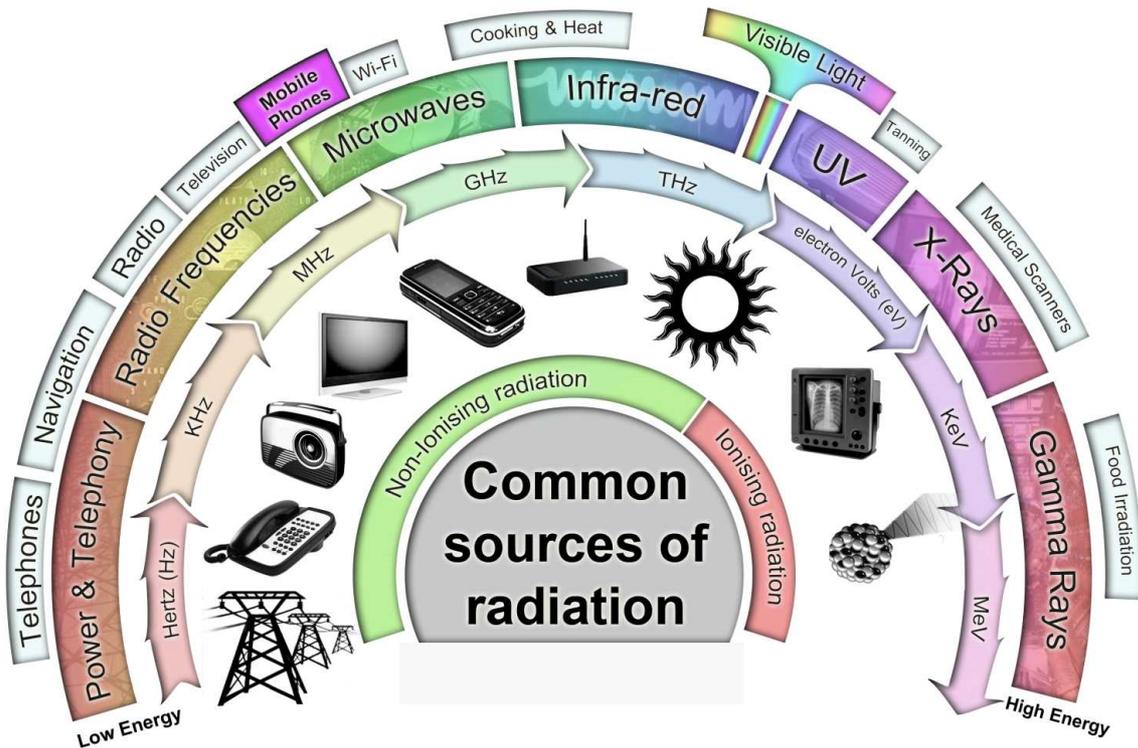


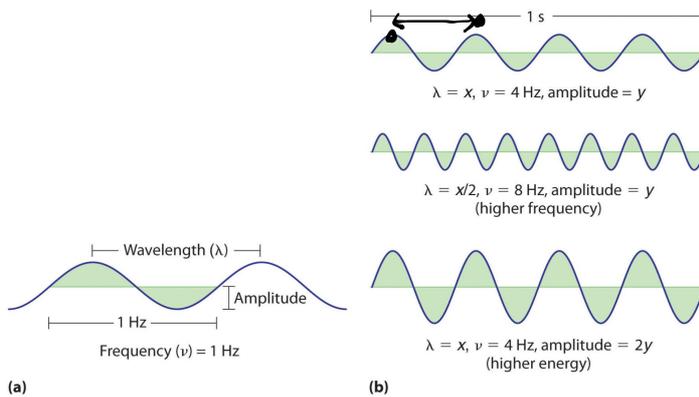
L01 - Electromagnetic Radiation (EMR)



Electromagnetic Radiation (EMR): Radiant energy, energy that travels outward in all directions from its source.

Frequency: The number of cycles per second (Hz). $T = \frac{1}{f}$

Wavelength: The distance between points that vibrate in phase with each other (m).



Universal Wave Equation: $v = f\lambda$

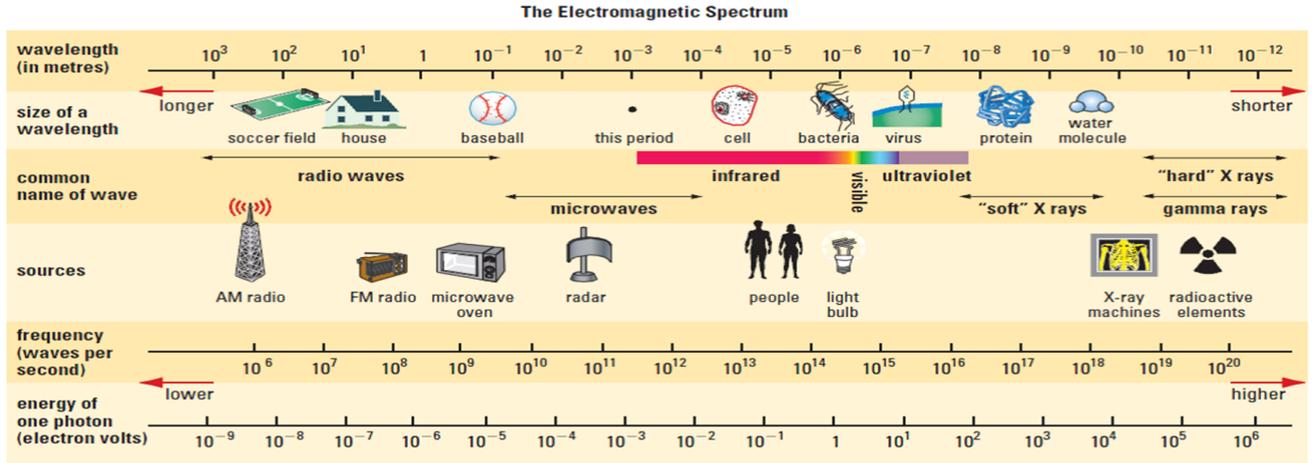
$c = 3.00 \times 10^8 \text{ m/s}$

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$f = \text{freq (Hz)}$
 $\lambda = \text{wavelength (m)}$
 $v = c = \text{speed}$

X-Ray →
 Visible → $c = 3.00 \times 10^8 \text{ m/s}$
 Gamma → in a vacuum.

The EMR Spectrum



You must know:

- The different types in order
- Wavelength of red and violet light

Helpful Mnemonic:

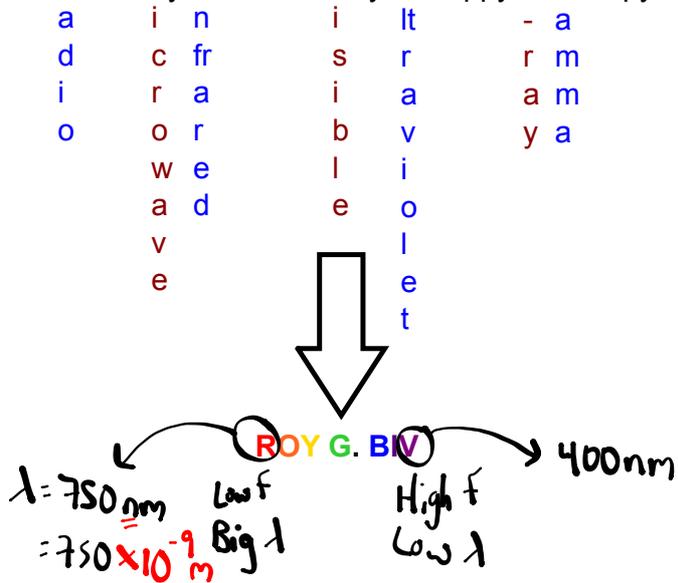


Increasingly frequent comment: "Rated My Instructor Very Unhappy X Grumpy"

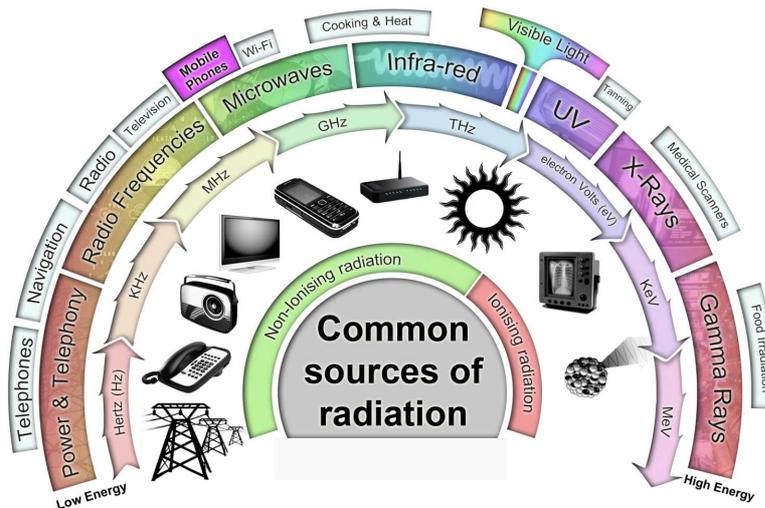
$\checkmark = f \lambda$
Constant

$12 = (3)(4)$

$12 = (6)(2)$



EMR Sources and Characteristics



Type of Electromagnetic Radiation	Method of Production	Characteristics	Problems
Radio and Radar $f = 10^4 - 10^{10}$ Hz $\lambda = 10^4 - 10^{-2}$ m relative energy: very low	oscillation of electrons in an electric circuit like an antenna L09 - EMR Lab - Part 1	long wavelength allows a large amount of diffraction making it useful for long-distance communication, e.g., PC broadband	requires government regulations to control transmission and avoid interference
Microwaves $f = 10^9 - 10^{12}$ Hz $\lambda = 10^{-1} - 10^{-4}$ m relative energy: low	oscillation of electrons in special tubes and solid state devices	shorter wavelength reduces diffraction for short-distance communication; frequency matches the natural resonant frequency of water molecules; used in microwave ovens and cell phones	may be linked to some forms of cancer; causes damage to living tissue due to heating of water molecules within tissues
Infrared $f = 10^{11} - 4.0 \times 10^{14}$ Hz $\lambda = 10^{-3} - 7.5 \times 10^{-7}$ m relative energy: low	motion of particles, transitions of valence electrons in atoms and molecules Unit 4 - Bohr Model	causes object absorbing it to become warm; used for remote sensing, night vision scopes, and identification of sources of heat	significant exposure can burn tissue
Visible $f = 4.0 \times 10^{14} - 7.5 \times 10^{14}$ Hz $\lambda = 7.5 \times 10^{-7} - 4.0 \times 10^{-7}$ m relative energy: medium	higher-energy transitions involving valence electrons in atoms Unit 4 - Bohr Model	reflects off small objects, making them visible; diffracts around very small objects, making them invisible	limits the size of objects that can be seen
Ultraviolet $f = 7.5 \times 10^{14} - 10^{17}$ Hz $\lambda = 4.0 \times 10^{-7} - 10^{-9}$ m relative energy: high	even higher-energy transitions involving valence electrons in atoms Unit 4 - Bohr Model	easily absorbed by objects; causes fluorescence of some materials, tanning in humans; kills bacteria	may cause sunburn; prolonged exposure can cause mutations and cancer in humans
X ray $f = 10^{17} - 10^{20}$ Hz $\lambda = 10^{-9} - 10^{-12}$ m relative energy: very high	transitions of electrons in an atom or the sudden acceleration of high-energy free electrons L13 - X-Ray Production	penetrates most matter and is absorbed by denser material (like bone or metal); destroys carcinogenic or mutant cells; used for medical imaging in humans and in industry	can cause mutations and cancer in humans
Gamma $f = 10^{19} - 10^{24}$ Hz $\lambda = 10^{-11} - 10^{-16}$ m relative energy: extremely high	decomposition of unstable nuclei, either spontaneously or by the sudden negative accelerations from high-energy particle accelerators Unit 4 - Radioactive Decay	penetrates matter very deeply; destroys carcinogenic or mutant cells on a local scale; used to probe the structure of matter and in industrial imaging	can cause radiation sickness and death
Cosmic $f = 10^{24}$ Hz and greater $\lambda = 10^{-16}$ m and less relative energy: extremely high	bombardment of Earth's atmosphere by extremely high-energy particles from space	penetrates matter very deeply; study of cosmic rays allows investigators to formulate ideas about the universe	can cause radiation sickness and death

Maxwell's Electromagnetic Theory

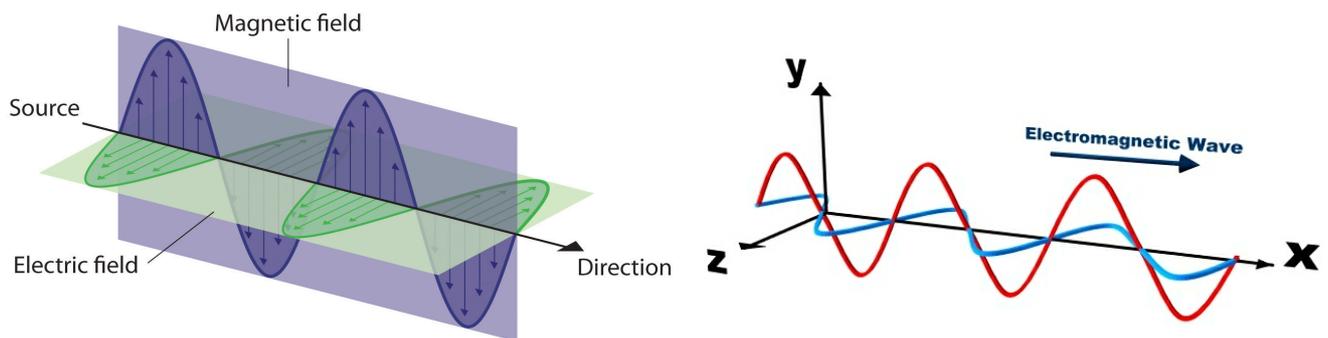
Maxwell's Theory:

- Changing Magnetic fields produce a changing electric field.
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Behavior of EMR Waves:

Electromagnetic fields are waves and should behave like waves. They should experience:

- Interference
- Diffraction
- Refraction
- Polarization



Equations from Physics 20

$$v = f\lambda$$

$$T = \frac{1}{f}$$

$$v_{\text{ave}} = \frac{\Delta d}{\Delta t}$$

Speed of light in a vacuum: 3.0×10^8 m/s

Speed of sound in air at 0°C: 331.3 m/s