Next Gen PET LC

UNIT WS

LESSON 3: Sound Waves

Purpose

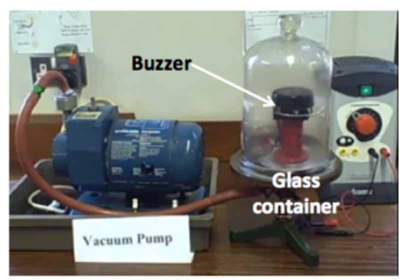
Sound is all around us every day, from the background noises of everyday life, to the conversations we have with other people, and the music we listen to. But what is sound? How is it produced and detected, and how does it travel from the source to the receiver? You are probably aware that sound can be regarded as a wave of some sort, but in this activity we will take a close look at these waves.

LESSON ?

What are sound waves and what are some of their characteristics?

Predictions, Observations and Making Sense

PART 1: What are sound waves?



To begin, watch a short segment of a movie **(UWS L3 Mov1 YT)** from YouTube of a buzzer placed inside a glass container. The glass container is connected to a vacuum pump that is able to remove all the air from inside the container.

CQ 3-1: What do you think will happen to the sound of the buzzer when the air is mostly removed from the glass container?

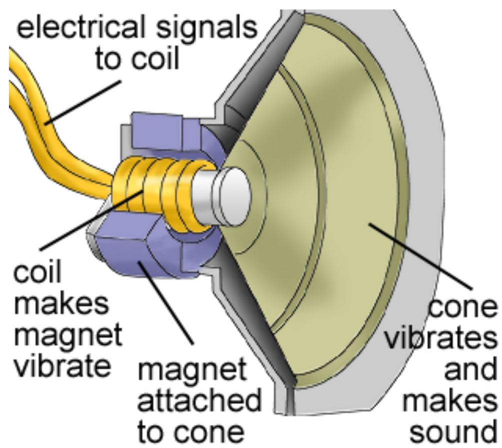
A. Nothing will change; the buzzer will be as loud as it had been before the air was removed.
B. The volume of the buzzer will be diminished just a little, but you will still be able to hear it very clearly.
C. The volume of the buzzer will be diminished significantly and you will barely be able to hear it, or not hear it at all.

To check your prediction, watch an extension of the previous YouTube movie **(UWS L3 Mov2 YT)** that shows what happens when the air is removed from the glass container with a vacuum pump.[1]

After the air was removed from the container, can the buzzer still be heard?

What can you conclude from this about sound traveling through a vacuum (no air)?

Let's consider how we can produce sound. Watch a YouTube movie **(UWS L3 Mov3 YT)** that shows what happens when part of a steel ruler extending out from the edge of a table is struck with a finger.[2]

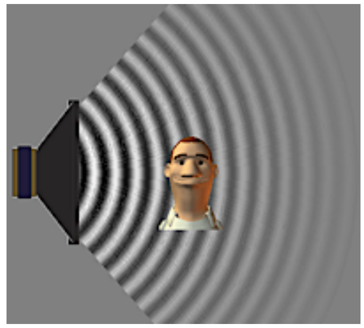


All sounds are produced by a source that vibrates. (In the previous movie, the source was the ruler.) The movement of the vibrating source affects the air around the object to produce sound waves. One common way to do this is using a device we call a loudspeaker, in which an oscillating electrical current is passed through a coil. Because of the *electromagnetic interaction* between them, a magnet located in the center of this coil then vibrates back and forth, causing the cone attached to this magnet also vibrates, producing sound waves.

Next, watch a movie **(USW L3 Mov4)** from the PhET 'Sound' simulation. If you wish, you can explore this simulation on your own at: http://phet.colorado.edu/en/simulation/sound. The source of the sound waves is a simulated loudspeaker.

[1] You can see the whole movie at: http://www.youtube.com/watch?v=ce7AMJdq0Gw

[2] You can see the YouTube movie of the steel ruler at http://youtu.be/dDshiu5um9g.



How does the speaker appear to be moving: forward and backward, or up and down?

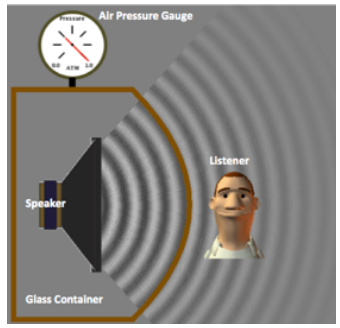
Does this observation suggest that sound waves are transverse or longitudinal? How does this evidence support your answer?

Does the simulation representation suggest that the amplitude of the sound waves increases, decreases, or remains the same as you get further away from the source? How do you know?

The amplitude of the sound waves reaching a person's ear is related to the loudness of the sound that a person would hear. The simulation shows a 'person' listening to the sound produced by the loudspeaker. In the next movie **(UWS L3 Mov5)**, you will observe what the listener 'hears' as he moves closer to, or further from, the loudspeaker.

How does the volume of the sound perceived by the listener depend on his distance from the source?

Now consider the clicker question CQ 3-1 posed at the beginning of this lesson. Watch the movie **(UWS L3 Mov6)** from the simulation with the speaker inside a glass container. The air will be removed from the container, and then let back in.

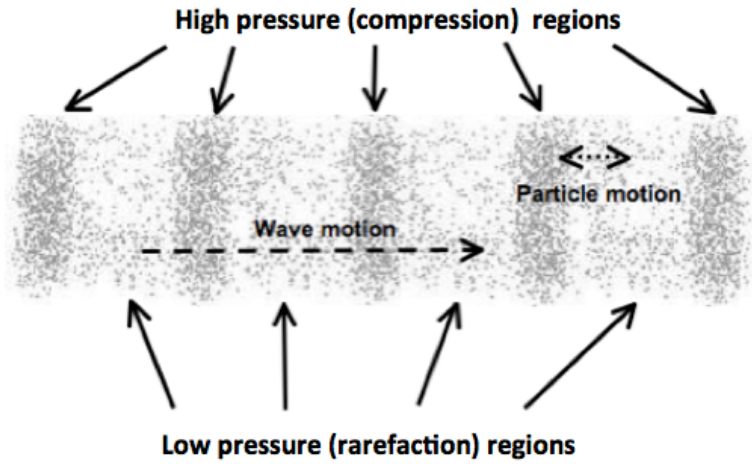


What happens in the movie of the simulation?

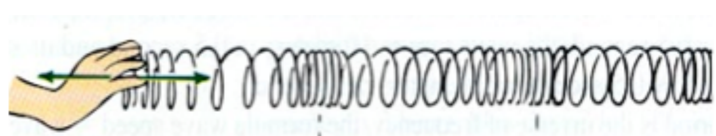
What can you conclude about whether sound can travel through a perfect vacuum (no air present at all)?

Next we briefly discuss how the sound travels through the air. The air consists of tiny particles (not visible to the eye) that move around in all directions. These particles can push against other particles or objects in their vicinity, creating air pressure. When the air particles are closer together on the average, the air pressure is higher, and when the air particles are further apart on the average, the air pressure is lower.

When a loud speaker continually moves forward and backward, it alternately pushes the air in front of it closer together and then further apart, then closer together and then further apart, and so forth, creating alternate regions of higher pressure and lower pressure that move outward from the loud speaker as a **sound wave**. Below is a picture representing the positions of air particles as a continuous sound wave is moving from the left to the right. In this picture the particles are represented as very tiny dots. The regions where the particles are much closer together than normal are regions of high pressure (sometimes referred to as a compression region). The regions where the particles are much further apart than normal are regions of low pressure (sometimes referred to as a rarefaction region). A sound wave can also be regarded as a compression wave. In an actual situation involving the loud speaker, however, the alternative high and low pressure regions move outward in all directions from the source, rather than just in one direction as suggested by this picture.



When considering sound waves in this way, you can see that the behvior of the air particles is very much like the behavior of the coils on a long spring that become stretched and compressed as a longitudinal wave moves along it.



PART 2: What are some properties of sound waves and how are they detected?

Now that you have seen how sound waves are created and how they move through the air, we will move on to investigate how they are detected and what some of their properties are.

One member of your group should hold a single sheet of paper at one end so it hangs straight down. Another group member should hold a large book or binder up vertically about 2 feet from the paper and facing toward it. Now move the book/binder forward and backward (toward and away from the paper) quickly many times, while the other group members watch the paper.

How does the paper behave while the binder is being moved forward and backward?

Why do you think the paper is behaving in this way? Explain your thinking in terms of what effect the moving board is having on the air in front of it, and what affect that air is having on the paper.

Just like the paper, the varying high and low air pressures of sound waves can make any object move, even if only a little.

As you are probably aware, the human ear contains a thin film called the eardrum. When a sound wave enters the ear, the alternating regions of higher and lower air pressure make the eardrum move in and out, just like the paper was moved by the pulses in the air created by the movement of the book or binder. A complex mechanism in the inner ear then converts these movements of the eardrum into electrical signals that travel to the brain, resulting in hearing[3].

Recall from the previous activities that the amplitude and frequency of a wave can be controlled by varying the motion of the source producing it. We will now investigate how these ideas apply to sound waves.

CQ 3-2: Suppose the amplitude of the backward and forward motion of the loudspeaker in the simulation was increased. What effect would that have on the pressure variations of the sound wave produced and on the loudness of the sound perceived by a listener?

A. Changing the amplitude of the motion of the source will have no effect on either the pressure variations of the sound wave or the loudness of the sound.
B. Increasing the amplitude of the motion of the source will increase the differences between the high and low pressure regions in the sound wave and will be perceived as a louder sound.
C. Increasing the amplitude of the motion of the source will decrease the differences between the high and low pressure regions in the sound wave and will be perceived as a softer sound.

[3] This is also the principle behind how microphones work; the varying air pressure of a sound wave makes a small object move and this motion is turned into electrical signals.

To check your idea, watch the movie **(UWS L3 Mov7)** from the simulation showing what happens when the amplitude of the source (loudspeaker) is increased from a low value to a high value. (Note that the amplitude is changed by moving the amplitude slider in the upper right corner of the movie.) The frequency of the sound wave remains the same.

As the amplitude of the loudspeaker movement is increased, does the **amplitude** of the high and low-pressure regions in the sound wave increase, decrease, or stay the same? How do you know?

As the amplitude of the loudspeaker movement is increased, does the **wavelength** of the sound wave increase, decrease, or stay the same? How do you know?

As the amplitude of the loudspeaker movement is increased, does the **perceived sound** by the listener get louder, quieter or remain the same?

CQ 3-3: Suppose, instead, the frequency of the backward and forward motion of the loudspeaker in the simulator was increased. Assuming the wave speed does not change, what effect do you think this would have on the wavelength of the sound wave?

A. The wavelength will increase.
B. The wavelength will decrease.
C. The wavelength will remain the same.

To check your idea, watch the movie **(UWS L3 Mov8)** from the simulation where the frequency is increased from a low value of 200 Hz to a high value of 1000 Hz. (Note that the frequency is changed by moving the frequency slider in the upper right corner of the movie.) The amplitude remains the same.

As the frequency of the loudspeaker movement increases, does the **wavelength** of the sound wave increase, decrease, or stay the same?

As the frequency of the loudspeaker movement increases, how does the quality of the perceived sound change?

The perceived characteristic of sound that changes when the frequency changes is called the *pitch* of the sound. Higher frequency sound waves have higher perceived pitches.

In Lesson 1, you learned that the speed of a wave on a string depends only on the properties of the medium (tension or tautness of the spring, or how heavy the string is). This is a general property of all mechanical waves. So, for sound waves moving through air, if the properties of the medium remain the same (the air remains at the same temperature and density), sound waves of different frequencies should all travel at the same wave speed.

Sound waves are longitudinal and can move through any form of matter, solid, liquid, or gas. In fact, because the particles in a liquid and a solid are closer together, sound waves move more quickly through them than they do though air. Under normal conditions, the speed of sound in air is about 340 m/s, but in water it is about 1,500 m/s, whereas in solid iron it is about 5,000 m/s. Also, the speed of sound depends on temperature of the medium. The higher the temperature, the more quickly the individual particles of the medium move, and the more rapidly the sound wave can move.

Human hearing

The frequency of a wave is measured in units of Hertz (Hz). For sound waves, this is a measure of how many cycles of pressure variation occur in one second. The human ear can only detect sound waves with a certain range of frequencies. Typically the range runs from a low of around 15 Hz (15 cycles per second) to an upper limit somewhere between 10 and 20 kHz (a kHz is one thousand Hz, so 20 kHz is 20,000 cycles per second).

The range of human hearing tends to diminish with age, particularly at the upper end. Other animals have very different ranges, with dogs and cats generally able to hear sounds at higher frequencies than any humans. Some bats can even hear sounds up to frequencies of 200 kHz!

Summarizing Questions

S1. In most science fiction movies set in space, weapons, explosions, and spacecraft engines can be heard. Is this realistic? Why or why not?

S2. Consider now the effects of wave speed on the frequency of the sound wave.

CQ 3-4: You are at the back of a crowd enjoying a concert in the park. At some point, a violin plays a high E (frequency = 2637 Hz) at the same moment that a bass plays a low E (41 Hz). Which note will you hear first, if either, and why?

A. You will hear them both at the same time.
B. You will hear the high E note from the violin first.
C. You will hear the low E note from the bass first.