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Waves of the Electromagnetic Spectrum – Reading Guide

Waves and Vibrating Electric Charge

1. A _____ is a disturbance that transfers energy.

2. An electric field that changes in time produces a _____ _____ that changes in time.

3. A changing magnetic field produces a changing _____ _____.

Properties of Electomagnetic Waves

4. The highest point of a wave is called the _____.

5. The lowest point of a wave is called the _____.

6. The distance from crest to crest is called _____ .

7. The number of wavelengths that pass by a certain point in a given time is the _____.

8. The distance from the midpoint of the wave to either the crest or trough is the _____.

9. _____ are the units for frequency, or number of waves per second.

Wave Speed

10. The speed of an electromagnetic wave is equal to _____ multiplied by _____.

11. The speed of light in a vacuum is_____.

12. A wave with a high frequency has a _____ wavelength.

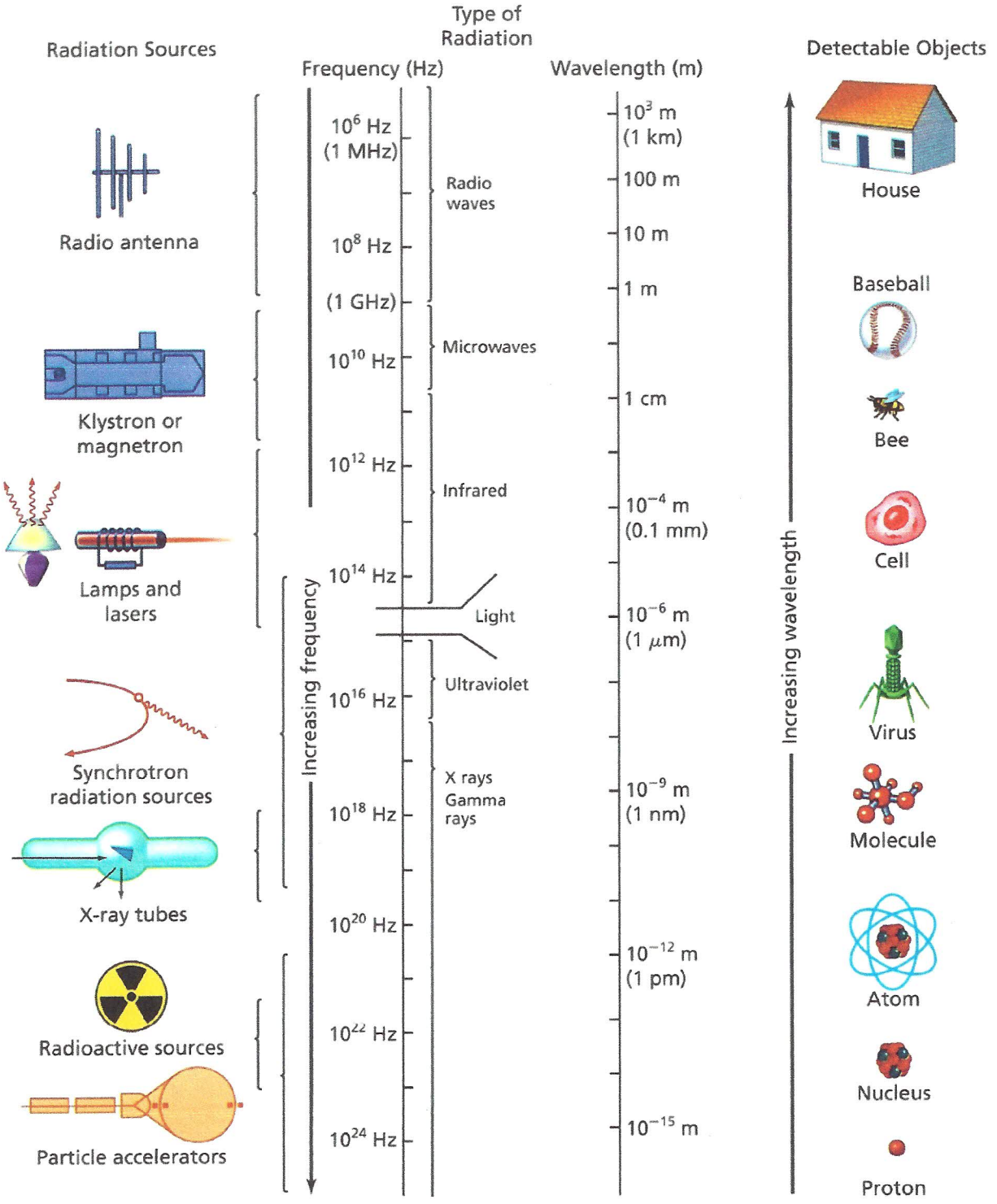
Electromagnetic Spectrum

13. _____ have the shortest wavelength and _____ have the longest wavelength.

14. _____ have the highest frequency and _____ have the lowest frequency.

15. _____ have the highest energy and _____ have the lowest energy.

The Electromagnetic Spectrum



$v = \lambda f$ The velocity of a wave is equal to its wavelength (λ) multiplied by its frequency (f).

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Getting the Idea

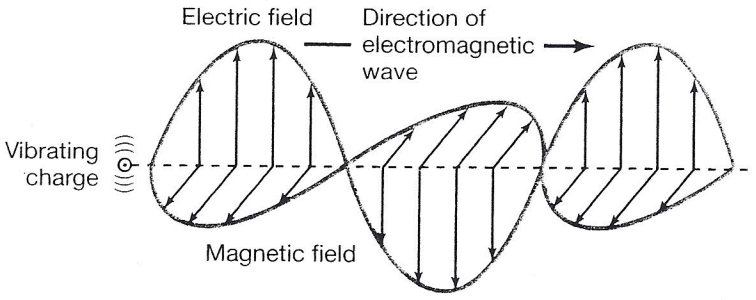
Key Words

electromagnetic wave
wave
crest
trough
wavelength
amplitude
frequency
electromagnetic spectrum

Radiation is energy in the form of electromagnetic waves. An **electromagnetic wave** is a sequence of alternating electric fields and magnetic fields that travels through space. Radiation can have different properties because electromagnetic waves can differ in their frequencies, wavelengths, and speeds.

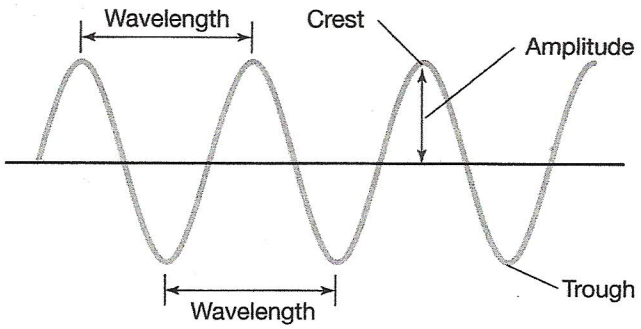
Waves and Vibrating Electric Charge

A **wave** is a disturbance that transfers energy. All waves are caused by something vibrating. Electromagnetic waves are caused by vibrating electric charges. A particle with an electric charge, such as an electron, is surrounded by an electric field. If the charge is vibrating, the field around it also vibrates and spreads out in all directions. This field continually increases and decreases with time. An electric field that changes in time produces a magnetic field that changes in time. Similarly, a changing magnetic field produces a changing electric field. A vibrating charge, then, is surrounded by waves composed of electric and magnetic fields that spread out from the charge. Because all matter contains charged particles, all matter emits radiation.



Properties of Electromagnetic Waves

The wave shown at the top of the next page illustrates properties that are used to describe waves. A **crest** is the highest point of a wave. For an electromagnetic wave, this is the point in time when the field is strongest. A **trough** is the lowest point of a wave. For an electromagnetic wave, this is the point in time when the field is weakest.



Different types of radiation are defined by their wavelength, amplitude, and frequency.

- **Wavelength** is the distance between two identical points on successive waves. In most cases, wavelength is measured according to the distance between two successive wave crests or two successive troughs. Wavelength is expressed in nanometers (nm).
- **Amplitude** is a measure of the energy a wave carries. It is determined by measuring the distance from the midpoint of the wave to either a crest or a trough.
- **Frequency** is the number of wavelengths that pass by a certain point in a given time. A wave with a high frequency generally has more energy than a wave with a lower frequency. Frequency is expressed in hertz (Hz). One hertz equals one cycle per second. Thus, hertz can be expressed as "number of waves per second."

Wave Speed

Unlike mechanical waves, which transfer energy through matter, electromagnetic waves transfer energy through a field. The speed of an electromagnetic wave is equal to the product of its wavelength (λ) and frequency (f). In an EM wave, these properties are inversely related. Thus, a wave with a high frequency has a short wavelength, while a wave with a low frequency has a long wavelength. When electromagnetic waves travel through a vacuum, their velocity is equal to the speed of light, which is 300,000 kilometers per second (km/s).

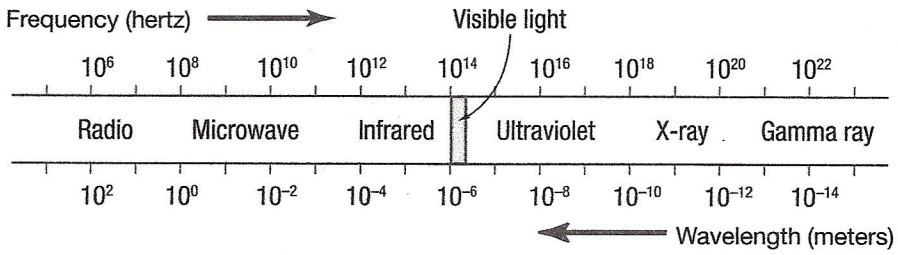
Electromagnetic Spectrum

The collection of all EM frequencies is known as the **electromagnetic spectrum**. As the diagram on the next page indicates, the electromagnetic spectrum is arranged according to wavelength and frequency. Radio waves have the longest wavelengths and lowest frequencies. Gamma rays have the shortest wavelengths and greatest frequencies. The electromagnetic spectrum also provides a way to compare wave energy. Waves with higher frequency have higher energy. Thus, gamma waves have the highest energy and radio waves have the lowest.

Did You Know

X-ray technology was invented by accident in 1895 by Wilhelm Roentgen. He noticed that a fluorescent screen in his lab glowed when the electron beam in a gas discharge tube was turned on. Although fluorescent material normally glows in reaction to electromagnetic radiation, the response was surprising because Roentgen's tube was surrounded by heavy cardboard.

Electromagnetic Spectrum



Radio waves have the longest wavelength, lowest frequency, and least energy. Radio waves travel long distances by reflecting their signals off Earth's atmosphere or off satellites above the planet.

Microwaves have shorter wavelengths, higher frequencies, and more energy than radio waves. Cell phones and radar are two important technologies that use microwaves.

Infrared light is most associated with heat. On the EM spectrum, infrared rays fall between visible light and microwaves, having mid-range wavelengths. For example, heat from the sun travels to Earth as infrared rays. Although you cannot see infrared rays, you can feel their warmth coming from the sun or from a campfire. A toaster oven uses infrared rays to help cook food.

Visible light is a narrow section of the electromagnetic spectrum that humans can see. You recognize the longest wavelengths of visible light as red and the shortest as violet.

Ultraviolet light falls between visible light and X-rays. Wavelengths of ultraviolet (UV) light are somewhat shorter, have a higher frequency, and carry more energy than visible light. UV rays can cause chemical reactions to take place. For example, UV rays from the sun can tan the skin, but too much exposure to UV rays may lead to skin cancer.

X-rays have short wavelengths, high frequencies, and high energy. X-rays can travel through most soft substances such as skin and muscle, but not hard, dense materials, such as bone. In airports, X-rays are used as a security measure to determine what might be hidden in people's luggage.

Gamma rays have the shortest waves, highest frequencies, and highest energy. Gamma rays can kill living cells and are used to sterilize medical equipment. The sun and other stars emit X-rays and gamma rays as well as lower-energy EM waves.

DISCUSSION QUESTION

A sound wave is a disturbance that moves through matter as particles push against each other. How is this different from a radio wave?

LESSON REVIEW

1. Microwave ovens use microwaves, a type of radio wave, to warm food. Which of the following is always true about microwaves?

   A. Their frequencies are lower than the frequencies of visible light.

   B. Their wavelengths are shorter than the wavelengths of infrared light.

   C. Their velocity is lower than the velocity of ultraviolet light.

   D. Their amplitude is higher than the amplitude of gamma rays.

2. A radio wave has a frequency of 25,000 hertz (Hz). How many waves pass a point in space during a 2.5 second time period?

   A. 625 **C.** 62,500

   B. 6,250 **D.** 625,000

3. Which type of electromagnetic waves has the greatest energy?

   A. gamma rays **C.** radio waves

   B. infrared waves **D.** X-rays

4. Maria spends several hours in the sun at the beach. Why should she be more concerned about the sun's ultraviolet light than visible sunlight that strikes her?

   A. Ultraviolet light has longer wavelengths than visible light.

   B. The frequency of visible light is higher than the frequency of ultraviolet light.

   C. Ultraviolet light has greater energy than visible light.

   D. The speed of ultraviolet light is greater than the speed of visible light.

5. Which of the following is a true statement about electromagnetic waves?

   A. A vibrating electric field is an example of an electromagnetic wave.

   B. Sound waves are electromagnetic waves with very low frequencies.

   C. The speed of an electromagnetic wave depends on its frequency.

   D. People emit electromagnetic waves in the form of infrared energy.