BERKELEY MATH CIRCLE

The Math of Chemistry

The Make-up of Atoms II:
Electrons, Light & the EM Spectrum

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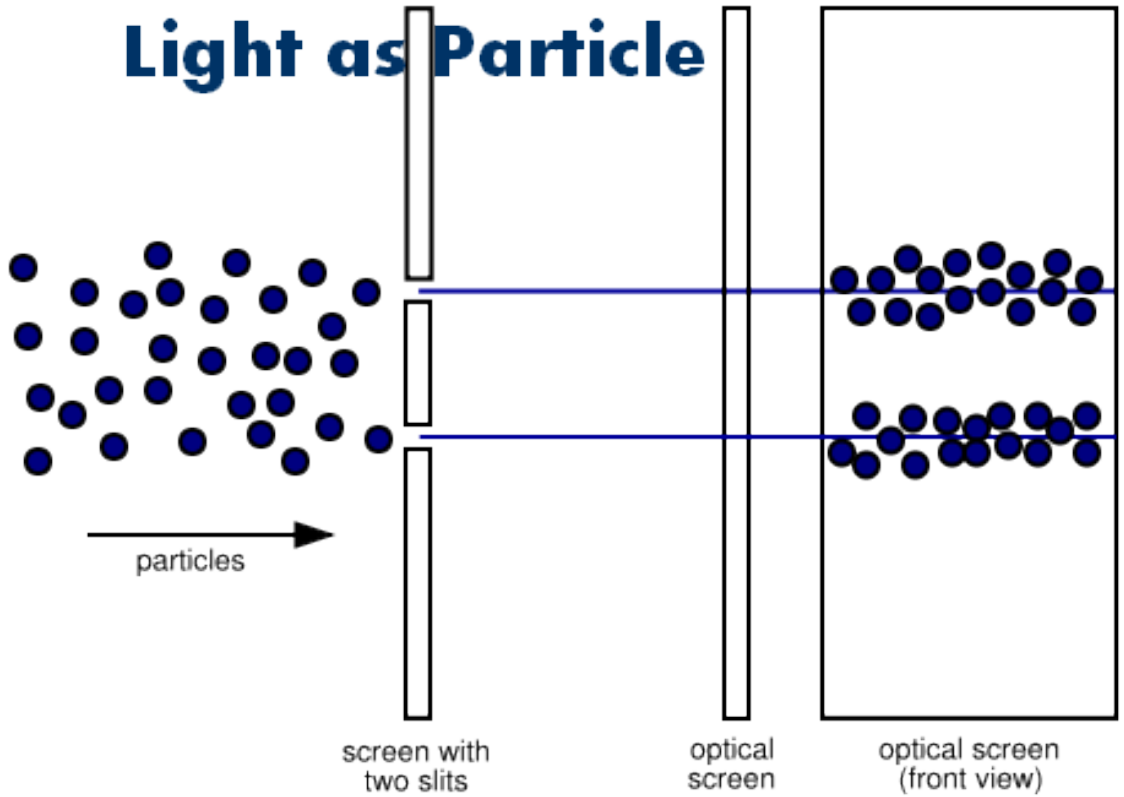
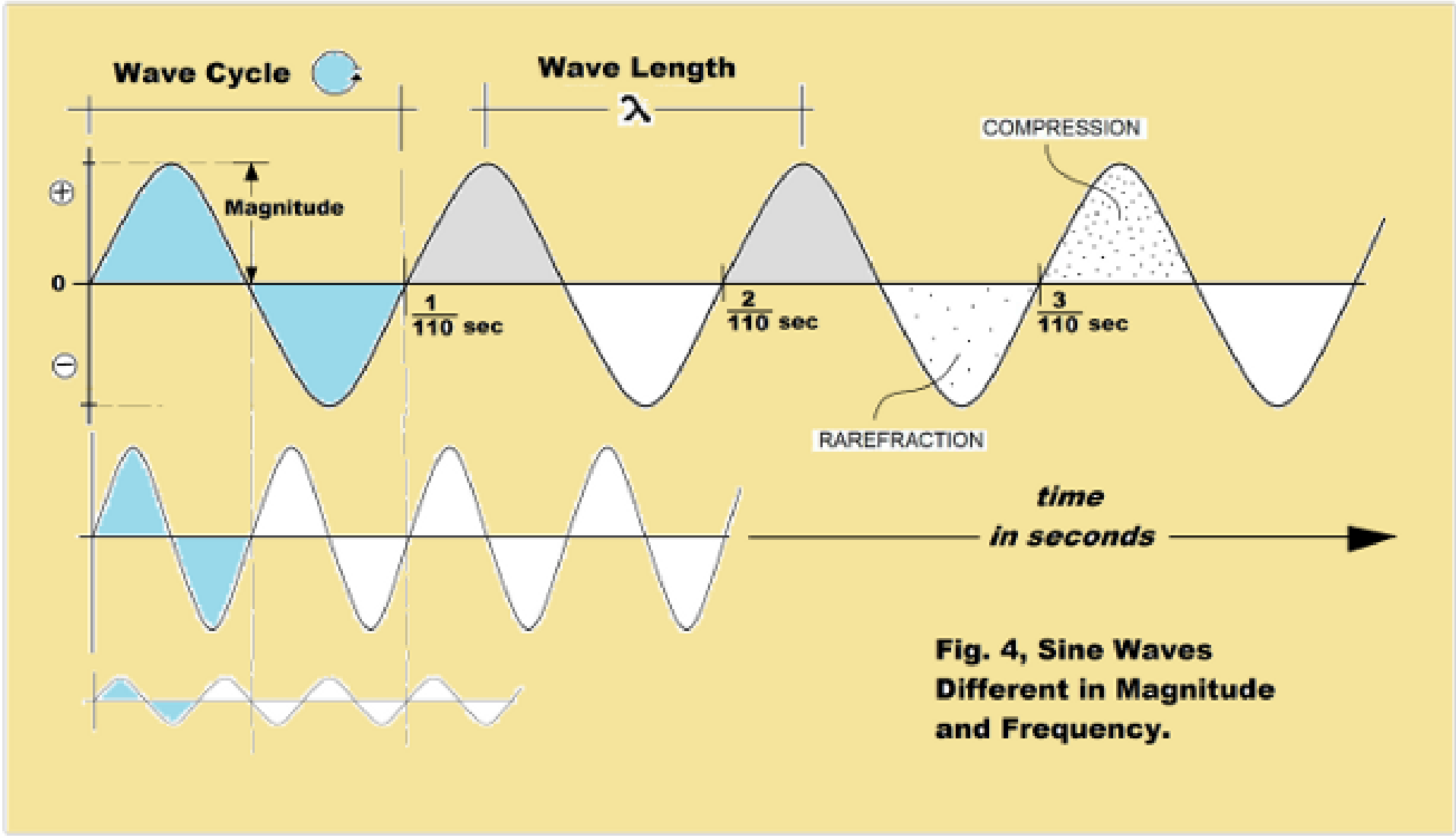
Let’s transition to light and PHOTONS! We will relate this soon to Electrons ;)

Light is defined as both a WAVE and a PARTICLE!

As a PARTICLE, light exists in defined quantities known as Light Quanta or Photons, and these photons have energy associated with them (same is true for ANY moving object – think physics!). A photon is considered to be massless with no electric charge.



As a WAVE, light has properties of waves, including frequency (how often the cycle occurs) and wavelength (the length of each cycle). Mathematically, it looks like this:



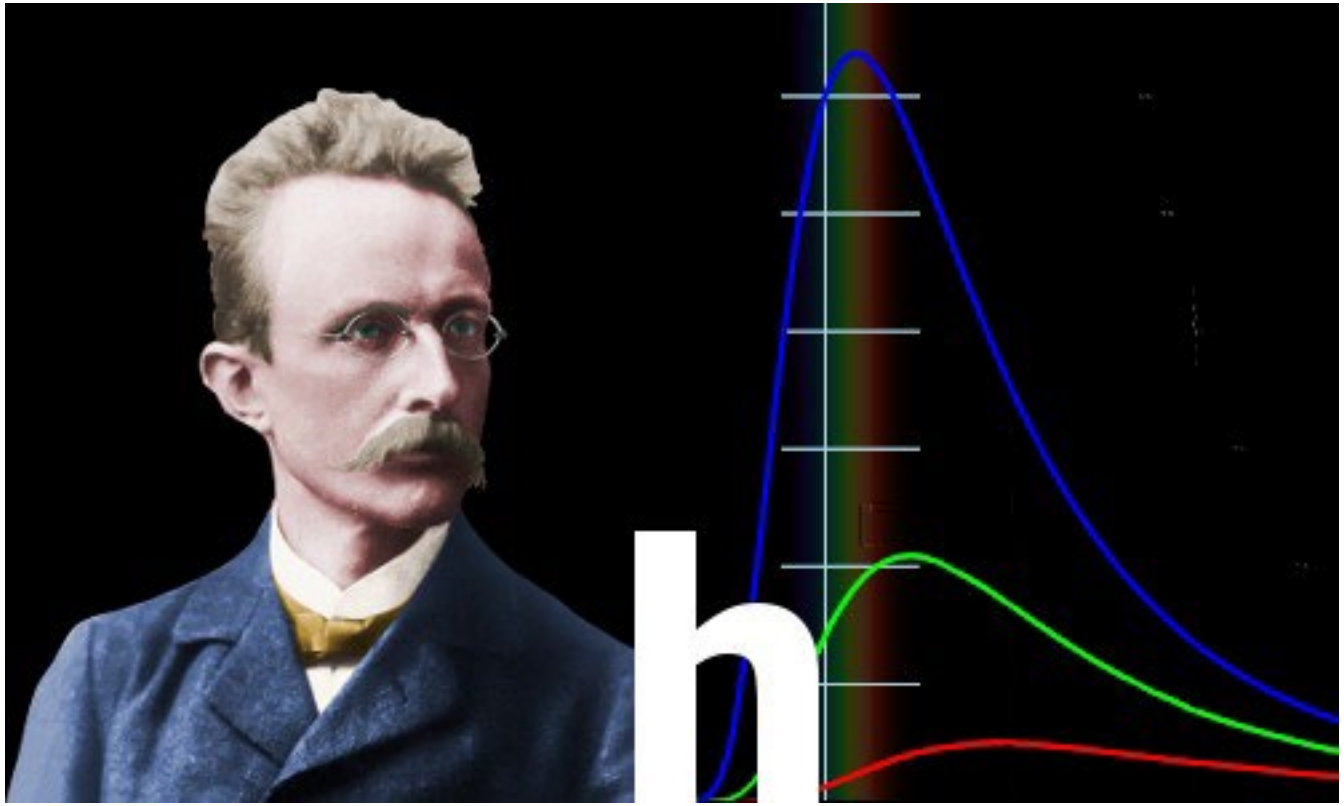
Anything that travels has energy, so therefore we can measure the energy of light, using this equation:

Planck's Equation → E = hf

E = Energy of the Photon (Joules)

h = Planck's Constant = 6.626 x 10^{-34} J-s = **6.6 x 10^{-34} J-s**

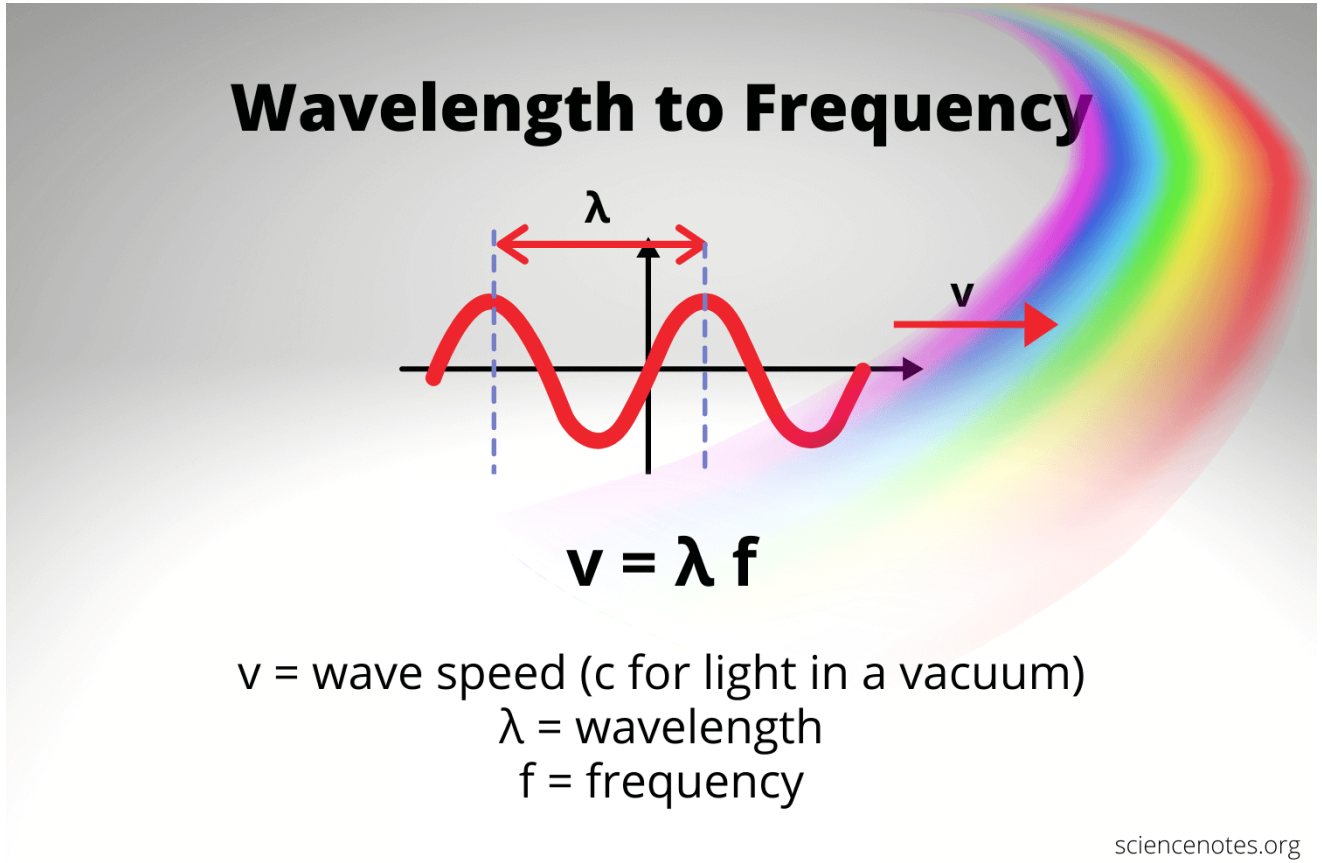
f = frequency of photon (hertz, cycles/second = 1/s)) = how often the light "particles" keep coming



For waves, we think of a wave's frequency as related to it's wavelength, and this gives us the waves speed (this is true for any constant wave)!

Speed of wave = frequency of wave (f) x wavelength (λ)

Speed = v = meters/sec
frequency (f) = as the previous page, cycles/second (1/s) = how often the wave passes through (peak to peak)
wavelength = λ (lambda), measured in meters



Going back to photons and light, we therefore have two items to consider:

Speed of Light
Speed = frequency (f) x wavelength (λ)
c = frequency (f) x wavelength (λ)
c = f x λ
Where c = speed of light = 3×10^8 meters/second – Super fast!

&

Plank's Equation
E = hf =

Substituting through, we get:

$E = hf = hc/\lambda$

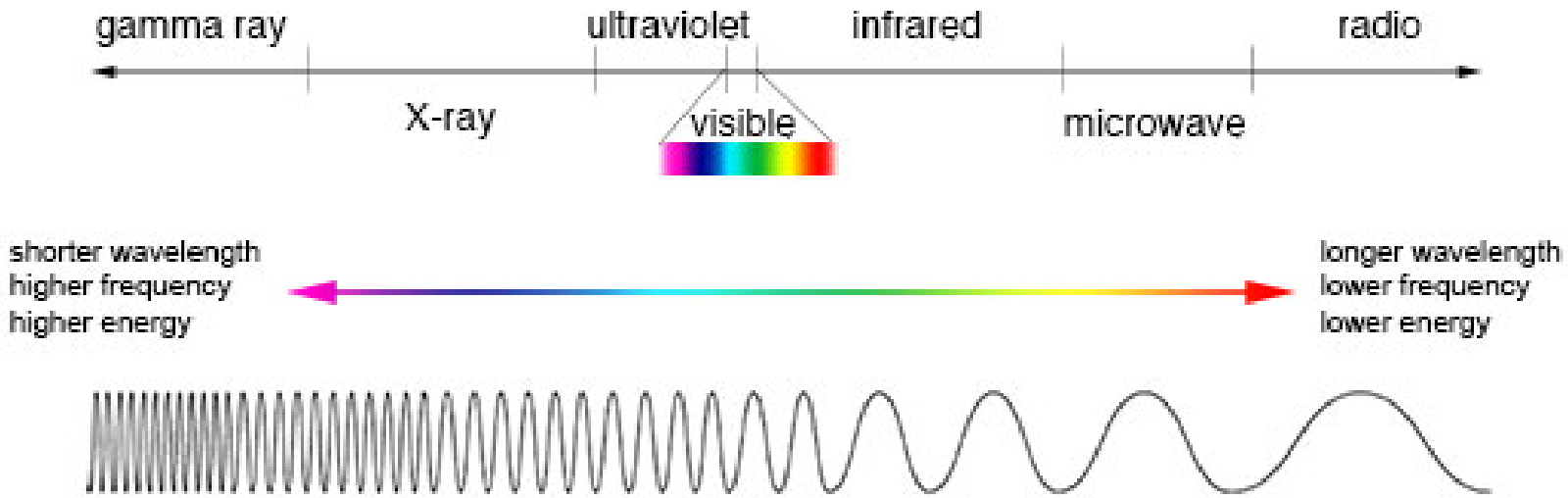
Why does this matter?

1. Properties of different light types can be studied!
2. Fun with exponent math! We can review as needed

$E = hf = hc/\lambda$

Energy and frequency are DIRECTLY related
Energy and wavelength are INVERSELY related

↑ Energy = ↑ frequency = ↓ wavelength
↓ Energy = ↓ frequency = ↑ wavelength

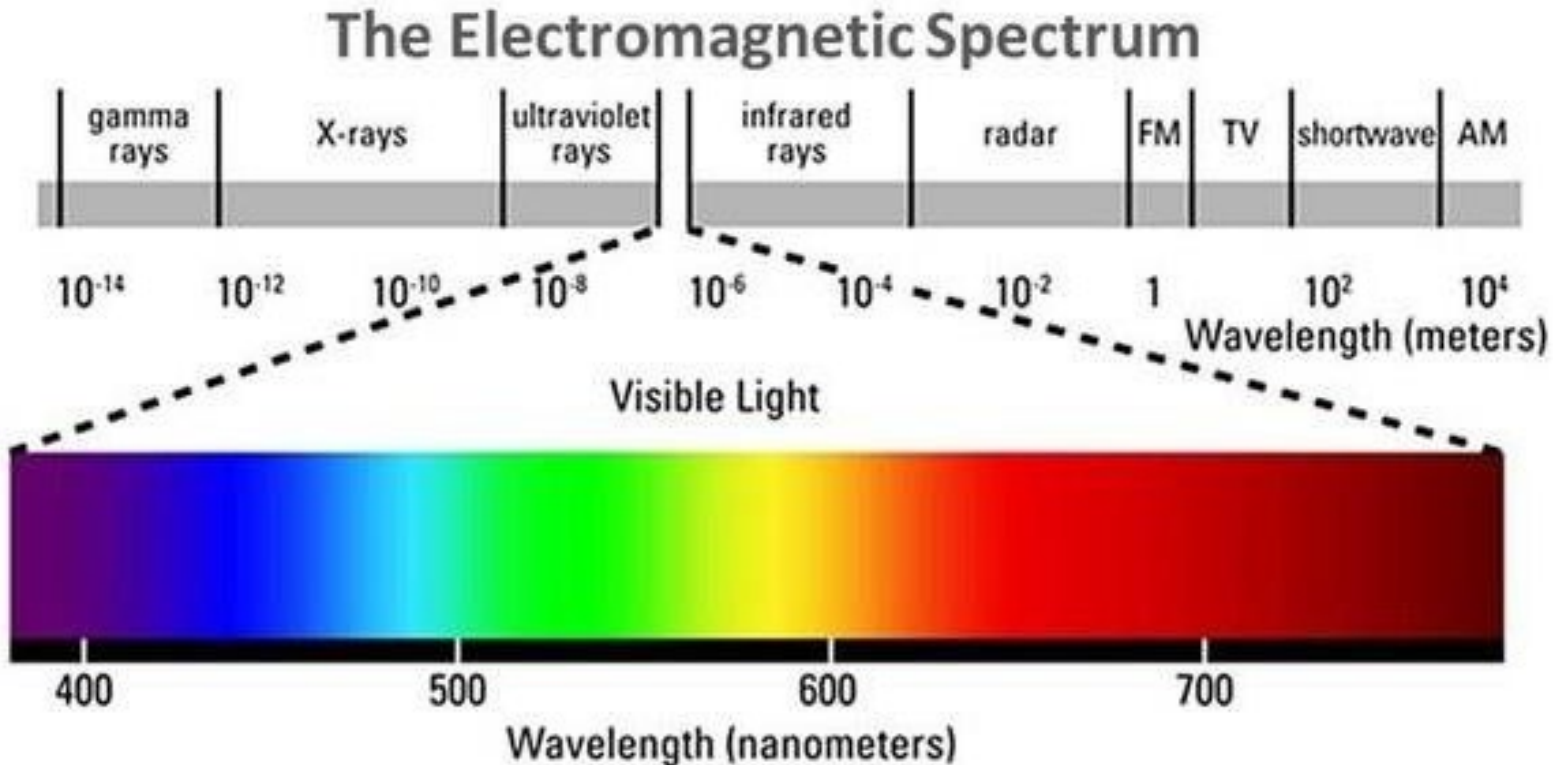


All light types have specified ranges for frequency and wavelength.
Commonly, wavelength is used to describe light.
The light we see, **visible light**, has wavelengths of 4×10^{-7} meters to 7×10^{-7} meters.

To measure visible light, we normally use nanometers:

1 meter = 1×10^{9} nanometers

Purple = 400 nm = 4×10^{-7}meters
Red = 700nm = 7×10^{-7}meters



Math Problems!

Pick your favorite rainbow color (ROYGBV) from this chart:

Color	Wavelength	Frequency	Energy
Violet	400nm		
Blue	450nm		
Green	500nm		
Yellow	550nm		
Orange	600nm		
Red	700nm		

Calculate your favorite visible light photon's frequency and Energy using $E = hf = hc/\lambda$.

For reference:

$h = 6.6 \times 10^{-34}$ J-s
$c = 3 \times 10^{8}$ m/s
$1\ m = 1 \times 10^{9}$ nm

This is a multi-step problem. Try as much mental math instead of using a calculator. Rounding off towards the final steps is acceptable ;)