Integrated Science

Science course from Educational Options

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Lesson 8: Light

Objectives

By the end of this lesson, students will be able to:

- summarize the properties of electromagnetic waves and the electromagnetic spectrum
- identify wave and particle characteristics of light
- explain how light behaves under certain conditions
- apply how light is used in technology
- explain and apply the laws of reflection and refraction
- explain the Doppler Effect as it relates to light

Click here for the course glossary

Introduction

Think of all of the things you did today. Did you talk on a cell phone? Did you microwave a meal? Did you go out into the sun? Did you watch television or listen to the radio? All of these activities are possible because of waves. Waves carry information to and from our cell phones and televisions, provide heat to our microwave meals, and transmit warmth and light from the sun. Even if you did not do any of these activities today, you are using light waves right now just by looking at this computer screen. Waves are invisible, but they are all around us.

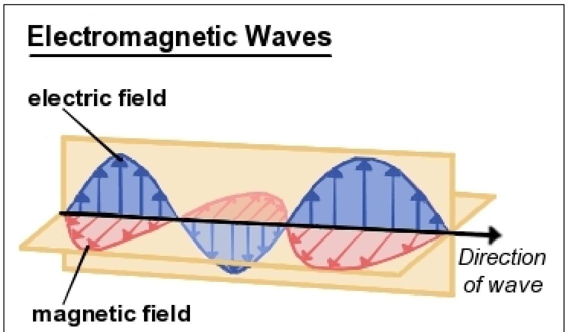
This sign warns of hazardous radio waves. Constant exposure can cause health problems.

So far you know about the properties of waves. You also know about sound waves and how they travel. This lesson focuses on electromagnetic waves and light, their properties, and how they are used. This lesson builds on the information from the previous lessons on waves, their properties, and interactions. If you are unfamiliar with any of the concepts presented here and would like more explanation than the glossary provides, refer to the Waves lesson and the Sound lesson.

What Is Light?

Before exploring the different types of light, take a look at the components of light. Light is made up of electromagnetic waves. Read on to learn more about these kind of waves and their characteristics.

Electromagnetic Waves



Electromagnetic waves are like mechanical waves in that they carry energy from place to place.

Electromagnetic waves are waves that are made up of changing electric fields and changing magnetic fields. They carry wave energy from place to place, but do not require a medium through which to travel. Electromagnetic waves are able to travel through solid, liquid, or gas **media**, but travel fastest through empty space.

An **electric field** is a region of space that exerts electric force on charged **particles**. Electric fields are produced by electrically vibrating charges and changing magnetic fields. A **magnetic field** is a region of space that produces magnetic forces. Magnetic fields are produced by changing electric fields or by vibrating charges. When an electric charge vibrates or accelerates, electric fields and magnetic fields come together to produce electromagnetic waves. The vibration of the electric field causes the magnetic field to vibrate as well. This chain reaction results in an electromagnetic wave.

Notice in the diagram that the fields vibrate at right angles to each other. Electromagnetic waves are considered **transverse waves**. The electric fields and the magnetic fields travel perpendicular to each other. They are also perpendicular to the direction of the wave.

Since changing electric fields cause magnetic fields to change, and changing magnetic fields cause electric fields to change, the fields keep each other going. For this reason, electromagnetic waves do not need a medium through which to travel. They can travel through a medium, but they travel best without a medium, through a **vacuum**. When electromagnetic waves travel through matter or in a vacuum, this is called **electromagnetic radiation**.

In a vacuum, all electromagnetic waves travel at the same rate. The speed of an electromagnetic wave in a vacuum is represented by *c* and is often referred to as the *speed of light*.

$$\textbf{Speed} = 3.00 \times 10^8\,\text{m/s}$$
$$c = 3.00 \times 10^8\,\text{m/s}$$

The speed of an electromagnetic wave is calculated in meters per second (m/s).

Wavelength and Frequency

Although all electromagnetic waves in a vacuum travel at the same speed, they are not all the same. Different types of electromagnetic waves have different wavelengths and frequencies. Light, x-rays, and radio waves are three types of electromagnetic waves.

The speed of an electromagnetic wave is the product of its wavelength and its frequency.

$$\textbf{Speed} = \textbf{Wavelength} \times \textbf{Frequency}$$
$$S = \lambda \times f$$

For example:

A radio station's signal is broadcast at a wavelength of 3.0 meters. What is the frequency of the wave?

Speed = **Wavelength** × **Frequency**
or

$$\text{Frequency} = \frac{\textbf{Speed}}{\textbf{Wavelength}}$$

$$f = \frac{c}{\lambda}$$

$$f = \frac{3.00 \times 10^8 \text{ m/s}}{3.0 \text{ m}}$$

$$f = 1.0 \times 10^8 \text{ hz}$$

The frequency of the radio wave is 1.0×10^8 hz.

Since the speed portion of the equation is always the same, the wavelength and frequency are inversely proportional. This means that as the wavelength increases, the frequency decreases. If you know either the wavelength or the frequency of an electromagnetic wave, you can calculate the other.

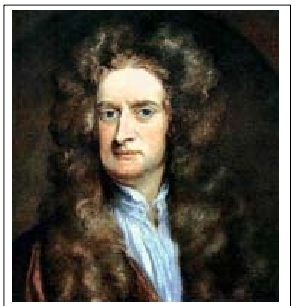
A flashlight close to a surface gives off a more intense light.

Intensity

In previous lessons you learned about intensity. **Intensity** is the rate at which energy flows through a given area in a given amount of time. When it comes to light, think of intensity as brightness. Light's intensity decreases as the distance from the source increases. For example, if you hold a flashlight close to a wall, the shining circle of light is bright and small. If you shine the flashlight at the same wall, but stand eight feet back, the circle of light is not as clear. The light that comes from the flashlight is no less bright. It is the same amount of light spread out over a larger area.

Light: The Debate Over Waves or Particles

For a long time, scientists knew that electromagnetic radiation traveled in waves. In the 1600s, Isaac Newton suggested that electromagnetic radiation (more specifically light) was made up of particles. He had a way to test this **hypothesis**. First, he used a prism to produce a rainbow to study the properties of light. Newton found that sunlight separated into many colors but appeared as white light when combined. He called those colors a *spectrum*, from the Latin word for ghost. Newton thought that if the colors of light were able to be separated when passing through the prism, this must be due to **refraction**, or bending, of light. Newton wondered what light was made from since it could separate itself into different colors.



Isaac Newton, 1642-1727

Newton's Particle Theory

Isaac Newton believed that light must be made out of many tiny particles. He could prove his hypothesis, but there were still a few questions that he could not answer. For example, when two beams of light cross, they do not interfere with each other. If light is made of particles, why don't the two beams of light affect each other? Why don't the particles get mixed up where the beams cross? Also, why do some colors refract better than others?

Newton and his followers used shadows to prove his theory. Light did not curve around obstacles, but continued on its straight path, leaving sharp shadows. This must mean that light rays contained particles.

Christiaan Huygens, 1629-1695

Huygens's Wave Theory

A Dutch physicist named Christiaan Huygens disagreed with Newton. He believed that light was made up of tiny waves instead of particles. His proof included arguments that there was a type of wave that moved in straight lines. He also believed that under certain conditions two beams made of waves could cross without interfering with each other. The problem with Huygens's theory was that many people could only imagine waves as they are in water. How could they not interact with a barrier such as another wave? Also, if light was made of waves, wouldn't it curve around barriers and cast only a fuzzy shadow? Huygens proposed that there were different lengths of waves, and only the longest ones cast shadows.

In the end, Huygens had a better argument, but Isaac Newton's popularity as a great scientist was growing. So, until the early 1800s most people believed light was made up of particles. In 1801, English physicist Thomas Young performed an experiment in which he allowed light to shine through slits in a box. If light was made of particles, then when the light from two slits overlapped it should be brighter as the particles combine. This did not happen. The parts that overlapped were made up of bands that alternated darker and lighter. Young could not explain this using the particle theory.

The wave theory, however, could explain this phenomenon using the properties of waves we now call **constructive interference** and **destructive interference**. The wave theory also explained some of the other behaviors of light. For the next 80 years, the scientific community accepted the fact that light was made of waves. That is, until people started to ask questions again. If light, like sound, was made up of waves, why could light travel through a vacuum but sound could not?

In 1905, Albert Einstein added his knowledge to the theories on light. He suggested that electromagnetic waves traveled in little packets of energy, now knows as **photons**. Photons are proportional to light's frequency. That means that the greater the electromagnetic wave's frequency, the more energy in each photon. This new definition of light supported the particle theory.

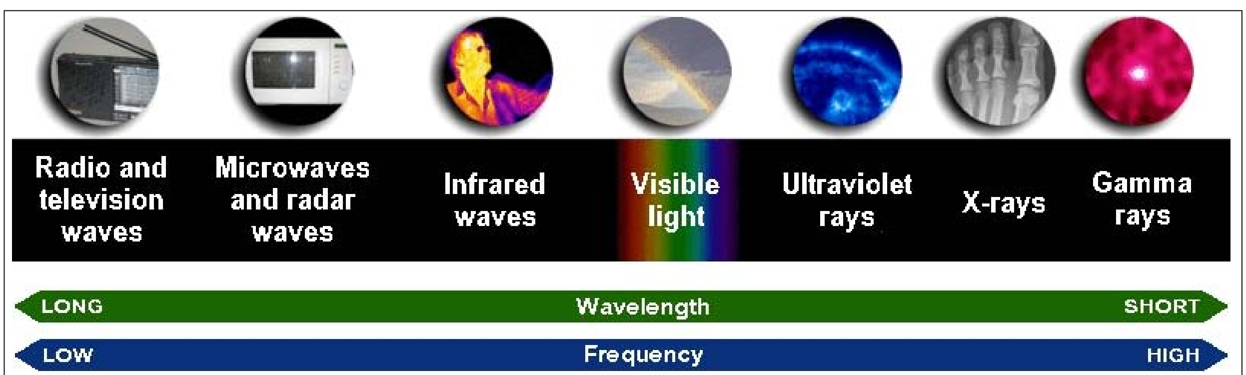
So which is light: waves or a stream of particles? The answer is both. Electromagnetic radiation can behave either like a wave or like a stream of particles.

The Electromagnetic Spectrum

Around 1800, a German scientist named William Herschel experimented with light. Like Newton, he used a prism to separate the wavelengths in sunlight. What he found was a range of color from red to violet. Herschel wondered if the individual colors had individual temperatures, and set up an experiment to find out. He used a prism to separate sunlight into colored bands on a table. Then he placed thermometers at the center of each color band. He found that each color band had its own temperature range. Temperatures at the violet end were cooler, and temperatures at the red end were hotter.

If each color band had its own temperature, Herschel wondered, what about the areas outside of the visible light? Are there wavelengths that we cannot see? He placed a thermometer just outside the band of visible red light. He found that the area just outside the red band measured a higher temperature than the red band. Herschel concluded that there was more to the spectrum than previously thought. In addition to the light that can be seen, clearly there is invisible radiation that the human eye cannot see. Herschel's work was a huge leap forward for scientists studying electromagnetic properties.

The **electromagnetic spectrum** refers to the entire range of frequencies of electromagnetic radiation. All of the waves that enable us to see are contained in the visible spectrum. The **visible spectrum** is the range of wavelengths that are visible to the human eye. It contains all of the colors in the rainbow. The visible spectrum is just a small portion of the electromagnetic spectrum. See the diagram below for the range of waves that are included in the spectrum. Each kind of wave has its own characteristics, wavelengths, and frequencies.



The electromagnetic spectrum in order of increasing frequency from left to right

Types of Electromagnetic Waves

Aside from visible light, there are many other types of electromagnetic waves.

Radio Waves

Radio waves have the longest wavelengths and the lowest frequencies on the electromagnetic spectrum. Radio stations use radio waves to broadcast their signals. Did you know that, in a car radio, AM signals travel farther and better around Earth's curved atmosphere? Particles in the atmosphere reflect AM radio waves much better than FM radio waves, which broadcast at higher frequencies.

Television stations also use radio waves. The radio waves for TV signals, however, carry information for picture as well as sound. If you have an antenna, your television receives the signal directly, but it is affected by location and weather. If you have cable television, the cable company receives the signals and then sends them to your TV. If you have a satellite dish, the TV signals are sent first to the satellites in space and then back to Earth.

Microwaves

Microwaves and radar waves are also types of radio waves. When you hear the word "microwave," you probably think of the machine that cooks food (like the one pictured here). It is true: microwave ovens are so-named because they use microwaves to increase thermal energy inside fat and water molecules in food.

There are other types of microwaves too. Cell phone conversations are transmitted by microwaves. Radar is another type of microwave. Radar, an acronym for **ra**dio **d**etection **a**nd **r**anging, sends out short bursts of radio waves. They bounce back and are read by a receiver, much like the sonar device mentioned in the lesson on Sound.

Infrared Waves

Infrared waves cannot be seen, but they can be felt. You may have seen infrared lamps in zoos or pet stores, where they are often used to keep animals and reptiles warm. They are also used on buffet tables to keep food warm. Building owners also use infrared imaging to find out where heat is leaking. This knowledge helps conserve energy.

Infrared technology is also used in search and rescue operations. After a disaster such as a building collapse, rescue workers use infrared cameras to search for survivors. These cameras pick up body heat from survivors, making them visible when buried under debris. Infrared cameras can even be used when searching underground.

Ultraviolet Waves

Ultraviolet rays, or UV radiation, have frequencies that are a little bit higher than visible violet light. You may think of them as the harmful rays from the sun that can cause a sunburn. But ultraviolet rays can be good, too. When skin is not overexposed to them, they help the body produce vitamin D. Vitamin D helps bones and teeth stay healthy.

Ultraviolet rays are also used to kill bacteria and other microorganisms. Water treatment facilities pump in and treat sewage to become usable again. One of the last steps of treatment is to run the water through UV lights. The UV lights sterilize any bacteria left in the water. This leaves them unable to reproduce, so they cannot cause harm if they are consumed.

X-Rays

If you have ever broken a bone, you have probably had an X-ray. X-rays have very short wavelengths that can travel through solid matter where light cannot. X-rays are used in medicine to take

pictures of teeth and bones. Tissue that is softer than bone appears dark on an X-ray, and dense bone shows up as white. When X-rays were first invented, they were used to treat many conditions, from cancer to skin treatments in beauty clinics. However, people who had received many treatments became sick. Soon, the doctors who used the machines became sick too. It was discovered that X-rays contain radiation, and their use was limited to only what was necessary.

X-rays are used in many industries. Airports use X-rays to examine luggage and packages before allowing them on planes. Canneries use X-rays to be sure cans are sealed before shipping. Cargo in shipping containers and trucks is often X-rayed to be sure it does not contain anything illegal.

Gamma Rays

Gamma rays have the shortest wavelengths on the entire spectrum. They are found in high energy events such as nuclear explosions and exploding stars. Human exposure to small amounts of gamma rays is not harmful, but too much can be deadly.

Gamma rays are used to kill cancerous cells without harming the surrounding cells. They are also used to take pictures of the brain. Scientists study the properties and interactions of gamma rays because they help them understand events in space that produce high-energy, such as black holes and **supernovae**.

Types of Light

An obvious source of light is the one we would have trouble living without: the sun. The sun gives off energy in the form of heat and light. Sunlight is **white light**, or visible light. White light occurs when all of the colors in the visible spectrum are combined. The sun is **luminous**, meaning it gives off its own light. Luminous objects may produce light in many different ways. Fireflies, lamps, flashlights, and the sun all produce their own light and, therefore, are luminous.

A glowing filament from a 50 watt light bulb

Incandescent Light

Incandescent light comes from an object that is hot enough to glow. A standard lightbulb is an example of incandescent light. Light is produced in a bulb when electrons flow through a thin wire called a *filament*. When electrons travel through the filament, it gets hot and glows. The glow is what gives off light (and heat too). The bulb itself is filled with a gas that helps the filament last longer.

Incandescent lightbulbs actually emit more energy as heat than light.

Fluorescent bulb

Fluorescent Light

Fluorescence is a process in which a material takes in light at one wavelength and gives off light at a longer wavelength. Phosphor is a solid material that can give off light using fluorescence. When phosphors emit photons they produce visible light. For example, the inside of a fluorescent bulb is coated with phosphors. As electric current flows into the bulb, pieces of metal inside heat up and produce electrons. The electrons interact with mercury vapor inside the bulb, which causes the mercury atoms to give off ultraviolet rays. The ultraviolet rays cause the phosphor coating to give off light.

Fluorescent light is very efficient and does not get as hot as incandescent light. For this reason, many office buildings and schools use fluorescent bulbs because they are safer and conserve energy.

A military scientist experiments with lasers.

Lasers

The word laser is an acronym for **l**ight **a**mplification by **s**timulated **e**mission of **r**adiation. Lasers create a beam of light by exciting atoms that emit photons. They give off a beam of light that is one color and does not spread out from the source. Laser light is focused on a small area and its intensity is constant.

Lasers have many applications. Because they are focused beams of intense light, they are used in medicine to make precise cuts during surgery, in jewelry-making to drill holes in diamonds, and in digging perfectly straight tunnels in construction projects. Lasers are also used in stores to scan bar codes on merchandise, in CD and DVD players, and to reshape the lens of the eye in certain types of surgery.

This neon light is produced by a mixture of mercury vapor and argon gas.

Neon Light

Neon is a gas that gives off light when electrons move through it. You have probably seen neon lights on signs. Actually, many of these use a mixture of gases that are not necessarily neon. Different gases produce the many different colors that can be found in "neon" lights. Each kind of gas gives off photons of different energies. Different energies emit different colors. For example, neon gas produces a reddish-orange glow, helium gives off a pinkish light, and krypton gives off a purple glow.

Neon light is used mostly in advertising signs. However, one of neon's properties is that it takes very little current to make it glow at a constant light. For this reason, small neon lamps are often used in electronic equipment to test if the machinery is getting power.

How Does Light Behave?

Different sources of light behave in different ways. However, there are some properties that all light sources have in common. How much light passes through or bounces off of objects, for example, determines whether or not they can be seen. Without light, you would not be able to see anything at all.

Light and Other Materials

Why can you see through water, but not a cardboard box? The behavior of light depends on many things. What an object is made of is just one of the factors that determines how light behaves around, on, or in that object. Every type of material affects light differently.

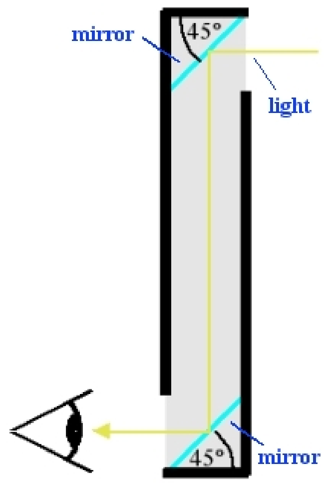
Pictured here are three different types of windows. Each one causes light to behave in a different way.

This window is transparent. **Transparent** materials transmit light. They allow almost all of the light to pass through the object. You can see through transparent materials completely. The image is not distorted in any way.

Stained glass windows are translucent. **Translucent** materials allow some of the light to pass through, but not all of it. You can see light through translucent materials, and maybe fuzzy shapes or shadows of things on the other side of the material.

One hundred percent tinted windows like the ones on the sides of this limousine are opaque. **Opaque** materials do not let light through. Light is either absorbed or reflected. The side windows on this limo are tinted to be opaque, so that no one can see into the vehicle.

Try This!



Reflecting Light
A periscope is an optical device that is used to view objects that are out of sight. Periscopes are commonly found on submarines, where they are used to view objects that are above sea level. A

periscope is able to project images by using the principles of reflection.

You can make your own periscope by using two mirrors. Sit below a window, facing the wall. Make sure that you are sitting low enough so that you cannot see out the window. Hold one mirror up in front of the window. Hold the other in front of your line of vision. Tilt each mirror at a 45° angle, as shown in the diagram above. The top mirror will reflect the light from the outside into the bottom mirror. You should be able to see a clear image of objects outside the window.

Reflection is a property of all waves. **Reflection** is the behavior of a wave when it bounces off of a barrier. When it comes to light, there are two types of reflection: regular reflection and diffuse reflection. **Regular reflection** occurs when light strikes a surface at many points that all bounce off in the same direction. This produces a clear reflected image. **Diffuse reflection** occurs when light strikes an uneven surface and bounces off in many different directions. This produces a blurry or distorted image.

Have you ever ordered printed photographs? Usually you have the choice to select a glossy or matte surface. A glossy print has a smooth surface that reflects light in the same direction. This can be a good thing, because the color and picture quality are sharper. However some people find the glare on the picture distracting. The matte surface is rough (if you looked at it through a microscope) and so it diffuses the light. That is, the light bounces off of the surface of the picture at many different angles. This eliminates the glare from the surface of the photograph, but some of the color and picture quality are lost.

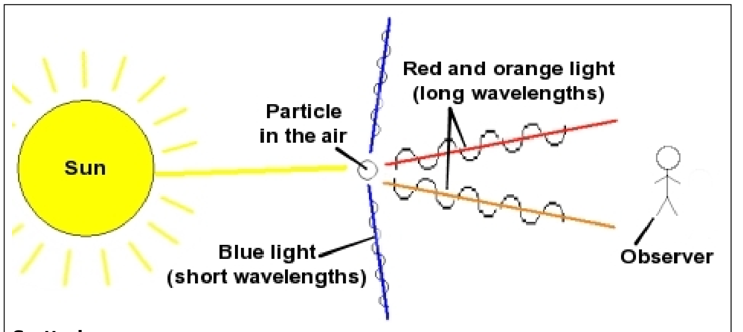
Think About It

Which of the following pictures shows regular reflection? Which shows diffuse reflection? How can you tell?

Light is made up of electromagnetic waves, and so the property of refraction is also in its nature. Recall that **refraction** is the bending of a wave as it passes at an angle from one medium to another. One example of refraction of light is the illusion of the bent straw in a glass of water (see the lesson on Waves). Another example of refraction is a *mirage*. A mirage occurs when light is refracted through layers of hotter and hotter air. Often this happens just above pavement or sand on a hot day. It can make the road or sand appear wavy or even watery.

This mirage makes the road look as if it dissolves into water.

When the sun sets, the sky lights up with reds, oranges, and yellows. Have you ever wondered why sunsets are not purple or blue? As the sun sets, its light has to pass through the atmosphere, a medium made up of lots of tiny particles and molecules. As the sunlight passes through this medium, some of its light reflects off of the tiny particles. Short wavelengths are easily reflected. Blue light and purple light have the shortest wavelengths, so those colors are reflected, or scattered. **Scattering** is when light is redirected as it passes through a medium. Blue and purple light is scattered. The colors with the longest wavelengths, red and orange, carry on to reach your eyes. The diagram below shows how scattering works. Keep in mind that scattering occurs as the sunlight runs into many particles, even though just one particle is shown in the diagram.



Scattering

Think About It

Why does the sky appear blue during the day? *Hint: think about what you just read about scattering, and remember that the Earth's atmosphere is curved.*

How Do We Use Light?

For many centuries, scientists struggled to define light. Once the properties of light were understood, scientists began to think of ways to use it.

Studying Space

You have learned about the **Doppler effect** as it applies to sound. The Doppler effect is the change in a sound's frequency caused by the motion of the sound's source, the listener's position, or both. But the Doppler effect applies to light as well. Scientists have found a way to measure and calculate the movement of far away stars using the Doppler effect as it applies to light. When it comes to light, the change appears as a shift in color.

Suppose an astronomer has been observing a certain star. By observing the color of the star, he can tell whether the star is moving closer to or farther away from Earth. If a star's light appears to be shifting to a violet color, the distance between the star and Earth is decreasing. This phenomenon is called *blueshift*.

If the star's light appears to shift toward the red end of the spectrum, then the distance between the star and the Earth is increasing. Longer wavelengths travel further, so when a celestial object is far away it appears red. The scientist measures the shift in color to find out the distance of a star. This phenomenon is called **redshift**.

Mirrors

The study of visible light and vision is called **optics**. Optics also includes the study and use of mirrors and lenses. Mirrors and lenses are a huge part of using light to study the world around us. One key part to understanding optics is to first understand that light travels in straight lines. These straight lines are called *rays*. Rays of light travel until their path is interrupted by something and then they interact with that barrier.

There are three types of mirrors: plane, concave, and convex. Each produces a different type of image. A plane mirror is flat, and produces a virtual image. A **virtual image** is a copy of an image that is formed at the place from where the light rays come. When you look into a bathroom mirror, you are seeing a virtual image.

A **concave mirror** is a mirror in which the inside of a curved surface is reflective. The curved part of the mirror causes the rays of light to come together. This focuses the light in a specific place, which makes an image. The image made by a concave mirror is called a real image. A **real image** is an image that is formed at the point at which the light rays actually meet. Depending on where an object is in relation to the mirror, concave mirrors can form either virtual images or real images.

Clerks can see more of the store when convex mirrors are installed.

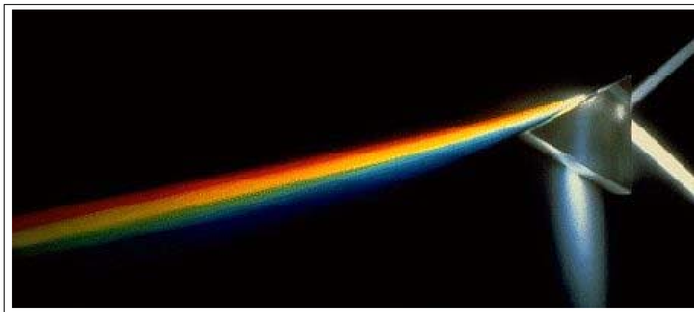
Concave mirrors are usually not used to project an image. They are used in devices like flashlights and car headlights to reflect and focus the light into a beam. When the light rays are reflected together, the beam of light is stronger and brighter.

A **convex mirror** is a mirror on which the outside is the reflective surface. The curved surface of the mirror makes the reflected light rays branch out. Convex mirrors always form virtual images. These virtual images are always smaller than the actual object, due to the curved surface of the mirror.

Because convex mirrors are curved and show images as smaller, they are often used in stores to deter shoplifters and at dangerous intersections so that cars can see better around corners. Have you ever noticed the warning on a car's side-view mirror that says "objects in mirror are closer than they appear"? The side-view mirror is a convex mirror that shows virtual images that are smaller than in real life.

Lenses

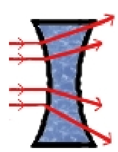
While mirrors use *reflection*, lenses use *refraction*. **Refraction** is the bending of a light as it enters a new medium at an angle. Depending on the medium through which it travels, light travels at different speeds. Look at the prism in the picture.

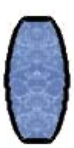

A prism splitting light

White light enters the prism from the right side. When the light goes from the air to the glass, it slows down and bends. How much it slows down is described by the index of refraction. The **index of refraction** is the ratio of the speed of light in a vacuum to the speed of light in a given material. A material with a low index causes light to refract very little. A material with a high index causes light to refract a lot. Air has a low index of refraction. Diamond has a high index of refraction.

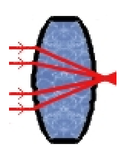
What does refraction have to do with lenses? A lens changes the path of light before it reaches your eyes. There are several different types of lenses, but they all work by refraction. Light rays that pass through lenses come out of the other side at different angles.

A **concave lens** curves inward in the middle and is thicker at the top and bottom. Light rays traveling through a concave lens spread out on the other side. Concave lenses can only form virtual images, and the image that is formed is always smaller than the actual object. Concave lenses are used in cameras to show what an image will look like when it is printed.



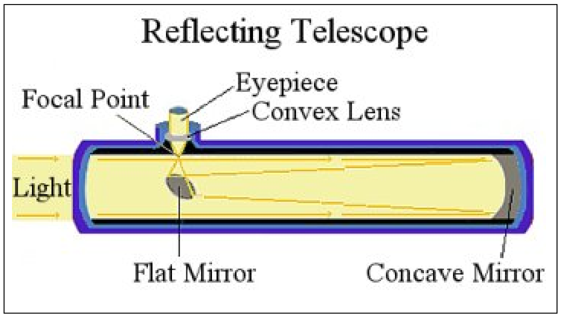


A **convex lens** curves outward and is thicker in the middle. It does not spread light out on the other side. Instead, it brings the rays of light together, where they meet. The point at which the rays meet is called the **focal point**. Convex lenses make either virtual or real images. Microscopes use two convex lenses to magnify very small objects.



Telescopes, Microscopes, and Cameras

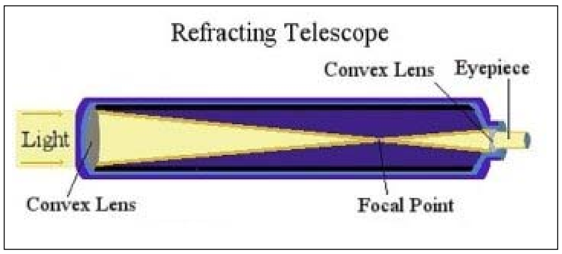
Optical instruments are designed to make use of light, lenses, and mirrors for observation. The invention of the microscope gave scientists a greater understanding of bacteria and disease. Telescopes are responsible for the first observations of space. They are now powerful enough to glimpse far away stars and galaxies. Cameras shaped how news was reported and are now part of our everyday lives. All of these devices use lenses and mirrors to form a picture.



The first telescope was invented around 1608. By the 1800s, scientists were using curved mirrors to look into the universe. Telescopes gather and focus light from distant sources. There are two types of telescopes that are widely used: reflecting telescopes and refracting telescopes.

Reflecting telescopes use mirrors and convex lenses. These focus and reflect light to form a real image for the user to examine. In the eyepiece there is a convex lens that makes the image larger.

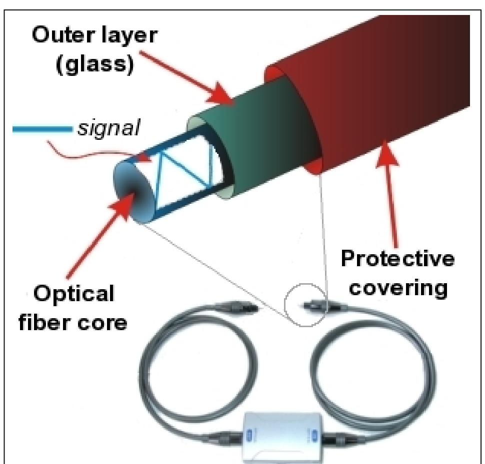
Refracting telescopes only use convex lenses. One convex lens gathers the light and another forms a real image at the focal point inside the telescope.



Microscopes gather and focus light to examine very near, small objects. The most common type of microscope is the compound microscope. It uses two convex lenses to enlarge very small objects. The first lens produces an enlarged but upside-down real image. This image is received by the second lens and is turned into a right-side-up virtual image. Microscopes produce a virtual image that is larger than the original, sometimes up to 1,000 times larger!

Cameras first appeared in the 1800s, but in 1490 Leonardo DaVinci constructed the first pinhole camera to project images from outside into a darkened room. In the past few centuries, many advances have been made in camera technology. But no matter what the type of camera, it always captures the image by the same process. Light rays enter an opening, are focused by a lens, and make an image that can be recorded.

Fiber Optics



Inside a fiber optic cable

Recently, technology has expanded to include the use of fiber optics in data transfer. Fiber optics is the branch of optics that deals with sending data through transparent wires. The data is sent by pulses of light through very thin tubes of glass or plastic.

Data is able to travel along fiber optic cable lines due to total internal reflection. **Total internal reflection** is the complete reflection of a light signal back into its original medium. Just as important as the internal reflection is the critical angle. The **critical angle** is the angle that causes light to refract at a 90 degree angle. At the critical angle, light is partly reflected and partly refracted. At angles more than the critical angle, all of the light is reflected, causing total internal reflection.

Inside a fiber optic cable, the light signal bounces back and forth along a tube that is usually made of glass. The glass has a very low index of refraction. That, along with the critical angle of the material, causes total internal reflection. The light reflects back and forth without losing any energy, and is able to carry data a long way without losing strength.

Making Connections

In this third and last lesson on waves, you read about electromagnetic waves. They share many of the same properties as other type of waves, but since light is an electromagnetic wave, it also has its own properties. As you move through the next few lessons on electricity and magnetism, refer back to the properties of electromagnetic fields in this lesson as necessary.

Advances in light-based technology are made every day. In a very short amount of time doctors have gone from using glasses to correct poor eyesight, to contact lenses, to the use of laser eye surgery to improve vision. Medicine overall has benefited from the study of the electromagnetic spectrum. It has allowed doctors and scientists to discover cures for many illnesses with many other treatments and cures just over the horizon. The next time you hear of a medical breakthrough, think of all of the instruments that worked toward discovering that treatment. Many would not be possible without hundreds of years of studying the properties of light.

Important Formulas to Remember

Speed of light = 3.00×10^8 m/s
$c = 3.00 \times 10^8$ m/s

Speed = Wavelength × Frequency
$c = \lambda \times f$

or

$$\textbf{Frequency} = \frac{\textbf{Speed}}{\textbf{Wavelength}}$$
$$f = \frac{c}{\lambda}$$

Practice Problems

Answer each question in your notebook. Click on the "Check Answers" button to check your answers.

1. White light belongs to what part of the electromagnetic spectrum?

2. Match the following vocabulary term with an example of it:

A. transparent	1. frosted mug
B. opaque	2. drinking glass
C. translucent	3. coffee mug

3. Explain how light behaves when it travels through a concave lens versus a convex lens.

Check Answers Hide Answers

Homework Questions

Click here to view a printable copy of this homework assignment.

Part I

Use the formulas in the "Important Formulas to Remember" boxes to solve the following problems.

1. The radio waves of an AM radio station vibrate at 480,000 times per second. What is the wavelength of the wave?

2. How fast does light travel in a vacuum?

3. An electromagnetic wave in space has a frequency of 0.8×10^8 hz. What is its wavelength?

Part II

Use the Internet or other available materials to research rainbows. A rainbow contains many of the properties of light, which makes it a good review for many of the concepts in this lesson. Answer the questions below to guide your research.

1. What is a rainbow? How is it formed?

2. When is the best time to see a rainbow? Why?

3. To what part of the electromagnetic spectrum does a rainbow belong?

4. If you could measure the temperature of a rainbow, what would be the difference in temperature from red to purple?

5. Would it be possible to see a rainbow that is in any shape other than bowed?

6. Look at this picture. Explain what behavior of light causes the secondary rainbow.

Click here for the course glossary

Useful External Resources
• High School Ace •
• Dictionary — Thesaurus — Encyclopedia — Almanac •