chapter 3 Electromagnetic Waves

section 2 The Electromagnetic Spectrum

What You'll Learn

- the differences among kinds of electromagnetic waves
- uses for different kinds of electromagnetic waves

Before You Read

What happens when you stay in the sun too long without sunscreen? Why do you think this happens?

Study Coach

Make Flash Cards For each paragraph you read, think of a question your teacher might ask on a test. Write the question on one side of a flash card. Then, write the answer to the question on the other side. Quiz yourself until you know the answers.

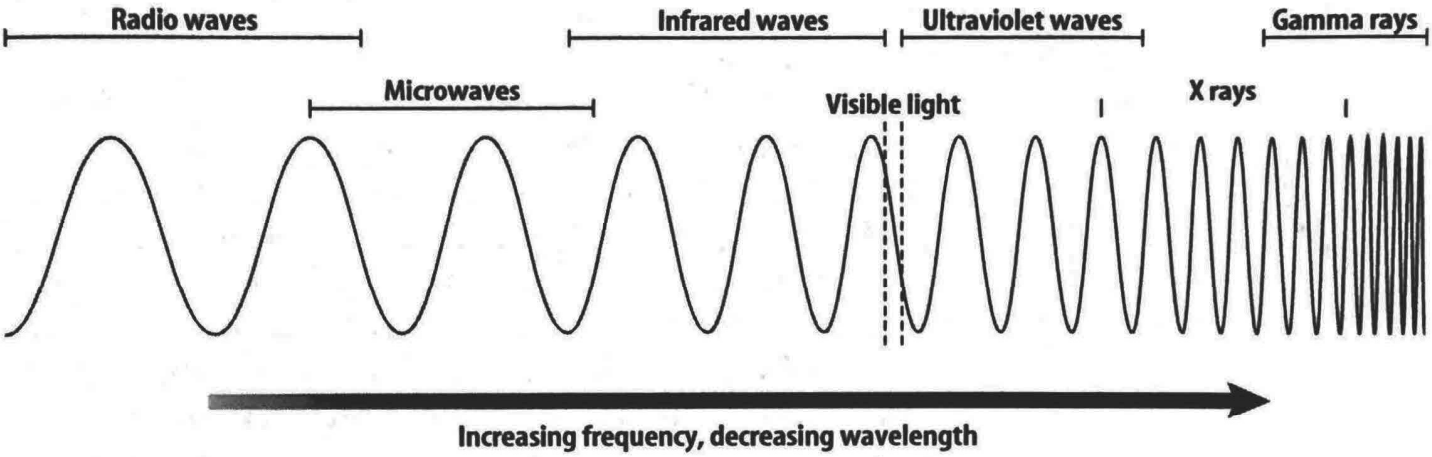
Read to Learn

Electromagnetic Waves

The room you are sitting in is filled with electromagnetic waves. These waves have many different wavelengths and frequencies. You cannot see many of these waves. TV and radio stations send electromagnetic waves that are invisible. They pass through walls and windows. These waves have wavelengths from about 1 m to over 500 m. Light waves are electromagnetic waves that you can see. They have wavelengths more than a million times shorter than those broadcast by radio stations.

How are electromagnetic waves grouped?

The **electromagnetic spectrum** is the wide range of electromagnetic waves with different wavelengths and frequencies. The electromagnetic spectrum is divided into different parts. Look at the figure at the top of the next page. It shows the electromagnetic spectrum and the names of the different waves that make up different parts of the spectrum. Even though electromagnetic waves have different names, they all travel at the same speed in empty space—the speed of light. Remember that for waves that travel at the same speed, the frequency increases as the wavelength decreases. So, as the frequency of electromagnetic waves increases, their wavelength decreases.



Radio Waves

Electromagnetic waves with wavelengths longer than about 0.3 m are called radio waves. **Radio waves** have the lowest frequencies of all the electromagnetic waves. They also carry the least energy. Television signals and AM and FM radio signals are types of radio waves. Like all electromagnetic waves, radio waves are produced by moving charged particles. One way to make radio waves is to make electrons vibrate in a piece of metal. This piece of metal is called an antenna. The moving electrons in an antenna cause radio waves to move outward from the antenna. By changing how fast the electrons in the antenna vibrate, radio waves of different frequencies can be made.

How are radio waves received?

Radio waves can cause electrons in another antenna to vibrate. Vibrating electrons in a receiving antenna form an alternating electric current. This current can be used to produce a picture on a TV screen and sound from a loudspeaker. Changing the frequency of the waves changes the alternating current in the receiving antenna. This produces the different pictures and sounds you hear on your TV. ☑

What are microwaves?

Radio waves with wavelengths from about 0.3 m to 0.001 m are called microwaves. Microwaves have a higher frequency and shorter wavelength than the waves used in your home radio. Cellular and portable phones use microwaves.

Microwave ovens use microwaves to heat food. The microwaves cause water molecules in food to vibrate. As the molecules vibrate faster, the food becomes warmer.

Picture This

1. **Interpret** What type of electromagnetic waves have the shortest wavelength?

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Reading Check

2. **Describe** What happens when radio waves cause electrons in an antenna to vibrate?

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What is radar?

Some animals, like bats, use echolocation. In echolocation, sound waves are sent out and bounce off objects. The reflected sound waves help determine the size and location of objects. Radar uses electromagnetic waves to detect objects in this way. Radar stands for RAdio Detecting And Ranging. Radar was first used in World War II to find enemy aircraft.

A radar station sends out radio waves that bounce off objects such as aircraft. Electronic equipment receives the reflected signals. The equipment measures the time it takes for the waves to return. Because the speed of the radio waves is known, the distance to the airplane can be found from the measured time. Electromagnetic waves travel so fast that this process takes less than one second. ☑

Reading Check

3. Identify What is known about radio waves that helps measure distance?

Infrared Waves

Have you ever stood close to a fireplace to warm up? It does not take long to feel the heat from the glowing fire. You can also warm up by standing next to a hot object that is not glowing. The heat you feel is from electromagnetic waves called infrared waves. **Infrared waves** are electromagnetic waves with wavelengths between about one thousandth and 0.7 millionths of a meter.

All objects send out electromagnetic waves. In any material, the atoms and molecules are always moving. The electrons in the atoms and molecules also vibrate and send out electromagnetic waves. Most electromagnetic waves given off by an object at room temperature are infrared waves. They have wavelengths of about 0.000 01 m, or one hundred thousandth of a meter.

Infrared detectors can detect infrared waves from objects that are warmer or cooler than their surroundings. Forests are usually cooler than their surroundings. Infrared detectors on satellites can be used to map forests, water, rock, and soil. Some types of night vision devices use infrared detectors. They make it possible for objects to be seen in nearly total darkness.

Think it Over

4. Infer Why are pit vipers able to hunt at night?

How do animals use infrared waves?

Some animals can detect infrared rays. Snakes called pit vipers have a pit between the nostril and the eye that detects infrared waves. These pits help them hunt at night by detecting the infrared waves their prey gives off.

Visible Light

Have you ever wondered why some hot objects glow? As an object gets warmer, its atoms and electrons vibrate faster and faster. The vibrating electrons produce electromagnetic waves with higher frequencies and shorter wavelengths. The object might glow if the temperature is high enough. Some of the electromagnetic waves the object gives off, or emits, can be seen. Electromagnetic waves you can see with your eyes are called **visible light**. ☑

Visible light has wavelengths between about 0.7 and 0.4 millionths of a meter. The different colors you see are electromagnetic waves with different wavelengths. Red light has the longest wavelength. Blue light has the shortest wavelength. Most objects you see do not give off visible light. They reflect visible light from another source, such as the Sun or a lightbulb.

Reading Check

5. Describe Why do some hot objects glow?

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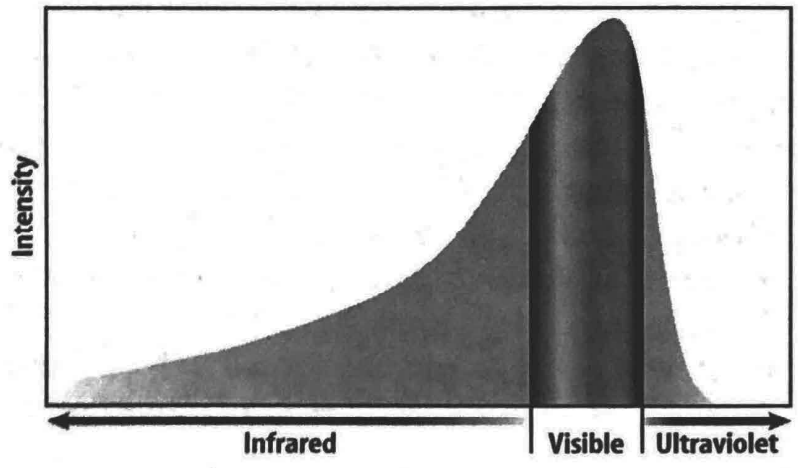
Ultraviolet Radiation

Ultraviolet radiation is higher in frequency than visible light and has even shorter wavelengths—between 0.4 millionths and about 10 billionths of a meter. Ultraviolet radiation also carries more energy. The radiant energy carried by an ultraviolet wave can damage or kill the molecules that make up living cells.

The figure below shows the intensity, or strength, of the electromagnetic waves from the sun. Most of the Sun's waves are infrared waves and visible light. But, too much exposure to the Sun's ultraviolet waves can cause sunburn. Exposure to these waves over a long period of time can cause the skin to age and might cause skin cancer. To protect your skin from ultraviolet waves, wear sunscreen and do not stay in the Sun too long.

Electromagnetic Waves from the Sun



Picture This

6. Identify Most of the electromagnetic waves emitted by the Sun are what type?

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Is ultraviolet radiation helpful?

Your body uses ultraviolet radiation from the Sun to produce vitamin D. A few minutes of sunlight each day is enough to produce all the vitamin D your body needs. Human skin tans as protection against too much ultraviolet radiation. But, a tan can be a sign that the skin has received too much ultraviolet radiation.

Because ultraviolet radiation can kill cells, it is used to disinfect objects such as surgical instruments and goggles.

Think it Over

7. Draw Conclusions Why is the ozone layer important to life on Earth?

What is the ozone layer?

Ozone is a molecule that contains three oxygen atoms. It is formed high in Earth's atmosphere. The ozone layer absorbs most of the ultraviolet radiation from the Sun before it reaches Earth's surface.

Chemical compounds called CFCs can react with ozone molecules and break them apart. CFCs are used in some air conditioners and refrigerators. There is evidence that CFCs in the atmosphere reduce the ozone over Antarctica at certain times of the year. This reduction is known as the ozone hole. To prevent this, CFCs are being used less.

The atmosphere also absorbs other types of electromagnetic radiation. It absorbs higher energy waves like X rays and gamma rays. Radio waves, light waves, and some infrared waves can pass through the atmosphere.

X Rays and Gamma Rays

Ultraviolet rays can go through, or penetrate, the top layer of your skin. **X rays** have an even higher frequency than ultraviolet rays and enough energy to go right through skin and muscle. A shield made out of a dense metal such as lead is needed to stop X rays.

Gamma rays have the highest frequency and carry the most energy. Gamma rays are the hardest to stop. They are produced by changes in the nuclei of atoms. In nuclear fusion, protons and neutrons bond together. In nuclear fission, protons and neutrons break apart. In both of these reactions, huge amounts of energy are released. Some of this energy is released as gamma rays.

The energy of X rays and gamma rays is much greater than ultraviolet rays. Like ultraviolet radiation, too much X-ray or gamma radiation can hurt or kill cells. This means that even small amounts of exposure can cause damage.

Think it Over

8. Explain Why do gamma rays have more energy than other forms of electromagnetic energy?

How are X rays used?

Have you ever had an X ray? If so, you know that doctors can use X rays to see inside your body. X rays can pass through the less dense tissues of skin and muscle. X rays strike a film and leave shadow images of bones and denser tissues. Doctors use X-ray images to find injuries and diseases such as broken bones and cancer. A CT scanner uses X rays to produce images of the human body as if it had been sliced like a loaf of bread.

Like ultraviolet waves, X rays can be harmful to cells and tissue. One or two X rays are not harmful. However, a large number of X rays could be harmful to your body. X-ray machine operators usually stand behind shields to protect themselves. A patient who gets an X ray usually wears a lead apron or shield to protect the body parts that are not receiving the X ray.

How are gamma rays used?

Even though gamma rays are dangerous to living organisms, they have some helpful uses, just like X rays do. A beam of gamma rays can be used to kill cancerous tumors. Gamma rays can also kill disease-causing bacteria in food. More than 1,000 Americans die each year from *Salmonella* bacteria in poultry and *E. coli* bacteria in meat. Gamma radiation has been used since 1963 to kill bacteria in food. However, this method is not often used in the food industry.

Astronomy with Different Wavelengths

Astronomers use more than visible light to study objects in space. Some objects that produce no visible light can be found through X rays, infrared waves, or radio waves that they give off. Scientists use instruments that can detect many types of electromagnetic radiation to study these objects.

Recall that Earth's atmosphere blocks X rays, gamma rays, most ultraviolet rays, and some infrared rays. To study these types of radiation from space, scientists have to get above Earth's atmosphere. Satellites have been built for this. Three of these sattelites are the Extreme Ultraviolet Explorer (EUVE), the Chandra X-Ray Observatory, and the Infrared Space Observatory (ISO). ☑

Think it Over

9. Draw Conclusions Why do doctors use X rays only when necessary?

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☑ Reading Check

10. Describe How are astronomers able to study X rays and gamma rays given off by objects in space?

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After You Read

Mini Glossary

electromagnetic spectrum: the wide range of electromagnetic waves with different wavelengths and frequencies

gamma rays: electromagnetic waves that have the highest frequency and carry the most energy

infrared waves: electromagnetic waves with wavelengths between about one thousandth and 0.7 millionths of a meter

radio waves: electromagnetic waves that have the lowest frequencies and carry the least energy

ultraviolet radiation: electromagnetic waves that are higher in frequency than visible light and have even shorter wavelengths—between 0.4 millionths and about 10 billionths of a meter

visible light: electromagnetic waves that you can see with your eyes

X rays: electromagnetic waves that have an even higher frequency than ultraviolet rays and enough energy to go right through skin and muscle

1. Review the terms and their definitions in the Mini Glossary. What are the two types of electromagnetic radiation that humans can sense?

2. In the table below, place the six types of electromagnetic radiation you learned about in this section in order from longest wavelength to shortest wavelength.

Types of Electromagnetic Radiation

3. Which type of harmful electromagnetic radiation are you exposed to most often? How can you protect yourself from too much exposure?

End of Section

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