Light

We can use different terms to describe light:

- Color
- Wavelength
- Frequency

Light is composed of electromagnetic waves that travel through some medium.

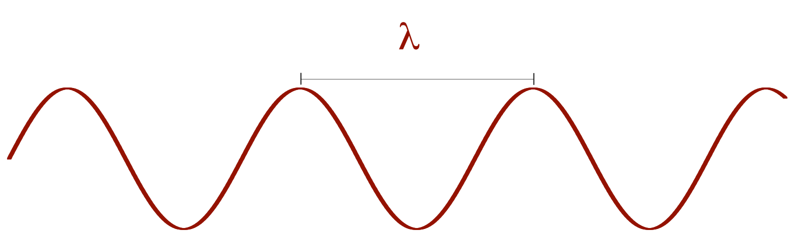
The properties of the medium determine how light travels through it.

In a vacuum, light waves travel at a speed of 3.00 x 108 m/s or 186,000 miles/s.

The speed of light in a vacuum is a constant that is tremendously important in nature and science—it is given the symbol, c.

Light (con't.)

Because light behaves like a wave, we can describe it in one of two ways—by its wavelength or by its frequency.



λ = wavelength—distance between two adjacent wave crests. λ has units of distance—frequently nanometers (nm).

ν = frequency—how many times the wave goes up and down in a period of time. ν has units of inverse time (1/s ≡ Hz[hertz]).

Light (con't.)

If you know either the frequency or the wavelength, you can calculate the other quantity through the relationship:

$$c = \lambda \bullet \nu$$

c = speed of light (3.00×10^8 m/s)
λ = wavelength (m)
ν = frequency (s^{-1})

A "particle" of light is called a photon.

Examples

Diode laser pointer: λ = 670 nm

670 nm = 670×10^{-9} m

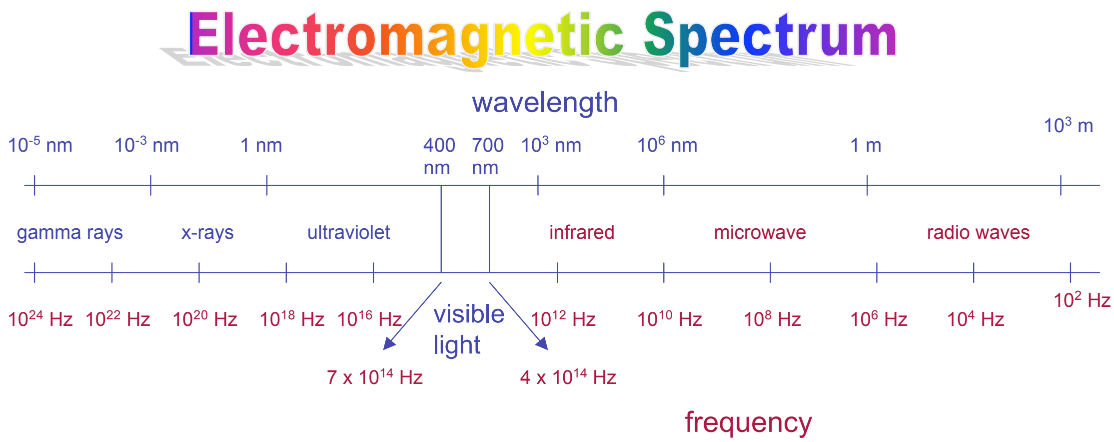
$$\nu = \frac{c}{\lambda} = \frac{3.00 \times 10^8 \text{ m s}^{-1}}{670 \times 10^{-9} \text{ m}} = 4.48 \times 10^{14} \text{ Hz}$$

$\nu = 4.3 \times 10^{13}$ Hz

$$\lambda = \frac{c}{\nu} = \frac{3.00 \times 10^8 \text{ m s}^{-1}}{4.3 \times 10^{13} \text{ s}^{-1}} = 6.98 \times 10^{-6} \text{ m} = 6.98\ \mu\text{m} = 6980 \text{ nm}$$

Light (con't.)

The type of light (ultraviolet, visible, infrared, x-ray, etc.) is defined by either its frequency or wavelength:



Light (con't.)

The energy of light can be determined either from its wavelength or frequency:

$$E = \frac{hc}{\lambda} \quad \text{or} \quad E = h\nu$$

Planck's constant: $h = 6.626 \times 10^{-34}$ J s

Examples

4.3×10^{13} Hz (ν) light:

$E = (6.626 \times 10^{-34}\ \text{J s})(4.3 \times 10^{13}\ \text{s}^{-1}) = 2.85 \times 10^{-20}\ \text{J}$

$= 17.2\ \text{kJ mol}^{-1}$

1 mole = 6.022×10^{23} things (atoms, molecules, photons, etc.)

670 nm (λ) diode laser:

$$E = \frac{(6.626 \times 10^{-34}\ \text{J s})(3.00 \times 10^{8}\ \text{m s}^{-1})}{(670 \times 10^{-9}\ \text{m})} = 2.97 \times 10^{-19}\ \text{J}$$

$= 179\ \text{kJ mol}^{-1}$

Examples (con't.)

Violet light from a mercury lamp has a wavelength of 436 nm:

$$E = \frac{(6.626 \times 10^{-34}\ \text{J s})(3.00 \times 10^{8}\ \text{m s}^{-1})}{(436 \times 10^{-9}\ \text{m})} = 4.56 \times 10^{-19}\ \text{J}$$

$= 275\ \text{kJ mol}^{-1}$

- Atoms and molecules absorb and emit light in the ultraviolet (UV), visible (vis), infrared (IR), and microwave (μwave) regions of the electromagnetic spectrum.
- Absorption or emission of light in the UV and vis regions involves movement of electrons in the atom or molecule.
  - One reason UV light is so damaging is that the light has enough energy to break chemical bonds—biological and chemical systems
    - E (λ = 300 nm) = 399 kJ mol
    - Average bond energy = 380 kJ mol^{-1}