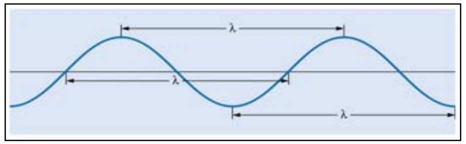
The Wave Nature of Light

- A wave can be characterized by its **wavelength** and **frequency.**
  - The **wavelength, λ (lambda),** is the distance between any two adjacent identical points of a wave.
  - The **frequency, ν (nu)**, of a wave is the number of wavelengths that pass a fixed point in one second.

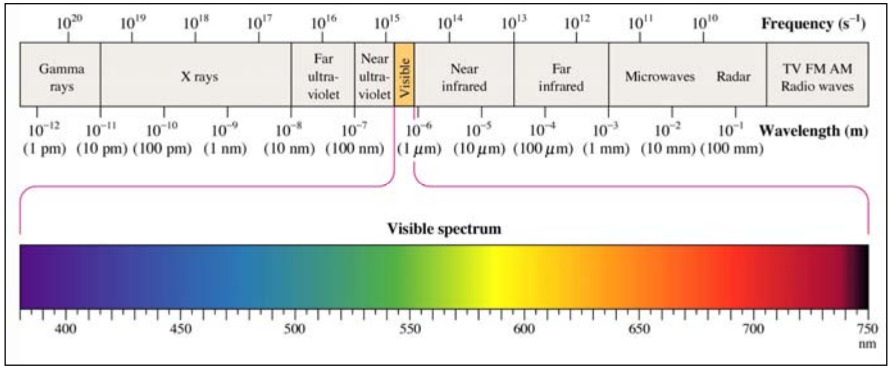


1 sec

frequency here ~ 2 per sec
Or 2 Hz

The Wave Nature of Light

- A **wave** is a continuously repeating change or oscillation in matter or in a physical field. Light is also a wave.
  - It consists of oscillations in electric and magnetic fields that travel through space.
  - Visible light, X rays, and radio waves are all forms of ***electromagnetic radiation***.



The Wave Nature of Light

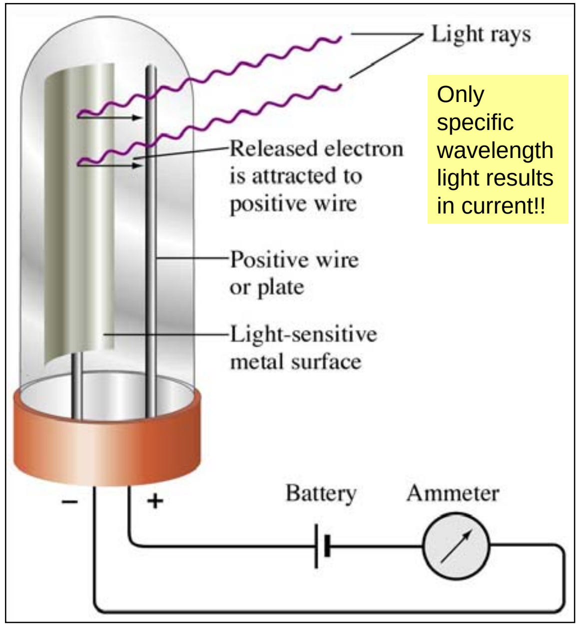
- The product of the frequency, ν (waves/sec) and the wavelength, λ (m/wave) would give the speed of the wave in m/s.
  - In a vacuum, the speed of light, c, is **3.00 x 10^8 m/s**. Therefore,

$$c = \nu\lambda$$

  - So, given the frequency of light, its wavelength can be calculated, or vice versa.
  - Examples:

Quantum Effects and Photons

- In 1905, Albert Einstein proposed that light had ***both*** **wave and particle properties** as observed in the **photoelectric effect.** Einstein based this idea on the work and ideas of **quantization** introduced by German physicist, **Max Planck.**



- **Planck's Quantization of Energy (1900)**
  - According to Max Planck, the atoms of a solid oscillate with a definite frequency, ν.
  - He proposed that an atom could have only certain energies of vibration, E, those allowed by the formula

$$E = nh\nu$$

where **h** (Planck's constant) is assigned a value of 6.63×10^{-34} J·s and **n** must be an integer.

  - Thus, the only energies a vibrating atom can have are $h\nu$, $2h\nu$, $3h\nu$, and so forth.
  - The numbers symbolized by *n* are **quantum numbers.**
  - The vibrational energies of the atoms are said to be **quantized.**

What does this have to do with photoelectric effect??

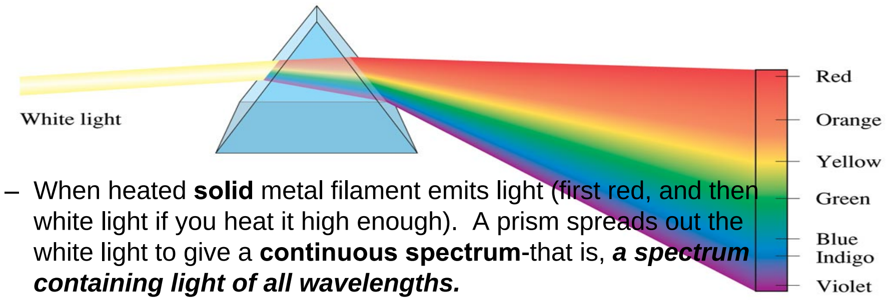
Photoelectric Effect

- The photoelectric effect is the ejection of electrons from the surface of a metal when light shines on it.
- Electrons are ejected only if the light exceeds a certain "threshold" frequency.
- Violet light, for example, will cause potassium to eject electrons, but no amount of red light (which has a lower frequency) has any effect.
- Einstein's assumption that an electron is ejected when struck by a single photon implies that it behaves like a **particle.**
- When the photon hits the metal, its energy, $h\nu$ is taken up by the electron and photon ceases to exist as a particle; it is said to be "absorbed."

•the **wave-particle duality of light** is reflected in the equation **E = hv**
E is the energy of the **"particle"** photon,
and **v** is the frequency of the associated **"wave."**

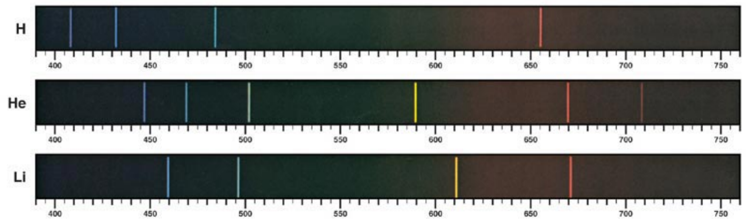
(this equation also allows energy and frequency calculations)

•Atomic Spectra:



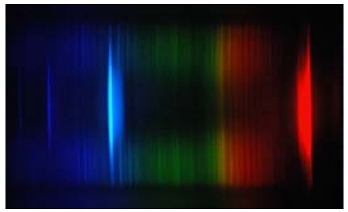
- When heated **solid** metal filament emits light (first red, and then white light if you heat it high enough). A prism spreads out the white light to give a **continuous spectrum**-that is, ***a spectrum containing light of all wavelengths.***
- However the light emitted by **a heated gas**, such as hydrogen, results in a **line spectrum- with *only specific wavelengths of light.***)

EMISSION (LINE) SPECTRA



Hydrogen gas discharge tube:

Look through Diffraction grid →



Glass tube filled with H2 gas.
When high voltage is applied to it - it starts glowing!