**Conceptual Physics POGIL: The Electromagnetic Spectrum**

The Nature of Electromagnetic Radiation

Electromagnetic radiation includes radio signals, microwaves, infrared, visible light, ultraviolet, X-rays, and gamma rays. One model of electromagnetic radiation is a propagating wave that is partially electric in nature and partially magnetic in nature. The following diagram is a pictorial description of this model:

electric part of wave

magnetic part of wave

direction of propagation

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This type of wave is called an *electromagnetic wave*.

Another model of electromagnetic radiation is a particle called a *photon*. It is a somewhat strange particle in that the laws of physics tell us that it has no mass and no volume, yet it must exist because we can observe its effects!

1. Scientist often say that light and other forms of electromagnetic radiation have a dual nature. What do you think they mean by this?
2. Are electromagnetic waves transverse or longitudinal? Justify your answer.

The Electromagnetic Spectrum

The electromagnetic spectrum is an ordered list of all the types of electromagnetic radiation. All electromagnetic radiation can be described using the wave model or particle model above. The only difference between each type is the wavelength and frequency of the associated electromagnetic wave. The types of radiation and their wavelength ranges are shown in the diagram below.

10─14 m

10─12 m

10─10 m

10─8 m

10─6 m

10─4 m

10─2 m

1 m

100 m

radio waves

microwaves

infrared

visible light

ultraviolet

X-rays

gamma rays

AM radio

FM radio, TV

Note that the wavelengths are listed on a logarithmic scale. In other words, each increment on the scale represents an increase in the wavelength by a factor of 10, not an addition of 10 m. Recall that the relationship between frequency and wavelength of an electromagnetic wave is described by the equation

$wavespeed=frequency×wavelength$,

or $c=fλ$.

All electromagnetic radiation propagates at a speed of *c* = 3x108 m/s (approximately 186,000 miles per second).

1. What is the difference between an X-ray, light, and a radio wave?
2. The Sun is approximately 150 billion meters from the Earth. Approximately how long does it take light to travel from the Sun to the Earth?
3. The Sun also emits infrared. Approximately how long does it take infrared to travel from the Sun to the Earth?
4. Which type of electromagnetic radiation has:
	1. the longest wavelength?
	2. the shortest wavelength?
	3. the highest frequency?
	4. the lowest frequency?
	5. the highest period?
	6. the lowest period?
5. What is the approximate range of wavelengths of visible light?
6. What is meant by the statement “Light is the only thing we can see”?

Electromagnetic Radiation and Energy

Electromagnetic radiation carries energy with it over space. The energy of a photon is given by the equation

$$energy=\frac{constant×wavespeed}{wavelength}$$

or

$$E=\frac{hc}{λ}$$

The constant *h* is called Plank's constant, equal to 6.63x10─34 J-s, a very small number.

1. List the types of electromagnetic radiation in order from lowest energy photons to highest energy photons.
2. The colors of the light spectrum (those wavelengths corresponding to visible light only) from shortest wavelength to longest wavelength are violet, blue, green, yellow, orange, and red. List the colors of the light spectrum in order from lowest energy photons to highest energy photons.

Application

Light Emitting Diodes

As we have seen through the course of our experiments with LEDs, certain types of semiconducting materials are capable of emitting specific types of E/M waves (light). While this process of emission is similar in nature to emission by single atoms (refer to “Neon and Other Discharge Lamps” PhET model), emission from the bulk semiconductor material occurs when electrons are excited to the conduction band and then fall back into the material’s valence band. The energy band gap of the semiconductor material plays a dominating role in whether or not the material can be used as an LED.

Critical Thinking Questions

1. Describe the role of energy in the production of light via emission.
2. What is the range of energies of visible light?
3. Given than 1 eV (electron volt) = 1.602 x 10-19J, would Aluminum Phosphide, which has a band gap of 2.45 ev ([complete list of semiconductor energy band gaps can be found here](http://en.wikipedia.org/wiki/Band_gap#List_of_band_gaps))be a good material to use in the manufacture of LEDs within the visible region of the electromagnetic spectrum? Justify your response.
4. Identify a semiconductor material suitable for the production of red light by referring to the link in the previous problem. Justify your response.
5. Is it possible to produce a white LED from a single semiconductor material? Why or why not?