Sound and Sound Waves
World of Physics. 2001. Lexile Measure: 1160L.

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Full Text:

Sound is produced when an object vibrates and transfers **kinetic energy** to the molecules of the medium surrounding it. This kinetic energy causes the molecules in the medium to vibrate, transferring kinetic energy to new molecules. Kinetic energy moving through a medium causes a series of compressions (areas where the molecules are crowded together) and rarefactions (areas where the molecules are spread out). These compressions and rarefactions move through the medium, away from the original vibration; thus, sound is a longitudinal wave--a series of compressions and rarefactions moving through a medium.

When people speak, air moves from their lungs past their vocal cords, causing them to vibrate. The vocal cords consist of two flaps of tissue that can move closer to or farther away from each other. When they move closer together, they cause a compression in the air between them. When they move farther apart, they cause a rarefaction. The continuous vibration as air moves over the vocal cords causes a series of compressions and rarefactions--in other words, sound. A stereo speaker operates in a similar manner: the speaker vibrates back and forth, causing the air in front of it to vibrate.

The speed of sound **waves** depends on several characteristics of the medium through which the waves are traveling: the medium's **temperature**, its **elasticity**, and its **density**. Sound travels more slowly at lower temperatures. For example, the **speed of sound** in air at 32°F (0°C) is 0.20 mi/sec (0.32 km/s), but its speed in air at 77° F (25°C) is 0.21 mi/sec (0.35 m/s). Sound travels most rapidly in solids and slowest in gases. This is because the molecules in a solid bounce back rapidly when vibrated; in other words, solids are more elastic than liquids or gases. When sound is moving through two different mediums, the speed of sound will be slowest in the material with the greater density. For example, solid nickel is denser than solid iron, and the speed of sound in nickel is 3 mi/sec (4.8 km/s), while the speed of sound in iron is 3.2 mi/sec (5.1 km/s). Therefore, the speed of sound would be greatest in a high-temperature, low-density solid.

Since sound is actually a series of longitudinal waves, it displays the wave properties of amplitude, **frequency**, and **wavelength**. The amplitude of a wave is the height of a wave crest above its origin, which determines how loud a sound is. The frequency of a wave is the number of wave crests that travel past a point per second. The wavelength is the distance between successive wave crests. Frequency and wavelength are inversely proportional to each other and they determine a sound's pitch--how high or low the sound is. The faster an object vibrates, the higher-pitched the sound it creates. The pitch depends on the frequency of the sound waves, which is measured as the number of waves, or cycles, per second, also known as hertz (Hz). One hertz is equal to one cycle per second. An opera singer's high note may have a frequency of 1000 Hz, whereas the low sound of **electricity** "humming" has a frequency around 60 Hz.

If all vibrating objects produce sound, why is there no audible sound when a person waves her hand in the air? The human ear can hear sounds that fall only in a relatively narrow range of frequencies, from about 20-20,000 Hz. A sound with a frequency lower than 20 Hz is called *infrasonic*; a sound with a frequency higher than 20,000 Hz is called *ultrasonic*. The sound produced when a hand is waved is infrasonic and therefore beyond **hearing** capacity. Elephants can hear and produce infrasonic sounds below 20 Hz. Dogs can hear sounds up to 35,000 Hz and cats can hear sounds up to 65,000 Hz. This is why a dog can hear the ultrasonic sound produced by a dog whistle, but a person cannot.

The amplitude of a sound wave determines how loud the sound is, or its intensity. The larger the amplitude, the more energy the wave carries and the higher the intensity of the waves. High-intensity waves are louder than low-intensity waves, and the relative intensity of sounds can be measured using the decibel (dB) scale. A sound with an intensity of 1 dB can barely be heard, while a rock concert produces sound with an intensity of around 120 dB. Any sound over 120 dB can cause pain and hearing loss in human beings.

Waves can combine with other waves to produce **interference**. If the waves are in phase (if their crests and troughs line up), the interference will be constructive, which means that it has an additive effect. If the waves are out of phase, the interference will be destructive, which means that the two waves' crests and troughs tend to cancel each other out. In sound waves, constructive interference increases intensity, making the sound louder, while destructive interference decreases intensity, making the sound softer. Engineers construct auditoriums and concert halls so that the sound waves coming from the stage bounce off of the walls, creating constructive interference. These engineers are especially careful to avoid floor plans that cause destructive interference. Destructive interference can create the absence of sound, or dead spots, in a room. Engineers who design buildings with this phenomenon in mind are called acoustical engineers.

Sound waves can benefit people in ways other than pleasing music or soothing sounds such as a babbling brook. Ultrasonic waves are used in Sound Navigation and Ranging (**sonar**) systems that use sound waves to explore ocean floors. A research vessel can send sound waves down into the water, which travel to the sea bed and bounce back up to the surface. Researchers who know the speed of sound in salt water can use the time it takes for the sound to travel to the floor and back to calculate the depth of the floor at that point. Applying this procedure over wide areas has allowed investigators to create extensive maps of the ocean floor. The auto focus feature on many cameras also uses sonar to determine the distance between the object to be photographed and the camera lens.

Ultrasonic waves can also be used to clean delicate objects, such as fine jewelry. The object is placed in a liquid and ultrasonic waves are sent through the liquid, creating high-speed vibrations that knock dirt and debris from the object's surface. Ultrasonic waves have medical applications as well; physicians use them to create a picture much like an x-ray, and to send vibrations to damaged muscle, thereby aiding the healing process.

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