

# Waves of the Electromagnetic Spectrum

Can you imagine trying to take a photo with a radio? How about trying to tune in a radio station on your flashlight or heat your food with X-rays? Light, radio waves, and X-rays are all electromagnetic waves. But each has properties that make it more useful for some purposes and less useful for others. What makes light different from radio waves and X-rays?

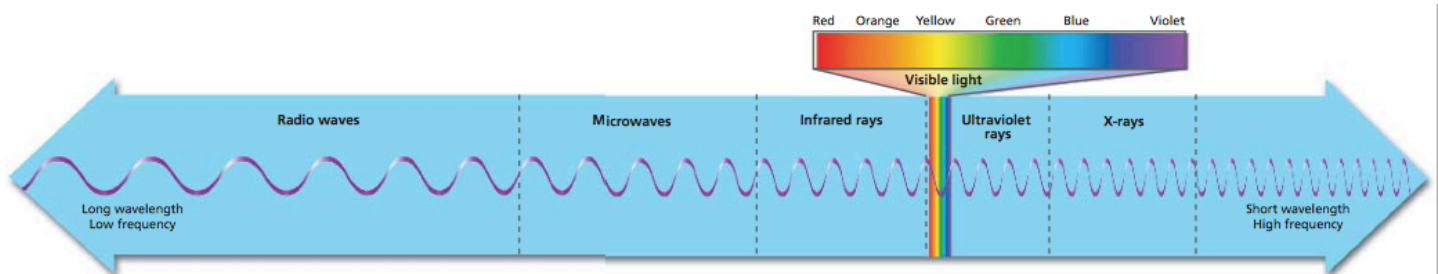
## What Is the Electromagnetic Spectrum?

**All electromagnetic waves travel at the same speed in a vacuum, but they have different wavelengths and different frequencies.** Radiation in the wavelengths that your eyes can see is called visible light. But only a small portion of electromagnetic radiation is visible light. The rest of the wavelengths are invisible. Your radio detects radio waves, which have much longer wavelengths than visible light. X-rays, on the other hand, are waves with much shorter wavelengths than visible light.

Recall how speed, wavelength, and frequency are related:

$$\text{Speed} = \text{Wavelength} \times \text{Frequency}$$

Because the speed of all electromagnetic waves is the same, as the wavelength decreases, the frequency increases. Waves with the longest wavelengths have the lowest frequencies. Waves with the shortest wavelengths have the highest frequencies. The amount of energy carried by an electromagnetic wave increases with frequency. The higher the frequency of a wave, the higher its energy.



The **electromagnetic spectrum** is the complete range of electromagnetic waves placed in order of increasing frequency. **The electromagnetic spectrum is made up of radio waves, infrared rays, visible light, ultraviolet rays, X-rays, and gamma rays.**

The electromagnetic spectrum shows the range of different electromagnetic waves in order of increasing frequency and decreasing wavelength.

## Radio Waves

**Radio waves** are the electromagnetic waves with the longest wavelengths and lowest frequencies. They include broadcast waves (for radio and television) and microwaves.

## Broadcast Waves

Radio waves with longer wavelengths are used in broadcasting. They carry signals for both radio and television programs. A broadcast station sends out radio waves at certain frequencies. Your radio or TV antenna picks up the waves and converts the radio signal into an electrical signal. Inside your radio, the electrical signal is converted to sound. Inside your TV, the signal is converted to sound and pictures.

## Microwaves

The radio waves with the shortest wavelengths and the highest frequencies are **microwaves**. When you think of microwaves, you probably think of microwave ovens that cook and heat your food. But microwaves have many uses, including cellular phone communication and radar.

*Radar* stands for **radio detection and ranging**.

**Radar** is a system that uses reflected radio waves to detect objects and measure their distance and speed. To measure distance, a radar device sends out radio waves that reflect off an object. The time it takes for the reflected waves to return is used to calculate the object's distance. To measure speed, a radar device uses the Doppler effect. Because the car is moving, the frequency of the reflected waves is different from the frequency of the original waves. The difference in frequency is used to calculate the car's speed.



## Infrared Rays

If you turn on a burner on an electric stove, you can feel it warm up before the heating element starts to glow. The invisible heat you feel is infrared radiation, or infrared rays. **Infrared rays** are electromagnetic waves with wavelengths shorter than those of radio waves.

## Heat Lamps

Infrared rays have a higher frequency than radio waves, so they have more energy than radio waves. Because you can feel the energy of infrared rays as heat, these rays are often called heat rays. Heat lamps have bulbs that give off mostly infrared rays and very little visible light. These lamps are used to keep food warm at a cafeteria counter. Some people use heat lamps to warm up their bathrooms quickly.



## Infrared Cameras

Most objects give off some infrared rays. Warmer objects give off infrared waves with more energy and higher frequencies than cooler objects. An infrared camera takes pictures using infrared rays instead of light. These pictures are called thermograms. A **thermogram** is an image that shows regions of different temperatures in different colors. You can use an infrared camera to see objects in the dark. Firefighters use infrared cameras to locate fire victims inside a dark or smoky building. Satellites in space use infrared cameras to study the growth of plants and the motions of clouds.

## Visible Light

Electromagnetic waves that you can see are called **visible light**. They make up only a small part of the electromagnetic spectrum. Visible light waves have shorter wavelengths and higher frequencies than infrared rays. Visible light waves with the longest wavelengths appear red in color. As the wavelengths decrease, you can see other colors of light. The shortest wavelengths of visible light appear violet in color.

Visible light that appears white is actually a mixture of many colors.

White light from the sun can be separated by a prism into the colors of the visible spectrum—red, orange, yellow, green, blue, and violet. Recall that when waves enter a new medium, the waves bend,



or refract. The prism refracts different wavelengths of visible light by different amounts and thereby separates the colors. Red light waves refract the least. Violet light waves refract the most.

## Ultraviolet Rays

Electromagnetic waves with wavelengths just shorter than those of visible light are called **ultraviolet rays**. Ultraviolet rays have higher frequencies than visible light, so they carry more energy. The energy of ultraviolet rays is great enough to damage or kill living cells. In fact, ultraviolet lamps are often used to kill bacteria on hospital equipment.

Small doses of ultraviolet rays are useful. For example, ultraviolet rays cause skin cells to produce vitamin D, which is needed for healthy bones and teeth. However, too much exposure to ultraviolet rays is dangerous. Ultraviolet rays can burn your skin, cause skin cancer, and damage your eyes. If you apply sunblock and wear sunglasses that block ultraviolet rays, you can limit the damage caused by ultraviolet rays.

## X-Rays

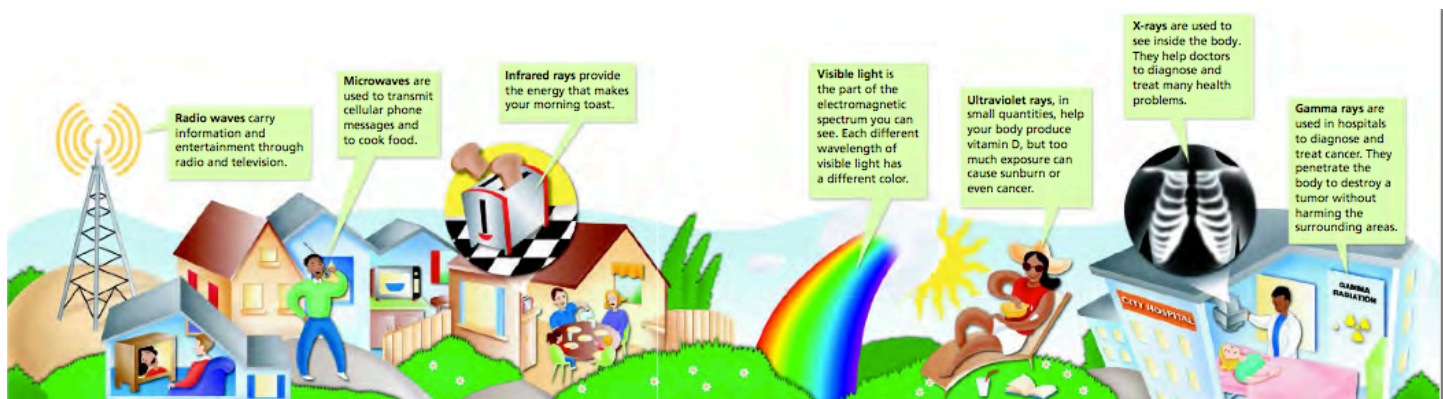
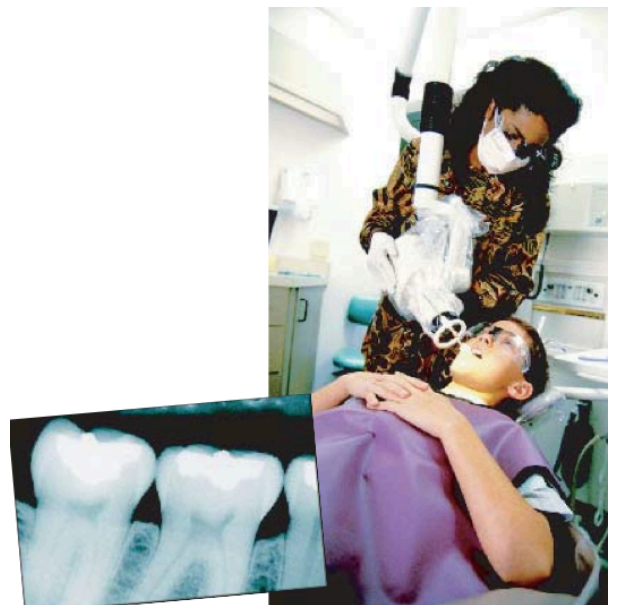
**X-rays** are electromagnetic waves with wavelengths just shorter than those of ultraviolet rays. Their frequencies are just a little higher than ultraviolet rays.

Because of their high frequencies, X-rays carry more energy than ultraviolet rays and can penetrate most matter. But dense matter, such as bone or lead, absorbs X-rays and does not allow them to pass through. Therefore, X-rays are used to make images of bones inside the body or of teeth. X-rays pass through skin and soft tissues, causing the photographic film in the X-ray machine to darken when it is developed. The bones, which absorb X-rays, appear as the lighter areas on the film.

Too much exposure to X-rays can cause cancer. If you've ever had a dental X-ray, you'll remember that the dentist gave you a lead apron to wear during the procedure. The lead absorbs X-rays and prevents them from reaching your body.

X-rays are sometimes used in industry and engineering.

For example, to find out if a steel or concrete structure has tiny cracks, engineers can take an X-ray image of the structure. X-rays will pass through tiny cracks that are invisible to the human eye. Dark areas on the X-ray film show the cracks. This technology is often used to check the quality of joints in oil and gas pipelines.



## **Gamma Rays**

**Gamma rays** are the electromagnetic waves with the shortest wavelengths and highest frequencies. Because they have the greatest amount of energy, gamma rays are the most penetrating of all the electromagnetic waves.

Some radioactive substances and certain nuclear reactions produce gamma rays. Because of their great penetrating ability, gamma rays have some medical uses. For example, gamma rays can be used to kill cancer cells inside the body. To examine the body's internal structures, a patient can be injected with a fluid that emits gamma rays. Then a gamma ray detector can form an image of the inside of the body. Some objects in space give off bursts of gamma rays. The gamma rays are blocked by Earth's atmosphere, so gamma ray telescopes that detect them must orbit above Earth's atmosphere. Astronomers think that explosions of stars in distant galaxies are one way of producing these gamma rays.