

After EM waves were experimentally detected, it became generally accepted that light is an EM wave. The **electromagnetic spectrum** includes EM waves of a wide variety of wavelengths, from microwaves and radio waves to visible light to X-rays and gamma rays, all of which travel through space at a speed $c = 3.0 \times 10^8$ m/s.

The average *intensity* (W/m^2) of an EM wave is

$$\bar{I} = \frac{1}{2} \epsilon_0 c E_0^2 = \frac{1}{2} \frac{c}{\mu_0} B_0^2 = \frac{1}{2} \frac{E_0 B_0}{\mu_0}, \quad (22-8)$$

Questions

- The electric field in an EM wave traveling north oscillates in an east–west plane. Describe the direction of the magnetic field vector in this wave. Explain.
- Is sound an EM wave? If not, what kind of wave is it?
- Can EM waves travel through a perfect vacuum? Can sound waves?
- When you flip a light switch on, does the light go on immediately? Explain.
- Are the wavelengths of radio and television signals longer or shorter than those detectable by the human eye?
- When you connect two loudspeakers to the output of a stereo amplifier, should you be sure the lead-in wires are equal in length to avoid a time lag between speakers? Explain.
- In the electromagnetic spectrum, what type of EM wave would have a wavelength of 10^3 km? 1 km? 1 m? 1 cm? 1 mm? $1 \mu\text{m}$?
- Can radio waves have the same frequencies as sound waves (20 Hz–20,000 Hz)?
- If a radio transmitter has a vertical antenna, should a receiver's antenna (rod type) be vertical or horizontal to obtain best reception?
- The carrier frequencies of FM broadcasts are much higher than for AM broadcasts. On the basis of what you learned about diffraction in Chapter 11, explain why AM signals can be detected more readily than FM signals behind low hills or buildings.
- Discuss how cordless telephones make use of EM waves. What about cell phones?
- A lost person may signal by switching a flashlight on and off using Morse code. This is actually a modulated EM wave. Is it AM or FM? What is the frequency of the carrier, approximately?

MisConceptual Questions

- In a vacuum, what is the difference between a radio wave and an X-ray?
(a) Wavelength. (b) Frequency. (c) Speed.
- The radius of an atom is on the order of 10^{-10} m. In comparison, the wavelength of visible light is
(a) much smaller. (b) about the same size. (c) much larger.
- Which of the following travel at the same speed as light? (Choose all that apply.)
(a) Radio waves. (d) Ultrasonic waves. (g) Gamma rays.
(b) Microwaves. (e) Infrared radiation. (h) X-rays.
(c) Radar. (f) Cell phone signals.
- Which of the following types of electromagnetic radiation travels the fastest?
(a) Radio waves.
(b) Visible light waves.
(c) X-rays.
(d) Gamma rays.
(e) All the above travel at the same speed.
- In empty space, which quantity is always larger for X-ray radiation than for a radio wave?
(a) Amplitude. (c) Frequency.
(b) Wavelength. (d) Speed.
- If electrons in a wire vibrate up and down 1000 times per second, they will create an electromagnetic wave having
(a) a wavelength of 1000 m. (c) a speed of 1000 m/s.
(b) a frequency of 1000 Hz. (d) an amplitude of 1000 m.
- If the Earth–Sun distance were doubled, the intensity of radiation from the Sun that reaches the Earth's surface would
(a) quadruple. (b) double. (c) drop to $\frac{1}{2}$. (d) drop to $\frac{1}{4}$.
- An electromagnetic wave is traveling straight down toward the center of the Earth. At a certain moment in time the electric field points west. In which direction does the magnetic field point at this moment?
(a) North. (d) West. (g) Either (a) or (b).
(b) South. (e) Up. (h) Either (c) or (d).
(c) East. (f) Down. (i) Either (e) or (f).
- If the intensity of an electromagnetic wave doubles,
(a) the electric field must also double.
(b) the magnetic field must also double.
(c) both the magnetic field and the electric field must increase by a factor of $\sqrt{2}$.
(d) Any of the above.
- If all else is the same, for which surface would the radiation pressure from light be the greatest?
(a) A black surface.
(b) A gray surface.
(c) A yellow surface.
(d) A white surface.
(e) All experience the same radiation pressure, because they are exposed to the same light.
- Starting in 2009, TV stations in the U.S. switched to digital signals. [See Sections 22–7, 17–10, and 17–11.] To watch today's digital broadcast TV, could you use a pre-2009 TV antenna meant for analog? Explain.
(a) No; analog antennas do not receive digital signals.
(b) No; digital signals are broadcast at different frequencies, so you need a different antenna.
(c) Yes; digital signals are broadcast with the same carrier frequencies, so your old antenna will be fine.
(d) No; you cannot receive digital signals through an antenna and need to switch to cable or satellite.