Hello, your last assignment was the Electromagnetic Spectrum project. You learned about the different types of light and some basic information about waves. This week you will be looking more closely at light including: Types of visible light and how light behaves and how its behavior is useful to us. I will be posting this on Google Classroom as well and if you have any questions email me!

Also, there have been questions about turning work in. You may take a picture of the completed questions and email them to me or, as the all-call stated, turn them in during food pick up. You will only need to turn in the pages with the questions on them.

Hope you are doing well!

Ms. Wiesen

22.1: The Light We See
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.

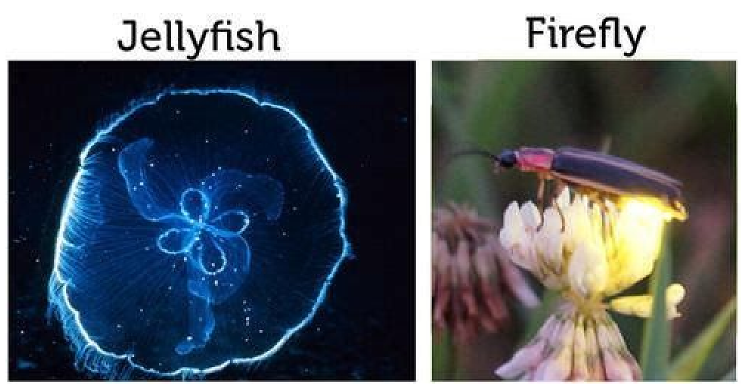
Sources of Visible Light
Look at the classroom in **Figure** below. It has several sources of visible light. One source of visible light is the sun. Sunlight enters the classroom through the windows. The sun provides virtually all of the visible light that living things need. Visible light travels across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

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

How Visible Light Is Produced

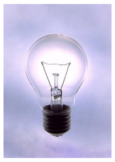
The sun and other stars produce light because they are so hot. They glow with light due to their extremely high temperatures. This way of producing light is called **incandescence**. Some objects produce light without becoming very hot. They generate light through chemical reactions or other processes. 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 below. Bioluminescent organisms include jellyfish and fireflies. Jellyfish give off visible light to startle predators. Fireflies give off visible light to attract mates.



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.

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.
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.
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.

Artificial Lights

The classroom in **Figure** above 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** below. 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?

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

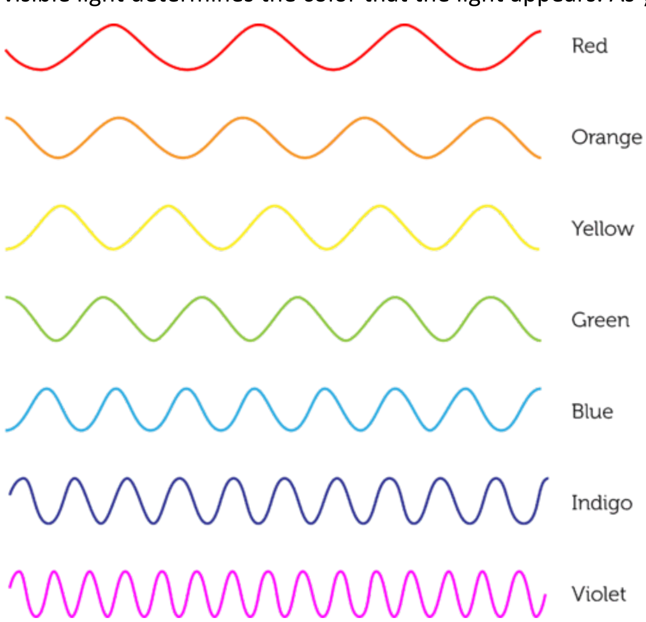
Matter can be classified on the basis of how light interacts with it. Matter may be transparent, translucent, or opaque. Each type of matter is illustrated in **Figure** below.

- **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.

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

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** below, 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.

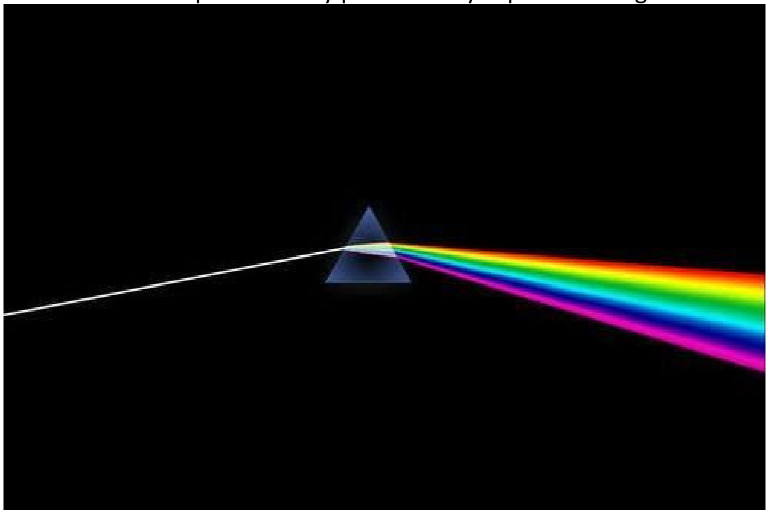


The color of light depends on its wavelength.

Separating Colors of Light

A prism, like the one in **Figure** below, 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.



A prism separates visible light into its different wavelengths.

Colors of Objects

We see an opaque object, such as the apple in **Figure** below, 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** below, 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.

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

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** below, 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** below. 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.

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?

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 "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** below come in just these three colors. They are the only colors needed for full-color printing.

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

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.

Think Critically

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

22.2: Optics
Introduction

Did you ever see trees or other objects reflected in the still waters of a lake, like the one in **Figure** below? The water in the lake is so calm that it reflects visible light almost as clearly as a mirror. A mirror is one of many devices that people use to extend their ability to see. Mirrors allow people to see themselves as other people see them and also to see behind their back. Mirrors are also used in instruments such as telescopes, which you will read about in this lesson. The use of light in devices such as these is possible because of optics. **Optics** is the study of visible light and the ways it can be used to extend human vision and do other tasks.

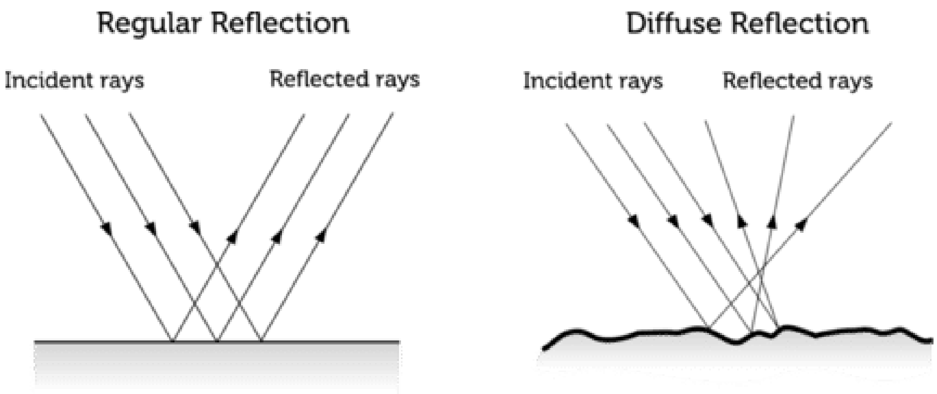
Still waters of a lake create a mirror image of the surrounding scenery.

Reflection of Light

Almost all surfaces reflect some of the light that strikes them. The still water of the lake in **Figure** above reflects almost all of the light that strikes it. The reflected light forms an image of nearby objects. An **image** is a copy of an object that is formed by reflected or refracted light.

Regular and Diffuse Reflection

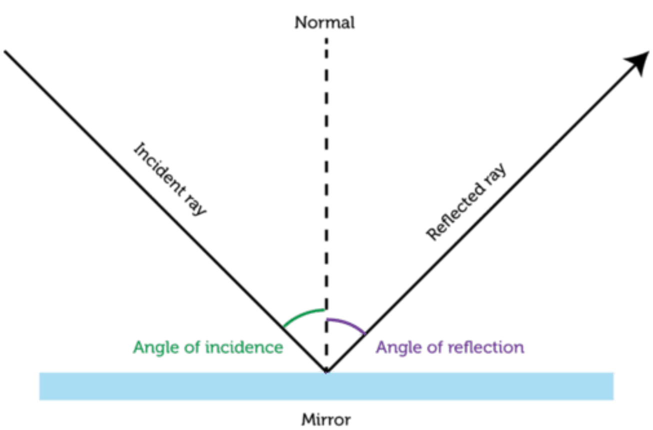
If a surface is extremely smooth, like very still water, then an image formed by reflection is sharp and clear. This is called regular reflection. If the surface is even slightly rough, an image may not form, or if there is an image, it is blurry or fuzzy. This is called diffuse reflection. Both types of reflection are represented in **Figure** below.



Whether reflection is regular or diffuse depends on the smoothness of the reflective surface.

In **Figure** above, the waves of light are represented by arrows called rays. Rays that strike the surface are referred to as incident rays, and rays that reflect off the surface are known as reflected rays. In regular reflection, all the rays are reflected in the same direction. This explains why regular reflection forms a clear image. In diffuse reflection, in contrast, the rays are reflected in many different directions. This is why diffuse reflection forms, at best, a blurry image.

Law of Reflection



One thing is true of both regular and diffuse reflection. The angle at which the reflected rays bounce off the surface is equal to the angle at which the incident rays strike the surface. This is the **law of reflection**, and it applies to the reflection of all light.

According to the law of reflection, the angle of reflection always equals the angle of incidence. The angles of both reflected and incident light are measured relative to an imaginary line, called normal, that is perpendicular (at right angles) to the reflective surface.

Mirrors

Mirrors are usually made of glass with a shiny metal backing that reflects all the light that strikes it. Mirrors may have flat or curved surfaces. The shape of a mirror's surface determines the type of image the mirror forms. For example, the image may be real or virtual. A real image forms in front of a mirror where reflected light rays actually meet. It is a true image that could be projected on a screen. A virtual image appears to be on the other side of the mirror. Of course, reflected rays don't actually go behind a mirror, so a virtual image doesn't really exist. It just appears to exist to the human eye and brain.

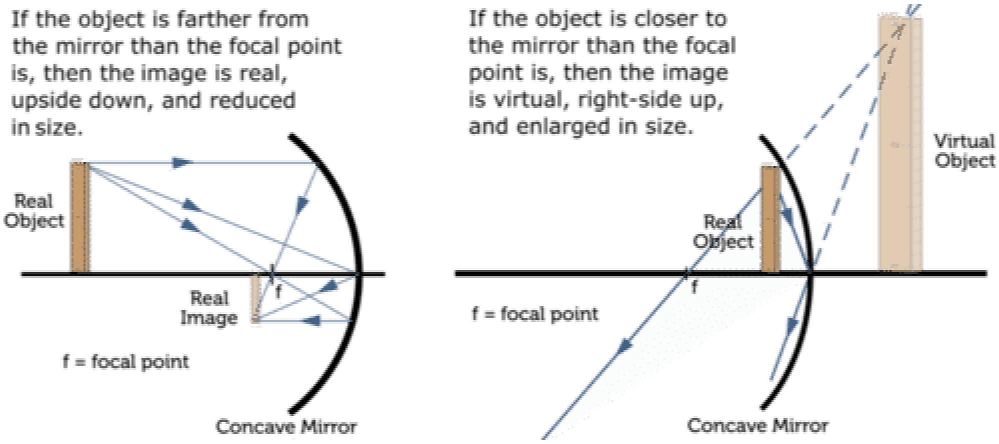
Plane Mirrors

Most mirrors are plane mirrors. A plane mirror has a flat reflective surface and forms only virtual images. The image formed by a plane mirror is also life sized. But something is different about the image compared with the real object in front of the mirror. Left and right are reversed. Look at the man shaving in **Figure** below. He is using his right hand to hold the razor, but his image appears to be holding the razor in the left hand. Almost all plane mirrors reverse left and right in this way.

The term "mirror image" refers to how left and right are reversed in the image compared with the real object.

Concave Mirrors

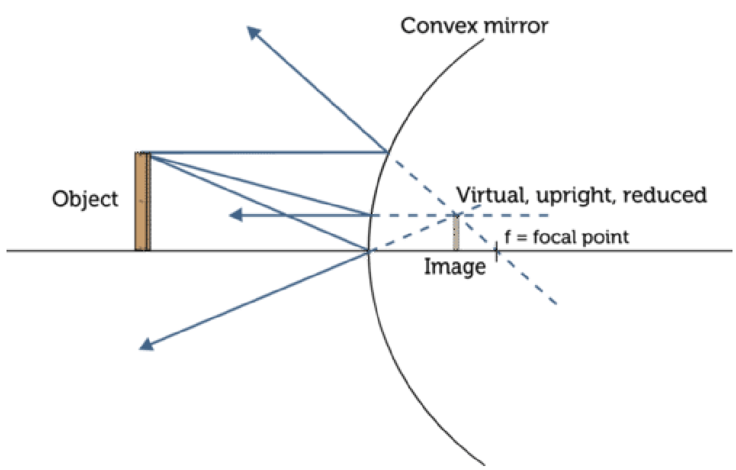
Some mirrors have a curved rather than flat surface. Curved mirrors can be concave or convex. A **concave** mirror is shaped like the inside of a bowl. This type of mirror forms either real or virtual images, depending on where the object is placed relative to the focal point. The focal point is the point in front of the mirror where the reflected rays intersect. You can see how concave mirrors form images in **Figure** below and in the interactive animation at the URL below. The animation allows you to move an object to see how its position affects the image. Concave mirrors are used behind car headlights. They focus the light and make it brighter.



The image created by a concave mirror depends on how far the object is from the mirror.

Convex Mirrors

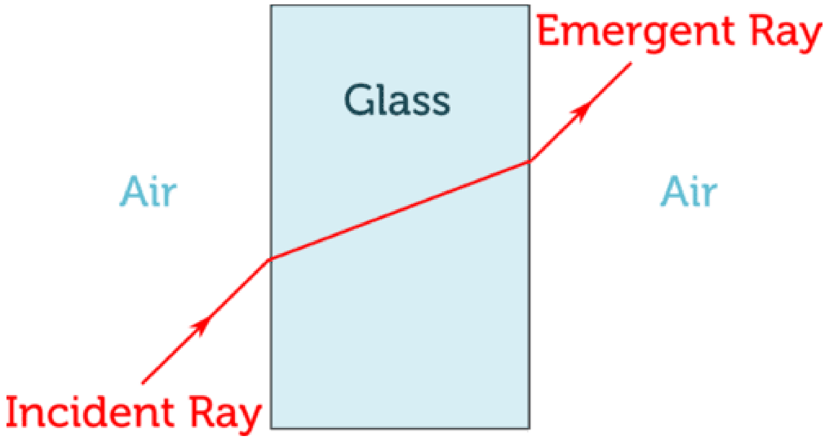
The other type of curved mirror, a **convex** mirror, is shaped like the outside of a bowl. This type of mirror forms only virtual images. The image is always right-side up and smaller than the actual object, which makes the object appear farther away than it really is. You can see how a convex mirror forms an image in **Figure** below and in the animation at the URL below. Because of their shape, convex mirrors can gather and reflect light from a wide area. This is why they are used as side mirrors on cars. They give the driver a wider view of the area around the vehicle than a plane mirror would.



A convex mirror forms a virtual image that appears to be on the opposite side of the mirror from the object. How is the image different from the object?

Refraction of Light

Although the speed of light is constant in a vacuum, light travels at different speeds in different kinds of matter. For example, light travels more slowly in glass than in air. Therefore, when light passes from air to glass, it slows down. If light strikes a sheet of glass straight on, or perpendicular to the glass, it slows down but passes straight through. However, if light enters the glass at an angle other than 90°, the wave refracts, or bends. This is illustrated in **Figure** below. How much light bends when it enters a new medium depends on how much it changes speed. The greater the change in speed, the more light bends.



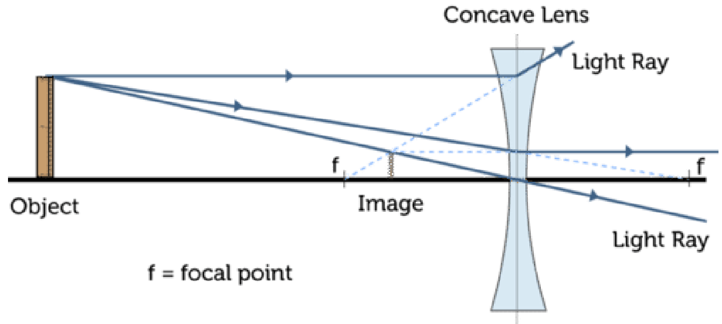
Light refracts when it passes from one medium to another at an angle other than 90°. Can you explain why?

Lenses

Lenses make use of the refraction of light to create images. A **lens** is a transparent object, typically made of glass, with one or two curved surfaces. The more curved the surface of a lens is, the more it refracts light. Like mirrors, lenses may be concave or convex.

Concave Lenses

Concave lenses are thicker at the edges than in the middle. They cause rays of light to diverge, or spread apart. **Figure** below shows how a concave lens forms an image. The image is always virtual and on the same side of the lens as the object. The image is also right-side up and smaller than the object. Concave lenses are used in cameras. They focus reduced images inside the camera, where they are captured and stored.

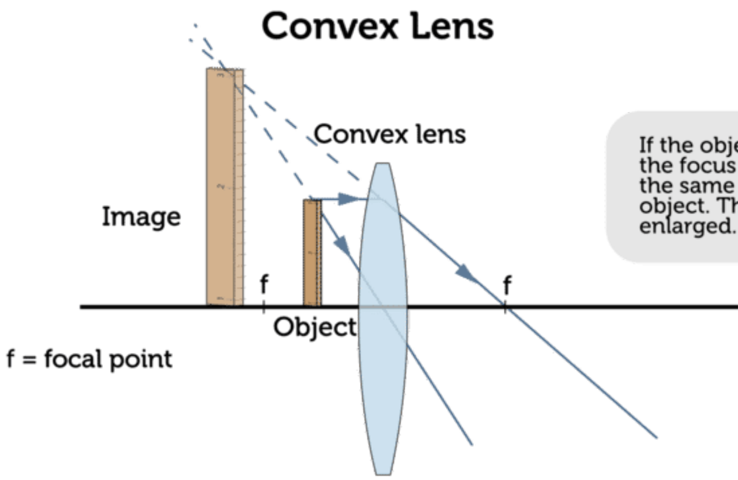


The image formed by a concave lens is a virtual image.

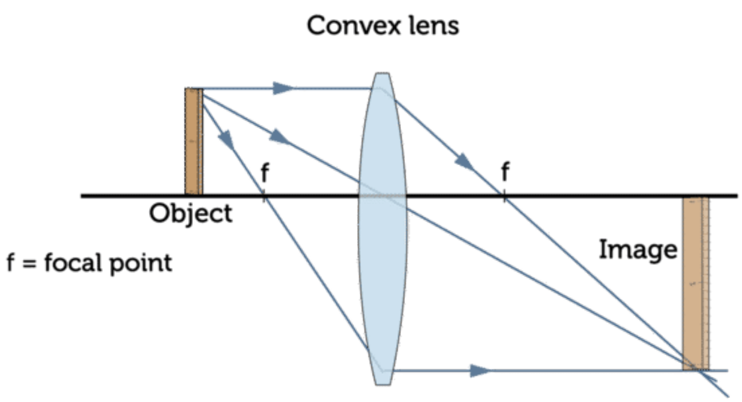
Convex Lenses

Convex lenses are thicker in the middle than at the edges. They cause rays of light to converge, or meet, at a point called the focus (F). Convex lenses form either real or virtual images. It depends on how close an object is to the lens relative to the focus. **Figure** below shows how a convex lens works. You can also interact with an animated convex lens at the URL below.

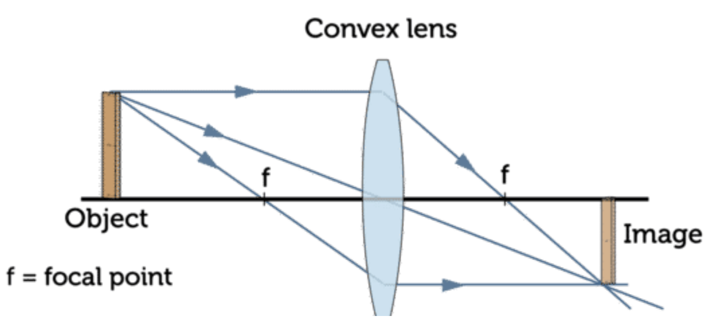
The type of image made by a convex lens depends on how close the object is to the lens. Which diagram shows how a hand lens makes an image?



If the object is closer to the lens than the focus is, a virtual image forms on the same side of the lens as the object. The image is right-side up and enlarged.



If the object is farther from the lens than the focus is, a real image forms on the side of the lens opposite the object, and the image is upside down. The image may be smaller, larger, or the same size as the object, depending on the object's distance from the lens. The farther away the object is, the more reduced the image is.



Lesson Review Questions

Recall

1. Define optics.
2. State the law of reflection.
3. What type of images does a convex mirror form?
4. What type of images does a concave lens form?

Apply Concepts

1. Assume that a light shines upward through the water of a swimming pool. Create a diagram to show what happens to the light when it passes from the water to the air above the water’s surface. The light should enter the air at an angle other than 90°.