

Electromagnetic Spectrum

Why do some things have colors? What makes color?

Why do fast food restaurants use red lights to keep food warm? Why don't they use green or blue light?

Why do X-rays pass through the body and let us see through the body?

What has the radio to do with radiation?

What are the night vision devices that the army uses in night time fighting?

To find the answers to these questions we have to examine the electromagnetic spectrum.

FASTER THAN A SPEEDING BULLET MORE POWERFUL THAN A LOCOMOTIVE

These words were used to introduce a fictional superhero named Superman. These same words can be used to help describe Electromagnetic Radiation.

Electromagnetic Radiation is like a two member team racing together at incredible speeds across the vast regions of space or flying from the clutches of a tiny atom. They travel together in packages called photons. Moving along as a wave with frequency and wavelength they travel at the velocity of 186,000 miles per second (300,000,000 meters per second) in a vacuum. The photons are so tiny they cannot be seen even with powerful microscopes. If the photon encounters any charged particles along its journey it pushes and pulls them at the same frequency that the wave had when it started. The waves can circle the earth more than seven times in one second!

If the waves are arranged in order of their wavelength and frequency the waves form the Electromagnetic Spectrum. They are described as electromagnetic because they are both electric and magnetic in nature.

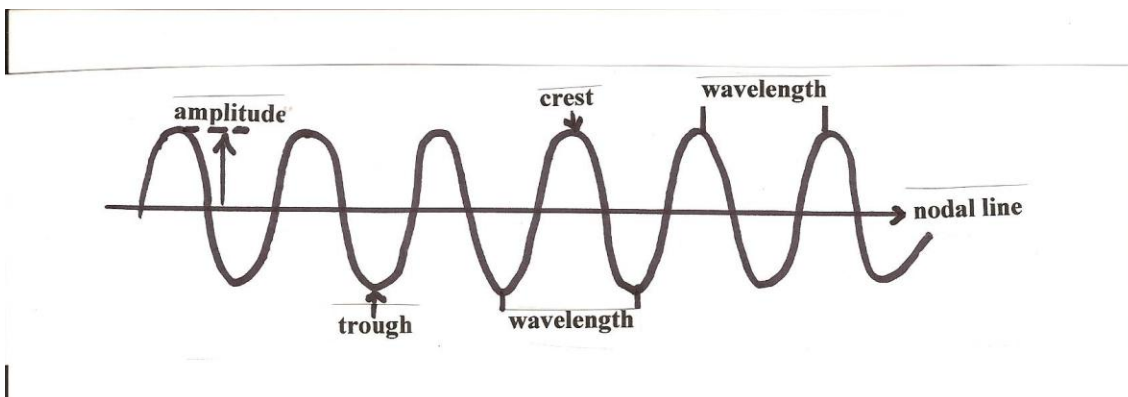
The Electromagnetic Spectrum consists of radio waves, microwaves (a type of radio wave), infrared rays, visible light, ultraviolet rays, X-rays, and gamma rays.

Waves with the longest wavelengths have the lowest frequencies. Waves with the shortest wavelengths have the highest frequencies.

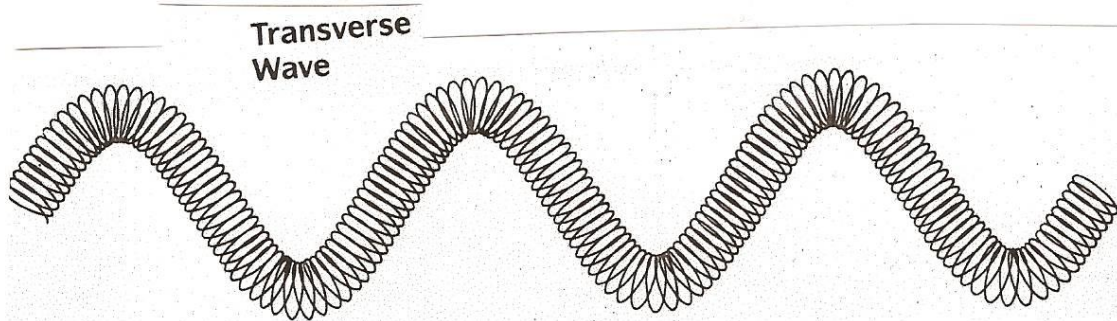
Electromagnetic waves in the spectrum range from very long wavelength, low frequency radio waves to very short wavelength high frequency gamma rays. Visible light is only a very small portion of the spectrum that you can detect with your eyes. The rest of the electromagnetic spectrum is invisible.

A wave is a rhythmic disturbance which travels through space or matter. Consider a water wave. The place where the water surface is highest is the crest. Where the water surface is lowest is the trough. The distance between crests or troughs is called its wavelength. The height of the wave above the normal water surface (nodal line) is the amplitude of the wave. If you count the number of crests that pass a certain point per second that quantity is the frequency of the wave. Suppose 14 crests pass a point in 10 seconds. The frequency is 14 crests divided by 10 or 1.4 crests per second. The modern metric system, known as SI, contains all the units scientists have agreed to use for all their measurements. The letters SI come from the French name for *international system*. The SI unit for the number per second is the hertz (Hz). So the frequency here would be 1.4 Hz.

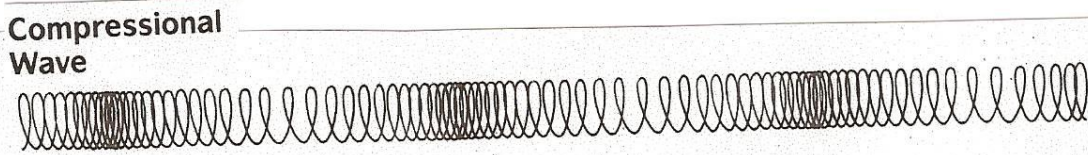
The frequency of a wave is related to its wavelength. The more crests that pass a point per second, the closer together they must be. Thus the higher the frequency the shorter the wavelength. Waves with lower frequencies have longer wavelengths.



Electromagnetic waves are transverse waves. The moving photons of energy generate electric and magnetic fields. Thus an electromagnetic wave is both electric and magnetic in nature. The electric and magnetic fields are at right angles to each other and to the direction of wave energy.



In a compressed wave, particles move back and forth along the direction of a wave motion.



RADIO WAVES, MICROWAVES, INFRARED, VISIBLE LIGHT, ULTRAVIOLET, X-RAYS, GAMMA RAYS

How can waves be so different from each other and yet be the same? In spite of their varying differences they are all electromagnetic radiation. All can be described as streams of photons traveling at the speed of light. Each photon contains a bundle of energy. What is different is the amount of energy each carries.

TYPES OF RADIATION IN THE ELECTROMAGNETIC SPECTRUM

RADIO WAVE: Radio waves have the longest wavelength. Their wavelengths can be as long as a football field or as short as the football lying on the field. These waves are part of the electromagnetic spectrum and travel at the speed of light. We are very familiar with two kinds of radio waves called AM waves and FM waves. AM waves are sine waves. Both AM radio stations and the picture part of a TV signal use amplitude modulation (AM) to encode information. FM radio stations and hundreds of other wireless technologies (including the sound portion of a TV signal, cordless phones, cell phones, etc.) use frequency modulation (FM). Antennas broadcast waves that travel through the air. Other antennas pick up the signals and produce an electric current which is carried to a receiver and amplified. Antennas come in all shapes and sizes, depending on the frequency the antenna is trying to receive.

MICROWAVES: Microwaves are very short radio waves. They are between ordinary radio waves and infrared rays. They are used not only for communication but also for heating our food. Since microwaves can pass through rain, smoke, and fog they are good for transmitting information. Shorter microwaves are used in remote sensing devices such as Doppler radar. Those microwaves are just a few inches long.

INFRARED: Infrared lies between visible light and microwaves on the electromagnetic spectrum. Their wavelengths vary from the size of a pin head to the size of cells. These are thermal waves and are used to dry or heat things. Cooked foods in restaurants are kept warm by infrared lamps. Shorter infrared waves are used by your TV's remote. Any object which has a temperature radiates in the infrared. Even ice cubes

emit infrared. Special cameras and film detect differences in temperatures and assign different brightness's or false colors to them. This provides a picture that our eyes can interpret.

VISIBLE LIGHT: Visible light lies between infrared and ultraviolet. It is the only part of the electromagnetic spectrum that we can see. Light wave frequencies are between 430 trillion hertz and 760 trillion hertz. While light actually consists of many different colors, each color has its own special frequency. Red has the lowest at 430 trillion hertz. It also carries the lowest energy. Violet has the highest frequency at 760 trillion hertz and carries the highest energy.

ULTRAVIOLET: Found just above visible light, ultraviolet radiation is present in sunlight. When sunlight strikes your body the ultraviolet radiation produces vitamin D in your skin. Vitamin D is needed for healthy bones and teeth. Ultraviolet radiation kills germs. For this reason hospitals often use ultraviolet lamps to kill germs in operating rooms. Ultraviolet radiation is invisible and its wavelength is shorter than visible light. It can be detected with a fluorescent material which will glow and give off light when struck by ultraviolet radiation. Overexposure to ultraviolet can be harmful and can cause skin cancer.

X-rays: Discovered in 1895 by German physicist W. K. Roentgen, X-rays lie just above ultraviolet on the Electromagnetic Spectrum. They have high energy and a short wavelength. X-rays can pass through all matter however all substances absorb them to some degree. The amount absorbed depends upon the density of the material. For this reason they are useful in looking at bones and teeth.

Gamma Radiation: Gamma rays are energy waves of short wavelengths and high frequency. They are photons of energy that travel at the speed of light. They are more penetrating than either alpha or beta rays. It takes a dense material such as lead or concrete to stop gamma rays. They are used to treat cancer.