SUPERCHARGED SCIENCE

Unit 6: Sound

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Appropriate for Grades:
Lesson 1 (K-12), Lesson 2 (K-12)
Duration: 6-15 hours, depending on how many activities you do!

Sound is a form of energy. Energy is the ability to move something over a distance against a force, remember? What is moving to make sound energy? All sounds come from vibrations. In this unit, we will be taking a careful look at vibration, frequency, and resonance.

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Key Vocabulary

Amplitude is the height of the wave.

Antennae are necessary to pick up energy. Our bodies have three antennae—eyes, ears, and skin. Eyes can detect light waves, which are a small portion of the electromagnetic spectrum. Skin can detect heat, which is another even smaller portion of the electromagnetic spectrum. Ears can detect sound waves. Our antennae pick up the energy, sound waves, heat, or light while our brain interprets them.

Energy is the ability to do work. Energy can be transferred. In other words, it can be changed from one form to another and transferred from one object to another. The more energy sound has, the larger the wave is (higher amplitude) and the louder it is.

Force is a push or a pull, like pulling a wagon or pushing a car. Particles in a wave are moving a distance against a force. They are having work done on them and they can do work.

Frequency is the number of vibrations there are in a given amount of time. The frequency of sound waves determines the pitch. Sound waves with a high frequency have high pitches. Sound waves with low frequencies have low pitches.

Hertz is a measurement of frequency and is equal to one vibration per second.

A **longitudinal wave** is where the particle moves parallel to the medium.

Natural frequency is how fast something vibrates. Everything has a natural frequency. The natural frequency of an object is due to the size, weight, and material the object is made of. Our ear drums have a natural frequency between 20–20,000 Hz. Anything that vibrates with enough energy at those frequencies can resonate our ear drums and cause us to hear sound.

Resonance is energy from one thing moving something else. When something is vibrating at a natural frequency that matches the natural frequency of something else, that something else may begin to vibrate as well. As long as energy continues, the object that is being resonated will continue to vibrate at higher and higher amplitudes. In other words, the vibration will get larger and larger.

Sound is a type of energy and moves by longitudinal waves. Sound moves faster in solid objects than it does in the air because the molecules are very close together in a solid and very far apart in a gas. Sound travels at about 760 mph in air, about 1000 ft/s. Sound can travel a mile in 5 seconds.

A **transverse wave** is a wave where the particle moves perpendicular to the medium.

All waves begin as **vibrating** particles. The particles vibrate back and forth. They do not move along the wave.

Energy moves by **waves**. Waves are the way energy moves from place to place. Waves are energy-mobiles.

The **wavelength** is the distance between two like parts of the wave.

Work is moving something against a force over a distance. Mathematically, work = force x distance. Work can be measured in Joules or calories.

Unit Description

Sound is a form of energy. Energy is the ability to move something over a distance against a force, remember? What is moving to make sound energy?

Molecules. Molecules are vibrating back and forth at fairly high rates of speed, creating waves. Energy moves from place to place by waves. Sound energy moves by longitudinal waves (the waves that are like a slinky). The molecules vibrate back and forth, crashing into the molecules next to them, causing them to vibrate, and so on and so forth. All sounds come from vibrations. In this unit, we will be taking a careful look at vibration, frequency, and resonance.

Objectives

Lesson 1: Sound Wave Vibrations

Sound is a fascinating form of energy. As you sit there reading this, there is energy flowing all around you in the form of light waves, sound waves, radio waves, heat and more. You are constantly being bombarded by energy.

Moving by waves at amazing speeds, sound energy brings you knowledge about the world around you. Does a tree make a sound if it falls without anyone there to hear it? This section will answer that question and many others.

Highlights

- Energy moves by waves.
- All waves begin as vibrating particles.
- The particles vibrate back and forth. They do not move along the wave.
- Frequency is the amount of vibrations there are in a given amount of time.
- Hertz is a measurement of frequency and is one vibration per second.
- Waves are the way energy moves from place to place. Waves are energy-mobiles.
- Particles in a wave are moving a distance against a force. They are having work done on them and they can do work.
- A transverse wave is a wave where the particle moves perpendicular to the medium.
- A longitudinal wave is where the particle moves parallel to the medium.
- The wavelength is the distance between two like parts of the wave.
- Amplitude is the height of the wave.
- Energy is all around us all the time.
- Antennae are necessary to pick up energy.
- Our bodies have three antennae—eyes, ears, and skin.
- Eyes can detect light waves, which are a small portion of the electromagnetic spectrum.
- Skin can detect heat, which is another even smaller

portion of the electromagnetic spectrum.

- Ears can detect sound waves.
- Our antennae pick up the energy, sound waves, heat, or light. Our brain interprets them.
- Since we have two ears, we are very good at determining the direction of a sound.
- Our ears are also very good at telling the difference between sound frequencies.

Objectives

Lesson 2: Resonance

We've been talking about the fact that sound is caused by something vibrating. If you can hear it, you can bet that somewhere, something is vibrating molecules and those molecules are vibrating your ear drums. The sound may be coming from a car, thunder, a balloon popping, clapping hands, or your gold fish blowing bubbles in her tank. However, no matter where it's coming from, what you are hearing is vibrating particles, usually vibrating air molecules.

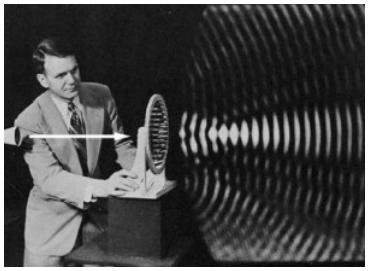
This lesson, I'd like to take the concepts of frequency and vibration just a bit further and talk about natural frequency and resonance.

Highlights

- Sound is a type of energy and moves by longitudinal waves.
- Sound moves faster in solid objects than it does in air because the molecules are very close together in a solid and very far apart in a gas.
- Sound travels at about 760 mph in air, or about 1000 feet/second. Sound can travel a mile in 5 seconds.
- Light travels much faster than sound.
- Sound is molecules moving back and forth (vibrating) creating longitudinal waves.
- All sound comes from something vibrating.
- Frequency of sound waves determines the pitch.
- Sound waves with a high frequency have high pitches. Sound waves with low frequencies have low pitches.
- The human ear can hear sound energy as low as 20 Hz and as high as 20,000 Hz.
- The more energy sound has, the larger the wave is (higher amplitude) and the louder it is.
- We hear sound because vibrating particles vibrate our eardrums, and our brain translates those vibrations into sound.
- Everything has a natural frequency.
- The natural frequency of an object is due to the size, weight, and material the object is made of.

- Natural frequency is how fast something vibrates.
- Resonance is energy from one thing moving something else.
- When something is vibrating at a natural frequency that matches the natural frequency of something else, that something else may begin to vibrate as well.
- As long as energy continues, the object that is being resonated will continue to vibrate at higher and higher amplitudes. In other words, the vibration will get larger and larger.
- Our ear drums have a natural frequency between 20–20,000 Hz. Anything that vibrates with enough energy at those frequencies can resonate our ear drums and cause us to hear sound.

Textbook Reading



In previous lessons, we've learned that **energy is the ability to do work**, and that work is moving something a distance against a force.

The concept of energy is fairly easy to see as far as lifting things or pushing things go. We are exerting energy to lift a box against the force of gravity. We are exerting energy to pedal our bike up a hill.

But how does this energy stuff relate to light, electricity, or sound? What's moving against a force *there*? (As usual, you have asked an excellent question!)

With much energy, what's happening is that outrageously tiny particles are moving back and forth outrageously tiny amounts at outrageously high speeds. Let me explain...

With light you've got little photons moving. With electricity, it's little electrons moving and with sound you've got molecules moving back and forth. This back and forth motion is called vibration and these vibrations make waves. When one particle moves back and forth, it does work on another particle, which does work on another particle and so on. As these particles do work on one another, they cause a wave to move from one place to another.

Energy moves by waves or, in other words, waves are energy-mobiles! Before we get in over our heads talking about waves however, we need to spend some time on this vibration thing. This lesson we will be taking a careful look at vibration and frequency.

Frequency

The concept of frequency is very important to understanding energy. When it comes to electromagnetic waves, it is frequency that determines whether the wave is radio, light, heat, microwave, or more. It's all the same type of energy, but it's the frequency that determines what that energy actually does. With sound energy, the frequency determines the pitch of the sound.

As we move forward with energy, it is quite important that you know that all waves

come from some sort of vibrating particle somewhere. The reason you can pick up a signal on your radio is because somewhere, maybe miles away, there is a particle vibrating at some ridiculous speed, creating a wave that moves across distances to finally vibrate the particles inside your radio's antenna. It's important to realize, however, that *the particle does not move over that distance*. The particle that started the wave back at the radio station is still there. It did not move to your radio. It just vibrated at the antenna and started the wave.

Frequency is a measure of how many times something moves back and forth. A swing, a pendulum, and the leg of a walking person all have a frequency. All those things start at one place, move, and come back to the same position that they started. This moving and coming back is one vibration. The faster something vibrates, the more frequency it has.

What's a Hertz?

Frequency is measured in Hertz. One Hertz (or Hz for short) is one vibration in one second. The Hertz is named after Heinrich Rudolf Hertz (1857-1894), a German physicist and professor. Hertz proved that electricity can be transmitted in electromagnetic waves, which travel at the speed of light and possess many other properties of light.

His experiments with these electromagnetic waves led to the development of the wireless telegraph and the radio.

A Hertz is a relatively slow vibration so there are also kilohertz (KHz), megahertz (MHz), and gigahertz (GHz). A kilohertz is 1000 Hz, a megahertz is 1,000,000 (a million) Hz, and a gigahertz is 100,000,000 (one thousand million) Hz.

Some examples of things that work at these frequencies are AM radio stations, which broadcast at KHz; FM stations, which broadcast at MHz; and microwaves, which cook your food with GHz. If your radio is "crankin'" tunes from radio station 750 AM, a part of your radio is vibrating at 750,000 times a second. If you're "pumping wattage into your cottage" with WSCI at 94.2 FM on your radio dial, a part of your radio is vibrating at 94,200,000 times a second. If your radio happens to be

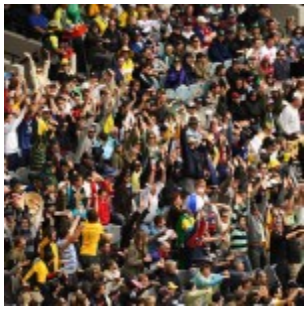
green, then light is vibrating off your radio at 6 x 1014 Hz. That's 6 with 14 zeros behind it, or 600,000,000,000,000 vibrations in one second. That's some serious vibes!

(By the way, if you can hear the sound coming out of your radio, your speakers are vibrating anywhere between 20 and 20,000 Hz. See how vibrations are important? They're everywhere!) Let's look more carefully at what those vibrations make—waves.

Waves

Waves are the way energy moves from place to place. Sound moves from a mouth to an ear by waves. Light moves from a light bulb to a book page to your eyes by waves. Waves are everywhere. As you sit there reading this, you are surrounded by radio waves, television waves, cell phone waves, light waves, sound waves, and more. (If you happen to be reading this in a boat or a bathtub, you're surrounded by water waves as well.) There are waves everywhere!

Do you remember where all waves come from? Waves come from vibrating particles and are made up of vibrating particles.



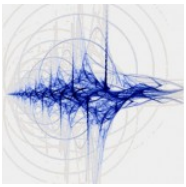
Here's rule one when it comes to waves—The waves move, the particles don't. The wave moves from place to place. The wave carries the energy from place to place. The particles, however, stay put. Here are a couple of examples to keep in mind.

If you've ever seen a crowd of people do the wave in the stands of a sporting event, you may have noticed that the people only "vibrated" up and down. They did not move along the wave. The wave, however, moved through the stands.

Another example would be a duck floating on a wavy lake. The duck is moving up and down (vibrating) just like the water particles but he is not moving with the waves. The waves move but the particles don't. When I talk to you, the vibrating air molecules that made the sound in my mouth do not travel across the room into your ears. (Which is especially handy if I've just eaten an onion sandwich!) The energy from my

mouth is moved by waves across the room.

Waves are Energy-Mobiles



Why are waves energy-mobiles? Remember that energy is the ability to do work, and work is moving something a distance against a force. Can you tell me what is moving against a force in a wave?

If you said particles you're right. Whether they are water particles, molecules, or electrons, some sort of small particles are moving back and forth at potentially incredible speeds against a force. Each particle moving does work on another particle which gets it moving. That particle then does work on another particle which gets it moving, which then does work on another particle getting it moving, which then gets another moving and so on and so forth. Particles moving and doing work on other particles is energy and waves are how energy moves.

Transverse and Longitudinal Waves

Physics is really nice to us here because, believe or not, with all the different forms of energy there are only two types of waves to remember—transverse and longitudinal. Neat, huh? That makes it pretty easy. So let's talk about them. A transverse wave is a wave where the particle moves perpendicular to the medium. A longitudinal wave is where the particle moves parallel to the medium. *"Ummm....so much for easy..."*

Hold on a minute, let me explain and make that a little simpler. Better yet, let's just see it. Jump over to your first experiment *(Transverse & Longitudinal Waves)* right now.

Resonance

Finally, we're done with the basics of energy and can get down to some fun stuff. Now that you folks know what energy is all about, you can begin to reap the rewards! We're going to focus on sound and resonance. **Sound is a form of energy.**

Sound Antennas

Here we will focus on our sound antennas, our ears. **Energy is everywhere.** As you sit reading

this, there is energy all around you in the form of sound waves, radio waves, television waves, cosmic rays, cell phone waves, wireless phone waves, etc. (By the way, except for sound waves the rest are all forms of electromagnetic waves. We will get to those later on.)

If you could somehow see all the energy that is around you all the time, it would look like a constantly moving foggy haze of energy. Most energy goes through walls and some goes through you!

For better or for worse, we can't detect all that energy. We can only detect energy in the form of sound waves and a small bit of electromagnetic waves (light and heat). For a radio to detect radio waves, it needs an antenna. The radio then takes the waves and, using the electronics inside the radio, turns the energy to sound energy. If the radio didn't have the antenna, it couldn't pick up the waves. The antenna alone couldn't make anything out of the waves.

Our ears are the same way. Our ears are our sound antenna. They pick up the sound waves. Nerves carry them to our brain, and our brain changes them to our perception of sound. Our eyes do the same thing with light, and our skin does the same thing with heat (another form of electromagnetic energy). These three antennae—ears, eyes, and skin—detect the outside energy. Our brain turns these detections into what we perceive as sound, light, or heat. Our antennae capture energy and our brains turn that into our perception of reality. Kinda neat, huh?

Now here's a new look at an old question: If a tree falls in the woods and there is no animal with ears around to hear it, does it make a sound? My answer to that question is "no". The falling tree makes air compressions/sound waves, but if there is no antenna there to pick up the energy, and no brain there to interpret the energy, then there is nothing there to turn the sound waves to sound. Just like in your house right now, there are radio waves all over the place. If you don't have a radio to catch those waves and turn them to sound, then there's no sound.

Ears and Sound

Our ears are very good antennae. They are very effective at picking up quiet, loud, high-pitched and low-pitched sounds. It is difficult for people to make

microphones that are as sensitive as our ears. Our ears can pick up and tell the difference between sounds as low-pitched as 20 Hz and as high-pitched as 20,000 Hz. Some animals can hear things that are even higher or lower pitched than that. Our ears and brain are also very good at picking out the direction a sound is coming from.

All of our senses do things naturally that are very difficult for science and technology to duplicate. Human beings (and other living things for that matter) have remarkable ways of perceiving the world around them.

Speed of Sound

Sound is a type of energy, and energy moves by waves. So sound moves from one place to another by waves—longitudinal waves to be more specific. So, how fast do sound waves travel? Well, that's a bit of a tricky question. The speed of the wave depends on what kind of stuff the wave is moving through. The denser (thicker) the material, the faster sound can travel through it.

Remember that waves move because the particles bounce off one another? Well, the farther the particles are from one another, the longer it takes one particle to bounce off another. Think about a row of dominoes. If you put them all close together and push one over they all fall down pretty quickly. If you spread them out a bit, the row falls much more slowly. Sound waves move the same way.

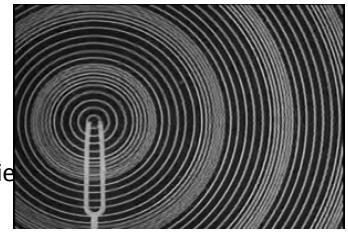
Sound moves faster in solid objects than it does in air because the molecules are very close together in a solid and very far apart in a gas. For example, sound travels at about 760 mph in air, 3,300 mph in water, 11,400 mph in aluminum, and *27,000 mph* in diamond!

The temperature of the material also makes a difference. The colder the material, the faster the sound travels. This is why sound seems to be louder or clearer in the winter or at night. The air is a little cooler and, since it's cooler, the molecules are a little more tightly packed.

What exactly IS sound?

Sound is a form of energy. Energy is the ability to move something over a distance against a force, remember? What is moving to make sound energy?

Molecules. Molecules are



vibrating back and forth at fairly high rates of speed, creating waves. Energy moves from place to place by waves. Sound energy moves by longitudinal waves (the waves that are like a slinky). The molecules vibrate back and forth, crashing into the molecules next to them, causing them to vibrate, and so on and so forth. All sounds come from vibrations.

Do you remember when we talked about frequency and Hertz? Those are both terms to describe vibrations, right? Frequency describes how fast something is vibrating. Hertz is a measurement of frequency and one Hertz is one vibration per second.

Our ears are our sound antennae. When something vibrates, it causes energy to move by longitudinal waves, from the object vibrating to our ears. If that something is vibrating between about 60 Hz and 20,000 Hz, it will cause your ear drum to vibrate. This is sound.

When something vibrates, it pushes particles. These pushed particles create a longitudinal wave. If the longitudinal wave has the right frequency and enough energy, your ear drum antennae will pick it up and your brain will turn the energy into what we call sound.

Sound is caused by something vibrating. If you can hear it, you can bet that somewhere, something is vibrating molecules and those molecules are vibrating your ear drums. The sound may be coming from a car, thunder, a balloon popping, clapping hands, or your gold fish blowing bubbles in her tank. However, no matter where it's coming from, what you are hearing is vibrating particles, and are usually vibrating air molecules.

Natural Frequency

Everything is vibrating. Absolutely everything is wiggling and jiggling, and most of those things are doing it really fast! Now, I can hear you saying, *"Hey…maybe you need to check your eyesight or lay off the coffee because in my house, I'm not seeing everything jiggling."*

Well, you may be right about both of those things, but indeed, everything is wiggling and jiggling. I don't mean that your couch is jumping up and down or that your dinner table is vibrating out of the room or anything like that. However, if you could get super, super small, you

could see that the atoms that make up that couch or that table are vibrating at a specific frequency (speed of vibration).

All things vibrate at specific frequencies and this is called their natural frequency. The size, the weight, and the material of something determine its natural frequency. If you were to close your eyes and someone dropped a penny, a quarter, a pencil, and a fork one at a time, you would be able to tell the difference between each object just by listening to the sound that each made. Each object vibrates with a different natural frequency. It is that difference in frequency that makes each object make a different noise.

