Electromagnetic Waves

Unit: Light & Optics

MA Curriculum Frameworks (2016): HS-PS4-1, HS-PS4-3, HS-PS4-5

AP® Physics 2 Learning Objectives: 6.F.1.1

Mastery Objective(s): (Students will be able to…)

- Describe the regions of the electromagnetic spectrum.

Success Criteria:

- Descriptions & explanations account for observed behavior.

Language Objectives:

- Explain why ultraviolet waves are more dangerous than infrared.

Tier 2 Vocabulary: wave, light, spectrum

Labs, Activities & Demonstrations:

- red *vs.* green *vs.* blue lasers on phosphorescent surface
- blue laser & tonic water
- wintergreen Life Savers™ (triboluminescence)

Notes:

<u>electromagnetic wave</u>: a transverse, traveling wave that is caused by oscillating electric and magnetic fields.

Electromagnetic waves travel through space and do not require a medium. The electric field creates a magnetic field, which creates an electric field, which creates another magnetic field, and so on. The repulsion from these induced fields causes the wave to propagate.

Electromagnetic waves (such as light, radio waves, etc.) travel at the speed of light. The speed of light depends on the medium it is traveling through, but it is a constant within its medium (or lack thereof), and is denoted by the letter "*c*" in equations. In a vacuum, the speed of light is:

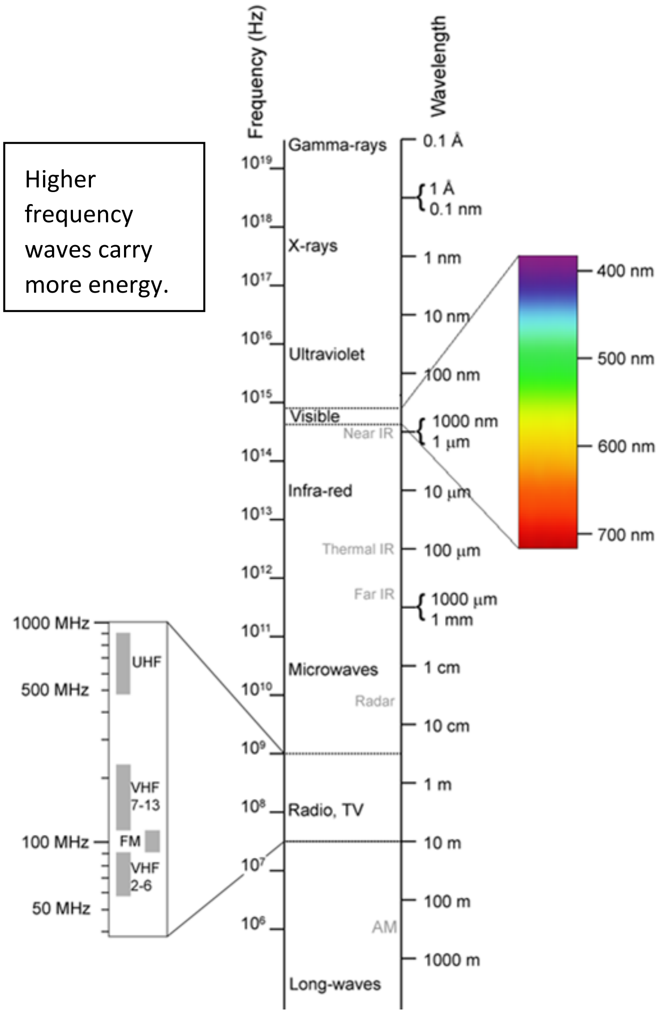
$$c = 3.00 \times 10^{8}\ ^{\text{m}}/_{\text{s}} = 186{,}000 \text{ miles per second}$$

Recall that the speed of a wave equals its frequency times its wavelength:

$$c = \lambda f$$

Use this space for summary and/or additional notes:

<u>electromagnetic spectrum</u>: the entire range of possible frequencies and wavelengths for electromagnetic waves. The waves that make up the electromagnetic spectrum are shown in the diagram below:



Higher frequency waves carry more energy.

<u>visible spectrum</u>: wavelengths of light that can be detected by the human eye. These are wavelengths from roughly 400 nm to 700 nm.

The energy (E) that a wave carries is proportional to the frequency. (Think of it as the number of bursts of energy that travel through the wave every second.) For electromagnetic waves (including light), the constant of proportionality is Planck's constant (named after the physicist Max Planck), which is denoted by a script h in equations.

The energy of a wave is given by the Planck-Einstein equation:

$$E = hf = \frac{hc}{\lambda}$$

where E is the energy of the wave in Joules, f is the frequency in Hz, h is Planck's constant, which is equal to $6.626 \times 10^{-34}\ \text{J}\cdot\text{s}$, c is the speed of light, and λ is the wavelength in meters.

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Antennas

An antenna is a piece of metal that is affected by electromagnetic waves and is used to amplify waves of specific wavelengths. The optimum length for an antenna is either the desired wavelength, or some fraction of the wavelength such that one wave is an exact multiple of the length of the antenna. (*E.g.,* good lengths for an antenna could be $\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{8}$, *etc.* of the wavelength.)

Sample problem:

Q: What is the wavelength of a radio station that broadcasts at 98.5 MHz?

A:

$$c = \lambda f$$

$$3.00\times10^{8} = \lambda(9.85\times10^{7})$$

$$\lambda = \frac{3.00\times10^{8}}{9.85\times10^{7}} = 3.05\,\text{m}$$

Q: What would be a good length for an antenna that might be used to receive this radio station?

A: 3.05 m (about 10 feet) is too long to be practical for an antenna. Somewhere between half a meter and a meter is a good size.

$\frac{1}{4}$ wave would be 0.76 m (76 cm), which would be a good choice.

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