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Light Energy and Matter

UNIT 9

Student Reader

Front Cover:

The front cover shows a photograph of a library's bookshelves that are illuminated by a large window.

Unit 9: Light Energy and Matter

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1 Engineering with Light

Designing a Library

When most people think of libraries, they think of books. But for Daniel Heuberger, a public library needs more than books. It also needs to draw people in and make them feel comfortable inside.

Daniel is an architect who helped to design the Bronx Library Center. This library is in the Bronx in New York City. Daniel and his team had two goals with their design. They wanted to make the building feel open and accessible to people on the outside. And they wanted to maximize the natural daylight on the inside.

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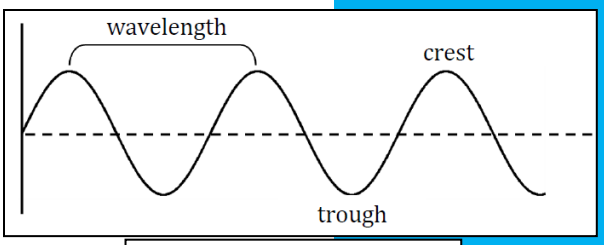
This is the outside of the Bronx Library Center.

What is Light?

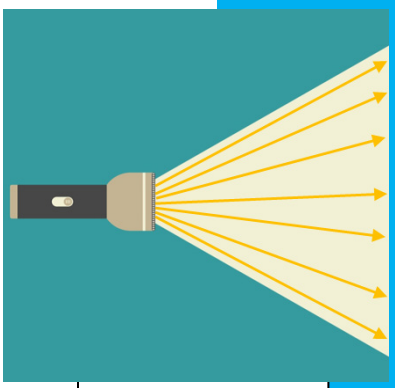
All **light** is a form of kinetic energy that travels through space. All light has a source. The sun is the largest source of light on Earth. The sun's energy travels through space to Earth. When it reaches Earth's surface, it is absorbed by the planet and changed into heat. When it is absorbed by plants, it is changed into chemical energy through photosynthesis. Ceiling lights, lamps, and flashlights are also sources of light.

Light is complex, and there is still much that scientists don't know about it. There are different models of light that scientists use to better understand how light moves and how it interacts with matter.



a light wave

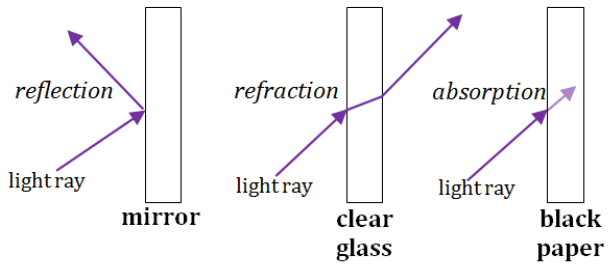
One model is a wave model. This is because in many instances, light behaves in a similar way to sound or water waves. Another model is a ray model. This is the model explored in this unit. This model describes how light moves in a straight line. These straight-line paths are called light rays. Whenever you see a narrow beam of light, it is actually a bundle of many parallel light rays. The ray model is useful for exploring how light interacts with different materials.



light rays

Light and Matter

Whenever a light ray interacts with matter, the light ray changes in some way. When a light ray comes into contact with matter, it can be reflected, refracted, or absorbed.



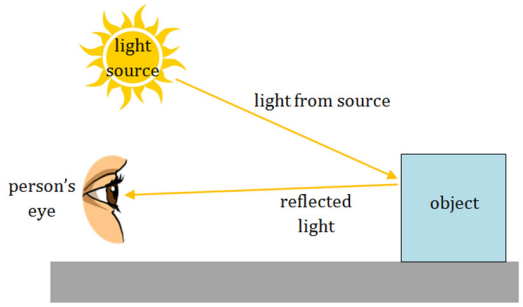
This metal rod appears to bend because of refraction.

Reflection occurs when a light ray bounces off of the surface of an object. **Refraction** occurs when a light ray passes from one medium to another and changes its direction. Unlike reflection, the light ray moves through the second material when it refracts. However, the direction of its path changes. Refraction is what happens when you look at an object that is partly in water and partly in air. The object appears bent at the water's surface because the light rays move in a different direction through the water than through the air.

When a light ray is absorbed by an object, the light energy turns into heat. Dark-colored objects absorb more light than light-colored objects. This is why they warm up faster.

Reflecting Light

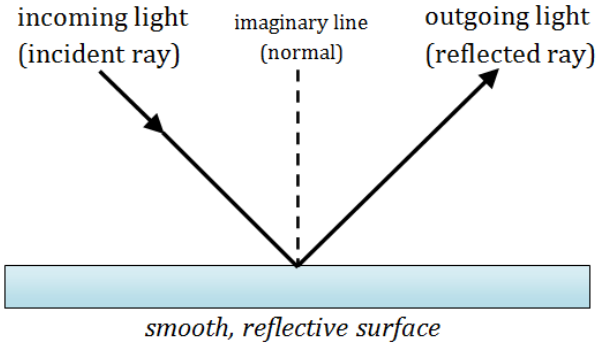
Almost all objects reflect some light. This is how we see. **Sight** is a sense that uses the eyes to take in light information about an object's position, shape, and color. Light rays reflect off of the object in all directions and into our eyes.



We see when light reflects off of objects and into our eyes.

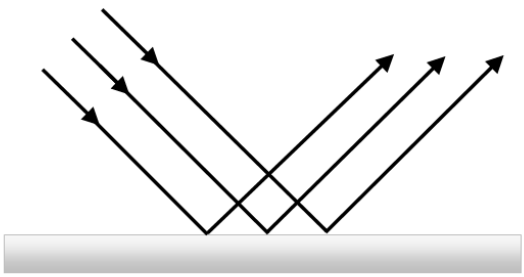
The incoming ray of light is called an incident ray. The outgoing ray is called a reflected ray. The direction of the reflected ray follows a predictable pattern. It always reflects off of the surface at an identical angle as the incident ray but on the opposite side of an imaginary line at a right angle to the mirror, located at the point where the rays meet. This is called the law of reflection.

the law of reflection

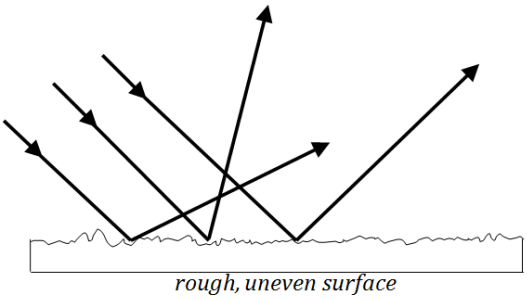


Light is always reflected in this way. However, the properties of the material light reflects off of affect how we see the object. Think of a mirror. The surface of the mirror is so smooth and reflective that you can see your image in it. This happens because the incident rays of light are reflected off of the smooth surface in the same pattern in which they arrived.

With a rougher surface, the light rays are reflected in many directions. This is because the roughness of the surface means that each ray of light hits the surface at a different orientation. Each ray still follows the law of reflection. However, the roughness of the surface causes the reflected rays to scatter in different directions.



smooth, reflective mirror



rough, uneven surface

The texture of a surface affects how light reflects off of it.

Understanding how light rays interact with different materials helped Daniel and his team achieve their goal of maximizing daylight inside the library.

Maximizing Light

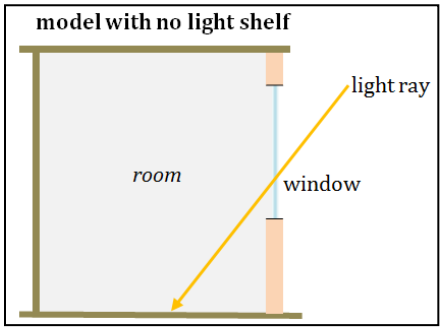
For example, the library's eastern wall is made up almost entirely of glass. Sunlight streams through the glass because glass is transparent. **Transparent** materials allow almost all light to pass through to the other side. Almost no light reflects off of transparent materials. Instead, it is slightly refracted. Having a wall that is almost entirely transparent increases the amount of sunlight that can reach the inside of the library.

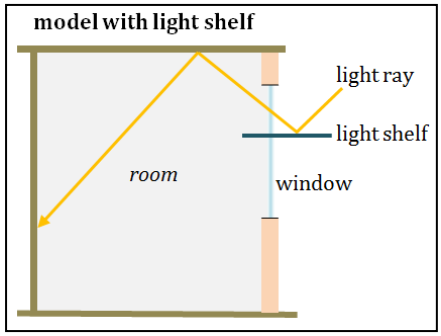
The glass windows at the Bronx Library Center are transparent, allowing sunlight to reach inside.

Some materials are **translucent**, which means some light passes through and some is blocked. This makes objects on the other side appear blurry. The library's main staircase has a translucent glass wall on one side so sunlight can light up the stairs.

Most materials are **opaque**, which means they block all light from passing through. When an object has a shadow, it is evidence that the object is opaque because it has blocked the light from passing through. Opaque objects either reflect or absorb light.

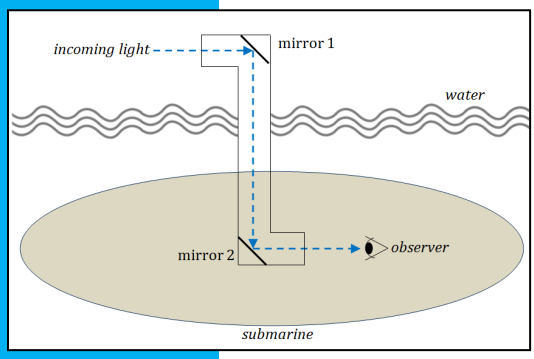
The light from a window is strongest right next to the window. Daniel and his team wanted to spread out the light in the library so it illuminated a greater area. They used special "light shelves" in front of part of the windows. The tops of these light shelves reflect light off of them and up to the ceiling. The ceiling reflects the light deeper into the room.





Light shelves redirect the path of light.

Light shelves are just one technology that people have developed to redirect light. Periscopes are another example of this. Periscopes use two mirrors to bounce light from one place to another. A typical periscope has each mirror angled at 45 degrees to the direction you want to see. The light reflects off of one mirror to the other and then out to your eye.



Periscopes are often used in submarines so the crew can see above the water without having to come to the surface.

Energy Efficiency

Having a lot of natural daylight does more than make the library feel comfortable. It also reduces the amount of electricity the building uses.

Remember that electricity is the flow of electrons through a conductor. Lamps and ceiling lights are powered by electricity. When you turn these lights on, you close the circuit so the electrons can flow from the energy source to the light.

Because energy cannot be created or destroyed, it has to come from somewhere. The energy that powers many buildings comes from a non-renewable source of energy such as coal, oil, or natural gas. Sometimes it comes from a renewable source such as wind or the sun.

When architects and engineers design buildings, they try to make them as energy efficient as possible. A building is energy efficient when it uses less energy to do the same amount of work. There are several benefits to energy efficiency. It saves money because the building uses less electricity. It is also good for the environment because fewer natural resources are used as the source of the energy.

Daniel and his team wanted to make sure that the natural light actually helped the library be more energy efficient. They added other features to their design. The ceiling lights dim automatically when there is enough natural light from the sun. This reduces the amount of electricity the library uses.

And there are skylights in the offices in the back of the library. These skylights are another source of natural light so people use less electricity.

As a result of these and other design features, the Bronx Library Center was the first "green" library in New York City. Green buildings are those that are designed to reduce their impact on the environment by using different resources, such as energy, efficiently.

The ceiling lights dim automatically when there is enough natural light from the sun.

Section 1 Review

Reading Comprehension Questions:

1. What features of the Bronx Library Center help it maximize the amount of daylight inside?

2. How does a large glass wall help the Bronx Library Center be more energy efficient?

3. According to the text, what is one way that green buildings help to protect Earth's resources and the environment?

4. What is the main idea of Section 1?

5. What key details does the text provide to support the main idea of the text?

Science Words to Know

light – a form of kinetic energy that travels through space

opaque – a material that blocks all light

refraction – occurs when a ray of light passes from one medium to another but changes direction

sight – the sense that uses the eyes to take in light information about an object's position, shape, and color

transparent – a material that light passes through completely

translucent – a material that some, but not all, light passes through

