The Light We See

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CHAPTER 1 The Light We See

Standard:

MS-PS4-2 Develop and use a model to describe how waves are reflected, absorbed, or transmitted through various materials. (SEP: 2; DCI: PS4.A, PS4.B; CCC: Structure)

Lesson Objectives

- Identify common sources of visible light.
- Explain how light interacts with matter.
- Describes the colors of visible light.

Lesson Vocabulary

- absorption
- incandescence
- luminescence
- opaque
- pigment
- primary color
- scattering
- translucent
- transmission
- transparent

Introduction

We can see rainbows because they are formed by visible light. Visible light includes all the wavelengths of light that the human eye can detect. It allows us to see objects in the world around us. Without visible light, we would only be able to sense most objects by sound or touch, and we would never see rainbows. Like humans, most other organisms also depend on visible light, either directly or indirectly. Many animals use it to see. All plants use it to make food in the process of photosynthesis. Without the food made by plants, most other organisms could not survive.

Sources of Visible Light

Look at the classroom in **Figure** 1.1. It has several sources of visible light. One source of visible light is the sun. Sunlight enters the classroom through the windows. The sun provides virtually all of the visible light that living things need. Visible light travels across space from the sun to Earth in electromagnetic waves. But how does the sun produce light? Read on to find out.

How Visible Light Is Produced

The sun and other stars produce light because they are so hot. They glow with light due to their extremely high temperatures. This way of producing light is called **incandescence**. Some objects produce light without becoming

FIGURE 1.1
This classroom has two obvious sources of visible light. Can you identify all of them?

very hot. They generate light through chemical reactions or other processes. Producing light without heat is called **luminescence**. Objects that produce light by luminescence are said to be luminous. Luminescence, in turn, can occur in different ways:

- One type of luminescence is called fluorescence. In this process, a substance absorbs shorter-wavelength light, such as ultraviolet light, and then gives off light in the visible range of wavelengths. Certain minerals produce light in this way.
- Another type of luminescence is called electroluminescence. In this process, a substance gives off light when an electric current runs through it. Some gases produce light in this way.
- A third type of luminescence is called bioluminescence. This is the production of light by living things as a result of chemical reactions. Examples of bioluminescent organisms are pictured in **Figure** 1.2. You can learn more about bioluminescence in the video at this URL: http://www.ted.com/talks/edith_widder_glowing_life_in_an_underwater_world.html .

Many other objects appear to produce their own light, but they actually just reflect light from another source. The moon is a good example. It appears to glow in the sky from its own light, but in reality it is just reflecting light from the sun. Objects like the moon that are lit up by another source of light are said to be illuminated. Everything you can see that doesn't produce its own light is illuminated.

Artificial Lights

The classroom in **Figure** 1.1 has artificial light sources in addition to natural sunlight. There are fluorescent lights on the ceiling of the room. There are also projectors on the ceiling that are shining light on screens. In these and most other artificial light sources, electricity provides the energy and some type of light bulb converts the electrical energy to visible light. How a light bulb produces visible light varies by type of bulb, as you can see in **Table** 1.1.

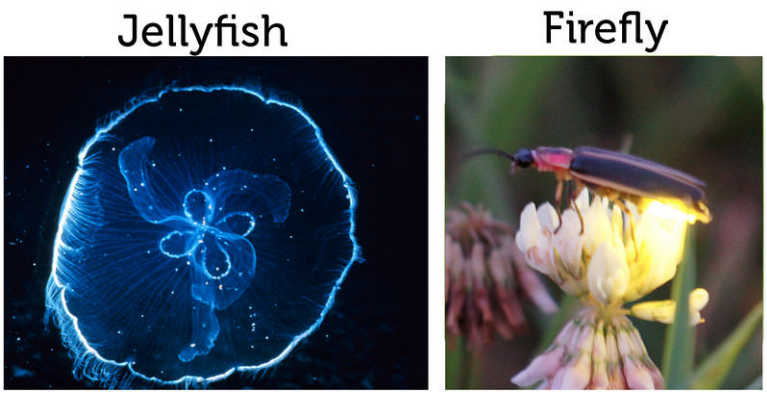


FIGURE 1.2
Bioluminescent organisms include jellyfish and fireflies. Jellyfish give off visible light to startle predators. Fireflies give off visible light to attract mates.

Incandescent light bulbs, which produce light by incandescence, give off a lot of heat as well as light, so they waste energy. Other light bulbs produce light by luminescence, so they produce little if any heat. These light bulbs use energy more efficiently. Which types of light bulbs do you use?

TABLE 1.1: Different types of light bulbs produce visible light in different ways.

Type of Light Bulb	Description
Incandescent Light 	An incandescent light bulb produces visible light by incandescence. The bulb contains a thin wire filament made of tungsten. When electric current passes through the filament, it gets extremely hot and glows. You can learn more about incandescent light bulbs at the URL below. http://science.discovery.com/videos/deconstructed-how-incandescent-light-bulbs-work.html
Fluorescent Light 	A fluorescent light bulb produces visible light by fluorescence. The bulb contains mercury gas that gives off ultraviolet light when electricity passes through it. The inside of the bulb is coated with a substance called phosphor. The phosphor absorbs the ultraviolet light and then gives off most of the energy as visible light. You can learn more about fluorescent light bulbs at this URL: http://science.discovery.com/videos/deconstructed-compact-fluorescent-light-bulb.html .

TABLE 1.1: (continued)

Type of Light Bulb	Description
Neon Light 	A neon light produces visible light by electroluminescence. The bulb is a glass tube that contains the noble gas neon. When electricity passes through the gas, it excites electrons of neon atoms, causing them to give off visible light. Neon produces red light. Other noble gases are also used in lights, and they produce light of different colors. For example, krypton produces violet light, and argon produces blue light.
Vapor Light 	A vapor light produces visible light by electroluminescence. The bulb contains a small amount of solid sodium or mercury as well as a mixture of neon and argon gases. When an electric current passes through the gases, it causes the solid sodium or mercury to change to a gas and emit visible light. Sodium vapor lights, like these streetlights, produce yellowish light. Mercury vapor lights produce bluish light. Vapor lights are very bright and energy efficient. The bulbs are also long lasting.
LED Light 	LED stands for "light-emitting diode." This type of light contains a material, called a semi-conductor, which gives off visible light when a current runs through it. LED lights are used for traffic lights and indicator lights on computers, cars, and many other devices. This type of light is very reliable and durable.

Light and Matter

When visible light strikes matter, it interacts with it. How light interacts with matter depends on the type of matter.

How Light Interacts with Matter

Light may interact with matter in several ways.

- Light may be reflected by matter. Reflected light bounces back when it strikes matter. Reflection of light is similar to reflection of sound waves. You can read more about reflection of light later on in this chapter in the lesson "Optics."
- Light may be refracted by matter. The light is bent when it passes from one type of matter to another. Refraction of light is similar to refraction of sound waves. You can also read more about refraction of light in the lesson "Optics."

- Light may pass through matter. This is called **transmission** of light. As light is transmitted, it may be scattered by particles of matter and spread out in all directions. This is called **scattering** of light.
- Light may be absorbed by matter. This is called **absorption** of light. When light is absorbed, it doesn't reflect from or pass through matter. Instead, its energy is transferred to particles of matter, which may increase the temperature of matter.

Classifying Matter in Terms of Light

Matter can be classified on the basis of how light interacts with it. Matter may be transparent, translucent, or opaque. Each type of matter is illustrated in **Figure** 1.3.

- **Transparent** matter is matter that transmits light without scattering it. Examples of transparent matter include air, pure water, and clear glass. You can see clearly through a transparent object, such as the revolving glass doors in the figure, because all the light passes straight through it.
- **Translucent** matter is matter that transmits but scatters light. Light passes through a translucent object but you cannot see clearly through the object because the light is scattered in all directions. The frosted glass doors in the figure are translucent.
- **Opaque** matter is matter that does not let any light pass through it. Matter may be opaque because it absorbs light, reflects light, or does both. Examples of opaque objects are solid wooden doors and glass mirrors. A wooden door absorbs most of the light that strikes it and reflects just a few wavelengths of visible light. A mirror, which is a sheet of glass with a shiny metal coating on the back, reflects all the light that strikes it.

Colors of Light

Visible light consists of a range of wavelengths. The wavelength of visible light determines the color that the light appears. As you can see in **Figure** 1.4, light with the longest wavelength appears red, and light with the shortest wavelength appears violet. In between is a continuum of all the other colors of light. Only a few colors of light are represented in the figure.

Separating Colors of Light

A prism, like the one in **Figure** 1.5, can be used to separate visible light into its different colors. A prism is a pyramid-shaped object made of transparent matter, usually clear glass. It transmits light but slows it down. When light passes from the air to the glass of the prism, the change in speed causes the light to bend. Different wavelengths of light bend at different angles. This causes the beam of light to separate into light of different wavelengths. What we see is a rainbow of colors. Look back at the rainbow that opened this chapter. Do you see all the different colors of light, from red at the top to violet at the bottom? Individual raindrops act as tiny prisms. They separate sunlight into its different wavelengths and create a rainbow.

For an animated version of **Figure** 1.5, go to the URL: http://en.wikipedia.org/wiki/File:Light_dispersion_conceptual_waves.gif .

Colors of Objects

We see an opaque object, such as the apple in **Figure** 1.6, because it reflects some wavelengths of visible light. The wavelengths that are reflected determine the color that the object appears. For example, the apple in the figure appears red because it reflects red light and absorbs light of other wavelengths. We see a transparent or translucent object, such as the bottle in **Figure** 1.6, because it transmits light. The wavelength of the transmitted light determines the color that the object appears. For example, the bottle in the figure appears blue because it transmits blue light.

FIGURE 1.3
The objects pictured here differ in the way light interacts with them.

The color of light that strikes an object may also affect the color that the object appears. For example, if only blue light strikes a red apple, the blue light is absorbed and no light is reflected. When no light reflects from an object, it looks black. Black isn't a color. It is the absence of light.

The Colors We See

The human eye can distinguish only red, green, and blue light. These three colors of light are called **primary colors**. All other colors of light can be created by combining the primary colors. As you can see in **Figure** 1.7, when red and green light combine, they form yellow. When red and blue light combine, they form magenta, a dark pinkish color, and when blue and green light combine, they form cyan, a bluish green color. Yellow, magenta, and cyan are called the secondary colors of light. Look at the center of the diagram in **Figure** 1.7. When all three primary colors combine, they form white light. White is the color of the full spectrum of visible light when all of its wavelengths are combined. You can explore the colors of visible light and how they combine with the interactive animations at this URL: http://www.phy.ntnu.edu.tw/oldjava/color/color_e.html .

Pigments

Many objects have color because they contain pigments. A **pigment** is a substance that colors materials by reflecting light of certain wavelengths and absorbing light of other wavelengths. A very common pigment is chlorophyll, which is found in plants. This dark green pigment absorbs all but green wavelengths of visible light. It is responsible for

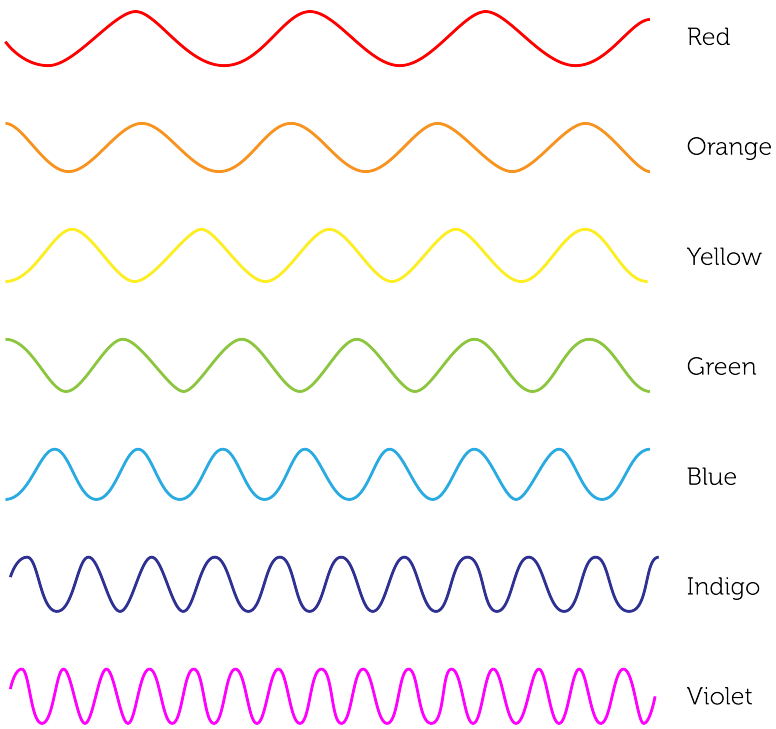


FIGURE 1.4
The color of light depends on its wavelength.

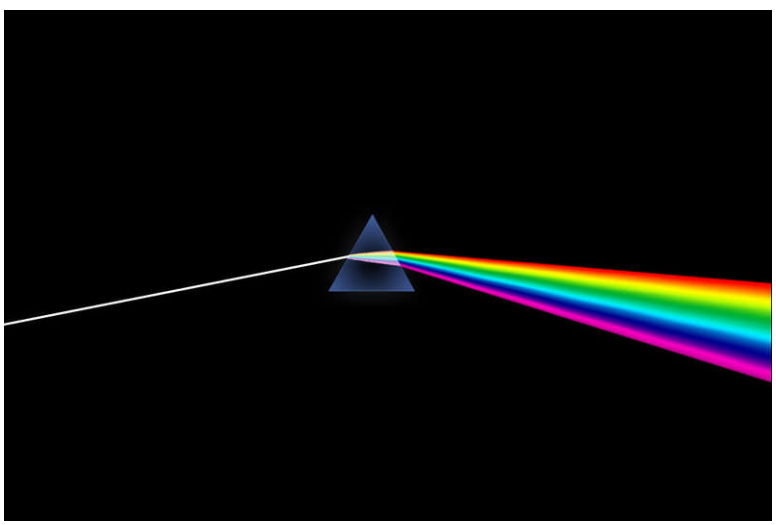


FIGURE 1.5
A prism separates visible light into its different wavelengths.

FIGURE 1.6
The color that objects appear depends on the wavelengths of light they reflect or transmit.

FIGURE 1.7

The three primary colors of light—red, green, and blue—combine to form white light in the center of the figure. What are the secondary colors of light? Can you find them in the diagram?

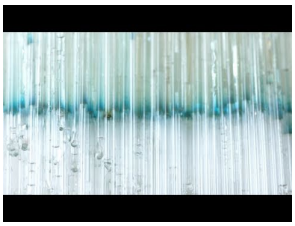
"capturing" the light energy needed for photosynthesis. Pigments are also found in paints, inks, and dyes. Just three pigments, called primary pigments, can be combined to produce all other colors. The primary pigment colors are the same as the secondary colors of light: cyan, magenta, and yellow. The printer ink cartridges in **Figure** 1.8 come in just these three colors. They are the only colors needed for full-color printing.

FIGURE 1.8

Printer ink comes in three primary pigment colors: cyan, magenta, and yellow.

KQED: Color By Nano

Artist Kate Nichols longed to paint with the iridescent colors of butterfly wings, but no such pigments existed. So she became the first artist-in-residence at Lawrence Berkeley National Laboratory to synthesize nanoparticles and incorporate them into her artwork. From the laboratory to the studio, see how Kate uses the phenomenon known as "structural color" to transform nanotechnology into creativity. For more information on using nanoparticles to create colors, see http://science.kqed.org/quest/video/science-on-the-spot-color-by-nano-the-art-of-kate-nichols/ .



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Lesson Summary

- Visible light can be produced by incandescence or luminescence. Incandescence is the production of light by an object that is so hot it glows. Luminescence is the production of light by other means, such as chemical reactions.
- Light may interact with matter in several ways, including reflection, refraction, transmission, and absorption. Matter can be classified on the basis of how light interacts with it as transparent, translucent, or opaque.
- The wavelength of visible light determines the color that the light appears. Red light has the longest wavelength, and violet light has the shortest wavelength. The primary colors of light are red, green, and blue. All other colors of light can be created by combining the primary colors.

Lesson Review Questions

Recall

1. What is incandescence?
2. Define luminescence.
3. Identify two types of light bulbs and describe how they produce visible light.
4. What determines the color of visible light?
5. List four ways that light interacts with matter.

Apply Concepts

6. If only blue light were to strike the bottle in **Figure** 1.6, what color would the bottle appear?

Think Critically

7. Compare and contrast transparent, translucent, and opaque matter.
8. Explain why snow appears white to the human eye.

Points to Consider

In this lesson, you were introduced to the reflection and refraction of light. The next lesson "Optics" describes how mirrors reflect light and how lenses refract light.

- Based on your own experiences with mirrors, how do you think a mirror forms an image of the person in front of it?
- An example of a lens is a hand lens, also called a magnifying glass. This type of lens makes objects look bigger than they really are. How do you think this happens?

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