10.2: The Electromagnetic Spectrum

Learning Objectives

- Know the properties of different types of electromagnetic radiation.

The light given off by the sun which allows us to see is a type of electromagnetic radiation and travels in electromagnetic waves. Electromagnetic waves have an extremely wide range of wavelengths, frequencies, and energies. The highest energy form of electromagnetic waves are gamma (γ) rays and the lowest energy form are radio waves. The figure below shows the **electromagnetic spectrum**, which includes all forms of electromagnetic radiation.

Electromagnetic radiation that lies to the left in Figure 10.2.1 are non-ionizing forms of radiation. Those furthest to the left have the lowest energy and are called **radio waves**. This portion of the electromagnetic spectrum is where we find the broadcast frequencies for AM and FM radio. **Microwaves** have the next higher energy of electromagnetic radiation. It should be most obvious that microwave ovens use radiation in the microwave portion of the spectrum. However, cellphones, wireless routers, and radar also use the microwave portion of the spectrum.

Infrared radiation has the next higher energy. Many of the things we associate with giving off heat are the result of infrared radiation. Believe it or not, humans give off abundant infrared radiation. So do heat lamps used to keep food warm. Night vision goggles and thermal imagining cameras detect infrared radiation and are thus used to "see" things that give off heat. The tiny section in the middle is called the **visible spectrum** or **visible light**. This portion of the spectrum is what is visible to humans and is described in further detail below.

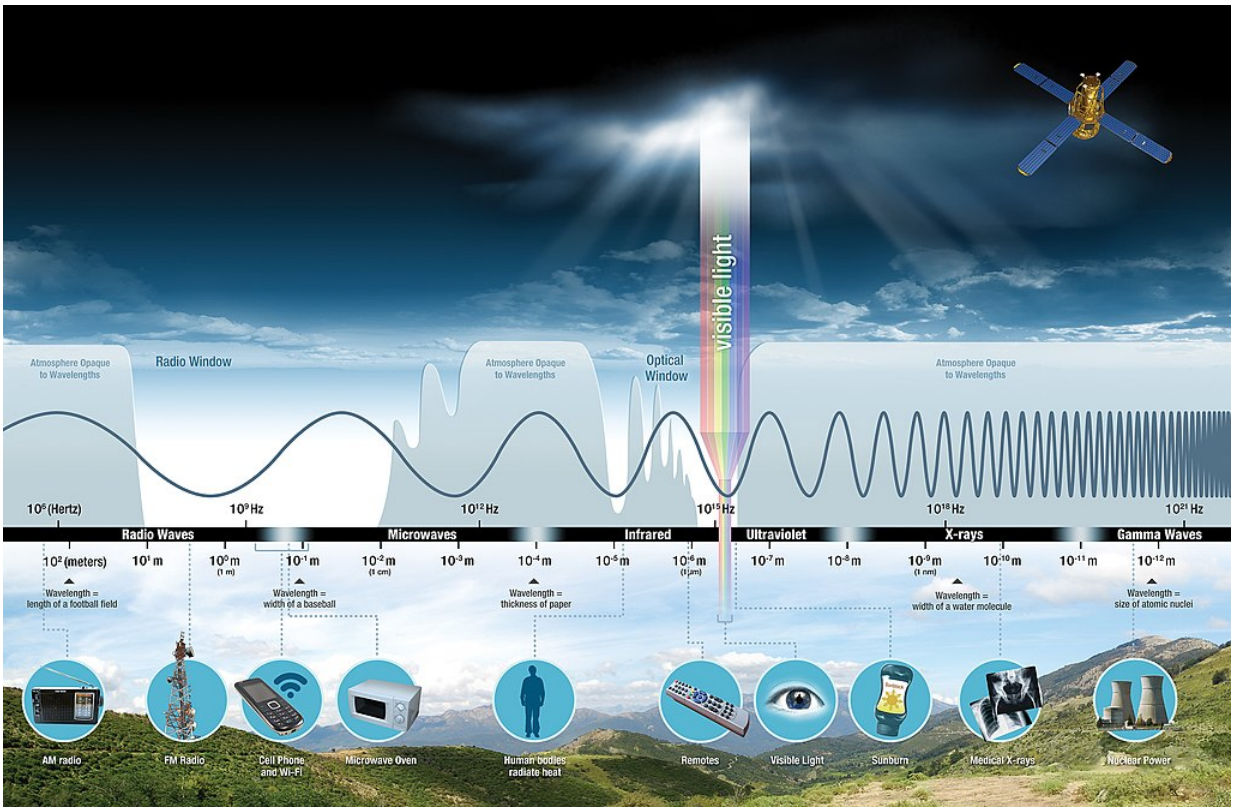
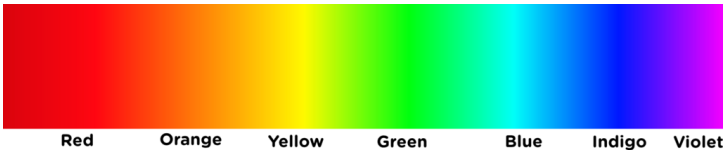


Figure 10.2.1: The electromagnetic spectrum, with its various regions labeled. The borders of each region are approximate. (NASA, Public domain, via Wikimedia Commons).

Electromagnetic radiation that lies to the right of visible light in Figure 10.2.1 are ionizing forms of radiation, i.e. they cause matter to form ions when they absorb these forms of radiation. Lying just above visible light, in terms of energy, are **ultraviolet rays**. Because ultraviolet rays are an ionizing form of radiation, they may cause skin damage and a long term risk of skin cancer.

Ultraviolet rays are only able to penetrate the outer layers of skin. On the other hand, **x-rays** have a higher energy and are able to penetrate the human body. This makes them useful for internal imaging of the human body. However, due to the fact they are an ionizing form of radiation, humans are advised to limit as much as possible the number of medical x-rays they have per year. **Gamma rays** have the highest energy and can be quite dangerous to living systems. Exposure is often a result of radioactive decay and should be greatly limited.

The colors of visible spectrum, shown below, may be learned using the mnemonic, ROY G BIV, for red orange yellow green blue indigo violet. Indigo is a color that lies between blue and violet on the spectrum and is simply used to make a handy mnemonic. When learning the colors in this order, you are learning them in order from low energy to high energy. Note that red lies next to the infrared portion of the electromagnetic spectrum and violet lies next to the ultraviolet portion of the spectrum.



The light energies that are in the visible range are electromagnetic waves that cause the human eye to respond when those frequencies enter the eye. The eye sends a signal to the brain and the individual "sees" various colors. The highest energy waves in the visible region cause the brain to see violet and as the energy decreases, the colors change to blue, green, yellow, orange, and red. When the energy of the wave is above or below the visible range, the eye does not respond to them. When the eye receives several different frequencies at the same time, the colors are blended by the brain. If all frequencies of light strike the eye together, the brain sees white. If there are no visible frequencies striking the eye, the brain sees black.

The objects that you see around you are light absorbers – that is, the chemicals on the surface of the object will absorb certain frequencies and not others. Your eyes detect the frequencies that strike your eye. Therefore, if your friend is wearing a red shirt, it means the dye in that shirt absorbs every frequency except red and the red frequencies are reflected. If your only light source was one exact frequency of blue light and you shined it on a shirt that was red in sunlight, the shirt would appear black because no light would be reflected. The light from fluorescent lights do not contain all the frequencies of sunlight and so clothes inside a store may appear to be a slightly different color when you get them home due to different lighting.

✅ Example 10.2.1

A. Which type of radiation has the longest wavelength, microwaves or ultraviolet rays?
B. Which type of radiation has the greatest frequency, microwaves or ultraviolet rays?
C. Which type of radiation has the greatest energy, microwaves or ultraviolet rays?

Solution

Referring to Figure 10.2.1,

A. Wavelengths decrease as one moves to the right on the diagram, so microwaves have the longest wavelength.
B. Frequencies increase as one moves to the right on the diagram, so ultraviolet rays have the greatest frequency.
C. Energy increases as one moves to the right on the diagram, so ultraviolet rays have the greatest energy.

✏️ Exercise 10.2.1

A. Which color of the visible spectrum has the longest wavelength?
B. Which color of the visible spectrum has the greatest frequency?
C. Which color of the visible spectrum has the greatest energy?

Answer A

red

Answer B

violet

Answer C

violet

Summary

- Electromagnetic radiation has a wide spectrum, including gamma rays, X-rays, UV rays, visible light, IR radiation, microwaves, and radio waves.
- The different colors of light differ in their frequencies (or wavelengths).