

# Properties of Electromagnetic Waves

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Printed: November 6, 2012

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# CONCEPT 1

## Properties of Electromagnetic Waves

- State the speed of light.
- Describe wavelengths and frequencies of electromagnetic waves.
- Relate wave frequency to wave energy.
- Show how to calculate wavelength or wave frequency if the other value is known.



What do these two photos have in common? They both represent electromagnetic waves. These are waves that consist of vibrating electric and magnetic fields. They transmit energy through matter or across space. Some electromagnetic waves are generally harmless. The light we use to see is a good example. Other electromagnetic waves can be very harmful and care must be taken to avoid too much exposure to them. X rays are a familiar example. Why do electromagnetic waves vary in these ways? It depends on their properties. Like other waves, electromagnetic waves have properties of speed, wavelength, and frequency.

### Speed of Electromagnetic Waves

All electromagnetic waves travel at the same speed through empty space. That speed, called the **speed of light**, is about 300 million meters per second ( $3.0 \times 10^8$  m/s). Nothing else in the universe is known to travel this fast. The sun is about 150 million kilometers (93 million miles) from Earth, but it takes electromagnetic radiation only 8 minutes to reach Earth from the sun. If you could move that fast, you would be able to travel around Earth 7.5 times in just 1 second! You can learn more about the speed of light at this URL: <http://videos.howstuffworks.com/discovery/29407-assignment-discovery-speed-of-light-video.htm>

## Wavelength and Frequency of Electromagnetic Waves

Although all electromagnetic waves travel at the same speed across space, they may differ in their wavelengths, frequencies, and energy levels.

- Wavelength is the distance between corresponding points of adjacent waves (see the **Figure 1.1**). Wavelengths of electromagnetic waves range from longer than a soccer field to shorter than the diameter of an atom.
- Wave frequency is the number of waves that pass a fixed point in a given amount of time. Frequencies of electromagnetic waves range from thousands of waves per second to trillions of waves per second.
- The energy of electromagnetic waves depends on their frequency. Low-frequency waves have little energy and are normally harmless. High-frequency waves have a lot of energy and are potentially very harmful.

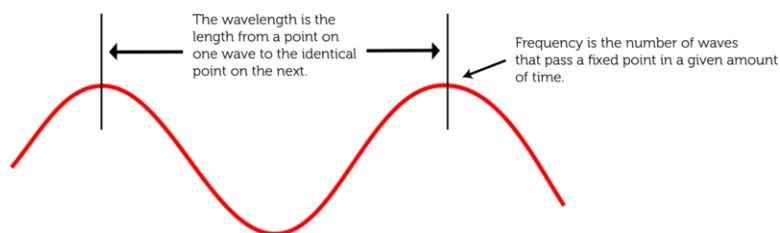


FIGURE 1.1

**Q:** Which electromagnetic waves do you think have higher frequencies: visible light or X rays?

**A:** X rays are harmful but visible light is harmless, so you can infer that X rays have higher frequencies than visible light.

## Speed, Wavelength, and Frequency

The speed of a wave is a product of its wavelength and frequency. Because all electromagnetic waves travel at the same speed through space, a wave with a shorter wavelength must have a higher frequency, and vice versa. This relationship is represented by the equation:

$$\text{Speed} = \text{Wavelength} \times \text{Frequency}$$

The equation for wave speed can be rewritten as:

$$\text{Frequency} = \frac{\text{Speed}}{\text{Wavelength}} \text{ or } \text{Wavelength} = \frac{\text{Speed}}{\text{Frequency}}$$

Therefore, if either wavelength or frequency is known, the missing value can be calculated. Consider an electromagnetic wave that has a wavelength of 3 meters. Its speed, like the speed of all electromagnetic waves, is  $3.0 \times 10^8$  meters per second. Its frequency can be found by substituting these values into the frequency equation:

$$\text{Frequency} = \frac{3.0 \times 10^8 \text{ m/s}}{3.0 \text{ m}} = 1.0 \times 10^8 \text{ waves/s, or } 1.0 \times 10^8 \text{ Hz}$$

**Q:** What is the wavelength of an electromagnetic wave that has a frequency of  $3.0 \times 10^8$  hertz?

**A:** Use the wavelength equation:

$$\text{Wavelength} = \frac{3.0 \times 10^8 \text{ m/s}}{3.0 \times 10^8 \text{ waves/s}} = 1.0 \text{ m}$$

You can learn more about calculating the frequency and wavelength of electromagnetic waves at these URLs: <http://www.youtube.com/watch?v=GwZvtfZRNNk> and <http://www.youtube.com/watch?v=wjPk108Ua8k&feature=related>

## Summary

- All electromagnetic waves travel across space at the speed of light, which is about 300 million meters per second ( $3.0 \times 10^8$  m/s).
- Electromagnetic waves vary in wavelength and frequency. Longer wavelength electromagnetic waves have lower frequencies, and shorter wavelength waves have higher frequencies. Higher frequency waves have more energy.
- The speed of a wave is a product of its wavelength and frequency. Because the speed of electromagnetic waves through space is constant, the wavelength or frequency of an electromagnetic wave can be calculated if the other value is known.

## Vocabulary

- **speed of light:** Speed at which all electromagnetic waves travel through space, which is  $3.0 \times 10^8$  m/s.

## Practice

Use the calculator at the following URL to find the frequency and energy of electromagnetic waves with different wavelengths. Use at least eight values for wavelength. Record and make a table of the results. <http://www.1728.org/freqwave.htm>

## Review

1. What is the speed of light across space?
2. Describe the range of wavelengths and frequencies of electromagnetic waves.
3. How is the energy of an electromagnetic wave related to its frequency?
4. If the frequency of an electromagnetic wave is  $6.0 \times 10^8$  Hz, what is its wavelength?