Electromagnetic Spectrum

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Concept 1 Electromagnetic Spectrum

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Key Equations

$$c = f\lambda$$

; Wave equation for light

$c = 3 \times 10^8 \text{m/s}$

Guidance

- When charged particles accelerate
- When using the wave equation for light keep in mind that light always travels at the speed of light. So plug in cv in the wave equation.
- The color of light that we observe is a measure of the wavelength of the light: the longer*redder* the light.

The spectrum of electromagnetic radiation can be roughly broken into the following ranges:

TABLE 1.1:

EM wave	Wavelength range	Comparison size
gamma-ray ($\gamma-$ ray)	10^{-11} m and shorter	atomic nucleus
$x-$ray	10^{-11} m $-$ 10^{-8} m	hydrogen atom
ultraviolet (UV)	10^{-8} m $-$ 10^{-7} m	small molecule
violet (visible)	$\sim 4 \times 10^{-7}$ m(400 nm)*	typical molecule
blue (visible)	$\sim$ 450 nm	typical molecule
green (visible)	$\sim$ 500 nm	typical molecule
red (visible)	$\sim$ 650 nm	typical molecule
infrared (IR)	10^{-6} m $-$ 1 mm	human hair
microwave	1 mm $-$ 10 cm	human finger
radio	Larger than 10 cm	car antenna

Example 1

Which has a higher frequency, green light or microwaves?

Answer

Green light has a higher frequency than microwaves. It is possible to calculate it, but since the speed of an electromagnetic wave is constant we know that waves with higher wavelengths must have a lower frequency based on the wave equation.

Example 2

Calculate the frequency for an ultraviolet wave of wavelength 10^{-7} m and compare it to the frequency of a radio wave (about $3 * 10^9$ Hz). Which type of wave do you think takes more energy to generate?

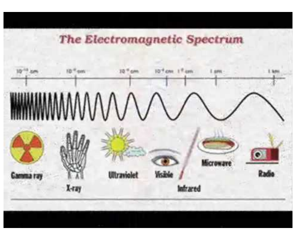
Solution

We'll use the wave equation to determine the wave length of ultraviolet light.

$$\begin{aligned}
c &= f\lambda \\
f &= \frac{c}{\lambda} \\
f &= \frac{3 * 10^8 \text{ m/s}}{10^{-7} \text{ m}} \\
f &= 3 * 10^{14} \text{ Hz}
\end{aligned}$$

The oscillating charged particles that create UV light are vibrating much more violently than the ones that create radio waves so they take more energy to generate.

Watch this Explanation



MEDIA

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Time for Practice

1. Which corresponds to light of longer wavelength, UV rays or IR rays?
2. Which corresponds to light of lower frequency, $x-$rays or millimeter-wavelength light?
3. Approximately how many blue wavelengths would fit end-to-end within a space of one millimeter?
4. Approximately how many short ("hard") $x-$rays would fit end-to-end within the space of a single red wavelength?
5. Calculate the frequency in Hz of a typical green photon emitted by the Sun. What is the physical interpretation of this (very high) frequency? (That is, what is oscillating?)
6. FM radio stations list the frequency of the light they are emitting in MHz, or millions of cycles per second. For instance, 90.3 FM would operate at a frequency of 90.3×10^6 Hz. What is the wavelength of the radio-frequency light emitted by this radio station? Compare this length to the size of your car's antenna, and make

an argument as to why the length of a car's antenna should be about the wavelength of the light you are receiving.

Answers to Selected Problems

1. .
2. .
3. 2200 blue wavelengths
4. 65000 $x-$rays
5. 6×10^{14} Hz
6. 3.3 m