

## PRE-LAB exercise for LAB EXPERIMENT #3 – Light and Energy

### BACKGROUND

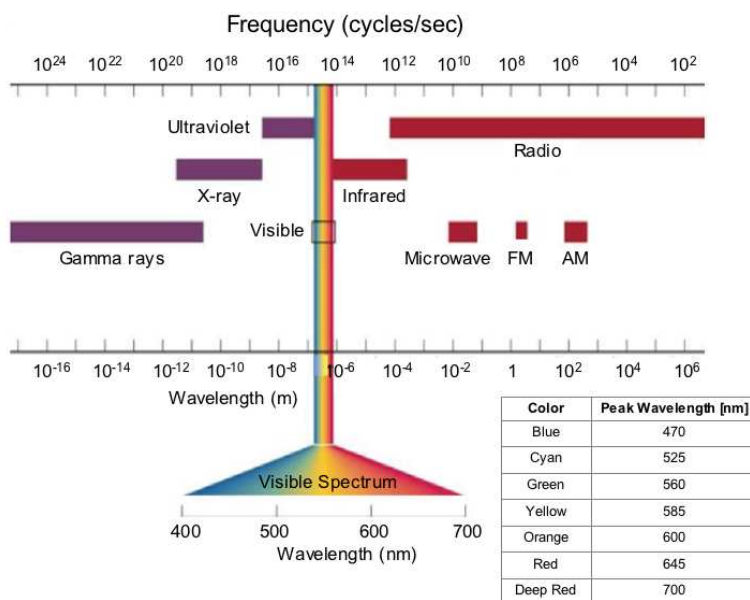


Figure 1. The electromagnetic spectrum (University of New Hampshire website, <http://mvh.sr.unh.edu/mvhtools/images/spectrumaa.png>)

### OBJECTIVE

The objective is for you to fill out the table on the next page by making calculations. The first line of the table is an example, and the last line is the type of calculations involved.

- Convert, within the metric system, the wavelength of blue light (470 nm) from nanometers to meters.** Scientific notation is much handier than writing a long line of zeros as decimal placeholders. **There are  $10^9$  nm in one meter.**
- Calculate the frequencies of blue light,** using  $4.7 \times 10^{-7}$  m wavelength (blue) and the speed of light (equation 2). **Make sure you can do these first two tasks, and that your answer matches that of the first line of the table.**

Light is a wave that travels at  $3 \times 10^8$  m/s. The mathematical product of the frequency of light and its wavelength is equal to its speed. Thus we can write two equations that are algebraically related to each other:

**(Equation 1)**  $v \times \lambda = c$

**(Equation 2)**  $v = c / \lambda$

with  $v$  = frequency,  $\lambda$  = wavelength, and  $c$  = speed.

Equation 1 says that the product of the frequency of light and its wavelength is equal to its speed.

Equation 2 says that the frequency is inversely proportional to its wavelength.

3. **Calculate the energy.** The quantum mechanical description of light is that it is composed of tiny particles called **photons**. The energy of each photon depends on its color. Quantitatively,

**(Equation 3)**  $E = h\nu$

**(Equation 4)**  $E = hc/\lambda$

Equation 3 says that the energy of a photon (a single particle of light) is proportional to the frequency of the light. In the SI system, energy is calculated in joules.

Equation 4 is built from equation 3 and equation 2 by algebraic substitution. You may wish to see how that works (optional).

**Planck's constant,  $h$ ,** has units of energy  $\times$  time, appears in equations 3 and 4.

**Speed of light**

$c = 3.00 \times 10^8$  m/s

**Planck's constant**

$h = 6.63 \times 10^{-34}$  Js (joule-seconds)

**Energy conversion factor**

$1.602 \times 10^{-19}$  joule = 1 eV (electron-volts)

4. **Calculate the energy in eV.** The energies of individual photons are much smaller than 0.5 joules, the energy of a single heartbeat. Energy may also be expressed in "electronvolts," (eV). A heartbeat is  $3 \times 10^{18}$  eV. A blue photon of only  $4.2 \times 10^{-19}$  J comes out to 2.6 eV.

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 Finish reproducing the first line of the table using your own calculations. Then repeat the calculations for red (645 nm), and the other given wavelengths that range from the visible to the near infrared.

Wavelength (nm)	$\lambda$ (m)	$\nu$ (sec <sup>-1</sup> or Hz)	Energy in joules (per photon)	Energy in eV (per photon)
470 nm (blue)	$4.7 \times 10^{-7}$ m	$6.4 \times 10^{14}$ Hz	$4.2 \times 10^{-19}$ J	2.6 eV
645 nm (red)				
400 nm				
560 nm				
720 nm				
(Given)	<i>Unit conversion</i>	$\nu = c / \lambda$	$E = h\nu$ (or $hc/\lambda$ )	<i>Unit conversion</i>

What is the relationship between wavelength and frequency? \_\_\_\_\_

What is the relationship between energy and frequency? \_\_\_\_\_

What is the relationship between wavelength and energy? \_\_\_\_\_

Answers: *inversely proportional* or (directly) *proportional*.

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