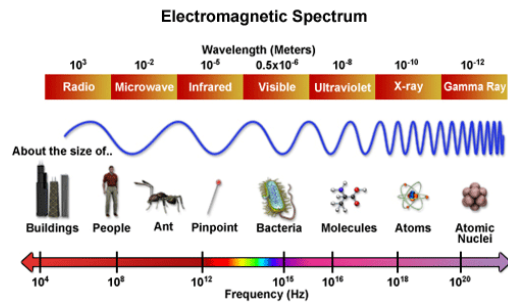


Physics Review: Electromagnetic Spectrum, Technology & Visible Light

Electromagnetic radiation is all around us everyday. Most forms of this radiation pose very little health risks and some forms, like light and infrared energy, are essential to life on earth. Some forms, like radio waves and microwaves, simply make life easier for us. These types of energy make up a category of radiation called **electromagnetic (EM) waves**.

All waves are produced by vibrations. **Electromagnetic waves are produced by vibrating electric charges that give off tiny packets of energy called photons.** But unlike mechanical waves such as ocean or sound waves, electromagnetic waves do not need a medium to transfer energy and can even transfer energy through electric and magnetic fields. The speed of electromagnetic radiation does not vary. In a vacuum, photons travel at a constant speed of approximately 3.0×10^8 meters per second (m/s). Thus, all electromagnetic radiation waves have the exact same speed.



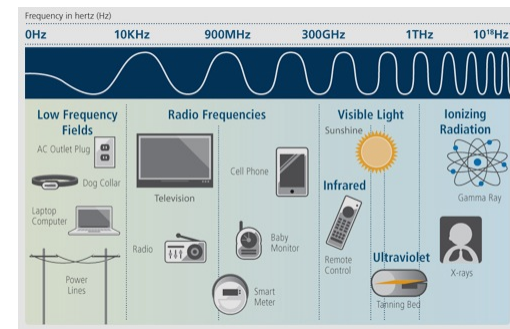
What distinguishes one wave on the electromagnetic spectrum from another is the amount of energy each wave carries -- specifically, the level of energy in the photons of each type of wave. This energy level determines the wavelength and frequency of a given wave: **The more energy each photon carries, the shorter the wavelength and the higher the frequency of the wave.** Gamma Rays contain the most energy and Radio waves the least. Along the spectrum, electromagnetic waves are categorized according to their wavelengths and frequencies, with radio waves occupying the low-frequency end, gamma waves at the high-frequency end, and visible light in the middle.

The Planet Earth and Human Society is impacted by electromagnetic waves on a daily basis. Infrared radiation is the warmth emitted by our bodies and detected when you stand next to a heat lamp. Visible light allows us to see during the day through detection by our eyes and is needed by plants for the process of Photosynthesis. The sun releases both infrared and visible light along with ultraviolet radiation. We can't see the UV light, but many animals, such as insects can.

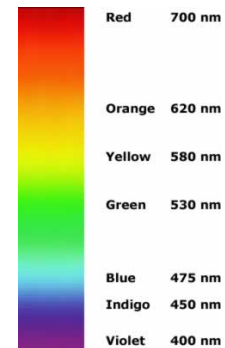
Many **technological advances** use various forms of electromagnetic waves. **TV and Radio stations** broadcast using radio waves. Two-way **"walkie-talkies"** also use radio waves to communicate. Radio waves are formed when negatively charged electrons vibrate in an antenna creating a field that radiates outwards from the antenna. **Microwave ovens** use microwave energy to vibrate water molecules in food, creating heat to warm up food. Infrared waves are radiant heat. All objects emit some infrared radiation due to the motion

of their molecules. A **radiator** emits heat in the form of infrared radiation. Infrared radiation can be used as a form of communication such as the **TV remote control** that uses LED (light-emitting diodes) to control a TV. **Light bulbs** give off energy in the form of visible light as do **laser beams**.

Ultraviolet (UV) radiation can be used to kill bacteria and **sterilize** objects. Many **fluorescent light bulbs** use UV radiation inside to excite phosphor powder, which then releases visible light. X-Rays are released from the super hot gas surrounding **supernova** explosions far off in space. Here on earth are used in the medical field. **X-ray radiographs** are used to see bone and organs inside the human body as well as tumors and cavities in teeth. X-Ray radiation can also be used to **treat tumors** by damaging the DNA of the cells that make up the tumor. Gamma rays can be produced by violent explosions throughout the universe. On earth, gamma rays are produced from the decay of **radioactive elements**. Gamma radiation can also be used to **sterilize food and medical instruments**.



Visible Light is the form of electromagnetic radiation we are most familiar with. Visible light is a very narrow band of electromagnetic radiation between wavelengths of 750 nm (7.5×10^{-7} meters) to 380 nm (3.8×10^{-7} meters). Each color of light has a corresponding wavelength, from the longest red light to medium green light to shortest violet light. The order of the visible light spectrum can be remembered by the acronym "ROYGBIV". In terms of energy, red light carries the least amount of energy and violet light carries the most amount of energy in the visible light spectrum.



The colors of the spectrum to the left are **"pure colors"** because they are made of only one wavelength. Colors such as pink or purple variations such as magenta are not found in the spectrum because they are actually **mixtures** of the pure colors. **White light is actually a mixture of all the light of the spectrum.**

Visible light is the light visible to the human eye. Electromagnetic radiation of wavelength below red light (infrared = "below" red) and wavelength above violet light (ultraviolet = "above" violet) are **invisible** to the human eye. The color a person sees is actually the specific type of **light reflected** by an object. A purple flower will reflect primarily the light of indigo / violet wavelength and absorb the light of all other wavelengths. A bright red car will mostly absorb orange to violet light and reflect red light that our eyes collect in specialized cells called "cones". The cones then transfer the information through the nervous system to the brain and converted into a form that our mind perceives as the color red.

Review Questions

1. What are photons? How do they take part in the generation the various types of electromagnetic waves?

2. Cell phones work by receiving and emitting radiation in the range of 1.9-2.2 Giga Hertz (GHz). This is about 2.2×10^9 Hz. Based on this information, what type of electromagnetic radiation do cell phones use?

3. The following are examples electromagnetic waves in the ultraviolet and microwave spectrum range. Use the information to calculate the speed of each wave (speed = frequency X wavelength). How do the speeds compare?

Ultraviolet light
frequency 1.2×10^{15} Hz
wavelength of 2.5×10^{-7} m

Microwave
frequency 3.0×10^{11} Hz
wavelength of 1.0×10^{-3} m

4. Fill in the following blanks with the terms "more", "less" or "equal":

- Electromagnetic waves with higher frequency contain _____ energy.
- Electromagnetic waves with longer wavelength contain _____ energy.
- Gamma Rays contain _____ energy than X-Rays.
- Microwaves contain _____ energy than microwaves.
- Ultraviolet light is _____ dangerous to our skin than visible light.

5. Name a natural source that emits or a technology that uses each of the following electromagnetic waves:

- Gamma Rays: _____
- X-Rays: _____
- Ultraviolet Light: _____
- Visible Light: _____
- Infrared: _____
- Microwaves: _____
- Radio Waves: _____

6. Why are Gamma Rays, X-Rays and Ultraviolet radiation the most damaging to cells?

7. What is Visible Light? Why is considered "visible"?

8. Compare the following by placing the symbol > (greater than), < (less than) or = (equal to).

- Yellow wavelength ____ Blue Wavelength
- Indigo Wavelength ____ Orange Wavelength
- Energy of Green light ____ Energy of Violet Light

9. You walk into a dark room and turn on a lamp. Almost immediately you see a green watermelon on a table in front of you. Trace the pathway of the visible light from the lamp to your eye that then causes you to see the green color. Be sure to include the terms color, reflection and absorption in your discussion.

Bonus Questions (not necessarily in the reading above, but related):

10. You look through a typical red filter at a mixture of various colors on a paper. Why would the colors blue, green and indigo / violet stand out to your eye?

11. Why can x-rays be used to take images of molecules and of solid bone in a human body and not waves like radio waves and microwaves? (Hint: has something to do with wavelength)