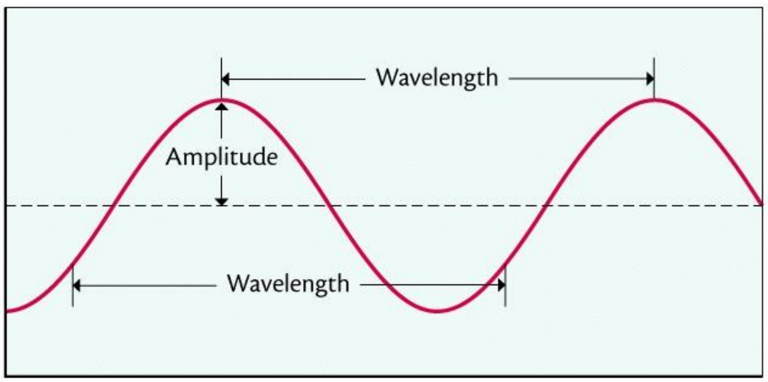
Spectral Signature

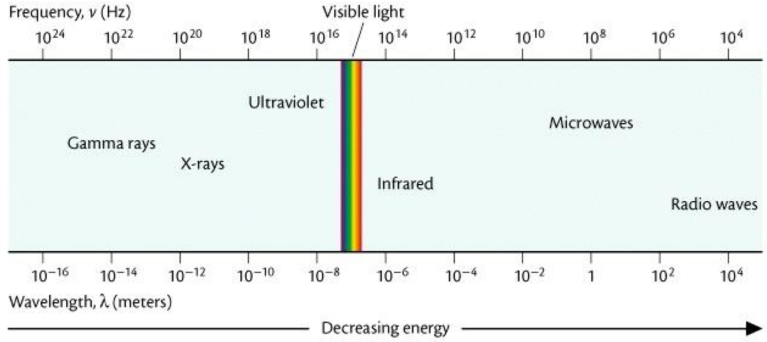
Electromagnetic radiation has a dual nature with characteristics of both waves and particles. For now, focus on the wave properties. Imagine a light weave having a shape similar to a sine wave. The distance from one wave peak to the next peak is called *wavelength.* Wavelength is measured in meters although the wavelengths of visible light are commonly expressed in hundreds of nanometers or thousands of Ångstroms (1nm = 10^{-9}m, 10nm = 1Å). The number of wave peaks that pass a set point each second is *frequency.* It is measured in Hertz. One Hertz represents one wavelength per second. Mathematically, Hertz is the inverse of seconds. *Amplitude* indicates wave height. In visible light, wavelength and frequency are related to color and amplitude is related to intensity or brightness.



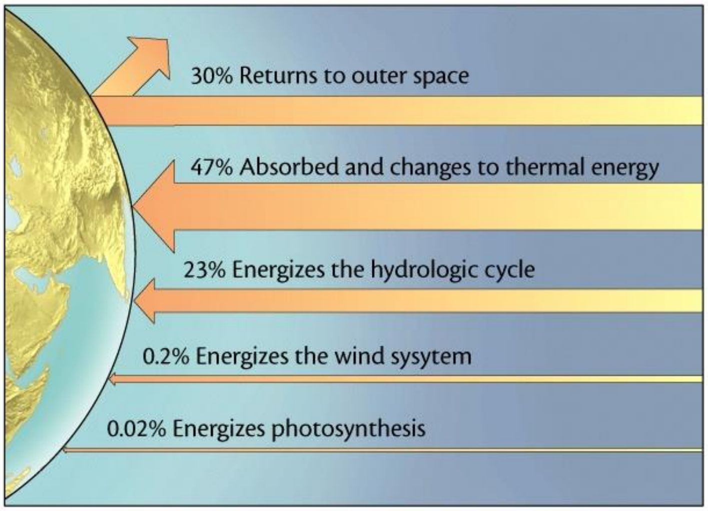
Wavelength (λ) and frequency (v) are inversely proportional to the velocity of electromagnetic radiation (speed of light, *c*) which is currently accepted as a universal constant. As wavelength gets shorter, frequency increases:

$$c = \lambda v$$

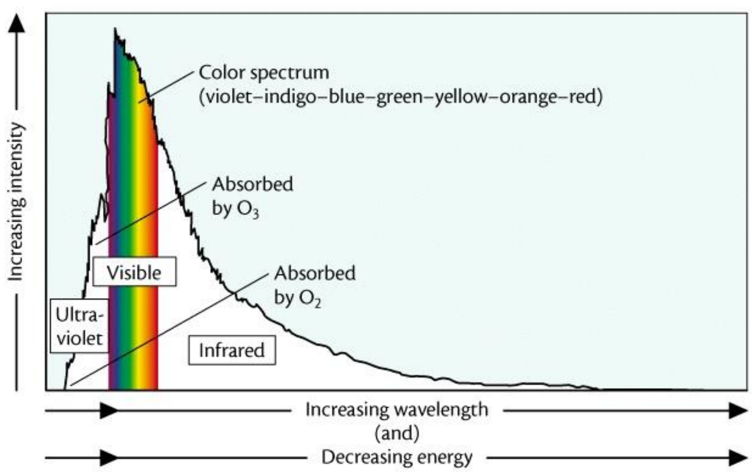
Wavelength and frequency are also proportional to the wave's energy. Higher frequency (shorter wavelength) radiation has more energy. As seen from the chart below, ultraviolet radiation is more energetic than infrared. Infrared has enough energy to cause atoms in molecules to vibrate more violently around their chemical bonds. This increased kinetic energy is often released as heat. On the other hand, ultraviolet radiation has sufficient energy to affect chemical bonds directly by disrupting electrons in their atomic orbitals, even ionizing atoms.



Only a small portion of the sun's energy is radiated towards the Earth. Almost a third of the radiation reaching the Earth bounces off the atmosphere and returns to space. Of the radiation passing into the atmosphere, much is absorbed in the upper layers. For example, most, but not all, of ultraviolet waves are absorbed as they activate chemical reactions in the stratospheric ozone (O_3) cycle. This is an important mechanism for reducing the concentration of high energy ultraviolet reaching the Earth's surface – energy capable of causing skin cancer. Radiation with wavelengths in the visible red, visible green, visible blue, near and mid infrared, and some long-wave ultraviolet bands reaches the surface and is absorbed or reflected by natural and cultural features there.



Solar Energy Reaching the Earth



Solar Energy Passing Through the Atmosphere

The specific amounts of specific wavelengths of electromagnetic radiation that are absorbed or reflected by a natural or cultural feature on the surface of the Earth or in the atmosphere constitutes the feature's **spectral signature**. It seems to be unique to each feature and to the particular condition of some features. Spectral signatures can be used easily to distinguish between rooftops and green grass, between healthy crops and distressed or diseased crops, between types of trees in a forest, between trees and shrubs. The **differential reflectivity** of spectral signatures is the foundation for satellite-based remote sensing.

Graphics credit:
Chemistry in the Community, Fourth Edition. American Chemical Society. New York: W.H. Freeman and Company. 2002.