**Lesson #7 – Light and Light Equations**

What we know as light is more properly called **electromagnetic radiation**.

We know from experiments that light acts as a wave. As such, it can be

described as having a **frequency** and a **wavelength**. The wavelength of light

is the distance between corresponding points in two adjacent light cycles,

and the frequency of light is the number of cycles of light that pass a given point

in one second. Therefore, the longer the wavelength a type of light has, the smaller

its frequency will be. The shorter the wavelength, the greater the frequency.

See the diagram below.



 1 second

Wavelength is typically represented by **λ**, the lowercase Greek letter lambda,

while frequency is represented by **ν**, the lowercase Greek letter nu

Wavelength has units of length (meters, centimeters, etc.), while frequency has

units of per second, written as s−1 and sometimes called a hertz (Hz).

The speed of light is a universal constant. The measured speed of light, ***c***,

is 3.00 × 108 m/s. The equation that relates wavelength and frequency is as follows:

**c = λ** x **ν**

**Speed of light = wavelength x frequency**

The relationship between wavelength and frequency is inverse. This means

 that as wavelength increases, frequency decreases.

Though we tend to think of light as that which can see with the naked eye, light is

actually a collection of many different forms of the electromagnetic spectrum.

The electromagnetic [spectrum](https://imagine.gsfc.nasa.gov/resources/dict_qz.html#spectrum) is the range of all types of radiation and includes

such components as: radio waves, [microwaves](https://imagine.gsfc.nasa.gov/resources/dict_jp.html#microwave), infrared, visible light, UV,

[X-rays](https://imagine.gsfc.nasa.gov/resources/dict_qz.html#X_ray) and [gamma-rays](https://imagine.gsfc.nasa.gov/resources/dict_ei.html#gamma_ray).

The chart below shows the electromagnetic spectrum. Note that the part we call

visible light is less than 1% of what scientist call light. But even visible light can be

broken down into the various colors of the rainbow: red, orange, yellow, green,

blue, indigo, and violet (ROYGBIV). Note also that the larger the wavelength, the

smaller the frequency.



Light is also a form of energy. Each frequency of the light spectrum proportional

to its energy. The mathematical equation that relates the energy, ***E***, of light to its

frequency is:

**E = h x ν**

where ν is the frequency of the light, and *h* is a constant called Planck’s constant.

Its value is 6.626 × 10−34 J·s and is another fundamental constant of our universe,

like the speed of light. As the frequency of light increases, so does its energy.

So for example: A **RED** light beam has a wavelength of around 700 nm and

a frequency of 4 x 1014 Hz. This gives red light an energy of 3 x 10-19 Joules.

Since red has the longest wavelength of all the colors, it has the smallest frequency,

and therefore, the least amount of energy in the visible spectrum.

A **VIOLET** light beam has a wavelength of around 400 nm and a frequency of

7 x 1014 Hz. This gives violet light an energy of 5 x 10-19 Joules. Since violet has

the shortest wavelength of all the colors, it has the largest frequency, and therefore

the greatest amount of energy in the visible spectrum.

A **continuous spectrum** contains many different colors, or wavelengths, with no

gaps. When “white light” is shined through a prism, it causes dispersion of the

light, and we see a rainbow. This is a **continuous spectrum**.

Atoms contain within them specific amounts of energy based on where its electrons

are located within the atom. The lowest possible energy level that an atom can

occupy is called the **ground state**. This is the energy state that would be considered

normal for the atom. When an atom is infused with energy, electrons may jump to

higher levels within the atom. An **excited state** is an energy level of an atom, ion,

or molecule in which an electron is at a higher energy level than its **ground state**.



A **photon** is the smallest discrete amount of electromagnetic radiation or energy.

It is the basic unit of all light. This discrete amount of energy of light is called a

**quantum** (plural: **quanta**)

When an electron gets “excited” and jumps to a higher energy level, it will

immediately fall back down to the ground state. When the electron returns to its

lower level, it must release the energy it originally absorbed from its jump. The

energy is released in the form of a **photon of light**. This photon has a specific

wavelength and energy. It therefore gives off a specific color. When viewed

through a light measuring device called a spectrometer, this wavelength appears as

an [emission line](https://astronomy.swin.edu.au/cosmos/E/Emission%2BLine). When multiple electrons jump and return to their ground states,

what is seen through a spectrometer is called a **line-emission spectrum**.



Though we tend to draw electrons travelling around the nucleus of an atom in a

circular pattern, this is simply not true. Electrons do not “orbit” an atom in a

specific trajectory. Instead they travel in random paths within a three-dimensional

areas of space around the atom. We call this region of space where the electron

resides an **orbital**.

When light hits a material (usually a metal), electrons can be emitted (discharged)

from the atoms on the surface of that material. The **photoelectric effect** is the

emission of [electrons](https://en.wikipedia.org/wiki/Electron) when [electromagnetic radiation](https://en.wikipedia.org/wiki/Electromagnetic_radiation), such as [light](https://en.wikipedia.org/wiki/Light), hits a material.

This may not seem important, but both Einstein and Millikan studied this

phenomenon that helped show that light can sometimes act not only a wave, but

also as a particle. For this, they both received the Nobel Prize in Physics.

