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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Materials for Experiments

How many of these items do you already have? We've tried to keep it simple for you by making the majority of the items things most people have within reach (both physically and budget-wise), and even have broken down the materials by experiment category so you can decide if those are ones you want to do. *NOTE: This material list is for the entire Experiment section online.*

Wave Demonstrations
3' & 10' string or rope
Weight that can be tied to the end of the string
A timer or stopwatch
Masking tape
2 slinky toys (both are the same size)
Optional: Bathtub, water, ball

Noise Makers
3 popsicle sticks (tongue depressor size)
2 index card (3×5")
Scissors, tape, hot glue gun
2 film canisters (or plastic snap-lid M&M containers)
Straw
Three 7-9" balloons
2 water balloons
3' string
Rubber bands (four 3"x 1/8" and four 3" x ¼")
Disposable cup (plastic, foam, paper…)
Hexnut (1/4" or smaller)
Razor or drill to make hole in the film canister
Optional: Violin rosin (it's worth it if you can find it!)

Properties of Sound
Empty glass bottle AND plastic water bottle
Metal fork
2 sheets of stiff paper
3 feet of each: yarn, string, thread, and/or fishing line
Disposable cup
Empty soup can
7-9" balloon
Flashlight or laser (if you have it)
Scissors, tape
Small mirror (from a compact or makeup kit, or use a 1" mosaic mirror from the craft store)
Sand (10-12 cups)
5' string
Dish towel

Optional Speaker Project:
Record player (turntable)
Margarine tub
Tack
Old record that can be scratched

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For Grades 9-12:

Chladni Resonance
(Hint – this experiment has the potential for a jaw-dropping science fair project.)
Salt (get two containers, both with a pour spout)
Scrap of metal plate (anything that's flat will work that's at least 6" square, preferably 12")
Clamp (to hold your plate to the table)
Bass fiddle bow (rent or borrow one if you can – this experiment is totally worth it!) with lots of violin rosin

Build Real Speakers
(You'll be making three different kinds of speakers here.)
Foam plate (paper and plastic don't work as well)
Sheet of copy paper
3 business cards
Magnet wire AWG 30 or 32 (RS#278-1345)
2 neodymium magnets**
Disc magnet (1" donut-shaped magnet) (RS#64-1888)
Index cards or stiff paper
Plastic disposable cup
Tape
Hot glue gun
Scissors
1 audio plug (RS #42-2420) or other cable that fits into your stereo (iPODs and other small devices are not recommended for this project – you need something with built-in amplifier)

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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. 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 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 amount of vibrations there are in a given amount of time. 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 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.

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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, 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.

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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, about 1000 ft/s. 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.

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- 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.

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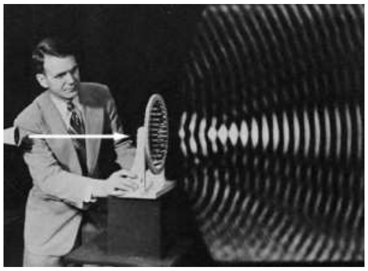
Textbook Reading



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 little electrons 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, 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

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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, a 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 that something 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 which 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.

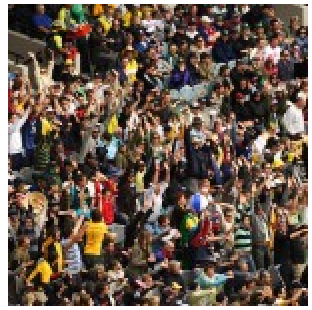
Some examples of things that work at these frequencies are AM radio stations which broadcast at KHz, FM stations which broadcast at MHz, and microwaves which cook your food with GHz. If your radio is "crankin" tunes from radio station 750 AM, a part of your radio is vibrating at 750,000 times a second.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

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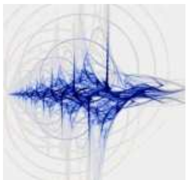
mouth is moved, by waves, across the room.

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?

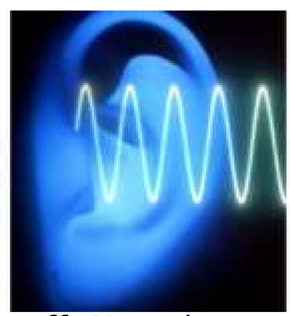
If you said particles you're right. Water particles, molecules, electrons, some sort of small particles are moving back and forth at potentially incredible speeds against a force. Each particle moving does work on another particle which gets it moving. That particle then does work on another particle 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 of which goes through walls and some of which 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 antenna 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 antennas. 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. The human being (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 more dense (thicker) the material, the faster sound can travel through it.

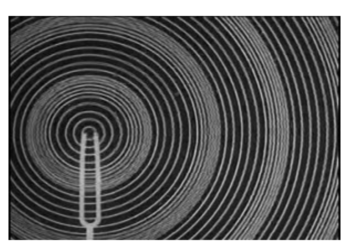
Remember that waves move because the particles bounce off one another? Well, the farther the particles are from one another, the longer it takes one particle to bounce off another. Think about a row of dominoes. If you put them all close together and push one over they all fall down pretty quick. If 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, 3300 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. 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 antennas. 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 antennas 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, 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

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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 determines 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 they made. Each of those objects vibrates with a different natural frequency. It is that difference in frequency that makes each object make a different noise.

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Activities, Experiments, Projects

Lesson 1: Sound Waves

Note: This section is an abbreviated overview of the experiments online.

Experiment: Different Types of Waves

This will let you see how a vibration can create a wave. You'll need at least 10 feet of rope (if you have 25 or 50 feet it's more fun), a piece of tape (colored if you have it), a slinky, and a partner. Are you ready?

1. Give one end of the rope to your partner.

2. Stretch the rope out so that it is a bit slack.

3. Now move your hand up and down. Feel free to do it several times in a row. Your partner should keep his or her hands as still as possible.

4. Watch the waves move from your hand to the other end of the rope.

5. Now let your partner create waves.

6. If you wish, you can try to time your vibrations and create waves with specific frequencies. A frequency of one Hertz is fairly easy to do (one rope shake per second). Can you create rope waves of higher frequencies? You may find that your arm gets tired pretty quickly!

Your hand is the vibrating particle. As your hand vibrated up and down, you moved the particles of the rope up and down. As those particles of rope vibrated, they vibrated the particles next to them. As they vibrated, they vibrated the particles next to them and so on and so forth. So the wave moved from your hand across the room. Did your hands move across the room. Nope, but the wave you created with your vibrating hand did.

This is the way energy travels. Why is the rope wave energy? Because the particles moved a distance against a force. Work was done on the particles. In fact, when you shook the rope, your energy from your body moved across the room with the wave and was transferred (moved to) your

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partner. Your partner's hands could feel the energy you put into the rope in the first place. The work you did on the rope was transferred by the rope wave and did work on your partners hand. You have moved energy across the room!

Now… let's add another element to this experiment…

Transverse Waves

1. Put a piece of (colored if possible) tape in about the middle of the rope.

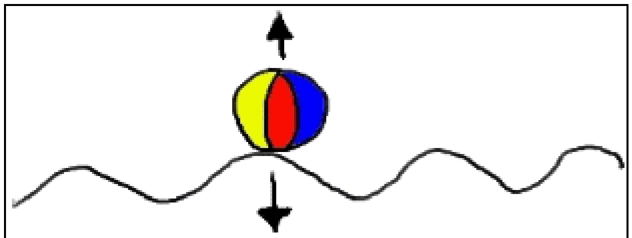
2. Tie your rope to something or let your friend hold on to one end of it.

3. Now pull the rope so that it is a bit slack but not quite touching the floor.

4. Vibrate your arm. Move your arm up and down once and watch what happens.

5. Now, vibrate your arm a bunch of times (not too fast) and see the results. Notice the action of the tape in the middle of the rope.

What you've done is create a transverse wave. With a transverse wave, if the particle (in this case your hand) moves up and down, the wave will move to the left and/or right of the particle. The word perpendicular means that if one thing is up and down, the other thing is left and right. A transverse wave is a wave where the particle moves perpendicular to the medium. The medium is the material that's in the wave. The medium in this case is the rope.



The beach ball is just like the particles. It vibrates up and down as the wave moves left or right. The ball is moving perpendicular to the wave.

For example, in a water wave, the medium is the water. Your hand moved up and down, but the wave created by your hand moved across the room, not up. The wave moved perpendicular to the motion of your hand. Did you take a look at the tape? The tape represents a particle in the wave. Notice that it too, was going up and down. It was not moving along the wave. In any wave the particles vibrate, they do not move along the wave.

Longitudinal Waves

Now that you've seen a transverse wave, let's take a look at a

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longitudinal wave. Here's what you do:

1. Put a piece of tape on one slinky wire in the middle or so of the slinky.

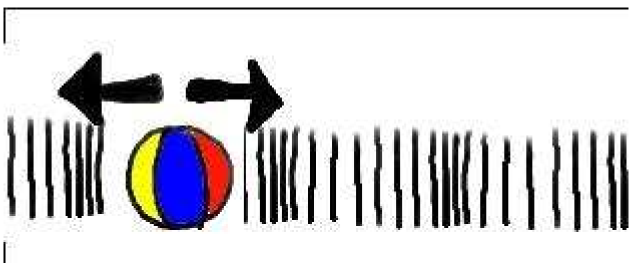
2. Let your friend hold on to one end of the slinky or anchor the slinky to a chair or table.

3. Now stretch the slinky out, but not too far.

4. Quickly push the slinky toward your friend, or the table, and then pull it back to its original position. Did you see the wave?

5. Now do it again, back and forth several times and watch where the slinky is bunched up and where it's spread out.

6. Notice the tape. What is it doing?



In this case the beach ball is moving back and forth same direction as the wave.

Here you made a longitudinal wave. A longitudinal wave is where the particle moves parallel to the medium. In other words, your hand vibrated in the same direction (parallel to the direction) the wave was moving in. Your vibrating hand created a wave that was moving in the same direction as the hand was moving in. Did you take a look at the tape? The tape was moving back and forth in the same direction the wave was going.

Do you see the difference between a transverse wave and a longitudinal wave? In a transverse waves the particles vibrate in a different direction (perpendicular) to the wave. In a longitudinal wave the particles vibrate in the same direction (parallel) to the wave.

What's the Difference between Amplitude and Wavelength?

Here's an easy way to get a feel for **amplitude**:

1. Put a piece of tape in about the middle of the rope.

2. Tie your rope to something or let your friend hold on to one end of it.

3. Now pull the rope so that it is a bit slack but not quite touching the floor.

4. Your friend should hold their hands as still as possible.

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5. Vibrate your hand but only move it up and down about a foot or so. Have your partner pay attention to how that feels when the wave hits him or her.

6. Now, vibrate your hand but now move it up and down 2 or 3 feet. How does that feel to your partner?

7. Have your partner do the vibrating now and see what you feel.

You created two different amplitude waves. The first wave had a smaller amplitude than the second wave. What you and your partner should have felt was more energy the second time. The wave should have hit your hand with more energy when the wave had more amplitude.

Here's a great way to visualize **wavelength**:

1. Tie your rope to something or let your friend hold on to it.

2. Now pull the rope so that it is a bit slack but not quite touching the floor.

3. Your friend should hold their hands as still as possible.

4. Now begin vibrating your hand fairly slowly. In this case, it works better if you move your hand in a circle.

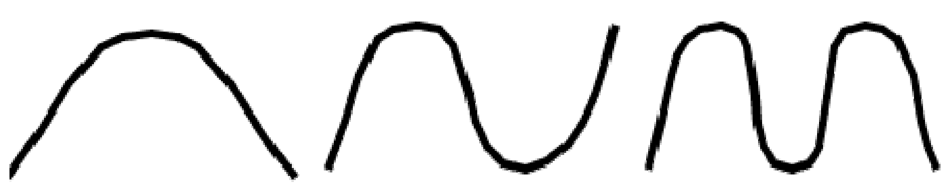
5. Try to make a wavelength with the rope. In other words it will look like you're playing jump rope.

6. Now try a one and a half wavelengths.

7. Can you get two or more wavelengths? You've really got to get your hand moving to get it.

In this image, the left wave is ONE wavelength, the middle is 1.5 wavelegnths, and the right is TWO wavelengths. See the difference?

Did you notice how the frequency of your hand determined the wavelength of the rope? The faster your hand, moved the more wavelengths you could get.



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Activities, Experiments, Projects

Lesson 2: Resonance

Note: This section is an abbreviated overview of the experiments online.

Experiment: Humming Balloon

What to do: Place a coin in a large balloon. Inflate the balloon and tie it. Swirl the balloon rapidly to cause the coin to roll inside the balloon. The coin will roll for a very long time on the smooth balloon surface. At high coin speeds, the frequency with which the coin circles the balloon may resonate with one of the balloon's "natural frequencies," and the balloon may hum loudly.

Experiment: Seeing Sounds Waves

This section is actually a collection of the experiments that build on each other. We'll be playing with sound waves, and the older students will continue on after this experiment to build speakers. You'll need a radio or some sort of music player, a balloon, a mixing bowl, water, and your parent's permission.

1. Turn on your music player and turn it up fairly loud. (Tell your parents that it's for science!)

2. Take a look at your speaker. You should be able to see it vibrating. If there's a song with a lot of bass, you should really be able to see it moving.

3. Put your hand on the speaker. Can you feel the vibrations?

4. ASK YOUR PARENTS if you can carefully put a half-filled bowl of water on top of your speaker. You should be able to see the water vibrate.

Remember that sound is nothing more than vibrating molecules. All speakers do is get molecules of air to vibrate, creating longitudinal waves. They push air. Your eardrums vibrate just like the speakers do when the longitudinal waves of sound energy hit your ears.

How to Feel the Beat

1. Inflate the balloon. Get it fairly large.

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2. Turn the music on loud (the more bass the better).

3. Put both hands lightly on the balloon.

4. Walk around the room holding the balloon lightly between your hands.

5. Try to feel the balloon vibrating.

6. Does the balloon vibrate more for low sounds or high sounds?

7. If you have a synthesizer (piano keyboard) you may want to try turning it up a bit and playing one note at a time. You should notice that the balloon vibrates more or less as you go up and down the musical scale. At very high notes, your balloon may not vibrate at all. We'll talk more about why this happens later.

What's causing the balloon to vibrate? Energy. Energy causes objects to move a distance against a force. The sound energy coming from the speakers is causing the balloon to vibrate. Your ear drums move in a very similar way to the balloon. Your ear drum is a very thin membrane (like the balloon) that is moved by the energy of the sound. Your ear drum, however, is even more sensitive to sounds than the balloon which is why you can hear sounds when the balloon is not vibrating. If you ear drum doesn't vibrate, you don't hear the sound.

What to do this experiment but no speakers?

Here's another version of the same idea – I'll bet you did this experiment when you were a small baby! You need: a mixing bowl (one of those metal bowls), something to hit it with (a wooden spoon works well), and water.

1. Take the mixing bowl and put it on the table.

2. Smack it with the wooden spoon.

3. Listen to the sound.

4. Put your ear next to the bowl and try to hear how long the sound continues.

5. Now hit the bowl again.

6. Touch the bowl with your hand a second or two after you hit it. You should hear the sound stop. This is called dampening.

7. Now, for fun, fill the bowl with water up to an inch or so from the top.

8. Smack the bowl again and look very carefully at where the bowl touches the water.

9. When you first hit the bowl, you should see very small waves in the water.

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I want you to notice two things here. Sound is vibration. When the bowl is vibrating, it's making a sound. When you stop it from vibrating, it stops making sound. Any sound you ever hear, comes from something that is vibrating. It may have vibrated once, like a balloon popping. Or it may be vibrating consistently, like a guitar string.

The other thing I want you to notice is that you can actually see the vibrations. If you put water in the bowl, the tiny waves that are formed when you first hit the bowl are caused by the vibrating sides of the bowl. Those same vibrations are causing the sound that you hear.

If your mom's worried about making a mess with water (and it's not bath night tonight) then try this alternate experiment: you'll need a mixing bowl, wooden spoon, and rubber bands.

1. Stretch a few rubber bands around the box or the bowl. If possible, use different thicknesses of rubber bands.

2. Strum the rubber bands.

3. Feel free to adjust how stretched the bands are. The more stretched, the higher the note.

4. Try plucking a rubber band softly.

5. Now pluck it fairly hard. The hard pluck should be louder.

Again I'd like you to notice three things here. Just like the last experiment, you should see that the sound is coming from the vibration. As long as the rubber band vibrates, you hear a sound. If you stop the rubber band from vibrating, you will stop the sound. Sound is vibration.

The second thing I'd like you to notice is that the rubber bands make different pitched sounds. The thinner the rubber band, or the tighter it's stretched, the faster it vibrates. Another way to say "vibrating faster" is to say higher frequency. In sound, the higher the frequency of vibration, the higher the pitch of the note. The lower the frequency, the lower the pitch of the note. The average human ear can hear sound at as high a frequency as 20,000 Hz, and as low as 20 Hz. Pianos, guitars, violins and other instruments have strings of various sizes so that they can vibrate at different frequencies and make different pitched sounds. When you talk or sing, you change the tension of your vocal cords to make different pitches.

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One last thing to notice here is what happened when you plucked the rubber band hard or softly. The rubber band made a louder noise the harder you plucked it right? Remember again that sound is energy. When you plucked that rubber band hard, you put more energy into it than when you plucked it softly. You gave energy (moved the band a distance against a force) to the rubber band. When you released the rubber band, it moved the air against a force which created sound energy. For sound, the more energy it has, the louder it is. Remember when we talked about amplitude a few lessons back? Amplitude is the size of the wave. The more energy a wave has the bigger it is. When it comes to sound, the larger the wave (the more energy it has) the louder it is. So when you plucked the rubber band hard (gave it lots of energy), you made a louder sound.

I said this in the beginning but I'll repeat it here, hoping that now it makes more sense. When something vibrates, it pushes particles against a force (creates energy). These pushed particles create longitudinal waves. If the longitudinal waves have the right frequency and enough energy (loudness), your ear drum antennas will pick it up and your brain will translate the energy into what we call sound.

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Exercises

Sound Wave Vibrations

Section One:

1. What starts waves?

2. Where is work being done in a wave?

3. With the rope wave, what moved from partner to partner?

4. What is frequency?

5. What is Hertz?

6. If a swing is vibrating at .5 Hz, how many times does it go back and forth in 1 second?

7. If a yo-yo goes up and down 10 times in 10 seconds what is its Hertz?

8. If you create a rope wave by moving your hand up and down twice in one second, what's the Hertz of that wave?

Section Two:

1. How does energy move?

2. True or false: the particles in a wave move from where the wave starts to where the wave ends up.

3. What is having work done on it in a wave?

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4. What are the two type of waves?

5. In which wave does the particles vibrate in the same direction as the wave?

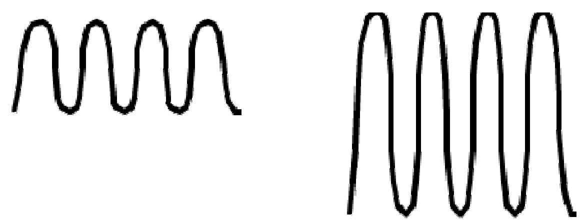
6. In which wave does the particles vibrate perpendicularly to the direction of the wave?

7. What does wavelength mean?

8. What does amplitude mean?

9. Which of the following has the longer wavelength?

10. Which of the following has the larger amplitude?



Resonance Exercises

Section One:

1. Which of our body parts function as antennae?

2. Why do I call those antennae?

3. Why do we have two ears?

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Section Two:

1. Sound travels by waves. Transverse or longitudinal waves?

2. Sound travels faster in air, water, or solids?

3. Why does sound travel faster in that medium?

4. Would sound travel faster on a hot day or a cold day? Why?

5. Which travels faster, light or sound?

6. If you see a firework and hear the sound one second later, how far away is the firework?

7. If you see lightning and hear the lightning 10 Mississippi's, uh I mean seconds, later, how far is the lightning?

Section Three:

1. If sound is a form of energy, what's moving?

2. All sound comes from what?

3. What kind of a wave is sound?

4. What does frequency have to do with sound?

5. What does amplitude have to do with sound?

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Section Four:

1. What causes sound?

2. What vibrates?

3. What is natural frequency?

4. Why do objects make different noises if they are hit or dropped or plunked?

5. What three things determine something's natural frequency?

6. What is resonance?

7. If something is vibrating at 30,000 Hz, can we hear it?

8. What happens if energy is continued to be put into something resonating?

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Answers to Vibrations Exercises

Section One:

1. Vibrating particles of some sort.

2. Work is done by the particles moving a distance against a force.

3. Energy. The particles didn't move from partner to partner, the rope didn't move across the room, the energy from one person moved in the form of a wave across the room.

4. Frequency is how many times something vibrates in a second. Something that is vibrating quickly is said to have a high frequency, something that is vibrating slowly is said to have a low frequency.

5. A Hertz is a measure of frequency. One Hertz is one vibration per second.

6. One half a time. The swing would swing forward or backward in one second. It would not go back and forth.

7. The yo-yo's Hertz would be one. One vibration (up and down) per second would be 10 vibrations in 10 seconds.

8. 2 Hz. 2 vibrations per second.

Section Two:

1. Energy moves by waves.

2. False; particles only vibrate, they do not move along the wave.

3. Particles are being moved against a force. Work is being done on them and they are doing work on other particles.

4. Transverse and longitudinal.

5. Longitudinal.

6. Transverse.

7. Wavelength is the distance between two like parts of the wave.

8. Amplitude is the height of the wave.

9. "A" has the longer wavelength.

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10. "B" has a larger amplitude.

1. Our antennae are our ears, eyes, and skin.

2. Antennae pick up energy. Our eyes, ears and skin all pick up energy. Our brain then interprets the energy as light, sound or heat. By the way, you may be asking, "What about the nose? Is our nose an antenna"? Not in my opinion. Molecules have to come into the nose and land on smell sensors to register as a smell. Noses detect matter (molecules), not energy.

3. Our two ears, plus our brain allow us to be fairly accurate at knowing where sounds are coming from. The sound will hit one ear before hitting the other and our brain can do the math and figure out which direction

Answers to Resonance Exercises

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Section Two:

1. Longitudinal. The waves travel with the medium.

2. Solids

3. The particles are close together. The closer the particles the faster sound travels.

4. A cold day, since the molecules are closer together.

5. Light is much faster.

6. Sound travels 1000 ft/sec, so that firework is 1000 feet away.

7. Take 10 seconds and divide it by 5. So the lightning is 2 miles away.

Section Three:

1. Energy is the ability to move something against a force. In the case of sound, molecules are moving.

2. Vibrations. No vibration, no sound.

3. Longitudinal wave.

4. Frequency determines the pitch of the sound. The higher the frequency, the higher the pitch. The lower the frequency the lower the pitch.

5. The higher the amplitude of the wave, the louder the sound is. Higher amplitude means more energy which means louder sound.

Section Four:

1. Something vibrating causes sound. The sound waves are carried from the vibrating thing to your ears by longitudinal waves.

2. Everything! Couches, clams, mobile homes, they all vibrate.

3. The frequency something tends to vibrate at.

4. They make different noises because they vibrate at their natural frequency. When they are plunked the frequency that they vibrate at causes the sound wave that we hear.

5. Size, weight, and the material of an object determine its natural frequency.

6. Resonance is when something is vibrating at the same natural frequency as something else and causes that something else to vibrate as well.

7. No. Our ears have a natural frequency between 20-20,000 Hz. They will not vibrate at frequencies outside that range so we cannot hear something that vibrates at 30,000 Hz. Our ears can only be resonated by vibrations between 20-20,000 Hz.

8. If something continues to be resonated by something else, the thing that's being resonated will vibrate more and more. Eventually, unless the energy is stopped or the vibration is slowed, the object being resonated may break. This is how singers can break wine glasses. They can hit a note that resonates the wine glass. As they keep singing, the wine glass vibrates more and more until it shatters!

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