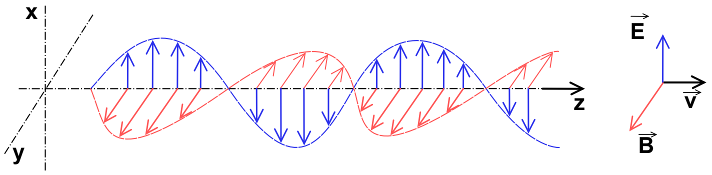
Transverse Versus Longitudinal Waves

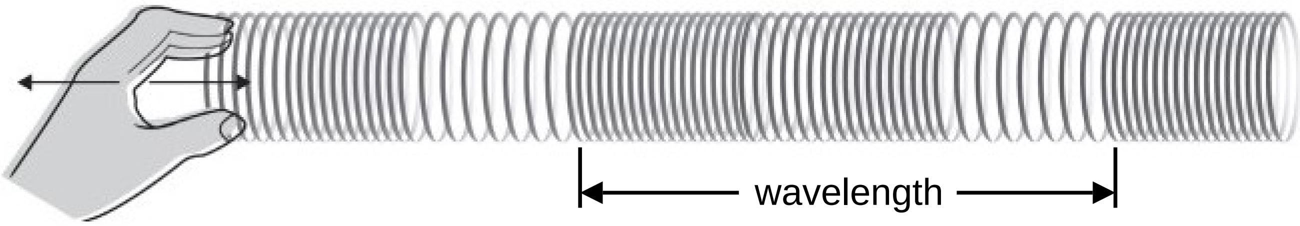
Waves can transmit energy without any net movement of *matter*. Wave movement may be ***transverse*** or ***longitudinal***.

With ***transverse waves***, the movement of the wave is ***perpendicular*** to the direction of travel of the energy transmitted by the wave. Perhaps the most common way we can observe transverse waves is with waves on water. Although the water waves move up and down, the direction of travel of the energy is along the surface of the water.

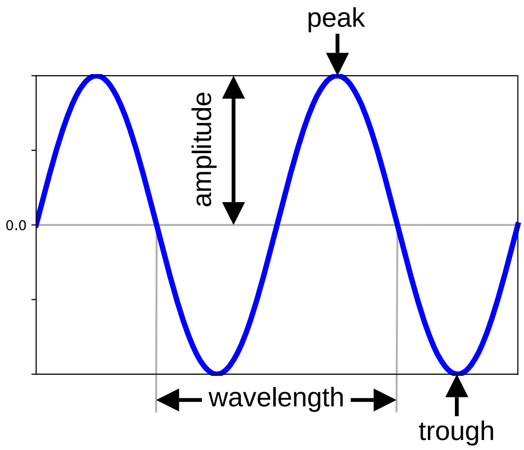


Electromagnetic radiation also travels as a transverse wave where both electric and magnetic fields are perpendicular to each other and to the direction of travel.

With ***longitudinal waves***, the movement of the wave is in the same (and opposite) direction to the direction of travel of the energy transmitted by the wave. We can visualize this as the way a wave travels along a spring that is repeatedly compressed and released. An especially good spring to use is a toy *Slinky*. Below is a diagram of a hand moving to make longitudinal waves on a slinky toy.



Features of a Wave



When discussing waves, there is some basic vocabulary to learn. The ***amplitude*** is the maximum displacement away from the equilibrium position. A ***peak***, or ***crest***, occurs at the highest point above the equilibrium, whereas a ***trough*** occurs at the lowest position. The ***wavelength***, represented by the symbol lambda (λ), is the distance between two consecutive peaks (or between two consecutive troughs).

Traveling waves will have a ***velocity*** (v). The ***period*** (T) is the time it takes for one cycle of the wave – one wavelength – to pass a point ($\lambda = v \cdot T$).

The ***frequency*** of a wave is how many times a complete cycle (a complete wavelength) of the wave is completed in each second. The following formula relates a wave's velocity to its frequency and wavelength:

$$v = f \cdot \lambda$$

The *frequency* (f) of a wave is measured with the units Hertz (Hz). One Hertz is the same as one cycle per second ($1\,\text{Hz} = 1\,\text{s}^{-1}$).

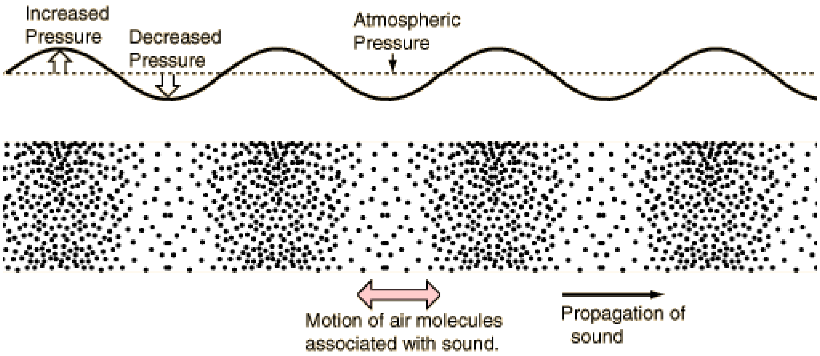
Document: Sound

Sound Waves

Both electromagnetic radiation and sound are types of energy that travels in waves. However, these two differ in many ways.

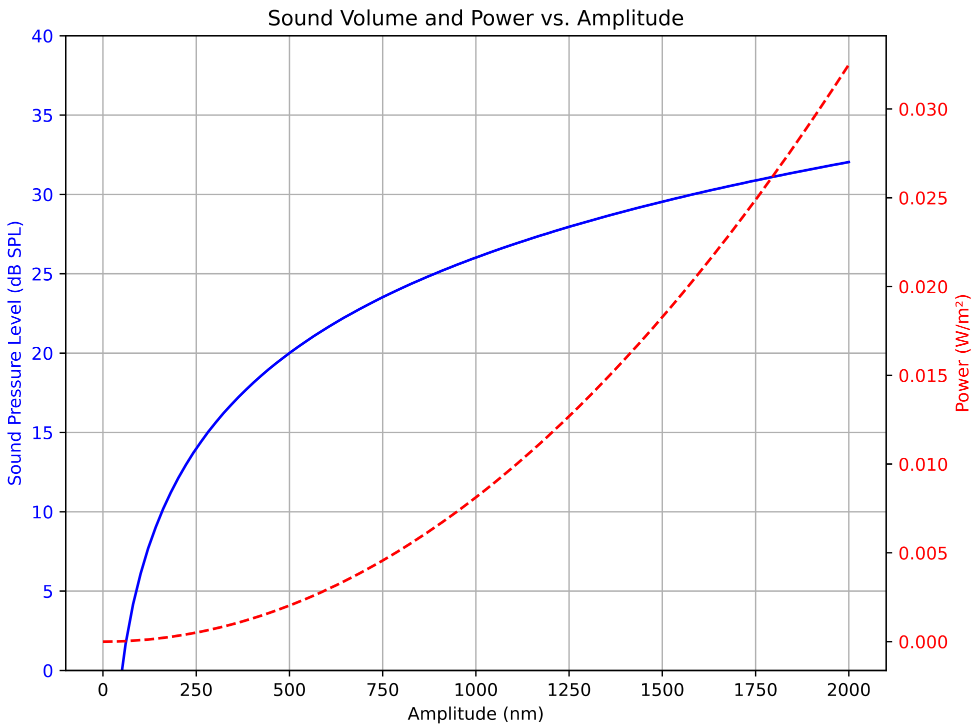
While electromagnetic waves can travel through a vacuum, sound requires a ***medium***. Said in another way, sound waves travel through ***matter*** (solids, liquids, gasses, etc.), while electromagnetic waves are able to travel through empty space.

As mentioned above, electromagnetic waves are *transverse waves*. Sound waves are *longitudinal waves*. The diagram below is intended to help you visualize how sound waves travel through a medium. Molecules in the medium are compressed (pushed closer together) and rarefied (spread apart) creating waves. Molecules are moving back and forth in the opposite and same direction as the direction that the energy travels. The sine wave at the top of the diagram represents the atmospheric pressure (and the density of molecules) at each point in the wave.



The ***volume*** of a sound is its *perceived* loudness.

While the ***amplitude*** of a sound wave is the maximum displacement of molecules from their equilibrium position, it isn't the same as volume. A sound wave with twice the amplitude is not perceived as twice as loud. The *volume* is proportional to the logarithm of the amplitude. This can be seen in the diagram below.



The power required to increase the amplitude is proportional to the square of the amplitude. This means that as we increase the volume of a sound, we need hugely more power. Examine the table, below.

Volume [dB]	**Impact to Hearing**	**Power (W/m^2)**	**Example**
0 dB	Threshold of human hearing	10^{-12} W/m^2	Near silence
30 dB	Very quiet	10^{-9} W/m^2	Whisper
60 dB	Normal conversation	10^{-6} W/m^2	Taking at 1m distance
85 dB	Prolonged exposure can cause damage	3.16×10^{-4} W/m^2	Lawnmower, heavy traffic
100 dB	Damage after about 15 minutes of exposure	10^{-2} W/m^2	Chainsaw, jackhammer
120 dB	Immediate pain threshold	1 W/m^2	Rock concert, jet engine at 100m
140 dB	Immediate hearing damage	100 W/m^2	9mm pistol (~160dB at shooter's ear)
150 dB	Severe pain, eardrum rupture	1 kW/m^2	.357 Magnum revolver, 12-gauge shotgun
160+ dB	Extreme danger, structural damage	10 kW/m^2	Explosives, .50 BMG rifle (~170+dB)

Other Vocabulary: Pitch and Fidelity

While mathematicians and scientists generally use the word *frequency*, musicians discuss the same concept using the word ***pitch***. Increased *frequency* means higher *pitch*, and vice-versa.

Fidelity is how accurately a recording matches the original. A recording that is extremely high-fidelity should be nearly indistinguishable from the original. If it is low-fidelity, then you should be able to easily tell it is not the original sound. An example of something that might be considered low-fidelity is the sound of someone talking on a telephone. The goal of the telephone was to transmit *intelligible* speech using minimal amount of bandwidth.

To ***amplify*** a signal is to increase the intensity or amplitude. For sound, if we increase the amplitude, we are increasing the volume. Thus if a sound undergoes ***amplification***, its volume is increased.

Summary

Not everything in this document will be tested. You will be required to know all the vocabulary words given in ***bold italics***.

Understand that while electromagnetic waves are *transverse waves* and can travel through empty space, sound waves are *longitudinal waves*, and require a *medium*. Sound energy is transmitted by the ***vibration*** of matter.

Remember that *volume* is the perceived loudness, and is related to the amplitude of the vibrations; however, doubling the volume – the perceived loudness – requires about ten times the amount of power. The loudest sounds, which are damaging to our ears, are created by explosions.

A higher *pitch* of sound is a higher *frequency* of sound.