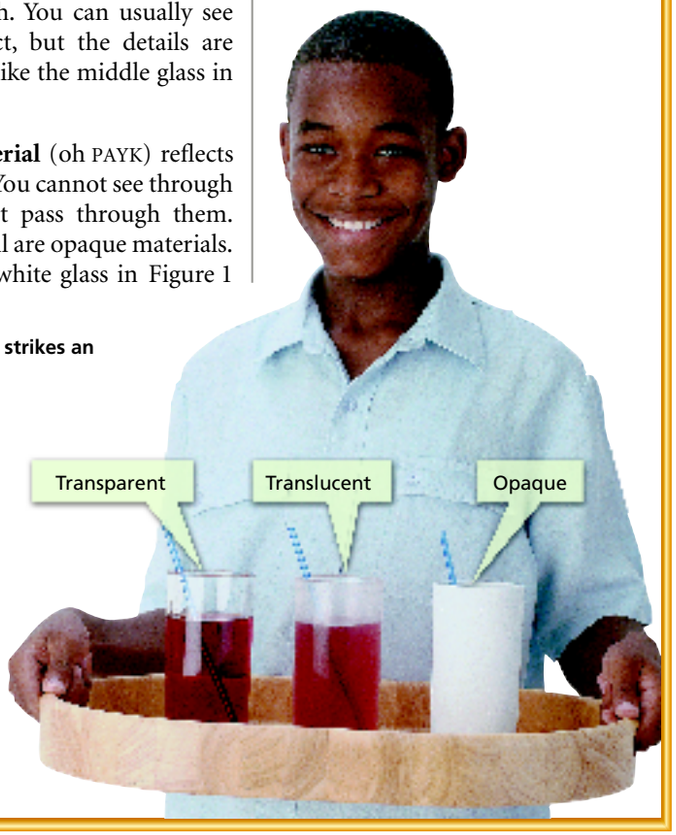



**FIGURE 1**
**Types of Materials**
Different types of materials reflect, transmit, and absorb different amounts of light.
**Comparing and Contrasting**
*How does a straw seen through transparent glass compare with a straw seen through translucent glass?*

## Differentiated Instruction

**English Learners/Beginning** L1
**Comprehension: Key Concepts** Work with students to make a Venn diagram comparing and contrasting materials that are transparent and translucent. *(Sample answer: Both types of materials let light pass through, but only transparent materials let you clearly see objects through them.)* **learning modality: visual**

**English Learners/Intermediate** L2
**Vocabulary: Word Analysis** Help students remember the difference between the similar-looking words, *transparent* and *translucent*. Write both words on the board and divide each word into its prefix and root. Explain that *trans-* means "through," *-parent* means "to show," and *-lucent* means "to shine." Challenge students to define each word by combining the meanings of the prefix and root. **learning modality: verbal**

## Instruct

## When Light Strikes an Object

### Teach Key Concepts L2

***Transparent, Translucent, and Opaque Materials***

**Focus** Tell students that most materials are transparent, translucent, or opaque.

**Teach** Write the three terms on the board. Explain that materials of the three types differ in how much light they reflect, scatter, and transmit. State that transparent materials transmit most of the light without scattering it; translucent materials transmit most of the light but scatter it; opaque materials either reflect or absorb all the light, so no light is transmitted. Ask: **What are some materials of each type in the classroom?** *(Sample answer: Wood for opaque material, glass for transparent material, thin paper for translucent material)*

**Apply** Ask: **Which type of material is water?** *(Transparent)* **learning modality: verbal**

### Independent Practice L2

**All in One Teaching Resources**

- Guided Reading and Study Worksheet: *Light and Color*

**Student Edition on Audio CD**

### Monitor Progress L2

**Skills Check** Have students make a table comparing and contrasting materials that are transparent, translucent, and opaque.

**Answers**

**Figure 1** A straw can be seen clearly through transparent glass. Through translucent glass, it can be seen only as a shape without details.

Reading Checkpoint It is reflected or absorbed.

# The Color of Objects

## Teach Key Concepts L2

### *Explaining an Object's Color*

**Focus** Ask students to find objects of different colors in the classroom.

**Teach** Tell students that the color of an object depends on the material it is made of. State that objects made of opaque materials are the same color as the light they reflect, whereas objects made of transparent or translucent materials are the same color as the light they transmit. Ask: **If a red object transmits red light, what type of material is it made of?** *(Transparent or translucent)*

**Apply** Ask: **Why is a blueberry blue?** *(It reflects blue light.)* **Why is blue glass blue?** *(The blue glass transmits only blue light.)* **learning modality: logical/mathematical**

**All in One Teaching Resources**

Transparency O39

Go Online SCILINKS NSTA

**For:** Links on colors
**Visit:** www.SciLinks.org
**Web Code:** scn-1543

Download a worksheet that will guide students' review of internet resources on colors.

Lab zone Teacher Demo L1

### *Light Reflected by Opaque Materials*

**Materials** white light source, blue filter, green filter, red paper triangle, sheet of white paper

**Time** 10 minutes

**Focus** Say that the color of light shining on an opaque object affects the object's color.

**Teach** Place the red triangle on the sheet of white paper. Without letting students see the triangle in white light, have them view it in blue light and then in green light. (The triangle appears black in both cases.) Ask: **What color will the triangle appear in white light?** *(Students should predict a color other than blue or green.)* Show students the triangle in white light.

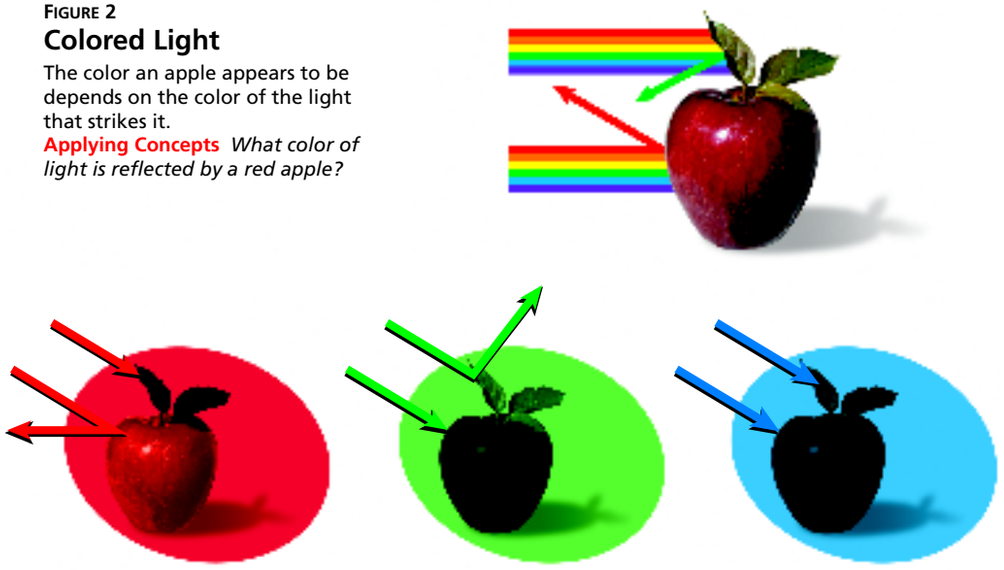
**Apply** Ask: **How can you explain your observations?** *(Sample answer: The red triangle reflects red light, but absorbs blue light and green light.)* **learning modality: logical/mathematical**

FIGURE 2

**Colored Light**

The color an apple appears to be depends on the color of the light that strikes it.

**Applying Concepts** *What color of light is reflected by a red apple?*



In red light, the apple appears red because it reflects the red light. But the leaves look black.

In green light, the apple appears black because no red light strikes it. But the leaves look green.

In blue light, both the apple and the leaves appear black.

## The Color of Objects

If you know how light interacts with objects, you can explain why objects such as flowers have different colors. The color of any object depends on the material the object is made of and the color of light striking the object.

**Color of Opaque Objects** The color of an opaque object depends on the wavelengths of light that the object reflects. Every opaque object absorbs some wavelengths of light and reflects others. **The color of an opaque object is the color of the light it reflects.** For example, look at the apple shown at the top of Figure 2. The apple appears red because it reflects red wavelengths of light. The apple absorbs the other colors of light. The leaf looks green because it reflects green light and absorbs the other colors.

Objects can appear to change color if you view them in a different color of light. In red light, the apple appears red because there is red light for it to reflect. But the leaf appears black because there is no green light to reflect. In green light, the leaf looks green but the apple looks black. And in blue light, both the apple and the leaf look black.

Go Online SCILINKS NSTA

**For:** Links on colors
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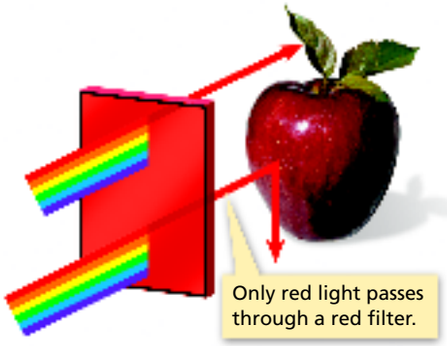
FIGURE 3
**Color Filters**
When you look at an apple through different filters, the color of the apple depends on the color of the filter.
**Interpreting Photographs** *Why do both the apple and the leaves appear black through the blue filter?*





The red filter transmits red light, so the apple looks red. But the leaf looks black.


The green filter transmits green light, so the leaf looks green. But the apple looks black.


The blue filter transmits blue light. Both the apple and the leaf look black.

**Color of Transparent and Translucent Objects** Materials that are transparent or translucent allow only certain colors of light to pass through them. They reflect or absorb the other colors. **The color of a transparent or translucent object is the color of the light it transmits.** For example, when white light shines through a transparent blue glass, the glass appears blue because it transmits blue light.

Transparent or translucent materials are used to make color filters. For example, a piece of glass or plastic that allows only red light to pass through is a red color filter. When you look at an object through a color filter, the color of the object may appear different than when you see the object in white light, as shown in Figure 3.

The lenses in sunglasses often are color filters. For example, lenses that are tinted yellow are yellow filters. Lenses that are tinted green are green filters. When you put on these tinted sunglasses, some objects appear to change color. The color you see depends on the color of the filter and on the color that the object appears in white light.

Reading Checkpoint **What is a color filter?**

Lab zone Skills Activity

**Developing Hypotheses**

1. Predict what colors you will see if you view a red, white, and blue flag through a red filter. Write a hypothesis of what the outcome will be. Write your hypothesis as an "If … then …" statement.
2. View an American flag using a red filter. What do you see? Is your hypothesis confirmed?
3. Repeat Steps 1 and 2 using a yellow filter.

Lab zone Skills Activity

**Skills Focus** Developing hypotheses L2

**Materials** American flag, light source, red and yellow filters

**Time** 10 minutes

**Tip** If the room is darkened, the affects of the filters will be more obvious.

**Expected Outcome** With a red filter, both red and white stripes appear red, and the white stars appear to be red on a black background. With a yellow filter, the white stripes and stars appear yellow, the red stripes appear orange, and the blue areas appear black.

## Help Students Read L1

**DRTA** Refer to the DRT guidelines in this chapter's Content Refresher.

Before students read this page, ask: **What determines the color of a transparent or translucent object?** *(Students may say the color of light the object reflects.)* Tell students to scan the text under the heading *Color of Transparent and Translucent Objects* for the answer. Ask: **Which sentence contains the answer?** *(The boldface sentence)* Check students' comprehension by asking: **What color of light is transmitted by blue glass?** *(Blue light)* **What colors of light are absorbed by blue glass?** *(All except blue)*

All in One **Teaching Resources**

- Transparency O40

Lab zone Teacher Demo L1

### *Color of Transmitted Light*

**Materials** differently-colored transparent or translucent materials such as glass, plastic, paper, and fabric; flashlight

**Time** 15 minutes

**Focus** Remind students that colored transparent and translucent materials transmit light of only certain colors.

**Teach** In a darkened room, shine a flashlight on a white screen or wall. Then, shine the flashlight on the white surface through each of the colored materials. In each case, ask: **How does the light appear?** *(It is the same color as the material it shines through.)*

**Apply** Ask: **What conclusion can you draw about the color of light transmitted by transparent and translucent materials?** *(Sample answer: It is the same as the color of the material.)* **learning modality: visual**

## Monitor Progress L2

**Writing** Have students write a paragraph explaining why green apples and green traffic lights appear green.

**Answers**

**Figure 2** A red apple reflects red light.
**Figure 3** Only blue light is transmitted.

Reading Checkpoint A color filter is a piece of glass or plastic that allows light of only a certain color to pass through.

# Combining Colors

## Teach Key Concepts L2

### *Primary and Secondary Colors*

**Focus** Remind students that colors can combine to form different colors.

**Teach** On the board, write the headings *Primary Colors of Light* and *Secondary Colors of Light*. Under *Primary Colors of Light*, list red, green, and blue. State that white light consists of equal amounts of light of the three primary colors and that the primary colors combine in different ways to make all other colors of light. Under *Secondary Colors of Light*, list magenta, cyan, and yellow. State that secondary colors result from combining equal amounts of two primary colors. Call students' attention to Figure 4. Then, ask: **Which two primary colors of light combine to produce magenta light?** *(Red and blue)* Repeat this procedure for pigment colors, listing the primary and secondary pigment colors under the correct headings. Then, have students look at Figure 6. Ask: **Which two primary colors of pigments combine to produce green pigment?** *(Cyan and yellow)*

**Apply** Ask: **Can you produce white light by combining magenta light and green light? Why or why not?** *(Yes, because magenta light contains red and blue light, and combining red, blue, and green light produces white light)* **learning modality: visual**

## Address Misconceptions L1

### *Primary Colors of Light vs. Pigments*

Students may not understand why they cannot combine red and green ink, paint, or dye to produce yellow, as shown in Figure 4. Help students overcome this misconception by having them color a square with a red marker and then with a green marker. When they are finished, ask: **What happens when you combine red and green markers?** *(The square appears black.)* Explain that Figure 4 applies only to light and that the colors in markers are pigments. Have students look at Figure 6, which applies to pigments. Point out that red and green are secondary colors in pigments and that they combine to produce black. **learning modality: kinesthetic**

**All in One Teaching Resources**

- Transparency O41

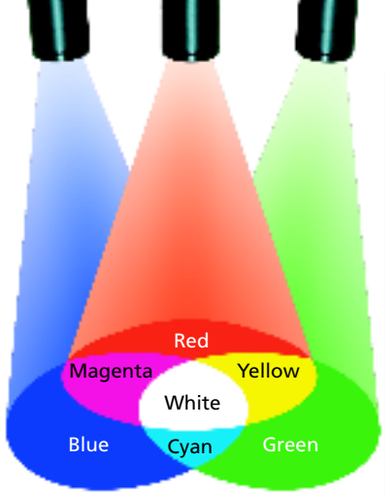



**FIGURE 4**
**Primary Colors of Light**
The primary colors of light combine in equal amounts to form white light.

## Combining Colors

Color is used in painting, photography, theater lighting, and printing. People who work with color must learn how to produce a wide range of colors using just a few basic colors. Three colors that can combine to make any other color are called **primary colors.** Two primary colors combine in equal amounts to produce a **secondary color.**

**Mixing Colors of Light** The primary colors of light are red, green, and blue. **When combined in equal amounts, the three primary colors of light produce white light.** If they are combined in different amounts, the primary colors can produce other colors. For example, red and green combine to form yellow light. Yellow is a secondary color of light because two primary colors produce it. The secondary colors of light are yellow (red + green), cyan (green + blue), and magenta (red + blue). Figure 4 shows the primary and secondary colors of light.

A primary and a secondary color can combine to make white light. Any two colors that combine to form white light are called **complementary colors.** Yellow and blue are complementary colors, as are cyan and red, and magenta and green.

A color television produces many colors using only the primary colors of light—red, green, and blue. Figure 5 shows a magnified view of a color television screen. The picture in the screen is made up of little groups of red, green, and blue light. By varying the brightness of each colored bar, the television can produce thousands of different colors.

**FIGURE 5**
**Colors in Television**
A television produces many colors using only the primary colors of light.
**Predicting** *For a yellow area on a television screen, what color would you expect the bars to be?*

Equal amounts of red, green, and blue appear white from a distance.

## Differentiated Instruction

### Less Proficient Readers L1

**Listing Important Points About Light and Color** Have students listen to this section of the chapter on the **Student Edition on Audio CD.** Tell them to write down important points as they listen. After students have finished, have them compare their list of points with the text and correct any errors or omissions. **learning modality: verbal**

### Special Needs L2

**Combining Colors of Pigment** Have students make a colored diagram similar to Figure 6 by combining primary pigment colors using markers. Tell students to draw three overlapping circles (like the circles in the figure) and to color each circle with one of the primary pigment colors. Have students identify and label the secondary pigment colors that appear in the areas where the circles overlap. **learning modality: kinesthetic**

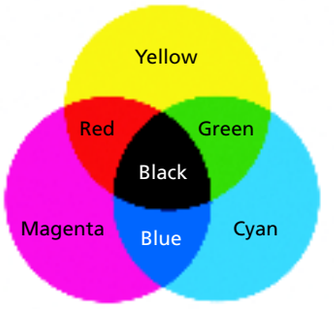
**Mixing Pigments** How does a printer produce the many shades of colors you see in this textbook? Inks, paints, and dyes contain **pigments,** or colored substances that are used to color other materials. Pigments absorb some colors and reflect others. The color you see is the result of the colors that particular pigment reflects.

Mixing colors of pigments is different from mixing colors of light. **As pigments are added together, fewer colors of light are reflected and more are absorbed.** The more pigments that are combined, the darker the mixture looks.

Cyan, yellow, and magenta are the primary colors of pigments. These colors combine in equal amounts to produce black. By combining pigments in varying amounts, you can produce many other colors. If you combine two primary colors of pigments, you get a secondary color, as shown in Figure 6. The secondary colors of pigments are red, green, and blue.

Look at the pictures in this book with a magnifying glass. You can see tiny dots of different colors of ink. The colors used are cyan, yellow, and magenta. Black ink is also used, so the printing process is called four-color printing.

**FIGURE 6**
**Primary Colors of Pigments**
The primary colors of pigments combine in equal amounts to form black.




Reading Checkpoint **What are pigments?**

## Section 1 Assessment

**Target Reading Skill** **Building Vocabulary** Use your definitions to help answer the questions.

### Reviewing Key Concepts

1. a. **Identifying** What three things may happen to the light that strikes an object?
   b. **Applying Concepts** What happens to light that strikes the following materials: clear plastic, aluminum foil, and tissue paper?
   c. **Problem Solving** Room-darkening window shades are used to keep sunlight out of a theater. What type of material should the shades be made of? Explain.
2. a. **Reviewing** What determines the color of an opaque object? Of a transparent or translucent object?
   b. **Drawing Conclusions** An actor's red shirt and blue pants both appear black. What color is the stage light shining on the actor?
3. a. **Describing** What are the primary colors of light? The primary colors of pigments?
   b. **Comparing and Contrasting** How does the result of mixing the primary colors of pigments compare to the result of mixing the primary colors of light?
   c. **Interpreting Diagrams** In Figure 6, which pairs of colors combine to make black?

### Lab zone At-Home Activity

**Color Mix** See how many different shades of green you can make by mixing blue and yellow paint in different proportions. On white paper, paint a "spectrum" from yellow to green to blue. Show the results to your family. Then explain how magazine photos reproduce thousands of colors.

## Monitor Progress L2

**Answers**

**Figure 5** For a yellow area on a television screen, you would expect to see red- and green-colored bars.

Reading Checkpoint Pigments are colored substances that are used to color other materials.

## Assess

### Reviewing Key Concepts

**1. a.** The light may be reflected, transmitted, or absorbed. **b.** Light that strikes clear plastic is mostly transmitted and partly reflected. Light that strikes aluminum foil is mostly reflected and partly absorbed. Light that strikes tissue paper is partly transmitted, reflected, and absorbed. **c.** The shades should be made of an opaque material, which does not transmit light.
**2. a.** The color of an opaque object is determined by the color of light it reflects. The color of a transparent or translucent object is determined by the color of light it transmits. **b.** The stage light does not contain red or blue light, because no red or blue light is reflected, so the stage light must be green.
**3. a.** The primary colors of light are red, blue, and green. The primary colors of pigments are cyan, yellow, and magenta. **b.** Mixing the primary colors of pigments in equal amounts produces black pigment. Mixing the primary colors of light in equal amounts produces white light. **c.** Pairs of pigment colors that add to make black: green and magenta, red and cyan, and yellow and blue

### Reteach L1

Read the definitions of the key terms, and call on students to identify the terms from their definitions.

### Performance Assessment L2

**Skills Check** Have students create a graphic organizer comparing and contrasting colors of light with colors of pigments.

### All in One Teaching Resources

- Section Summary: *Light and Color*
- Review and Reinforcement: *Light and Color*
- Enrich: *Light and Color*

### Lab zone At-Home Activity

**Color Mix** L2 Suggest that students start with a small amount of yellow paint and gradually add very small quantities of blue, until the mixture contains mostly blue paint. Remind students to paint a stripe of each color on white paper to create a "spectrum" of colors from yellow through green to blue.

### Lab zone Chapter Project

**Keep Students on Track** Check that students have decided on the purpose of their optical instrument. Tell them to draw and label a sketch of the optical instrument they would like to build. Urge them to consider how light will enter the instrument and be affected by lenses or mirrors. Encourage students to try out different mirrors and lenses as they plan their designs.

# Changing Colors

L2

## Prepare for Inquiry

### Skills Objective

After this lab, students will be able to

- observe how color filters affect white light
- infer what color(s) of light different filters allow through
- predict how colored objects appear through different filters

**Prep Time** 15 minutes
**Class Time** 40 minutes

### Advance Planning

Gather colored objects, cellophane, flashlights, and shoe boxes.

### Safety

Caution students to take care when using the scissors.

**All in One Teaching Resources**

- Lab Worksheet: *Changing Colors*

## Guide Inquiry

### Introduce the Procedure

Tell students that they will observe objects in light of just one color at a time.

### Troubleshooting the Experiment

Pair any students who are colorblind with those who are not.

### Expected Outcome

Colored objects are their usual colors when viewed through a filter of the same color; they are another color when viewed through filters of other colors. White objects viewed through colored filters are the color of the filter.

### Analyze and Conclude

**1.** A red filter absorbs green and blue light, but allows red light to pass through. The red object appeared red, because the light it reflected passed through the filter. The blue object appeared black, because the light it reflected was absorbed by the filter. The yellow object appeared red or orange, depending on the filter.

**2.** A blue filter absorbs red and green light and transmits blue light. The yellow and green objects appeared black, because the light they reflect was absorbed by the filter. The blue object appeared blue.

**3.** Red—red; green—green; blue—blue

**4.** Students may predict that a white object will appear the same color as the cellophane.

**5.** Students may predict that the red object will appear black. Their diagrams might show that light reflected by the red object is absorbed by the yellow cellophane. By viewing a red object through yellow cellophane, they will see that the red object appears orange.

**6.** Students' diagrams are expected to show that each colored filter transmits light of its own color.

## Extend Inquiry

**Design an Experiment** Experiments should test whether overlapping red and green filters produce yellow or black. The filters are, in fact, more like pigments, because overlapping red and green filters produce gray or black.

Lab zone Skills Lab

# Changing Colors

## Problem

How do color filters affect the appearance of objects in white light?

## Skills Focus

observing, inferring, predicting

## Materials

- shoe box
- scissors
- flashlight
- removable tape
- red object (such as a ripe tomato)
- yellow object (such as a ripe lemon)
- blue object (such as blue construction paper)
- red, green, and blue cellophane, enough to cover the top of the shoe box

## Procedure

1. Carefully cut a large rectangular hole in the lid of the shoe box.
2. Carefully cut a small, round hole in the center of one of the ends of the shoe box.
3. Tape the red cellophane under the lid of the shoe box, covering the hole in the lid.
4. Place the objects in the box and put the lid on.
5. In a darkened room, shine the flashlight into the shoe box through the side hole. Note the apparent color of each object in the box.
6. Repeat Steps 3–5 using the other colors of cellophane.

## Analyze and Conclude

1. **Observing** What did you see when you looked through the red cellophane? Explain why each object appeared as it did.
2. **Observing** What did you see when you looked through the blue cellophane? Explain.
3. **Inferring** What color(s) of light does each piece of cellophane allow through?
4. **Predicting** Predict what you would see under each piece of cellophane if you put a white object in the box. Test your prediction.
5. **Predicting** What do you think would happen if you viewed a red object through yellow cellophane? Draw a diagram to support your prediction. Then test you prediction.
6. **Communicating** Summarize your conclusions by drawing diagrams to show how each color filter affects white light. Write captions to explain your diagrams.

## Design an Experiment

Do color filters work like pigments or like colors of light? Design an experiment to find out what happens if you shine a light through both a red and a green filter. *Obtain your teacher's permission before carrying out your investigation.*