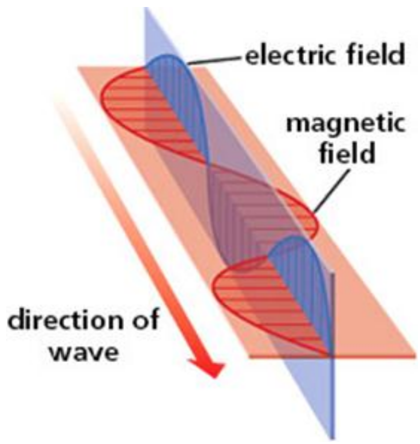
SECTION 1 (PP. 553-558): ELECTROMAGNETIC WAVES HAVE UNIQUE TRAITS.

Georgia Standards: S8P4a – *Identify the characteristics of electromagnetic and mechanical waves;* S8P4d – *Describe how the behavior of waves is affected by a medium (such as air, water, or a solid).*

1. **An electromagnetic wave is a disturbance in a field.**
   An **electromagnetic wave** is a disturbance that transfers energy through a field.

   A **field** is the area around an object where the object applies force to another object without touching it. The two fields of an electromagnetic (EM) wave, electric and magnetic, vibrate at right angles to each other and are perpendicular to the direction the wave is moving.



   An electromagnetic wave is emitted whenever a charged atomic particle accelerates. The Sun and human technology are the two main sources of EM waves. Other stars give off as many EM waves as the Sun, but because these bodies are so far away, fewer of their EM waves reach Earth.

2. **Electromagnetic waves can travel in a vacuum.**
   Once EM waves are produced, they travel on their own, independent of the source that emitted them. They don't need a medium and can travel at about 300,000 kilometers per second (approximately 186,000 miles per second). EM waves cross the great distances that separate stars and galaxies. For example, rays from the Sun travel about 150 million kilometers (93 million mi) to reach Earth. EM waves from the most distant galaxies travel for billions of years before reaching Earth.

   Radiation is the transfer of energy in the form of EM waves. EM waves do not lose energy as they travel in a vacuum. EM radiation from the Sun travels in a straight line through the vacuum of outer space. Only a very small part of the energy radiated from the Sun is transferred to Earth. But that energy is still a great amount—enough to sustain life on the planet.

In 1 second, an EM wave can travel a distance greater than 7 times the distance around Earth. Even at this speed, rays from the Sun take about 8 minutes to reach Earth. This constant speed is called the ***speed of light***.

3. **Electromagnetic waves can interact with a material medium.**
   When EM waves encounter a material medium, they may transfer energy to it. Different mediums act differently with EM waves, and can change the direction of the wave and affect energy transfer.
   - In a vacuum, EM waves transfer energy by moving potential energy from one place to another.
   - In a medium, an EM wave's potential energy can be converted into other forms, such as heat.

SECTION 2 (PP. 559-567): ELECTROMAGNETIC WAVES HAVE MANY USES.

Georgia Standards: S8P4a – *Identify the characteristics of electromagnetic and mechanical waves*; S8CS4b – *Use appropriate tools and units for measuring objects and/or substances.*

1. **EM waves have different frequencies.**
   An EM wave's frequency determines the wave's characteristics. The higher the frequency, the more energy the wave carries. The electromagnetic spectrum is a continuum of waves from the lowest-frequency radio waves (longest wavelength) to the highest-frequency gamma rays (shortest wavelength).

   EM wave frequency is measured in **hertz** (Hz). One hertz equals one cycle per second. The frequency of a 30-kilometer radio wave would be 10,000 Hz. Gamma ray frequencies reach trillions of trillions of hertz.

2. **Radio waves and microwaves have long wavelengths and low frequencies.**
   Radio waves are long, low energy EM waves. They can be modified and converted into sound and pictures of radios and televisions. **Microwaves** have more energy and shorter wavelengths than radio waves.
   - In ***radar***, microwaves are reflected off an object and returned to their source as a way of locating the object.
   - ***Cell phone*** technology is like radio transmission but uses microwaves. A system of towers connects cell phones to each other and to a regular phone system.

3. **Infrared, visible light and ultraviolet light have mid-range wavelengths and frequencies.**
   The range of frequencies that humans can see is just a tiny part of the EM spectrum.
   - **Infrared waves** lie between visible light and microwaves. They are emitted by warm objects. Infrared technology is used to cook food, detect warm objects, and provide heat.

   - **Visible light** is the part of the EM spectrum that human eyes can see. It lies between 1014 Hz and 1015 Hz. We perceive the longest wavelengths of visible light as red and the shortest as violet.

- **Ultraviolet light** carries more energy than visible light and can damage human tissue. It is used to sterilize medical equipment and kill bacteria in food.

4. **X-rays and gamma rays have the shortest wavelengths and high frequencies.**
Because of their high frequencies, x-rays and gamma rays carry very high energies. They are naturally produced by stars.
    - **X-rays** can penetrate *soft tissues* (muscles, tendons, and ligaments) but not *hard tissues* (bone) of the body, making the waves useful for medical imaging. However, too much exposure to x-rays can damage tissue. Even in small doses, repeated exposure to x-rays can cause cancer over time. When you have your teeth x-rayed, you usually wear a vest made out of lead for protection. Lead blocks high-frequency radiation.
    - **Gamma rays** can penetrate all the tissues of the body, killing normal cells and causing cancer cells to grow. If carefully controlled, this destructive power can be beneficial. Doctors can also use gamma rays to kill cancer cells and fight tumors.

SECTION 3 (PP. 568-572): THE SUN IS THE SOURCE OF MOST VISIBLE LIGHT.

Georgia Standards: S8P2 – *Students will be familiar with the forms and transformations of energy;* S8CS6a – *Write clear, step-by-step instructions for conducting scientific investigations, operating a piece of equipment, or following a procedure.*

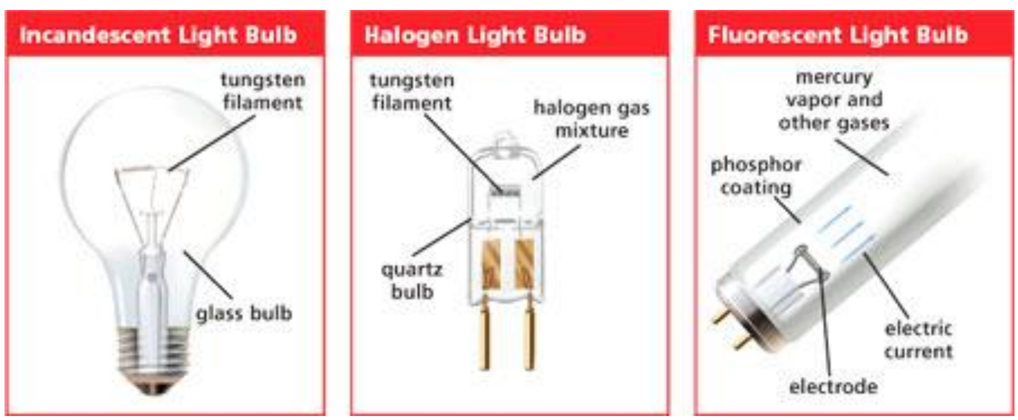
1. **Light comes from the Sun and other natural sources.**
Almost all organisms depend on light for survival. Virtually all light on Earth begins as sunlight. Green plants need light to make their own food. Plants, in turn, supply food directly or indirectly for nearly all other living creatures. With very few exceptions, living creatures depend on light for their existence.

   Most of the visible light waves in the environment come from the Sun. The Sun's high temperature produces light of every wavelength. The production of light by materials at high temperatures is called i**ncandescence**. When a material gets hot enough, it gives off light by glowing or by bursting into flames.

   Other than the Sun, few natural sources of incandescent light strongly affect life on Earth. Most other stars give off as much light as the Sun, or even more, but little light from stars reaches Earth because they are so far away. Lightning produces bright, short-lived bursts of light. Fire, which can occur naturally, is a lower-level, longer-lasting source of visible light.

2. **Some living things produce visible light.**
Many organisms produce their own visible light, which they use in a variety of ways. They produce this light through luminescence. **Luminescence** is the production of light without the high temperatures needed for incandescence. The production of light by living organisms is called **bioluminescence**. Bioluminescent organisms produce light from chemical reactions rather than from intense heat. Bioluminescence enables organisms to produce light inside their tissues without being harmed.

3. **Human technologies produce visible light.**
   The discovery of electricity has led to several artificial lighting technologies.
   - Most ***incandescent*** light bulbs use tungsten filaments and produce light and heat.
   - ***Halogen*** lighting also produces lots of heat, but the tungsten filament lasts longer than in ordinary incandescent light bulbs and produces more light.
   - ***Fluorescent*** lighting is cool and efficient. Many electric lights in use today are fluorescent. *Fluorescence* occurs when a material absorbs EM radiation of one wavelength and gives off EM radiation of another. Fluorescent bulbs are filled with a mixture of mercury vapor and other gases that give off ultraviolet light when an electric current passes through them.
   - One of fastest-growing types of artificial lighting is the LED (***light emitting diode)***, or **LED**. LEDs do not involve bulbs, filaments, or gases. Instead, they produce light electronically. A diode is a type of semiconductor—a device that regulates electric current. An LED is a semiconductor that converts electric energy directly into visible light. LEDs have many advantages over traditional forms of lighting. They produce a very bright light, do not break easily, use little energy, produce little heat, and can last for decades. Some technologists believe that LEDs will eventually replace most traditional forms of artificial lighting.



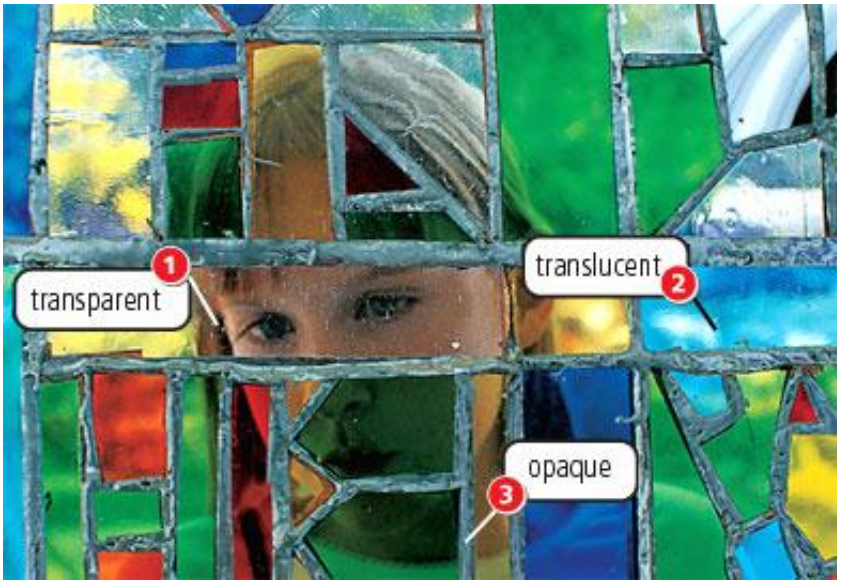
SECTION 4 (PP. 573-581): LIGHT WAVES INTERACT WITH MATERIALS.

Georgia Standards: S84c – *Explain how the human eye sees objects and colors in terms of wavelengths;* S8P4d – *Describe how the behavior of waves is affected by a medium (such as air, water, or a solid).*

1. **Light can be reflected, transmitted, or absorbed.**
   EM waves can interact with a material medium in the same ways that mechanical waves do. The medium can reflect, transmit, or absorb the waves. Most objects are visible because they reflect light. **Transmission** and **absorption** affect how objects appear to the human eye.
   - ***Transparent*** materials allow most of the light that strikes them to pass through. It is possible to see objects through a transparent material. Air, water, and clear

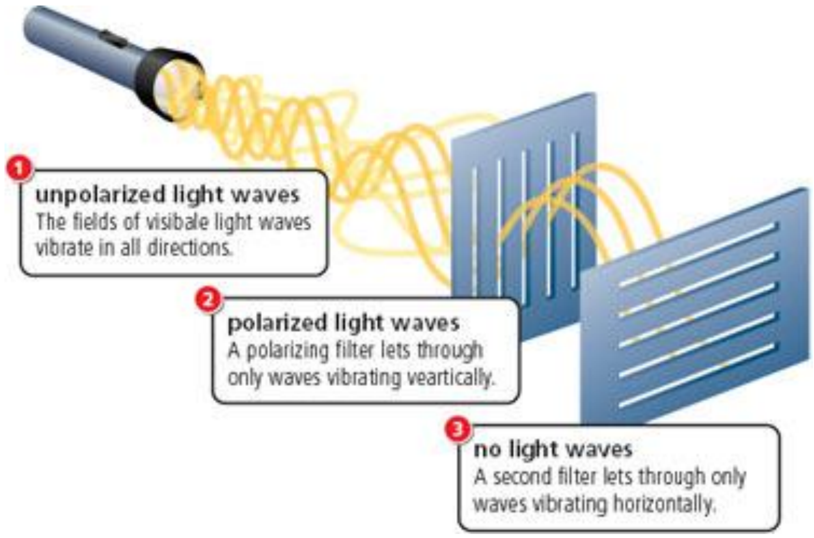
glass are transparent. Transparent materials are used for items such as windows, light bulbs, thermometers, sandwich bags, and clock faces.

- ***Translucen***t materials transmit some light, but they also cause it to spread out in all directions. You can see light through translucent materials, but you cannot see objects clearly through them. Some examples are lampshades, frosted light bulbs, frosted windows, sheer fabrics, and notepaper.
- ***Opaque*** materials do not allow any light to pass through them, because they reflect light, absorb light, or both. Heavy fabrics, construction paper, and ceramic mugs are opaque. Shiny materials may be opaque mainly because they reflect light. Other materials, such as wood and rock, are opaque mainly because they absorb light.

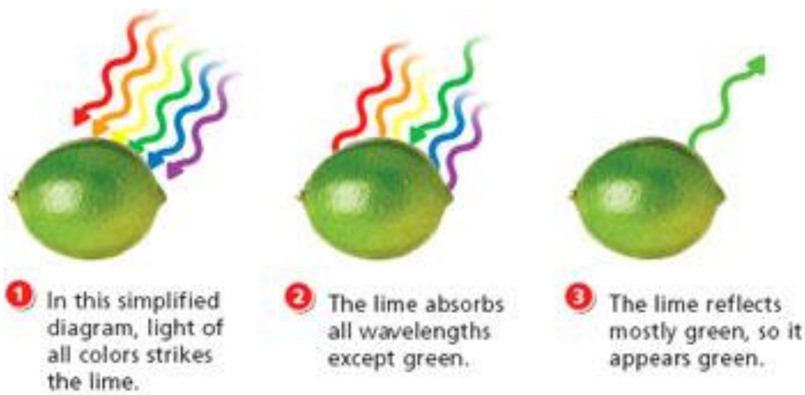


Scattering is the spreading out of light rays in all directions, because particles reflect and absorb the light. Fog or dust in the air, mud in water, and scratches or smudges on glass can all cause scattering. Scattering creates glare and makes it hard to see through even a transparent material. Making a light brighter will cause the scattering of light to increase.

Polarization is a quality of light in which all of its waves vibrate in the same direction. Remember that EM waves are made of electric and magnetic fields vibrating at right angles to each other. Polarization describes the electric fields of a light wave. When all of the electric fields of a group of light waves vibrate in the same direction, the light is polarized.



2. **Wavelength determines color.**
The color of an object or material is determined by the wavelengths it absorbs and those it reflects. An object has the color of the wavelengths it reflects. A material that ***reflects*** all wavelengths of visible light appears **white**. A material that ***absorbs*** all wavelengths of visible light appears **black**. Visible light is a spectrum that is usually divided into seven colors **(**remember, **ROY G BIV**). Visible light is ***reflected*** from an object that gives it color. For example, a green leaf appears to be green because it reflects green wavelengths and absorbs all other visible wavelengths.



The three **primary colors** are light of different wavelengths that produce white light when mixed equally. They are **red**, **green**, and **blue**. Mixing colors by adding wavelengths is called additive ***color mixing***. An example of the practical use of primary colors is a color television or computer monitor. The screen is divided into thousands of tiny bundles of red, green, and blue dots, or pixels. A television broadcast or DVD sends signals that tell the monitor which pixels to light up and when to do so. By causing only some pixels to give off light, the monitor can mix the three colors to create an amazing variety of colorful images.

The **primary pigments** reflect wavelengths of **cyan**, **yellow**, and **magenta**. When you mix pigments, the mixture absorbs more colors and reflects fewer wavelengths. The visual below shows the primary pigments.