SECTION 4

Light and Color

Why are strawberries red and bananas yellow? How can a soda bottle be green, yet you can still see through it?

If white light is made of all the colors of light, how do things get their color from white light? Why aren't all things white in white light? Good questions! To answer these questions, you need to know how light interacts with matter.

What You Will Learn

- Name and describe the three ways light interacts with matter.
- Explain how the color of an object is determined.
- Explain why mixing colors of light is called *color addition*.
- Describe why mixing colors of pigments is called *color subtraction*.

Vocabulary

transmission
transparent
translucent
opaque
pigment

READING STRATEGY

Discussion Read this section silently. Write down questions that you have about this section. Discuss your questions in a small group.

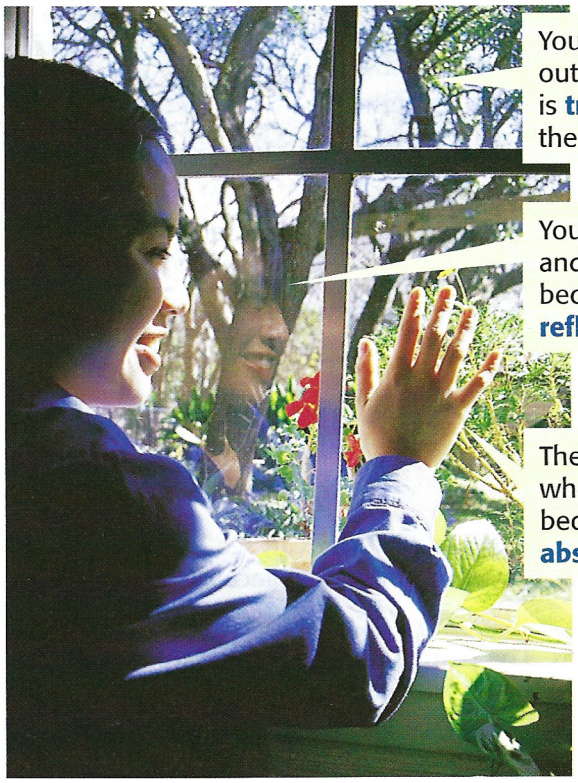
transmission the passing of light or other form of energy through matter

Light and Matter

When light strikes any form of matter, it can interact with the matter in three different ways—the light can be reflected, absorbed, or transmitted.

Reflection happens when light bounces off an object. Reflected light allows you to see things. Absorption is the transfer of light energy to matter. Absorbed light can make things feel warmer. **Transmission** is the passing of light through matter. You see the transmission of light all the time. All of the light that reaches your eyes is transmitted through air. Light can interact with matter in several ways at the same time. Look at **Figure 1.** Light is transmitted, reflected, and absorbed when it strikes the glass in a window.

Figure 1 **Transmission, Reflection, and Absorption**



You can see objects outside because light is **transmitted** through the glass.

You can see the glass and your reflection in it because light is **reflected** off the glass.

The glass feels warm when you touch it because some light is **absorbed** by the glass.

Figure 2 **Transparent, Translucent, and Opaque**

Transparent plastic makes it easy to see what you are having for lunch.

Translucent wax paper makes it a little harder to see exactly what's for lunch.

Opaque aluminum foil makes it impossible to see your lunch without unwrapping it.

Types of Matter

Matter through which visible light is easily transmitted is said to be **transparent.** Air, glass, and water are examples of transparent matter. You can see objects clearly when you view them through transparent matter.

Sometimes, windows in bathrooms are made of frosted glass. If you look through one of these windows, you will see only blurry shapes. You can't see clearly through a frosted window because it is translucent (trans LOO suhnt). **Translucent** matter transmits light but also scatters the light as it passes through the matter. Wax paper is an example of translucent matter.

Matter that does not transmit any light is said to be **opaque** (oh PAYK). You cannot see through opaque objects. Metal, wood, and this book are examples of opaque objects. You can compare transparent, translucent, and opaque matter in **Figure 2.**

transparent describes matter that allows light to pass through with little interference

translucent describes matter that transmits light but that does not transmit an image

opaque describes an object that is not transparent or translucent

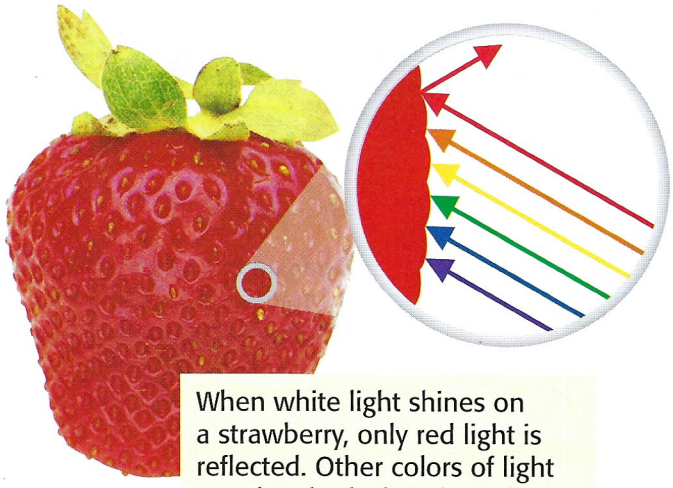
Reading Check **List two examples of translucent objects.**
(*See the Appendix for answers to Reading Checks.*)

Colors of Objects

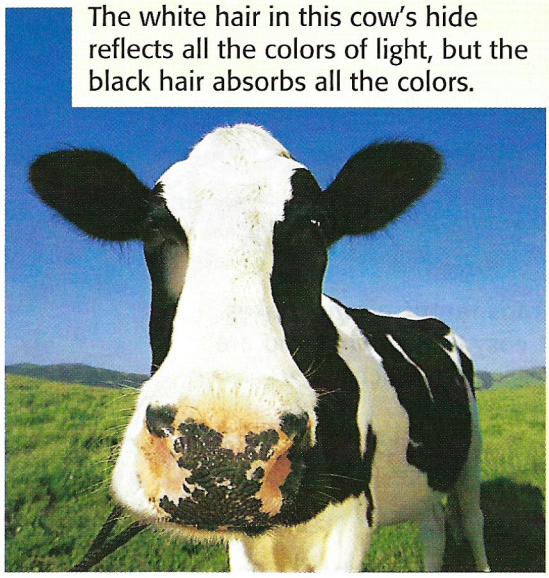
How is an object's color determined? Humans see different wavelengths of light as different colors. For example, humans see long wavelengths as red and short wavelengths as violet. And, some colors, like pink and brown, are seen when certain combinations of wavelengths are present.

The color that an object appears to be is determined by the wavelengths of light that reach your eyes. Light reaches your eyes after being reflected off an object or after being transmitted through an object. When your eyes receive the light, they send signals to your brain. Your brain interprets the signals as colors.

Figure 3 Opaque Objects and Color



When white light shines on a strawberry, only red light is reflected. Other colors of light are absorbed. Therefore, the strawberry looks red to you.



The white hair in this cow's hide reflects all the colors of light, but the black hair absorbs all the colors.

Colors of Opaque Objects

When white light strikes a colored opaque object, some colors of light are absorbed, and some are reflected. Only the light that is reflected reaches your eyes and is detected. So, the colors of light that are reflected by an opaque object determine the color you see. For example, if a sweater reflects blue light and absorbs all other colors, you will see that the sweater is blue. Another example is shown on the left in **Figure 3.**

What colors of light are reflected by the cow shown on the right in **Figure 3**? Remember that white light includes all colors of light. So, white objects—such as the white hair in the cow's hide—appear white because all the colors of light are reflected. On the other hand, black is the absence of color. When light strikes a black object, all the colors are absorbed.

Reading Check **What happens when white light strikes a colored opaque object?**

Figure 4 *This bottle is green because the plastic transmits green light.*

Colors of Transparent and Translucent Objects

The color of transparent and translucent objects is determined differently than the color of opaque objects. Ordinary window glass is colorless in white light because it transmits all the colors that strike it. But some transparent objects are colored. When you look through colored transparent or translucent objects, you see the color of light that was transmitted through the material. The other colors were absorbed, as shown in **Figure 4.**

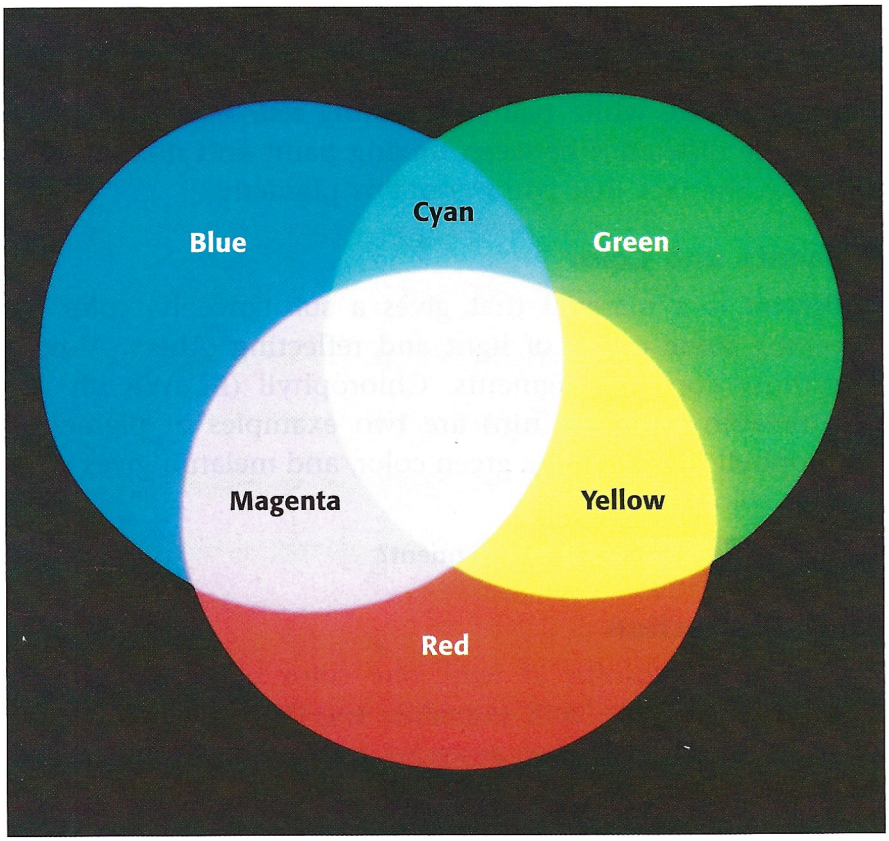


Figure 5 *Primary colors of light—written in white—combine to produce white light. Secondary colors of light—written in black—are the result of two primary colors added together.*

Mixing Colors of Light

In order to get white light, you must combine all colors of light, right? This method is one way of doing it. But you can also get light that appears white by adding just three colors of light together—red, blue, and green. The combination of these three colors is shown in **Figure 5.** In fact, these three colors can be combined in different ratios to produce many colors. Red, blue, and green are called the *primary colors of light.*

Color Addition

When colors of light combine, you see different colors. Combining colors of light is called *color addition*. When two primary colors of light are added together, you see a *secondary color of light*. The secondary colors of light are cyan (blue plus green), magenta (blue plus red), and yellow (red plus green). **Figure 5** shows how secondary colors of light are formed.

Light and Color Television

The colors on a color television are produced by color addition of the primary colors of light. A television screen is made up of groups of tiny red, green, and blue dots. Each dot will glow when the dot is hit by an electron beam. The colors given off by the glowing dots add together to produce all the different colors you see on the screen.

SCHOOL to HOME

Television Colors

Turn on a color television. Ask an adult to carefully sprinkle a few tiny drops of water onto the television screen. Look closely at the drops of water, and discuss what you see. In your **science journal,** write a description of what you saw.

ACTIVITY

Mixing Colors of Pigment

If you have ever tried mixing paints in art class, you know that you can't make white paint by mixing red, blue, and green paint. The difference between mixing paint and mixing light is due to the fact that paint contains pigments.

Pigments and Color

pigment a substance that gives another substance or a mixture its color

A **pigment** is a material that gives a substance its color by absorbing some colors of light and reflecting others. Almost everything contains pigments. Chlorophyll (KLAWR uh FIL) and melanin (MEL uh nin) are two examples of pigments. Chlorophyll gives plants a green color, and melanin gives your skin its color.

Reading Check **What is a pigment?**

Color Subtraction

Each pigment absorbs at least one color of light. Look at **Figure 6.** When you mix pigments together, more colors of light are absorbed or taken away. So, mixing pigments is called *color subtraction*.

The *primary pigments* are yellow, cyan, and magenta. They can be combined to produce any other color. In fact, every color in this book was produced by using just the primary pigments and black ink. The black ink was used to provide contrast to the images. **Figure 7** shows how the four pigments combine to produce many different colors.

QUICK LAB

Rose-Colored Glasses?

1. Obtain **four plastic filters**—red, blue, yellow, and green.
2. Look through one filter at an object across the room. Describe the object's color.
3. Repeat step 2 with each of the filters.
4. Repeat step 2 with two or three filters together.
5. Why do you think the colors change when you use more than one filter?
6. Write your observations and answers.

Figure 6 *Primary pigments—written in black—combine to produce black. Secondary pigments—written in white—are the result of the subtraction of two primary pigments.*

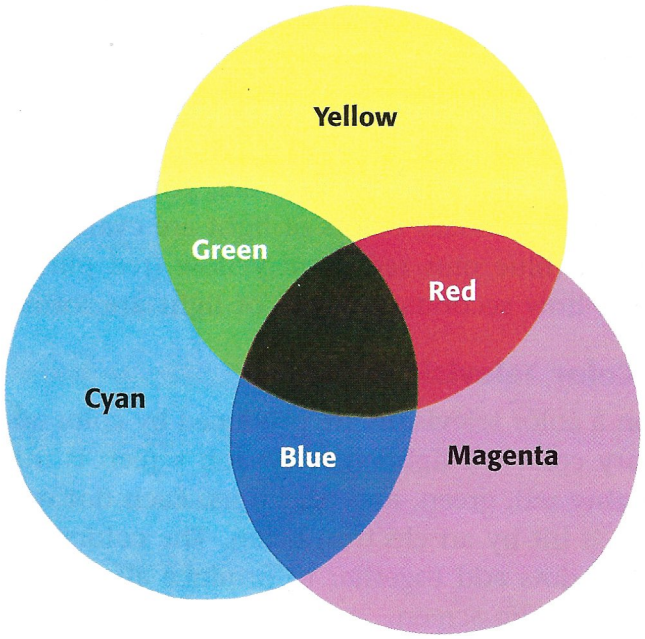


Figure 7 **Color Subtraction and Color Printing**

The picture of the balloon on the left was made by overlapping yellow ink, cyan ink, magenta ink, and black ink.

Yellow Cyan Magenta Black

SECTION Review

Summary

- Objects are transparent, translucent, or opaque, depending on their ability to transmit light.
- Colors of opaque objects are determined by the color of light that they reflect.
- Colors of translucent and transparent objects are determined by the color of light they transmit.
- White light is a mixture of all colors of light.
- Light combines by color addition. The primary colors of light are red, blue, and green.
- Pigments give objects color. Pigments combine by color subtraction. The primary pigments are magenta, cyan, and yellow.

Using Key Terms

1. Use the following terms in the same sentence: *transmission* and *transparent*.
2. In your own words, write a definition for each of the following terms: *translucent* and *opaque*.

Understanding Key Ideas

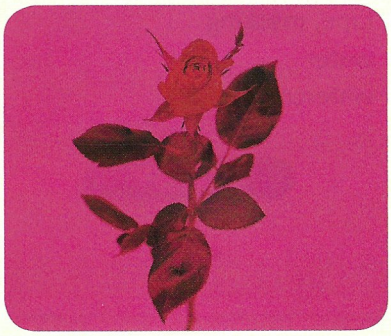
3. You can see through a car window because the window is
   a. opaque. **c.** transparent.
   b. translucent. **d.** transmitted.
4. Name and describe three different ways light interacts with matter.
5. How is the color of an opaque object determined?
6. Describe how the color of a transparent object is determined.
7. What are the primary colors of light, and why are they called *primary colors*?
8. What four colors of ink were used to print this book?

Critical Thinking

9. **Applying Concepts** What happens to the different colors of light when white light shines on an opaque violet object?
10. **Analyzing Ideas** Explain why mixing colors of light is called *color addition* but mixing pigments is called *color subtraction*.

Interpreting Graphics

11. Look at the image below. The red rose was photographed in red light. Explain why the leaves appear black and the petals appear red.



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Topic: Colors
SciLinks code: HSM0314

Chapter Review

USING KEY TERMS

Complete each of the following sentences by choosing the correct term from the word bank.

interference	radiation
scattering	opaque
translucent	transmission
electromagnetic wave	electromagnetic spectrum

1. _____ is the transfer of energy by electromagnetic waves.
2. This book is a(n) _____ object.
3. _____ is a wave interaction that occurs when two or more waves overlap and combine.
4. Light is a kind of _____ and can therefore travel through matter and space.
5. During _____, light travels through an object.

UNDERSTANDING KEY IDEAS

Multiple Choice

6. Electromagnetic waves transmit
   - **a.** charges.
   - **b.** fields.
   - **c.** matter.
   - **d.** energy.
7. Objects that transmit light easily are
   - **a.** opaque.
   - **b.** translucent.
   - **c.** transparent.
   - **d.** colored.
8. You can see yourself in a mirror because of
   - **a.** absorption.
   - **b.** scattering.
   - **c.** regular reflection.
   - **d.** diffuse reflection.
9. Shadows have blurry edges because of
   - **a.** diffraction.
   - **b.** scattering.
   - **c.** diffuse reflection.
   - **d.** refraction.
10. What color of light is produced when red light is added to green light?
    - **a.** cyan
    - **b.** blue
    - **c.** yellow
    - **d.** white
11. Prisms produce the colors of the rainbow through
    - **a.** reflection.
    - **b.** refraction.
    - **c.** diffraction.
    - **d.** interference.
12. Which kind of electromagnetic wave travels fastest in a vacuum?
    - **a.** radio wave
    - **b.** visible light
    - **c.** gamma ray
    - **d.** They all travel at the same speed.
13. Electromagnetic waves are made of
    - **a.** vibrating particles.
    - **b.** vibrating charged particles.
    - **c.** vibrating electric and magnetic fields.
    - **d.** All of the above

Short Answer

14 How are gamma rays used?

15 What are two uses for radio waves?

16 Why is it difficult to see through glass that has frost on it?

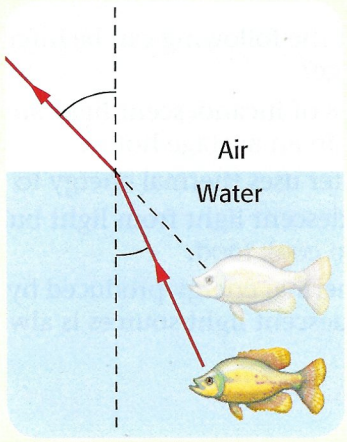
Math Skills

17 Calculate the time it takes for light from the sun to reach Mercury. Mercury is 54,900,000 km away from the sun.

CRITICAL THINKING

18 **Concept Mapping** Use the following terms to create a concept map: *light, matter, reflection, absorption,* and *transmission.*

19 **Applying Concepts** A tern is a type of bird that dives underwater to catch fish. When a young tern begins learning to catch fish, the bird is rarely successful. The tern has to learn that when a fish appears to be in a certain place underwater, the fish is actually in a slightly different place. Why does the tern see the fish in the wrong place?



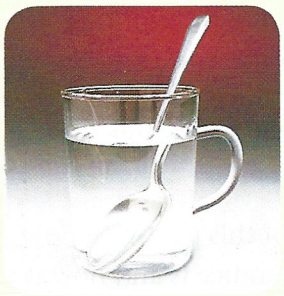
20 **Evaluating Conclusions** Imagine that you are teaching your younger brother about light. You tell him that white light is light of all the colors of the rainbow combined. But your brother says that you are wrong because mixing different colors of paint produces black and not white. Explain why your brother's conclusion is wrong.

21 **Making Inferences** If you look around a parking lot during the summer, you might see sunshades set up in the windshields of cars. How do sunshades help keep the insides of cars cool?

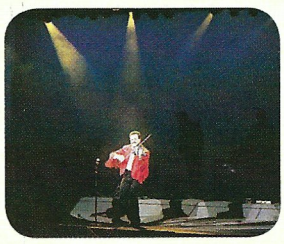
INTERPRETING GRAPHICS

22 Each of the pictures below shows the effects of a wave interaction of light. Identify the interaction involved.

a.



b.



c.