Matter and Sound

UNIT 8

Student Reader

Front Cover:

The front cover shows a photograph of three students practicing in a band.

Unit 8: Matter and Sound

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Sound is Energy

Slamming a Door

There is a mausoleum in Scotland where the sound of a door slammed with enough force will echo for 15 seconds. Mausoleums are structures that hold burial chambers.

Sound is energy that is carried in waves by vibrating molecules. To **vibrate** means to move back and forth quickly.

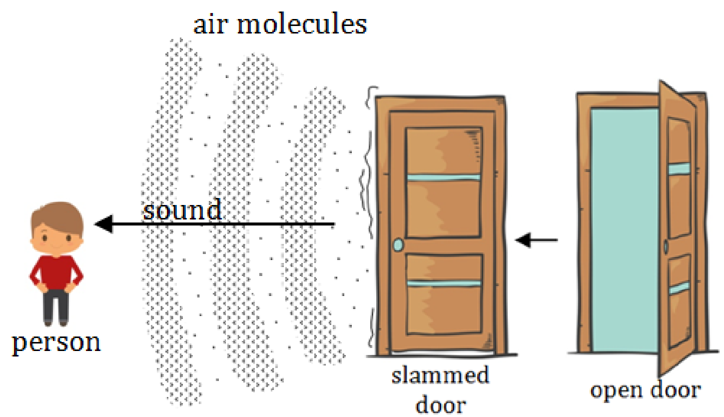
When you slam a door, you transfer mechanical energy to the door. When the door collides with the doorframe, the door transfers energy to the doorframe. This collision causes the molecules that make up the door and doorframe to vibrate. Some of the mechanical energy is converted to sound.

The energy from the door slamming causes nearby air molecules to vibrate and bump into the molecules closest to them. This passes on the energy and makes them vibrate too. Then *those* molecules bump into more particles, and so on. Particles stop vibrating once they have passed on the energy.

How Sound Travels

When you slam a door, the sound travels outward from the source. It is carried in **sound waves**, which are patterns of vibrating molecules caused by the movement of sound through a medium. A medium is the matter a wave travels through. It can be solid, liquid, or gas.

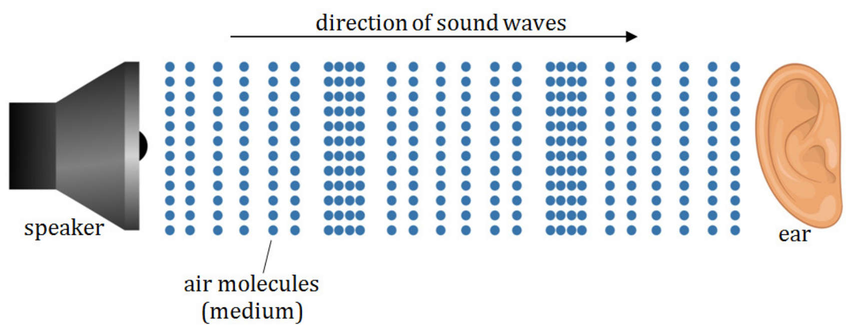
Sound travels through the molecules of air that fill the room. If you are within the range of these vibrating molecules, your ears pick up the vibrations and hear them as the sound of the slamming door. The farther away you are from the source of the sound, the quieter the sound seems.



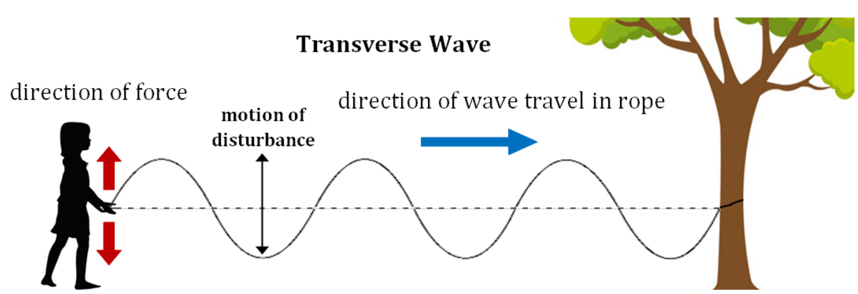
Because sound energy is transferred from molecule to molecule, sound waves cannot travel in a vacuum, where there is no matter. It is important to note that waves don't carry matter. Molecules stop vibrating and return to their original position once they have passed on the energy.

Movement of a Sound Wave

Sound waves are called longitudinal waves. They are caused by the back-and-forth vibration of the molecules of the medium. If a sound wave is moving from left to right through the air, air molecules will vibrate to the right and left as the energy of the sound wave passes through it.

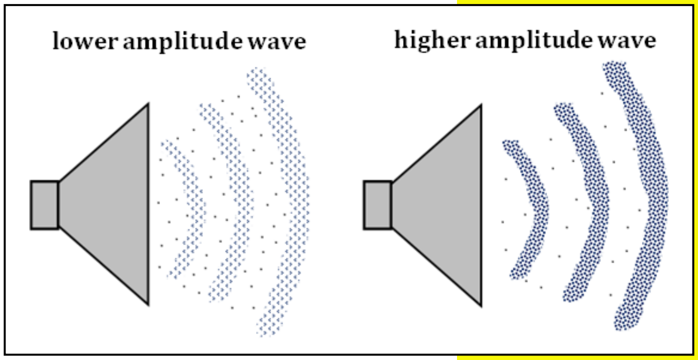


A transverse wave is the other kind of wave. In a transverse wave, if the wave moves from left to right, the disturbance moves up and down. When a crowd of people in a stadium do “the wave,” they are modeling a transverse wave. The individual people move up and down, while the wave moves from left to right (or right to left). After the disturbance passes through, the people go back to where they were before the wave moved through.



Parts of a Sound Wave

As sound energy moves through matter, it causes molecules to press together. This is called compression. When this happens, the molecules on either side of the compression spread out. This is called rarefaction.

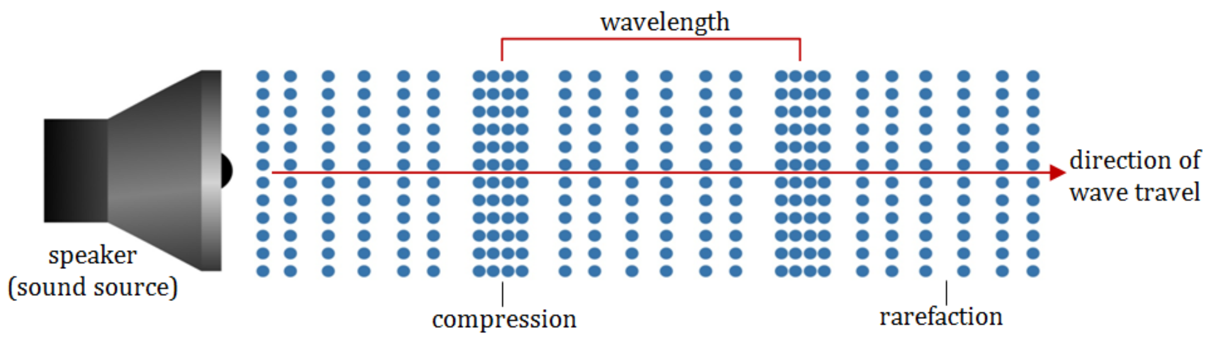


In some waves, the molecules become more compressed than in other waves. This has to do with the wave's amplitude. **Amplitude** is a measure of the wave's displacement from its resting position. Displacement refers to the movement of a substance from its resting position.

The larger the force is that causes the disturbance, the greater a wave's amplitude will be. Because of this, amplitude is related to the amount of energy a sound wave carries. The greater the amplitude of a sound wave, the more energy it is carrying and the louder it will be. The loudness of sound is measured in decibels.

If you gently close a door instead of slamming it, air molecules don't become as compressed because you apply less of a force. This means there is less energy, which results in a quieter sound.

In a sound wave, the distance from one compression to the next or from one rarefaction to the next is the wavelength. In other words, the **wavelength** is the distance spanned by one cycle of the motion of the wave.

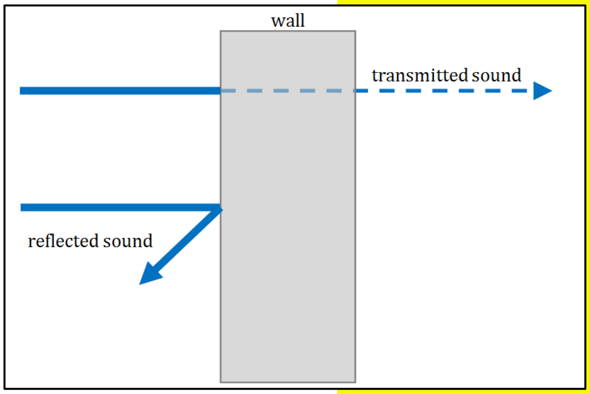


The **frequency** of a wave is the number of waves that pass a set point in a given amount of time. Frequency is closely related to pitch, which describes how high or low a sound seems.

A sound wave with greater frequency has a higher pitch than a sound wave moving at a slower frequency. A whistle is an example of a high-pitched sound. The sound waves produced when you blow into the whistle have a high frequency. A door slamming is an example of a low-pitched sound. The sound waves produced when you slam the door move at a slower frequency.

How Sound Interacts with Matter

If you are in one room and you hear a door from another room slam, it means the sound has been transmitted through the air. To **transmit** means to pass from one place to another.



In order for there to be an echo, the sound waves have to come into contact with a reflective material. To **reflect** means to bounce off of something. Sound waves are reflected when they collide with matter that acts as a barrier.

Echoes can only happen in large spaces. Sound moves very quickly, but it still takes time for the energy to move from one place to another. Echoes happen when there is a break between when you hear the original sound and when you hear the reflected sound.

Finally, the sound needs to be loud enough so that it has enough energy to move through the large space and back. In the mausoleum, the sound waves produced by the slamming door were transmitted through the air. They traveled until they reached the hard, reflective walls and high domed ceiling. They were then reflected off of the surfaces and produced the 15-second echo.

Name: ____ Date: ____________________

Sound Investigation

Focus Question: How does sound from your voice cause the kazoo membrane to vibrate? Use your kazoo and a slinky spring to investigate the question.

Analyze the Kazoo

1. Describe how the sound from your voice interacted with the kazoo membrane.

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2. Draw a diagram of what your kazoo looks like when it is being played. Label the parts of the kazoo and the source of sound.

Model Sound Waves with a Slinky

1. Work with your team to model the motion of a longitudinal sound wave with a slinky spring.

A. Stretch out the slinky spring on the floor approximately 3 meters (10 feet), with different team members holding opposite ends of the slinky. Keep the slinky spring against the floor.
B. One person, representing the sound from a person's voice, takes their end of the slinky and quickly compresses (pushes) it towards the opposite person three times so the energy travels through the slinky. The opposite person, representing the kazoo's membrane, holds their end of the slinky firmly during this process. Repeat the movement several times.

2. Diagram the wave patterns you observe in the slinky. Label a compression, rarefaction, and wavelength in your wave diagram. Include labels for the person holding each end of the slinky spring in your diagram and what they represent (sound from a voice and the kazoo membrane).

3. Look at the diagram you made of your kazoo instrument and the diagram of your sound wave. How do the waves in the slinky spring relate to the way sound energy from your voice is transferred to the kazoo membrane, causing it to vibrate and make a sound?

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4. In order for the kazoo's membrane to vibrate, what medium does the sound energy from your voice have to travel through?

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Model Loud and Soft Sounds with a Slinky

1. Take out your kazoo and play it with a loud voice and then a quiet voice. Feel the membrane vibrate as you play the kazoo. How does the volume of your voice affect how much the membrane vibrates?

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2. Use your slinky spring to model the sound waves of a loud sound and a soft sound. To do this, use the same steps for testing the slinky spring, except this time push on the slinky spring with a lot of force to represent a loud sound and with less force to represent a soft sound.

- Diagram the patterns you observed in the slinky spring when you modeled loud and soft sounds. Label a compression, rarefaction and wavelength in your diagrams.

“loud” sound wave diagram

“soft” sound wave diagram

Section 1 Review

Reading Comprehension Questions:

1. Why does sound energy move through matter but not through empty space?

2. How can you use sound waves to explain why sounds get softer the farther you move away from the source?

3. What makes one sound louder than another?

4. What is the main idea of Section 1?

5. What key details does the text provide to support the main idea of the text?

Renovating a Concert Hall

This is Jordan Hall.

Jordan Hall is part of the New England Conservatory, located in Boston, Massachusetts. It is considered one of the United States' best performance spaces because of its acoustics. **Acoustics** is the properties of a space that determine how sound waves travel. It is important when designing buildings such as auditoriums, theaters, and libraries.

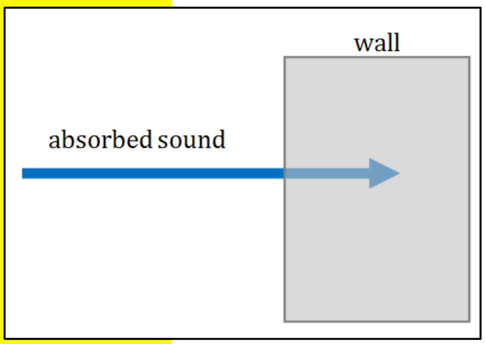
In 1995, Jordan Hall was renovated. To renovate means to make repairs. These renovations were done carefully to keep the acoustics of the hall. No structures of the room were changed that might affect how sound was carried.

But the first night musicians played after the renovations, the music sounded different. Many people said it sounded too "bright." Some audience members covered their ears with their hands.

How Materials Absorb Sound

It turned out that the new paint may have had a role to play in the changed sound. The new paint wasn't as porous as the old paint. This means it didn't have a lot of spaces between its particles.

It's possible the new paint was much more reflective than the old paint. As the musicians played, their instruments made vibrations. These vibrations moved through the air in sound waves. As the waves came into contact with the painted walls, they were reflected back.



The more porous paint absorbed more of the sound waves. To **absorb** means to take in. When a sound wave is fully absorbed into a material, all of the sound energy transfers to the material and is changed to another form, such as heat. When this happens, no sound is transmitted through the material.

Many materials absorb some, reflect some, and transmit some sound energy. It depends on the properties of the material, including how porous it is and how thick. When sound waves are partially absorbed and partially transmitted, some of the sound is carried through the material, but it isn't as loud because some of the energy has been converted to another form.

Acoustics of a Room

The old paint of the concert hall absorbed more of the sound waves than the new paint did. This resulted in a softer sound. After a year, the concert hall added felt cloth to its walls. This returned the acoustics to the previous sound because felt is more absorbent than the new paint. In general, softer, rougher materials tend to be more absorbent. Harder, smoother materials tend to be more reflective.

Concert halls like Jordan Hall are designed so that everyone in the room can hear the music. One way these halls achieve this is their shape. They are often designed with many curves that move the sound around the room.

Concert halls also have carpet to absorb sound energy. This transfers the sound energy into heat and prevents echoes.

Libraries have a different acoustical design goal. Libraries are designed to keep sound from traveling to help them stay quiet.

Name: ____ Date: ____________________

Sound Energy and Materials Investigation

Focus Question: How does the thickness of a porous material affect how much sound energy it absorbs and transmits?

Use what you know about sound waves and energy to write a hypothesis for the focus question in the space below.

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Materials

- 1 foam cup with battery and buzzer set up
- 1 sheet of tissue paper
- 1 sheet of foam
- 1 cardboard base
- 1 index card
- 1 rubber band
- 1 roll of invisible tape
- 1 sample of sand

Investigation Summary: In this investigation, you will observe how materials with different thicknesses absorb and transmit sound energy from a buzzer.

Test Procedure

1. Place the tissue paper over the foam cup with the buzzer. Use the rubber band to secure the tissue paper to the cup so it lies flat (if needed).

2. Sprinkle a little sand on the center of the tissue paper. Turn on the buzzer for a few seconds and observe the motion of the sand. Turn the buzzer off and return the sand. Record your observations in Table 1.
3. Repeat steps 1-2 with each material: index card (paper), foam sheet, and cardboard.

Data Table

Table 1: Comparing Sound Absorption by Thick and Thin Porous Materials		
Material	**Relative Thickness (scale 1-4; 1= thickest and 4=thinnest)**	**Relative Amount of Vibrating Sand Particles (many, several, none)**
tissue paper		
index card (paper)		
foam		
cardboard		

Analyze the Data

1. What patterns did you notice as you tested each material with the sand and buzzer? Use information you recorded in Table 1 to help you answer the question.

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2. What did you noticed about the volume of the buzzer when different materials covered the cup?

3. Explain how the data you collected in the investigation do or do not support the hypothesis you wrote. Use specific evidence and observations from the investigation to support your argument.

4. Draw a diagram that shows how sound energy from the buzzer interacted with one of the materials covering the cup (your choice). Include what you observed as you carried out the test and also what you couldn't actually see, using what you know about matter and sound waves.

Section 2 Review

Reading Comprehension Questions:

1. What happens to sound energy when it is fully absorbed into a material?

2. What happens to sound waves when they are reflected, absorbed, or transmitted?

3. According to the text, why did the new paint in Jordan Hall change the way music sounded?

4. What is the main idea of Section 2? What details support this main idea?

<u>Science Words to Know</u>

absorb – to take in

acoustics – the properties of a space that determine how sound waves travel

amplitude – a measure of a wave's displacement from its resting position

frequency – the number of waves that pass a set point in a given amount of time

reflect – to bounce off of

sound – energy that is carried in waves by vibrating molecules

sound wave – a pattern of vibrating molecules caused by the movement of sound through a medium

transmit – to pass through

vibrate – to move back and forth quickly

wavelength – the distance spanned by one cycle of the motion of a wave

