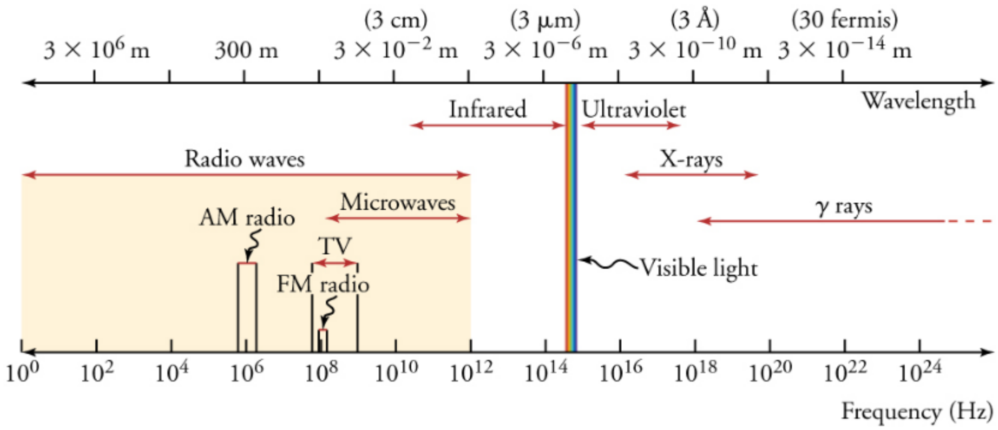
11.3: Electromagnetic Spectrum

As discussed, the fact that wave speed can be written as the product of frequency and wavelength means that there are two ways to describe the electromagnetic spectrum. Below is an image showing the wavelength and corresponding frequencies for various types of electromagnetic radiation. Note the tiny slice of the entire spectrum that encompasses all visible light.



EMR spectrum taken from OpenStax *Physics* and is licensed under CC-BY

Wavelengths just longer than red light are called *infrared* and it is these waves that we experience as heat when standing in the sunshine, or near a fire. Wavelengths shorter than violet are called *ultraviolet* and are responsible for skin damage. Sunscreens are designed to absorb and reflect these damaging wavelengths.

Although the most common way of describing light is in terms of the wavelength, this can be misleading. Recall that the frequency of the oscillations is set by the source. Since the frequency is set by the source and the wave speed is set by the medium, that means the wavelengths change as the wave speed changes. Because of this, the standard wavelengths used to describe light assume the light is traveling in vacuum.

Example 11.3.1

The frequency of a microwave is 10^{10} Hertz. The speed of light in air is 3 x 10^8 meters per second. The speed of light in water is about 2.25 x 10^8 meters per second. Calculate the wavelength of microwaves in water and air.

Solution

$$v_{\text{wave}} = \lambda\, f, \text{ so } \lambda = \frac{v_{wave}}{f}$$

For water: $\lambda = \frac{2.25 \times 10^8 \text{meters per second}}{10^{10}\text{Hertz}}$ = 2.25 millimeters

For air: $\lambda = \frac{3 \times 10^8 \text{meters per second}}{10^{10}\text{Hertz}}$ = 3 millimeters

An overview of electromagnetic waves, their means of production and some applications are summarized in the table below:

Type of wave	Production	Applications	Issues
Radio	Accelerating charges	Communications Remote controls MRI	Requires control for band use
Microwaves	Accelerating charges and thermal agitation	Communications Ovens Radar Cell phone use	
Infrared	Thermal agitation and electronic transitions	Thermal imaging Heating	Absorbed by atmosphere Greenhouse effect
Visible light	Thermal agitation and electronic transitions	Photosynthesis Human vision	
Ultraviolet	Thermal agitation and electronic transitions	Sterilization Vitamin D production	Ozone depletion Cancer causing
X-rays	Inner electronic transitions and fast collisions	Security Medical diagnosis Cancer therapy	Cancer causing
Gamma rays	Nuclear decay	Nuclear medicine Security Medical diagnosis Cancer therapy	Cancer causing Radiation damage

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