chapter 11

Electromagnetic Waves

section 2 The Electromagnetic Spectrum

What You'll Learn

- the different kinds of electromagnetic waves
- the properties of electromagnetic waves
- how electromagnetic waves are used

Before You Read

Radio waves, microwaves, and X rays are examples of electromagnetic waves. On the lines below, write a sentence about how you or someone you know has used electromagnetic waves.

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Mark the Text

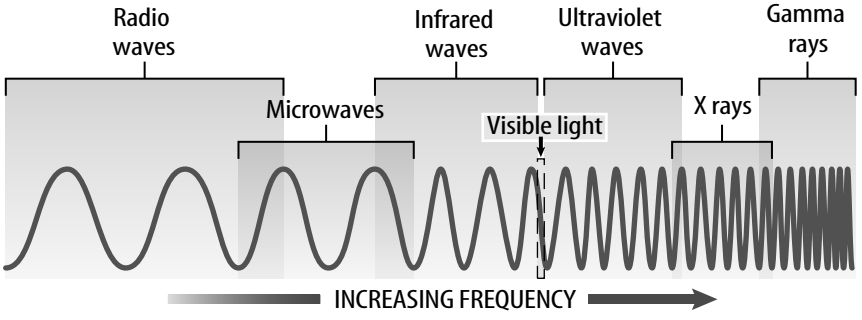
Identify Definitions As you read this section, highlight each vocabulary term and its definition.

Read to Learn

A Range of Frequencies

Electromagnetic waves have a wide range of frequencies. Some vibrate once a second. Others vibrate trillions of times a second. The whole range of electromagnetic wave frequencies is called the electromagnetic spectrum. The electromagnetic spectrum is shown below.

Different parts of the electromagnetic spectrum interact with matter in different ways. Because of this, the parts of the spectrum have different names. **Visible light**, the range of electromagnetic waves that humans can see, is a small part of the whole electromagnetic spectrum. But a number of devices have been created to detect the other frequencies. For example, the antenna of a radio detects radio waves.



Picture This

1. **Identify** Which electromagnetic waves have the lowest frequency?

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Radio Waves

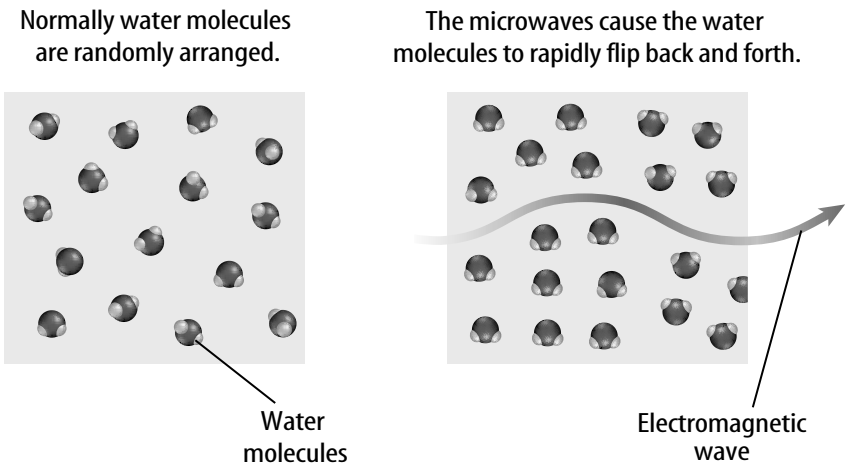
Even though you can't see them, radio waves are moving everywhere. **Radio waves** are low-frequency electromagnetic waves with wavelengths longer than about 1 mm. Radio stations make use of these waves. Microphones are used to change sound waves from voices and music into radio waves. The radio waves carry signals that can be picked up by radios. Radios then change the signals back into sound waves. Remember, you hear sounds when compressions and rarefactions from a sound wave reach your ears. A radio wave does not produce compressions and rarefactions, so you cannot hear an actual radio wave. It needs to be turned into a sound wave by a radio before you can hear it.

What are microwaves?

Microwaves are radio waves with wavelengths less than 30 cm. They have a higher frequency and shorter wavelength than the waves used by radios. Microwaves with wavelengths between about 20 cm and 1 cm are used for communication. Cell phones and satellites use microwaves of this wavelength.

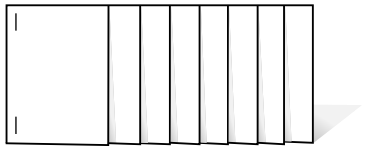
How do microwave ovens work?

In microwave ovens, microwaves interact with water molecules in food. The figure shows how microwave ovens work. Each water molecule is positively charged on one side and negatively charged on the other side. There is a vibrating electric field inside a microwave oven. It causes the water molecules in food to rotate billions of times a second. The rotation causes friction. Friction creates thermal energy. Thermal energy made by the interactions between the water molecules heats food.



FOLDABLES

B Find Main Ideas Make a layered book Foldable using four sheets of paper to describe each part of the electromagnetic spectrum. Write spectrum on the first tab and label the other tabs.



Reading Check

2. **Explain** Why is it impossible to heat items that do not contain water in a microwave oven?

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Picture This

3. **Analyze a Diagram** Look at the figure. List two differences between the left part and right part of the figure.

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How does radar work?

Radar stands for **RA**dio **D**etecting **A**nd **R**anging. Radar is used to find the position and speed of objects. Radio waves are sent toward an object. The waves bounce off the object and return. The time this takes gives the object's position. Radar can show the position of airplanes, boats, and cars. It also can measure the speed of moving vehicles.

Reading Check

4. **Describe** What does radar show?

What is magnetic resonance imaging?

Researchers developed a technique called magnetic resonance imaging, or MRI, in the 1980s. MRI uses radio waves to help diagnose illnesses. The patient lies inside a large tube surrounded by a strong magnet, a radio-wave emitter, and a radio-wave detector.

Protons in the hydrogen atoms in bones and soft tissue act like magnets. They line up with the strong magnetic field of the MRI. Energy from radio waves makes some of the protons flip. When the protons flip, they release energy. Different tissues release different amounts of energy. A radio receiver detects the released energy and makes a map of the body's tissues. A picture of the inside of the patient's body is made.

Infrared Waves

When you stand in front of a fireplace, you feel warmth from the fire. Why do you feel heat? The warmth is thermal energy transmitted by infrared waves. **Infrared waves** are electromagnetic waves with wavelengths between about one millimeter and about 750 billionths of a meter.

Think it Over

5. **Predict** If your body heat were to show up on an infrared detector, which parts of your body would be giving off the least amount of infrared waves?

You use infrared waves every day. A remote control sends out infrared waves to a television. A computer uses infrared waves to read CD-ROMs. In fact, every object gives off infrared waves. Hotter objects give off more infrared waves than cooler objects. Infrared detectors can make pictures of objects from the infrared waves they give off, or emit. Infrared sensors on satellites can identify where plants are growing in a region.

Visible Light

Visible light is the range of electromagnetic waves that people can see. Visible light has wavelengths of about 750 billionths to 400 billionths of a meter. The electromagnetic waves you can see have different wavelengths. You see the different wavelengths as different colors. Blue light has the shortest wavelength. Red light has a longest wavelength. The light looks white if all the colors are present.

Applying Math

6. **Write Decimals** You can write 10 billionths as a decimal by moving the decimal point in 1.0 ten places to the left. Write 10 billionths as a decimal.

Ultraviolet Waves

Ultraviolet waves are electromagnetic waves with wavelengths from about 400 billionths to 10 billionths of a meter. Ultraviolet (UV) waves have enough energy to enter skin cells. Being exposed to too many UV rays can cause skin damage and cancer. Sunlight contains ultraviolet waves.

Most of the ultraviolet radiation that reaches Earth's surface is longer-wavelength rays. They are called UVA rays. Shorter-wavelength rays are called UVB rays. UVB rays are the rays that cause sunburn. Both UVA and UVB rays can damage the skin and cause skin cancer.

Reading Check

7. **Describe** How can ultraviolet waves harm you?

Can UV radiation be useful?

Some UV rays are useful. A few minutes of UVs from the Sun each day helps your body make vitamin D. Vitamin D is needed for healthy bones and teeth.

UVs are also used to sterilize objects such as medical supplies and hospital equipment. When ultraviolet light enters a cell, it damages protein and DNA molecules. This can kill some single-celled organisms such as bacteria.

Ultraviolet waves make some materials light up, or fluoresce. Fluorescent materials absorb ultraviolet waves. Then they emit the energy as visible light. Police detectives sometimes use fluorescent powder to find fingerprints when solving crimes.

What is the ozone layer?

The ozone layer is an area in Earth's upper atmosphere. It is between 20 km to 50 km above Earth's surface. Ozone is a molecule made up of three oxygen atoms. The ozone layer is necessary to life on Earth because it absorbs most of the Sun's harmful ultraviolet waves. Over the past few decades, the amount of ozone in the ozone layer has decreased.

What chemicals harm the ozone layer? Ozone has decreased because of the presence of certain chemicals in Earth's atmosphere. The chemicals are called chlorofluorocarbons, or CFCs. CFCs are used in air conditioners, refrigerators, and cleaning fluids. CFC molecules react with ozone molecules. One chlorine atom from a CFC molecule can break apart thousands of ozone molecules. Many countries are using fewer CFCs and other chemicals that destroy ozone.

If too much ozone is destroyed, the ozone layer will be damaged or lost altogether. Without the ozone layer, everything on the surface of Earth would become exposed to a much higher level of damaging ultraviolet waves.

Think it Over

8. **Think Critically** What could happen to humans if the ozone layer were destroyed?

Think it Over

9. Infer Why might MRIs cause less harm to the body than X rays?

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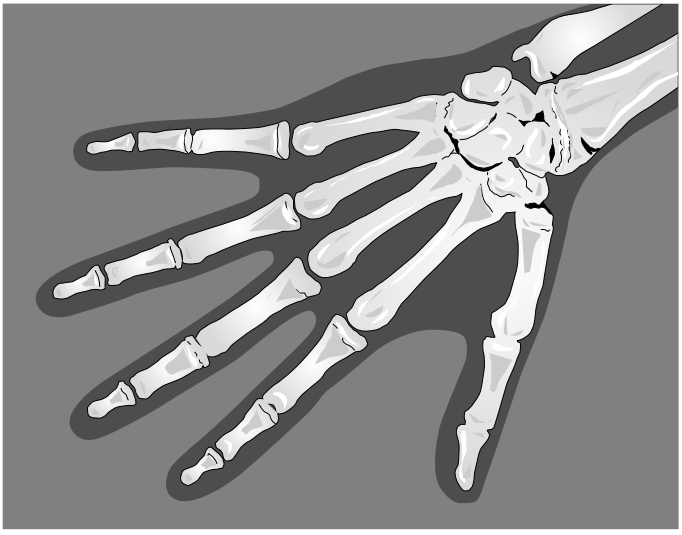
X Rays and Gamma Rays

X rays and gamma rays are the electromagnetic waves with the shortest wavelengths. They also have the highest frequencies. Both X rays and gamma rays are high-energy electromagnetic waves. **X rays** have wavelengths between 10 billionths and 10 trillionths of a meter. They have enough energy to go through skin and muscle. Doctors and dentists use low levels of X rays to take pictures of internal organs, bones, and teeth. High levels of X rays are dangerous and can cause cancer. X rays are projected only at very specific areas of the body. Lead aprons or shielding are used to protect other areas from exposure. X rays cannot travel through lead.



X Ray of Bone

Reading Check

10. Identify Which statement is *not* true. (Circle your answer.)

- **a.** Gamma rays are low-frequency waves.
- **b.** X rays are high-energy waves.
- **c.** Gamma rays are used to treat diseases.

Gamma rays are electromagnetic waves with wavelengths shorter than 10 trillionths of a meter. They are the highest-energy electromagnetic waves. They can travel through several centimeters of lead. Gamma rays are produced in the nuclei of atoms. Both X rays and gamma rays are used in radiation therapy. Radiation therapy is used to kill diseased cells in the human body. X rays and gamma rays can kill both healthy and diseased cells. Doctors carefully control the amount of X-ray or gamma-ray radiation the diseased area receives. This reduces the damage to healthy cells.

After You Read

Mini Glossary

gamma rays: electromagnetic waves with wavelengths shorter than 10 trillionths of a meter

infrared waves: electromagnetic waves with wavelengths between about 1 mm and about 750 billionths of a meter

microwaves: radio waves with wavelengths of less than 30 cm

radio waves: low-frequency electromagnetic waves with wavelengths longer than about 1 mm

ultraviolet waves: electromagnetic waves that have wavelengths from about 400 billionths to 10 billionths of a meter

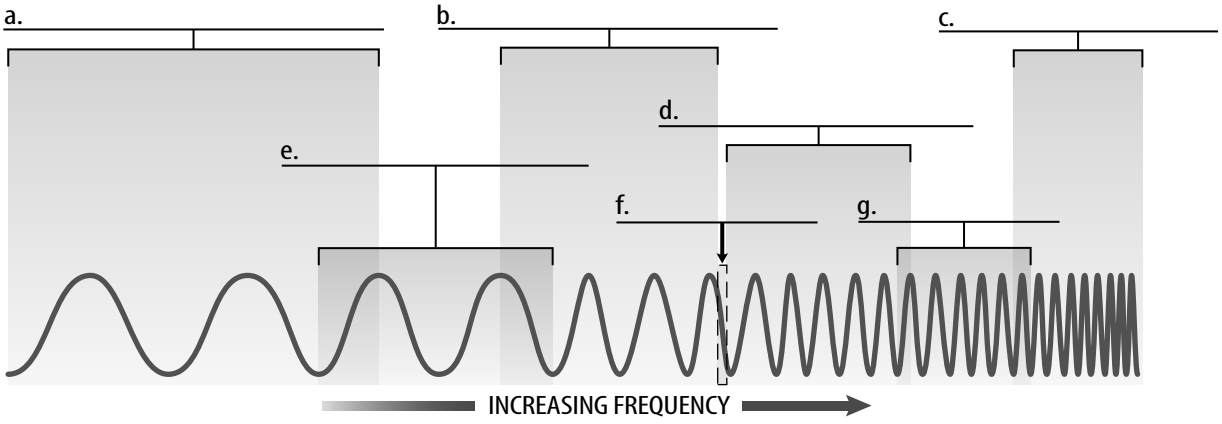
visible light: the range of electromagnetic waves that people can see

X rays: electromagnetic waves with a wavelength of between 10 billionths of a meter and 10 trillionths of a meter

1. Draw a line to match the name of each ray in the first column with its wavelength in the second column.

Column 1	Column 2
Visible light	less than 30 cm
X ray	400 billionths to 10 billionths of a meter
Microwave	longer than 1 mm
Gamma ray	1 mm to 750 billionths of a meter
Radio wave	10 billionths to 10 trillionths of a meter
Ultraviolet wave	750 billionths to 400 billionths of a meter
Infrared wave	shorter than 10 trillionths of a meter

2. Write the names of the waves listed in question 2 in the electromagnetic spectrum pyramid.



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