10.1: Waves

Learning Objectives

- Define the terms wavelength and frequency with respect to wave-form energy.
- State the relationship between wavelength and frequency with respect to electromagnetic radiation.

During the summer, many people enjoy going to the beach. Beach-goers can swim, have picnics, and work on their tans. If a person gets too much sun, a case of sunburn is often the result. A particular set of solar wavelengths are especially harmful to the skin. This portion of the solar spectrum is known as UV-B, with wavelengths of 280 to 320 nm. Sunscreens can be effective in protecting skin against both the immediate skin damage and the long-term possibility of skin cancer due to UV-B radiation.

Waves

Waves are characterized by their repetitive motion. Imagine a toy boat riding the waves in a wave pool. As the water wave passes under the boat, it moves up and down in a regular and repeated fashion. While the wave travels horizontally, the boat only travels vertically up and down. The figure below shows two examples of waves.

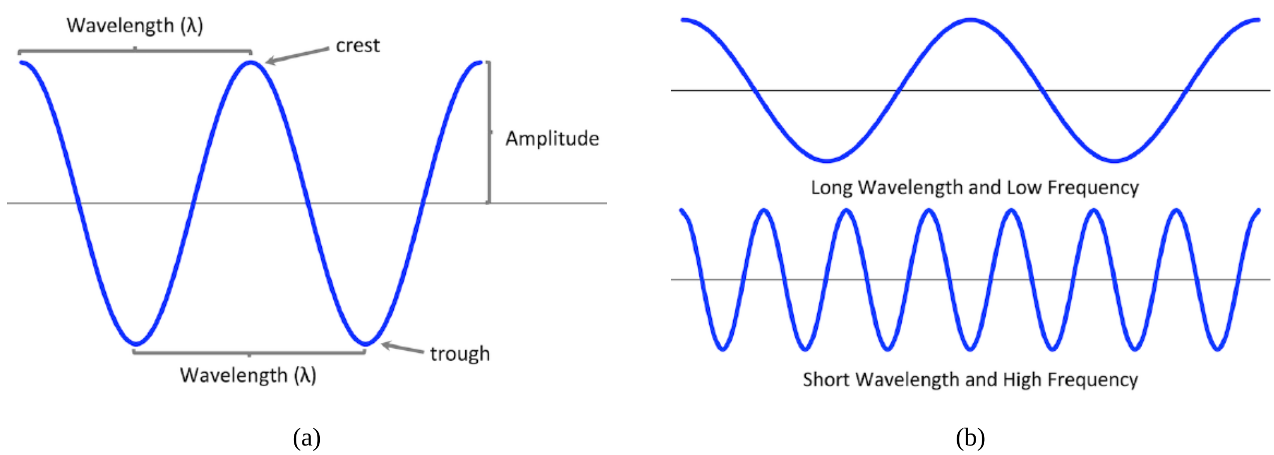

Figure 10.1.1: A wave consists of alternating crests and troughs. The wavelength (λ) is defined as the distance between any two identical points on adjacent waves. The amplitude is the height of the wave. A wave with a longer wavelength has a low frequency because fewer waves pass a given point in a certain amount of time. A wave with a shorter wavelength has a higher frequency.

A wave cycle consists of one complete wave – starting at the zero point, going up to a wave **crest**, going back down to a wave **trough**, and back to the zero point again. The **wavelength** of a wave is the distance between any two corresponding points on adjacent waves. It is easiest to visualize the wavelength of a wave as the distance from one wave crest to the next. In an equation, wavelength is represented by the Greek letter lambda (λ). Depending on the type of wave, wavelength can be measured in meters, centimeters, or nanometers ($1\text{ m} = 10^9\text{ nm}$). The **frequency**, represented by the Greek letter nu (ν), is the number of waves that pass a certain point in a specified amount of time. Typically, frequency is measured in units of cycles per second or waves per second. One wave per second is also called a hertz (Hz) and in SI units is a reciprocal second (s^{-1}).

Figure 10.1.1 (b) above shows an important relationship between the wavelength and frequency of a wave. The top wave has a longer wavelength than the bottom wave. However, if you picture yourself at a stationary point watching these waves pass by, fewer of the top waves would pass by in a given amount of time. Thus the frequency of the top wave is less than that of the bottom wave. Wavelength and frequency are therefore inversely related. As the wavelength of a wave increases, its frequency decreases. The equation that relates the two is:

$$c = \lambda\nu \tag{10.1.1}$$

where c is the speed of light and has a value of 2.998×10^8 m/s. For the relationship to hold mathematically, if the speed of light is used in m/s, the wavelength is measured in units of meters and the frequency in units of hertz.

Summary

- All waves can be defined in terms of their wavelength and frequency.
- $c = \lambda\nu$ expresses the relationship between wavelength and frequency.