10.2 Producing Visible Light

Here is a summary of what you will learn in this section:

- Fluorescent light bulbs use much less energy than incandescent light bulbs to produce the same amount of light.
- In both fluorescent and phosphorescent light, a phosphor glows after being exposed to energized particles.
- Chemiluminescence, including bioluminescence, produces cool light from a chemical reaction.
- An electric current passing through a gas or a solid can produce light.

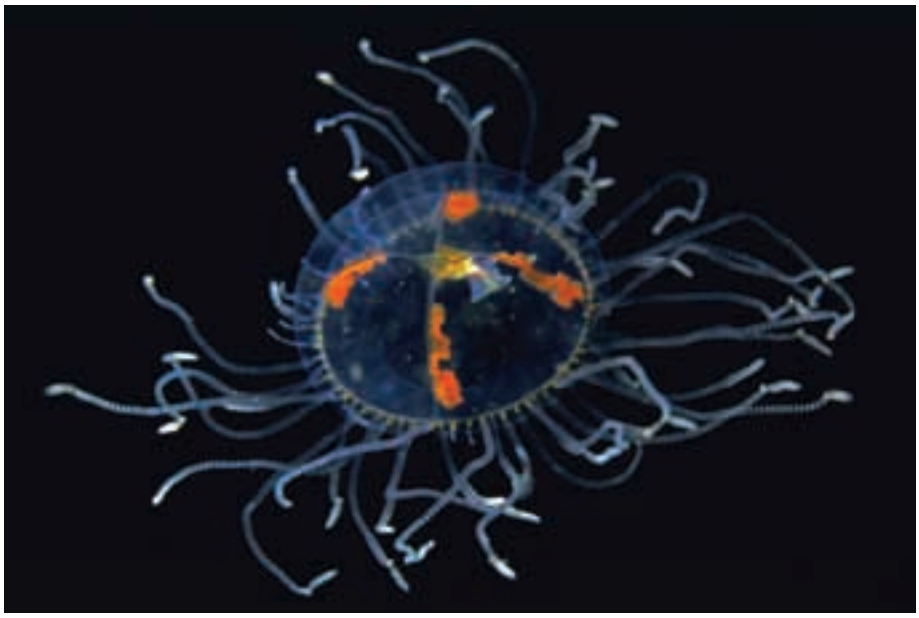

Figure 10.21 In the deep, dark ocean water, this jellyfish uses its light to attract fish, which become trapped in the jellyfish's tentacles.

WORDS MATTER

"Bioluminescence" comes from the Greek word *bios*, meaning living, and the Latin word *lumen*, meaning light.

Lighting Up the Deep

The most important natural source of light on Earth is the Sun. There are, however, other natural sources of light, such as light from other stars, fire, and lightning. Light is also produced by some plants and animals.

The ability of a plant or animal to produce light is called **bioluminescence**. Some algae, jellyfish, insects, crustaceans, bacteria, earthworms, and fungi produce light by bioluminescence (Figure 10.21).

Bioluminescence is very common among sea creatures. In fact, 90 percent of all sea creatures are bioluminescent. Fish that live deep in the ocean have to create their own light because no sunlight can reach that far down. They use their light to find prey, scare off predators, attract mates, or to camouflage themselves. Some fish produce their own light, while others have bacteria that carry out the light-producing chemical reaction for them.

The black sea dragon and the angler fish have a special long spine with a bulb as a lure, attracting smaller fish into their waiting jaws (Figure 10.22). Flashlight fish use their light to help keep their school together as they swim. They can quickly turn off their light if a predator approaches.

Figure 10.22 Angler fish

If you have ever walked through a meadow on a warm summer evening, you may have seen flickering light produced by fireflies. Fireflies attract mates by flashing light in a specific pattern. Fireflies produce their light by a chemical reaction (Figure 10.23).

Figure 10.23 Fireflies emit light from a light-producing organ in their abdomen.

D5 *Quick Lab*

Sources of Light Emission (Teacher Demonstration)

Purpose

To observe several methods of producing light

Materials & Equipment

Some or all of:

- light bulb connected to a dimmer switch
- beaker
- tonic water
- overhead projector
- black light
- pliers
- wintergreen candy
- glow-in-the-dark paints
- plasma ball

CAUTION: Do not shine bright light into anyone's eyes. Incandescent light sources can become very hot. Do not touch the bulbs or block air flow around the light bulbs. Keep all electrical devices and metals away from the plasma ball.

Figure 10.24 A plasma ball

Procedure

1. Work with a partner or in your group to predict all the possible sources that can produce light. Record your predictions in your notebook.
2. Observe as your teacher demonstrates various sources of light. After each demonstration, record your answer for questions 3 and 4.

Sample Demonstrations

A. A clear light bulb containing a filament is connected to a dimmer switch. Observe as the switch is turned up and down.

B. Fill the beaker with tonic water, and place it on an overhead projector. Hold a black light near the beaker. Then, apply clear sunscreen to the outside of the beaker and hold the black light near the beaker again.

C. Use a pair of pliers to crush wintergreen-flavoured candy in a darkened room.

D. Use glow-in-the-dark paints to write a message on a piece of paper. Hold the paper near a light source. Remove the light source, darken the room, and observe the message.

E. Turn on a plasma ball, and touch it.

Questions

3. For each demonstration, was the light produced by high temperature, electricity, chemical reaction, or some combination of these?
4. For each demonstration, explain in a sentence or two why or how light is produced.
5. Return to your predictions from step 1. How do the sources of light demonstrated apply to your predictions in step 1?

Sources of Light

Light produced by the Sun or other stars is called natural light. Light produced through human technology is called artificial light. Think about how many times you flip on a switch and the light immediately comes on. In most cases, the light bulb that lights up is either a fluorescent bulb or an incandescent bulb.

Incandescent Light

Incandescent light is light that is produced by an object, such as a metal, that is at a very high temperature. Inside an incandescent light bulb is a filament, which is a thin piece of wire (Figure 10.25(a)). When you turn on an incandescent bulb, electric current flows through the filament, heating it to an extremely high temperature. The filament emits light as a way to release some of its energy. The light you see from an incandescent bulb is the filament glowing.

Incandescent bulbs are extremely inefficient. Only 5 percent of the electrical energy used in an incandescent light bulb is converted to light. The rest of the energy is released as heat. Because they waste more energy than fluorescent lights, incandescent bulbs are being eliminated from widespread use.

WORDS MATTER

"Incandescent" has its roots in the Latin word *incandescere*, which means to become white with heat.

Figure 10.25 (a) An incandescent bulb and (b) a compact fluorescent bulb. The fluorescent bulb uses a quarter the energy of the incandescent bulb but contains more toxic materials than an incandescent bulb.

Fluorescent Light

Fluorescent light is light emitted by some substances when they are exposed to electromagnetic radiation. A fluorescent light bulb is a glass tube filled with a small amount of a gas such as mercury vapour. The inside of the bulb is coated with a white powder called a phosphor. A **phosphor** is a substance that glows after being exposed to energized particles. As electric current passes through a fluorescent bulb, it energizes the atoms in the gas, which then emit ultraviolet radiation. The ultraviolet radiation strikes the phosphor on the inside of the bulb, which then glows and emits light (Figure 10.25(b)). Compact fluorescent light bulbs are much more efficient than incandescent light bulbs, but they still release up to 80 percent of their energy as heat (Figure 10.26).

Figure 10.26 A researcher testing the endurance of fluorescent light tubes

Phosphorescent Light

In fluorescent lights, the phosphor emits light only while it is exposed to ultraviolet radiation. However, some substances have the ability to store energy from radiation. **Phosphorescence** is the ability to store the energy from a source of light and then emit it slowly over a long period. Phosphorescent materials glow in the dark for some time after being energized by light (Figure 10.27). The light from glow-in-the-dark objects eventually fades, but it can be re-energized if the object is held close to a light source for a few minutes.

Figure 10.27 This glow-in-the-dark toy emits light by phosphorescence.

Chemiluminescence

Chemiluminescence is light produced from a chemical reaction without a rise in temperature. Because the chemical reaction gives off very little heat, the light produced is sometimes referred to as cool light. All forms of bioluminescence are special kinds of chemiluminescence.

An example of chemiluminescence is the light produced in glow sticks (Figure 10.28). Chemiluminescence is also used in analyzing crime scenes. Investigators use a chemical called luminol to detect traces of blood because the chemical glows when it reacts with the iron found in blood (Figure 10.29).

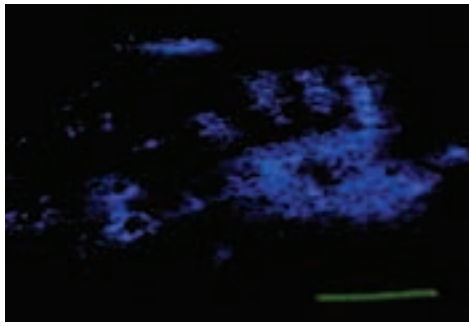

Figure 10.29 Luminol makes a blood stain glow in the dark.

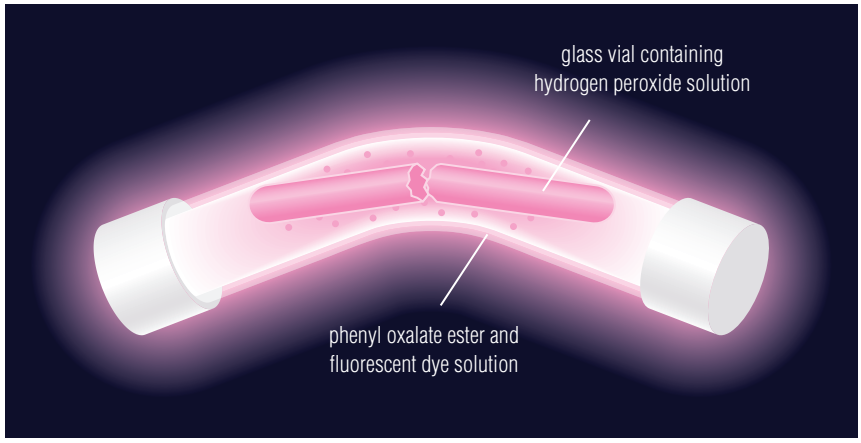

Figure 10.28 A glow stick is activated when the stick is bent. This action breaks a glass vial inside the stick and allows two chemicals to mix and react.

Learning Checkpoint

1. What do all incandescent materials have in common to cause them to emit light?
2. What percentage of electrical energy used in an incandescent light bulb is converted to light?
3. How is the ultraviolet radiation produced in a fluorescent light transformed into visible light?
4. What is phosphorescence?
5. Why is chemiluminescence sometimes referred to as cool light?

During Reading

Thinking Literacy

Get the Picture

Even without an accompanying photograph, good readers use words to make pictures in their minds. Read the passage describing triboluminescence. Try to see the examples vividly in your mind.

Triboluminescence

Producing light from friction is called **triboluminescence**. Some crystals can be made to glow simply by rubbing them together or crushing them. The Ute Aboriginal people of Utah and Colorado traditionally made ceremonial rattles containing 30 pieces of quartz. The rattle was made of thin buffalo hide to permit flashes of light to pass through. Triboluminescence can also be produced by breaking apart sugar crystals or rubbing a diamond (Figure 10.30).

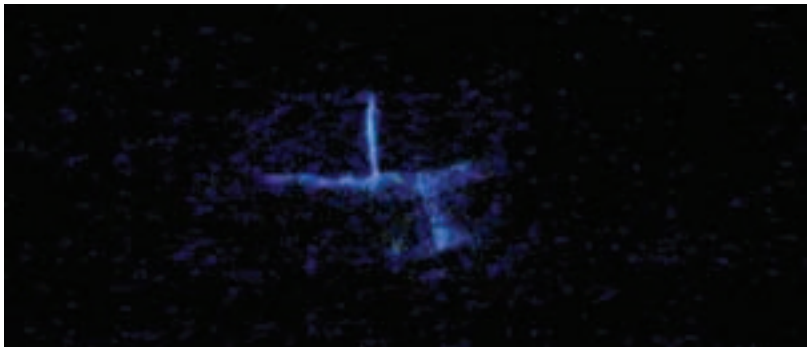

Figure 10.30 This faint light was produced by crushing a wintergreen candy with a hammer.

WORDS MATTER

"Triboluminescence" comes from the Greek word *tribein*, meaning to rub, and the Latin word *lumen*, meaning light.

Electric Discharge

An **electric discharge** is a method for producing light in which an electric current passes through the air or another gas, such as neon (Figure 10.31). Lightning is one example of an electric discharge. Just as a bolt of lightning can light up the sky, carbon-arc light sources can be used to produce searchlights with beams so powerful that their light can reflect off of the bottoms of high clouds. A carbon-arc light involves passing an electric current through the air, or another gas, between two carbon rods (Figure 10.32).

Figure 10.31 When electricity is discharged through the element neon, which is a gas, the neon glows intensely.

Figure 10.32 Carbon arc lighting was once used in lighthouses.

Light-Emitting Diode (LED)

The process of transforming electrical energy directly into light energy is called **electroluminescence**. Electroluminescent devices consume much less energy than sources such as fluorescent devices. A **light-emitting diode** (LED) is an electroluminescent light source made out of a material called a semiconductor. A semiconductor is a material that can be made to change how well it conducts electricity. Some semiconductors can be made to emit light when a small electric current is passed through them.

LEDs do not have a filament. Instead, they are solid materials. This makes them very rugged, because they do not contain any delicate parts (Figure 10.33). In fact, some LED devices from the 1960s are still operating today. Because they can operate using small amounts of electricity, LEDs are very efficient producers of light and radiate very little heat. LEDs are used in many places, such as in electronic billboards, traffic lights, decorative lights, and handheld displays (Figure 10.34). LEDs can also replace incandescent and fluorescent light bulbs, conserving energy and lasting a longer time. For example, LEDs can light up much faster than incandescent bulbs, so LEDs are often used for rear brake lights in automobiles. Their faster lighting time means that the driver following the automobile has more time to react and avoid an accident.

Figure 10.33 An LED is a device that produces large amounts of light from very little energy input.

Figure 10.34 LEDs provide the backlight for many handheld devices.

OLEDs

An **organic light-emitting display** (OLED) is a light source made of several extremely thin layers of organic molecules that use an electric current to produce light. An OLED is made of thousands of individual organic light-emitting diodes that use different organic molecules to emit different colours of light. OLEDs use less energy than some other displays because they do not require a backlight to function. They are thinner, lighter, brighter, and more flexible (Figure 10.35). In fact, they are so flexible that OLEDs can be rolled up or embedded in fabrics or clothing. OLED technology has potential application in small screens such as cellphones, medical equipment, and head-mounted displays, and in large screens, such as television and computer screens. OLEDs are more expensive to produce than some other displays and are easily damaged by water, but these disadvantages are diminishing as their design continues to be refined.

Figure 10.35 A researcher holds a panel of organic light-emitting diodes.

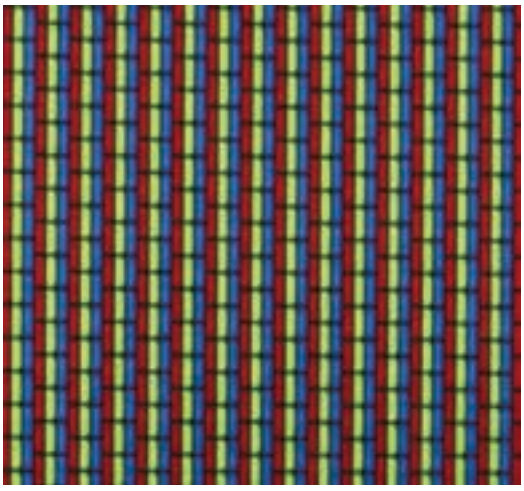

Figure 10.36 Plasma screens use fluorescence to emit light.

Plasma Displays

Many large-screen televisions use a technology called a plasma display, which can produce brighter images than an LCD display but requires much more electrical power to operate (Figure 10.36). In a **plasma display**, each colour is a tiny fluorescent light in which an electrical signal causes a gas, such as neon, to release ultraviolet radiation. The ultraviolet radiation is absorbed by phosphors that then radiate light in the visible spectrum. Different phosphors are used to produce red, green, and blue light. By varying the brightness of each primary colour, millions of colours can be produced.

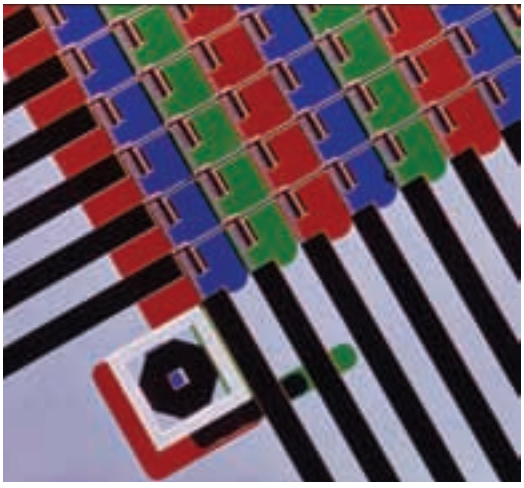

Figure 10.37 A light micrograph of a colour LCD screen, magnification 20× at 6 × 7 cm

Liquid Crystal Displays

Laptop computers, digital watches, cellphones, iPods, and many flat-panel television sets use a different technology than plasma displays and LEDs. In a **liquid crystal display** (LCD), a white light, such as a fluorescent light or light-emitting diode, shines behind a liquid crystal. A **liquid crystal** is a solid that can change the orientation of its molecules like a liquid, but only when electricity is applied. The crystal can block light or transmit light depending on how much electricity is applied to it. Red, green, and blue filters are placed in front of the crystal to produce these colours. A special filter called a polarizing filter blocks the red, blue, or green colours in any combination to produce any colour of light. In Figure 10.37, each tiny square of colour is called a pixel.

Since liquid crystal displays work by blocking light, the white light that shines behind the crystals is always on, and just like blinds that cover a window, the crystal does not block all the light coming through. For this reason, the black in LCDs does not appear completely black, but only dark grey.

Suggested STSE Activity
D6 Decision-Making Analysis on page 399

Suggested Activity
D7 Quick Lab on page 400

Learning Checkpoint

1. What term is used to describe light produced by friction?
2. How does an electric discharge produce light?
3. One of the main components of a light-emitting diode is a semiconductor. What is a semiconductor?
4. What happens in each tiny fluorescent light in a plasma display?
5. What is a liquid crystal?

D6 STSE *Decision-Making Analysis* Skills Reference 4

SKILLS YOU WILL USE
- Organizing information from research
- Drawing conclusions

Is a Plasma Television or an LCD Television Better for the Environment?

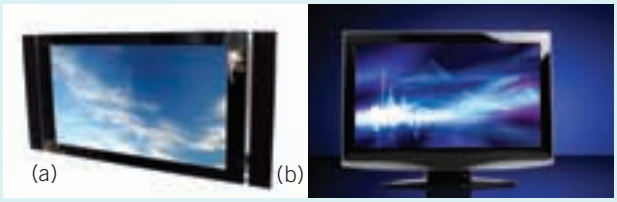

Figure 10.38 (a) Plasma screen and (b) LCD screen. Each type of screen has advantages and disadvantages.

Issue

What is on tonight? In Canada, the answer is sure to be a lot of televisions. Most Canadian homes have one or more televisions, and unlike many small or portable electronic devices, televisions can use a considerable amount of electrical energy. This means that by consuming electricity, televisions are significant producers of greenhouse gases. Televisions may also contain toxic and difficult to recycle materials,

The environmental impact of a particular type of television can vary depending on how large its screen is and how often it is used. Which kind of television is best for the environment?

Background Information

There are different types of televisions depending on what technology is used to make the display screen. Two very common recent technologies are plasma and liquid crystal display (LCD). Each type has its advantages and disadvantages, and there may not be just one correct answer when it comes to which is more eco-friendly.

The biggest advantage of LCD televisions may be that they last up to twice as long as other types. LCD televisions are lighter weight and thinner, and they consume less energy than a plasma type. However, the largest LCD screens use significantly more energy than smaller ones. The biggest disadvantage of LCD televisions may be in their components. LCD components use both mercury and nitrogen trifluoride (NF_3), a gas that is over 10 000 times more potent a greenhouse gas than carbon dioxide. Currently, the amount of NF_3 being added to the atmosphere is about equal to the amount of other greenhouse gases being added from operating two million cars.

Plasma televisions are often used in very large displays and are known for a sharp and detailed picture. They have a wide viewing angle so they can be seen more easily from the side. Also, black appears darker on plasma screens. Some plasma televisions use up to 30% less power than other plasma brands of the same screen size. Power consumption increases greatly with screen size, more than other style displays. For example, a very large living room plasma display may consume more than four times more energy than that of a traditional picture tube television. The electricity bill is correspondingly higher as well. Some types of plasma screen include lead in their components.

Analyze and Evaluate

Your task is to compare plasma versus LCD televisions in terms of which is better for the environment. The most eco-friendly choice might be to not have a television at all, especially one with a very large screen. Complete the following steps in your analysis.

1. ***ScienceSource*** Update the background information given above. Look for new technologies that might be better than plasma or LCD displays. If so, then you will need to explain why they are better. Manufacturing processes change. For example, LCD manufacture that does not involve mercury is currently being developed.
2. Make a list in point form of advantages and disadvantages of each technology.

Skill Practice

3. Make a list of ways you or your family make use of television and what features in a television you think are important for the way you use one.
4. Make a conclusion about whether your family wishes to use a television and, if so, what kind is best for you.