

# Electromagnetic Spectrum

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## CONCEPT

## 1

# Electromagnetic Spectrum

Students will learn what an electromagnetic wave is, gain a feel for the main parts of the spectrum and work problems involving basic properties of electromagnetic waves.

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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  $c$  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  $3 \times 10^9$  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.

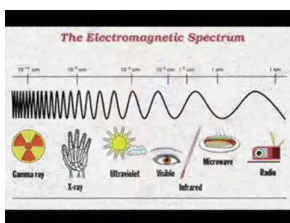
$$c = f\lambda$$

$$f = \frac{c}{\lambda}$$

$$f = \frac{3 \times 10^8 \text{ m/s}}{10^{-7} \text{ m}}$$

$$f = 3 \times 10^{14} \text{ Hz}$$

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  $90.3 \times 10^6$  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.  $6 \times 10^{14}$  Hz
6. 3.3 m