What Are Electromagnetic Waves?

- How are electromagnetic waves different from mechanical waves?
- Electromagnetic waves are produced when an electric charge vibrates or accelerates.
- Electromagnetic waves can travel through a vacuum, or empty space, as well as through matter.

What Are Electromagnetic Waves?

Electromagnetic waves are transverse waves consisting of changing electric fields and changing magnetic fields.

- Like mechanical waves, electromagnetic waves carry energy from place to place.
- Electromagnetic waves differ from mechanical waves in how they are produced and how they travel.

DOK Question:

Construct a visual model of this difference.

What Are Electromagnetic Waves?

How They Travel

Changing electric fields produce changing magnetic fields, and changing magnetic fields produce changing electric fields, so the fields regenerate each other.

- Electromagnetic waves do not need a medium.
- The transfer of energy by electromagnetic waves traveling through matter or across space is called **electromagnetic radiation.**

The Speed of Electromagnetic Waves

- **What is the maximum speed of light?**
- **The speed of light in a vacuum, *c*, is 3.00 × 10^8 meters per second.**

Wavelength and Frequency

- **How do electromagnetic waves differ from one another?**
- **Electromagnetic waves vary in wavelength and frequency.**

Wavelength and Frequency

Math Practice

1. A global positioning satellite transmits a radio wave with a wavelength of 19 cm. What is the frequency of the radio wave? (*Hint:* Convert the wavelength to meters before calculating the frequency.)

Answer: Speed = Wavelength × Frequency

Frequency = Speed/Wavelength =

$(3.00 \times 10^8 \text{ m/s})/(0.19 \text{ m}) = 1.6 \times 10^9 \text{ Hz}$

Wavelength and Frequency

Math Practice

2. The radio waves of a particular AM radio station vibrate 680,000 times per second. What is the wavelength of the wave?

Answer: Speed = Wavelength × Frequency

Wavelength = Speed/Frequency = $(3.00 \times 10^8$ m/s)/680,000 Hz = 440 m

Wavelength and Frequency

Math Practice

3. Radio waves that vibrate 160,000,000 times per second are used on some train lines for communications. If radio waves that vibrate half as many times per second were used instead, how would the wavelength change?

Answer: At 160 MHz: Wavelength = Speed/Frequency = $(3.00 \times 10^8$ m/s)/(160,000,000 Hz) = 1.9 m

At 80 MHz: Wavelength = Speed/Frequency = $(3.00 \times 10^8$ m/s)/(80,000,000 Hz) = 3.8 m.

The wavelength would be twice as long.

Wave or Particle?

- **What is the dual nature of electromagnetic radiation?**
- **Electromagnetic radiation behaves sometimes like a wave and sometimes like a stream of particles.**

Wave or Particle?

Scientists know that electromagnetic radiation travels as a wave. Scientists also have evidence that electromagnetic radiation behaves like a stream of particles.

- So which is light, wave or particle?
- It is both.

DOK Question:

Construct a visual model of this difference.

Wave or Particle?

The emission of electrons from a metal caused by light striking the metal is called the **photoelectric effect.**

In 1905, Albert Einstein (1879–1955) proposed that light, and all electromagnetic radiation, consists of packets of energy.

These packets of electromagnetic energy are now called **photons.**

DOK Question

Hypothesize who was Einstein.

Intensity

- What happens as light travels farther from its source?
- The intensity of light decreases as photons travel farther from the source.

Intensity

Intensity is the rate at which a wave's energy flows through a given unit of area. A wave model also explains how intensity decreases.

- As waves travel away from the source, they pass through a larger and larger area.
- The total energy does not change, so the wave's intensity decreases.

Assessment Questions

1. How are electromagnetic waves different from all mechanical waves?
   a. Electromagnetic waves don't carry energy.
   b. Electromagnetic waves are invisible.
   c. Electromagnetic waves are longitudinal waves.
   d. Electromagnetic waves can travel through a vacuum.

Assessment Questions

1. How are electromagnetic waves different from all mechanical waves?
   a. Electromagnetic waves don't carry energy.
   b. Electromagnetic waves are invisible.
   c. Electromagnetic waves are longitudinal waves.
   d. Electromagnetic waves can travel through a vacuum.

   ANS: D

Assessment Questions

2. What is the wavelength of a radio wave that has a frequency of 1.5×10^6 Hz? ($c = 3.0 \times 10^8$ m/s)
   a. 45 m
   b. 200 m
   c. 450 m
   d. 2 km

Assessment Questions

2. What is the wavelength of a radio wave that has a frequency of 1.5×10^6 Hz? ($c = 3.0 \times 10^8$ m/s)
   a. 45 m
   b. 200 m
   c. 450 m
   d. 2 km

   ANS: B

Assessment Questions

3. The photoelectric effect is evidence that light behaves like
   a. a wave.
   b. a particle.
   c. both a wave and a particle.
   d. neither a wave nor a particle.

Assessment Questions

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   a. a wave.
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   ANS: B

Assessment Questions

1. As photons travel farther from a light source, the intensity of light stays the same.

   True
   False

Assessment Questions

1. As photons travel farther from a light source, the intensity of light stays the same.

   True
   False

   ANS: F, decreases