Outline of Sound/Waves Show

Idea	**Presenter**	**Elementary**	**Middle School**
Introductions	All	Terminology slide	Terminology slide
Vibrations	1	Move hand	Move hand
Many waves	1	–	Waves slides
Frequency	2	Move hand	Move hand
Amplitude	3	Move hand	Move hand
Freq/Amp	4	Move hand	Move hand
Pitch	2	Sing	Sing
Loudness	3	Sing	Sing
Sound Freq/Amp	4	Kids' sounds	Recorded sounds
Freq. Graph	2	Freq. slides	Freq. slides
Amp. Graph	3	Amp. slides	Amp. slides
Freq/Amp Graph	4	Freq/amp slide	Freq/amp slide
Traveling	1	Spring	Spring
Polarization	1	–	Spring
Traveling	2	Dowel chain	Dowel chain
Need medium	4	Human chain	The Wave
Need medium	3	Bell in vacuum	Bell in vacuum
Natural frequency	2	Earthquake balls	Earthquake balls
Natural frequency	1 or 3	Singing rod	Singing rod
Frequency vs. length	4	Hoot tubes	Hoot tubes
Frequency vs. length	3 or 1	Trombone	Trombone
Resonance	4	Driven air track	Driven air track car
Resonance	2	Earthquake balls	Earthquake balls
Resonance	4	–	Laser
Standing Wave	1	Spring	Spring
Standing Wave	3	Sound flames	Sound flames
Review	4	Oscilloscope and problem	Oscilloscope and problem
Hands-on	All	Springs, earthquake balls, oscilloscopes	

Equipment Required from School Custodian

- Overhead Projector
- Projection Screen
- Tables at back and sides of room for Oscilloscope stations.

Sound Script (Elementary Show)

Note: **the name of the demonstration is in boldface,** stage instructions are in a small blue font, and slides appear in a small red font.

The four presenters are labeled 1, 2, 3, and 4.

Opening (Tsunami) slide While kids enter.

Terminology (Definitions) slide Once show starts.

4) Welcome to our assembly about sound. My name is _and I am studying _at UC Irvine.

Don't just give the name of your major–briefly explain in ordinary language what it is & why you study it (e.g., "I am studying Biology–the science of life–because I want to become a doctor someday).

2) My name is _and I am studying _at UC Irvine. I'm going to teach you about vibrations.

2) My name is _and I am studying _at UC Irvine. I'm going to teach you about frequency.

3) My name is ___and I am studying ___at UCI. I'm going to teach you about amplitude.

All together) And we are all going to teach you about resonance.

Elementary only: 2 and 3 make various noises while 4 talks.

4) Sounds are all around you. In fact, you are hearing the sound of my voice, look with irritation at 2 or 3 and a lot of other noises too. Today we are going to teach you four different ideas about the science of sound. The words for those four ideas are up on the screen. Please read them after I say them. The first word is: vibration. Audience repeats. The second word is: frequency. Audience repeats. The third word is: amplitude. Audience repeats. The fourth word is: resonance. Audience repeats.

1) The first idea is easy. A vibration happens when something moves back and forth. Rock body back and forth. My body is vibrating. Here is one vibration of my hand. Move hand back and forth one time.

Frequency slide

2) Our second important idea is frequency. Frequency is how many times each second something wiggles or vibrates. Wiggle hand as you speak. (Make sure the amplitude stays the same.) This is a low frequency because it doesn't wiggle back and forth very many times in a second. This is a high frequency because it vibrates back and forth many times in a second.

Amplitude slide

3) Our third important idea is amplitude. Amplitude is how far something vibrates. Wiggle hand as you speak. (Make sure the frequency stays the same.) This is a large amplitude because my hand vibrates back and forth over a large distance. This is a low amplitude because I only wiggle a small distance.

4) Let's make sure you understand the difference between frequency and amplitude for hand vibrations. Take your hand out and we'll practice making vibrations. Make a low frequency, small amplitude vibration. Move your hand. Make a high frequency, small amplitude vibration. Move your hand. Make a low frequency, large amplitude vibration. Move your hand. Good, you understand about vibrations.

2) Just like my hand can have different frequencies, sound waves can have different frequencies too. Some sound waves have high frequencies and they sound high. Sing high pitch. Other sound waves have low frequencies and they sound low. Sing low pitch.

3) Just like my hand can have different amplitudes, sound waves can have different amplitudes too. When a sound has a small amplitude we call it soft. Speak softly. When a sound has a large amplitude we call it loud. Yell.

4) Let's make sure you understand the difference between frequency and amplitude for sound waves. When I say "Go" I want you to make the type of sound I say and when I say "Stop" I want you to stop and listen to me. First we'll make a loud, low frequency sound. Go! Kids yell. Stop! That's right, the frequency was low because you used a low voice and the amplitude was large because you used a loud voice. Now we'll make a high, soft sound. Go! Kids screech. Stop! That's right, the frequency was high because you used a high voice and the amplitude was small because you used a soft voice.

Frequency graphs

1) Scientists use mathematics all the time. Raise your hand if you have ever made a graph during math. Oh good. We're going to show you some graphs of sound waves. These curves point to slide show the wave vibrating back and forth.

2) The x-axis on this graph is the time: one second, two seconds. point to figure as you speak If something is vibrating fast and has a high frequency, it goes back and forth many times in two seconds. point to right-hand figure If it has a lower frequency, it doesn't vibrate as many times in two seconds. point to left-hand figure Let's measure the frequency from this graph. We can count the number of vibrations–shout them out with me–1, 2, 3, 4. Now, the frequency is the number of vibrations something makes in one second. We can make a math formula for this. We'll call the number of vibrations "V." We'll call the amount of time "T." The frequency is the number of vibrations "V" divided by the time "T." (Scientists

often use this "/" to mean "divides.") In this case, the number of vibrations is $V = 4$ and the amount of time is $T = 2$, so the frequency is? Four divided by two is? Shout out the frequency if you know the answer. Kids shout. Advance to next slide You're right: it's two.

Slide with "What's the frequency?" under right-hand figure

2) How about the right-hand graph? What is the time T? The x-axis hasn't changed so T is still 2. But how many vibrations are there now? What is V? Let's count them–shout it out with me–1, 2, ..., 10. So the frequency is 10 divided by 2 which equals? Advance slide That's right; it is 5.

Amplitude slide

3) We can also use the graph to measure the amplitude of the wave. The y-axis shows how far the wave vibrates. The graph on the left shows a large amplitude. Point at vertical motion of wave. The graph on the right shows a small amplitude. Let's read the graph to measure the amplitude of the wave on the left. What is it? Point out how you read it as you speak. It is 10-high so the amplitude is 10.

Amplitude slide with $A =?$ on the right

3) What is the amplitude of the wave on the right? Can you read this graph? It is smaller than 5. There are 1-2-3-4-5 tick marks and the wave lines up with the second tick mark, so the amplitude is? Advance slide The amplitude is 2.

Frequency and amplitude graphs

4) The graphs tell us about both frequency and amplitude at once. This wave on the left Point to graph vibrates many times in two seconds so it has a high frequency. It does not vibrate very far in the y-direction so it has a small amplitude. It has high frequency and low amplitude so if it was a hand motion it would look like this: move hand. If it was a sound it would sound like this: make soft, high pitch sound. The graph on the right does not vibrate very many times in two seconds so it has a low frequency. But it moves a lot in the y-direction so it has a large amplitude. If it was a hand motion, it would look like this. Move hand If it was a sound, it would sound loud and low. Make sound

Spring

Traveling wave slide.

1) In a sound wave, the vibrations travel from one place to the next. It works kind of like the vibrations on this spring. If I hit the spring here launch a pulse, this part will start to vibrate but the vibration travels down the spring. This is how sound waves work. Right now my vocal cards are vibrating and making the air in my mouth wiggle back and forth. Walk from stage up to someone's ear in the audience while you wiggle your hand and speak. That air makes the air next to it vibrate, which makes the air next to it vibrate, and the vibrations go all the way up to your ear,

where the air makes your eardrum vibrate.

Dowel chain

2) Here's something else to show you how waves work. This are several pieces of wood that are held together by rubber bands. If it start this piece of wood vibrating do it, it will make the wood next to it vibrate, which will make the wood next to it vibrate and so on. A wave travels down the chain.

Elementary only: Human chain.

4) For sound waves to travel from one place to the next, each clump of air has to make the air next to it vibrate. I need some volunteers to help me show how this works. Prearrange to have one of the rows at the front stand up. I've already chosen my volunteers. 2 and 3 help get them in position (close together), with their hands on the shoulders of the person in front of them. I'm going to push Rosario here at one end and we'll see what happens. Shove Rosario. Look, the wave travels from one end to another just like it does for sound waves. Now I'm going to have everyone in the line sit down except the two people at the ends. 2 and 3 get them to sit down but keep the person at the far end in the same place. What happens when I shove Rosario now? Shove her. The wave doesn't travel anymore because there is nothing next to Rosario to push on. Thank you; sit down now.

Bell in vacuum.

Block slide projector and use overhead.

3) Sound works just like this. Here is a bell that makes sound waves. The waves travel through the air in this container, make the walls of the container vibrate, the container makes the air outside vibrate, then the wave travels all the way out to your ears. You can see that the little hammer is hitting the bell to make it vibrate. Point to screen. But what will happen if I suck the air out of this container? I will use this vacuum pump to suck the air out. Turn on pump. It takes awhile to pull all the air out. The hammer is still hitting the bell like before but now it is getting quieter. Without any air in the chamber, the sound waves can't travel from the bell to the walls of the chamber. It's like our line of children when there were only two children left. Now I'll let the air back in. Turn off pump. Vent gradually. You can hear the air rushing in. The bell is getting louder again because now the vibrations make it from the bell to our ears.

Earthquake balls

2) So far, we've learned about frequency, amplitude, and vibration. The last part of our show is about resonance. Resonance is important because that is how you make a loud sound wave. But before we talk about resonance I need to explain about something called the "natural frequency." Most objects have a frequency that they naturally vibrate at. Here's an example. This red weight is on a stiff

plastic rod. When I pull it, it vibrates back and forth at a high frequency. Pull it. The yellow weight is on a thinner rod that doesn't snap back as hard as the thick rod. When I pull it, it vibrates with a lower frequency. Pull it. The blue weight is on a very thin, weak rod. When I pull it, it vibrates with a very low frequency. You see, each of these weights has a certain frequency that it likes to vibrate at. That's its natural frequency.

Singing rod

1 or 3) Sound waves in this rod have a natural frequency and I can give them a large amplitude. I'm going to pull my hands across the rod and we'll hear the natural frequency of the sound waves. Excite rod. If we hold a cup up against the end of the rod the sound gets louder 2 holds cup on end because the vibrations are going back and forth along the rod.

Hoot tubes

4) Tubes have natural frequencies too. This tube has a piece of metal in the bottom. If I heat it up over this fire heat it, it makes a very loud sound. It only makes the loud sound when the hot metal is on the bottom. Raise your hand if you think you know why that is? Take no more than two ideas. Does anyone know what happens to hot air? Take no more than two ideas. Hot air rises. When the tube is upright hot air rushes through it and the sound waves vibrate at their natural frequency.

4) In science we like to make guesses about what will happen before we do an experiment. We call this guess a "hypothesis." I have a shorter tube here and I am going to heat up its metal piece. Will the natural frequency of this tube be higher or lower than the natural frequency of the first tube? Raise your hand: how many think it will have a higher frequency? Lower? Let's try it and see. Heat them both. The shorter one has a higher frequency. Smaller things usually have higher frequencies than bigger things, just like your voice is higher than your father's voice.

Trombone.

3 or 1) Musical instruments have natural frequencies too. Here is a trombone. If I buzz my lips like this and put them up against the mouthpiece, the trombone will pick out the natural frequency it likes to vibrate at. Do it. The nice thing about trombones is that it is easy to make them longer or shorter. When you do this the natural frequency changes. Do it. When the trombone is longer, the frequency is lower; when it is shorter, the frequency is higher.

Air track resonance.

2 unblocks slide projector to show Resonance definition slide

4) This car on the air track has a natural frequency too. Launch it with driving

power supply off. Now the way resonance works is that if you push or "drive" something at its natural frequency, it will absorb lots of energy and have a large amplitude vibration. This is what happens when you push somebody on a swing. Let me show you how that works for this car. Here is the natural frequency of this car. We measured it earlier and its natural frequency is 3.78. Now I'm going to use this little motor to push the car at a higher frequency of 6.0: see, the red tag that is attached to the motor is moving back and forth pretty fast. Drive above natural frequency at 6.0 V. The car hardly moves. But, if I push it at its natural frequency tune power supply to 3.78 V, I pump lots of energy into the car and the amplitude gets very large. This is a resonance. If you want to make a big wave, it's best to drive the system at its natural frequency.

Earthquake balls

2) Remember my three rods with the high frequency, the medium frequency, and the low frequency. Excite each of them as you speak. I'm going to shake the bottom back and forth. Let me see your hypothesis by a show of hands. Who thinks the red one will vibrate the most? The yellow? The blue? Excite whichever one is selected least. Actually this is a cheat. I could have made it the yellow if I wanted excite it or the red excite it. What did I do differently in each case? That's right, I matched the shaking frequency to the natural frequency of the rod I wanted to give a large amplitude. When you vibrate something at its natural frequency you can give it a large amplitude. This is called resonance.

Spring standing waves Standing Wave slide

1) Often, resonances occur when waves bounce back and forth. When this happens, the bouncing waves add to each other at certain natural frequencies. At these frequencies, it is easy to drive the system to large amplitudes. The waves make a special pattern called a "standing wave." This is what was happening in our singing rod 3 holds up and our trombone 3 holds up and our loud fire tubes 4 holds up. In those examples, we could hear the standing waves but we could not see them. With a spring, it is easy to see the standing waves. 2 holds opposite end as 1 stretches spring. If I slowly vibrate my hand back and forth make the fundamental, I make a large amplitude wave that looks like a jump rope. If I vibrate my hand faster at the correct frequency, I can make a different pattern make 2nd, 3rd, or 4th harmonic. I can make other patterns too make another harmonic. But, if I wiggle my hand at a frequency that is different than any of the natural frequencies, I get a messy pattern do it and it is hard to pump energy into the spring. When I vibrate my hand at a natural frequency do it, I make one of the standing-wave patterns you see on the screen.

4) pointing to screen You are making this standing wave pattern now.

Propane standing waves 3) In this final demonstration, we use fire to see the standing wave pattern formed by sound waves. This tank has propane in it. People burn propane in barbeques. I'll open this valve to put propane in this long pipe. The pipe has small holes on the top and propane leaks out of the holes. Let me light my "barbeque." At this end of our tube, we have a speaker and an amplifier that will vibrate the gas in the tube. I'll adjust the frequency of the sound wave to match a natural frequency of the tube, then turn up the amplitude of the wave to make a large standing wave pattern in the tube. See the pattern! Now I'll change the frequency of the sound waves to make a different standing wave pattern. Let me turn the amplitude back up. Notice how the pattern has changed: before we had 7? peaks but now we have 5? peaks in the pattern.

BE SURE THE TANK VALVE (ROUND,BRASS KNOB LOCATED AT THE TOP OF TANK) AND HOSE VALVE (BLACK PLASTIC VALVE LOCATED NEAR THE HOSE) ARE BOTH TURNED OFF!

Oscilloscope

Review slide

4) You may have noticed the screens we have set up around the room. This machine is called an oscilloscope. Point at one. The oscilloscope is a kind of graphing machine. All during the show, these speakers and the oscilloscopes have made graphs of the sound waves in the room. Let's see how much you've learned about sound waves. Which wave has the largest amplitude? Point to screen. Raise your hand if you think it is A. B. C. Right, it is C. Which wave has the largest frequency? Raise your hand if you think it is A. B. C. Right, it is B.

Springs, earthquake balls, and oscilloscopes for hands-on portion as time permits.

1) 3 helps hold spring Now it is time for you to do some experiments. One experiment you can do is with these springs. You can make a vibration and watch the wave travel down the spring.

2) Another thing you can do is vibrate the bottom back and forth and make a resonance with one of the colored weights.

4) A third thing you can do is make loud and soft & high and low sounds in a speaker and watch the oscilloscope graph the sound waves you make.

Waves Script (Middle School Show)

Note: The portions that differ from the Elementary school version appear in italics. **the name of the demonstration is in boldface,** stage instructions are in a small blue font, and slides appear in a small red font.

The four presenters are labeled 1, 2, 3, and 4.

Opening (Tsunami) slide While kids enter.

Terminology (Definitions) slide Once show starts.

4) Welcome to our assembly about *waves*. My name is _and I am studying _at UC Irvine.

Don't just give the name of your major–briefly explain in ordinary language what it is & why you study it (e.g., "I am studying Biology–the science of life–because I want to become a doctor someday).

2) My name is _and I am studying _at UC Irvine. I'm going to teach you about vibrations.

2) My name is _and I am studying _at UC Irvine. I'm going to teach you about frequency.

3) My name is ___and I am studying ___at UCI. I'm going to teach you about amplitude.

All together) And we are all going to teach you about resonance.

4) Our assembly will teach you about the four wave concepts that are up on the screen: vibration, frequency, amplitude, and resonance.

1) The first concept is easy: A vibration happens when something–like my body–moves back and forth. Rock body back and forth. There are many types of waves but they all involve some type of vibration.

Middle only: slides of sound, water, light, and earthquake waves.

Middle only: Say the name of the type of wave & point to the vibration as the slide appears. 3 advances slides as 1 speaks.

1) For sound waves the air vibrates. For water waves the water vibrates. For light waves electric and magnetic fields vibrate. For earthquakes the ground vibrates.

4) And there are many other types of waves too. But all waves involve some kind of vibration, have a frequency and an amplitude, and are usually generated through some kind of resonance.

Frequency slide

2) Our second important idea is frequency. Frequency is how many times each second something wiggles or vibrates. Wiggle hand as you speak. (Make sure the amplitude stays the same.) This is a low frequency because it doesn't wiggle

back and forth very many times in a second. This is a high frequency because it vibrates back and forth many times in a second.

Amplitude slide

3) Our third important idea is amplitude. Amplitude is how far something vibrates. Wiggle hand as you speak. (Make sure the frequency stays the same.) This is a large amplitude because my hand vibrates back and forth over a large distance. This is a low amplitude because I only wiggle a small distance.

4) All waves involve vibrations. You might think this is kind of dumb but it will help you remember about frequency, amplitude, and vibration. Take your hand out. Come on, we have some cool stuff to show you & we don't want to waste the entire assembly on this. OK, make a high frequency, small amplitude vibration. Yes, you have to wiggle back and forth fast but you can't go very far. Now make a low frequency, large amplitude vibration. Good, you've got it; now we can keep going to the cool stuff.

2) Just like my hand can have different frequencies, sound waves can have different frequencies too. Some sound waves have high frequencies and they sound high. Sing high pitch. Other sound waves have low frequencies and they sound low. Sing low pitch.

3) Just like my hand can have different amplitudes, sound waves can have different amplitudes too. When a sound has a small amplitude we call it soft. Speak softly. When a sound has a large amplitude we call it loud. Yell.

4) Let's listen to some sounds to make sure we understand the distinction between amplitude and frequency. Play or make high, soft sound. What is the frequency here: high or low? What is the amplitude here: large or small? Right. Let's listen to another sound. Play booming bass. That's obviously the opposite. The frequency is low but the amplitude is very large.

Frequency graphs

1) Scientists use graphs all the time. We're going to show you some graphs of waves. These curves point to slide represent the wave vibrating back and forth.

2) The x-axis on this graph is the time: one second, two seconds. point to figure as you speak If something is vibrating fast and has a high frequency, it goes back and forth many times in two seconds. point to right-hand figure If it has a lower frequency, it doesn't vibrate as many times in two seconds. point to left-hand figure Let's measure the frequency from this graph. We can count the number of vibrations: 1, 2, 3, 4. Now, the frequency is the number of vibrations something makes in one second. We can write this as formula using algebra. We'll call the number of vibrations "V." We'll call the amount of time "T." The frequency is the number of vibrations "V" divided by the time "T." (In algebra, this "/" symbol *means "divides.") In this case, the number of vibrations is $V = 4$ and the amount of time is $T = 2$, so the frequency is? Do you have your answer?* *Advance to next slide* *It's 4 divided by 2 equals 2.*

Slide with "What's the frequency?" under right-hand figure

2) How about the right-hand graph? What is the time T? The x-axis hasn't changed so T is still 2. But how many vibrations are there now? What is V? Let's count them–shout it out with me–1, 2, ..., 10. So the frequency is 10 divided by 2 which equals? Advance slide That's right; it is 5.

Amplitude slide

3) We can also use the graph to measure the amplitude of the wave. The y-axis shows how far the wave vibrates. The graph on the left shows a large amplitude. Point at vertical motion of wave. The graph on the right shows a small amplitude. Let's read the graph to measure the amplitude of the wave on the left. What is it? Point out how you read it as you speak. It is 10-high so the amplitude is 10.

Amplitude slide with $A =?$ on the right

3) What is the amplitude of the wave on the right? Can you read this graph? It is smaller than 5. There are 1-2-3-4-5 tick marks and the wave lines up with the second tick mark, so the amplitude is? Advance slide The amplitude is 2.

Frequency and amplitude graphs

4) The graphs tell us about both frequency and amplitude at once. This wave on the left Point to graph vibrates many times in two seconds so it has a high frequency. It does not vibrate very far in the y-direction so it has a small amplitude. It has high frequency and low amplitude so if it was a hand motion it would look like this: move hand. If it was a sound it would sound like this: make soft, high pitch sound. The graph on the right does not vibrate very many times in two seconds so it has a low frequency. But it moves a lot in the y-direction so it has a large amplitude. If it was a hand motion, it would look like this. Move hand If it was a sound, it would sound loud and low. Make sound

Spring

Traveling wave slide.

1) In a wave, the vibrations travel from one place to the next. If I hit the spring here, I'll set up vibrations in the spring. Pretend to vibrate the spring in slow motion as you talk. But these vibrations will pull on an adjacent part of the spring, causing it to vibrate, which will pull on an adjacent part, causing it to vibrate, and the vibrations will travel down the spring. When I strike the spring, I create a traveling wave. Strike spring. It makes this cool sound because different frequencies travel at different speeds down the spring.

1) Even though the waves always travel along the spring, the amplitude of *the vibrations can be in different directions. If the spring vibrates in a direction opposite to the direction the wave goes, it is called a transverse wave.* Launch a transverse wave as before. *There are two opposite directions possible for transverse waves.* Launch the other linear polarization. *You can also make the vibrations go in the same direction as the wave travels; this is called a longitudinal wave.* Launch it. *You can also launch combinations of these three if you want.* Launch a mixed polarization wave.

Dowel chain

2) Here's another type of wave. This is a clump of pieces of wood–called dowels–held together by elastic bands. If I start this dowel vibrating do it*, it will make the dowel next to it vibrate, which will make the dowel next to it vibrate and so on. A wave travels down the chain. Which type of wave is this: transverse or longitudinal? The wave direction is this way* point *but the vibration is this way* point*. They are in opposite directions, so it is a transverse wave.*

Middle school only: The Wave.

4) Have you ever been in a stadium where they do the wave? When the people next to you move their arms, you move your arms do it*, then the people next to you move their arms, and the wave goes around and around the stadium. Let's try it. Now, sometimes you are at the stadium and a group of people aren't doing it–maybe it's a baseball game and there is a whole section of empty seats–and the Wave just dies out. It's like that for ordinary waves too: if something breaks the chain, the waves die out.*

Bell in vacuum.

Block slide projector and use overhead.

3) For all mechanical waves, the vibrations are passed from one object to the next like they are for the spring and the dowel chain. Sound is a longitudinal mechanical wave that travels through the air. If the air disappears, sound waves can't travel. Here is a demonstration that proves this. It consists of a vaccum chamber with a bell inside. When there is air in the chamber, the little hammer hits the bell to make it vibrate, the waves travel through the air in the container, air that hits the walls of the container make it vibrate, the vibrations of the container makes the air outside vibrate, then the wave travels through the air to your ears. You can see the vibrating hammer on the screen. Point to screen. *and you can hear the bell. I'll use this vacuum pump to suck the air out of the chamber.* Turn on pump. *It takes awhile to get the air out. The hammer is still hitting the bell like before but now it is getting quieter. Without any air in the chamber, the sound waves can't travel from the bell to the walls of the chamber. Sound waves can't travel where there is no air. Now I'll let the air back in.* Turn off pump. Vent gradually.

You can hear the air rushing in. The bell is getting louder again because now the vibrations make it from the bell to our ears.

Earthquake balls

2) So far, we've learned about frequency, amplitude, and vibration. The last part of our show is about resonance. Resonance is important because that is how you make a loud sound wave. But before we talk about resonance I need to explain about something called the "natural frequency." Most objects have a frequency that they naturally vibrate at. Here's an example. This red weight is on a stiff plastic rod. When I pull it, it vibrates back and forth at a high frequency. Pull it. The yellow weight is on a thinner rod that doesn't snap back as hard as the thick rod. When I pull it, it vibrates with a lower frequency. Pull it. The blue weight is on a very thin, weak rod. When I pull it, it vibrates with a very low frequency. You see, each of these weights has a certain frequency that it likes to vibrate at. That's its natural frequency.

Singing rod

1 or 3) Sound waves in this rod have a natural frequency and I can give them a large amplitude. I'm going to pull my hands across the rod and we'll hear the natural frequency of the sound waves. Excite rod. There is an easy way to tell if these waves are longitudinal or transverse. We'll hold this cup on the end to amplify the sound. 2 holds cup on end and above end. The natural frequency we are hearing are the frequency of longitudinal vibrations in the rod that are bouncing back and forth in the same direction that the wave travels. 2 illustrates direction with his hand. If it was a transverse wave, the vibrations would be vertical but they aren't.

Hoot tubes

4) Tubes have natural frequencies too. This tube has a piece of metal in the bottom. If I heat it up over this fire heat it, it makes a very loud sound. It only makes the loud sound when the hot metal is on the bottom. Raise your hand if you think you know why that is? Take no more than two ideas. Does anyone know what happens to hot air? Take no more than two ideas. Hot air rises. When the tube is upright hot air rushes through it and the sound waves vibrate at their natural frequency.

4) We have a similar tube except that it is shorter. Let's make a hypothesis before we do the experiment. Will the natural frequency of this tube be higher or lower than the natural frequency of the first tube. Raise your hand: how many think it will have a higher frequency? Lower? Let's try it and see. Heat them both. The shorter one has a higher natural frequency. This is because the sound waves bounce back and forth more times per second in a short tube than in a long tube.

Trombone.

3 or 1) Musical instruments have natural frequencies too. Here is a trombone. If I buzz my lips like this and put them up against the mouthpiece, the trombone will pick out the natural frequency it likes to vibrate at. Do it. The nice thing about trombones is that it is easy to make them longer or shorter. When you do this the natural frequency changes. Do it. When the trombone is longer, the frequency is lower; when it is shorter, the frequency is higher.

Air track resonance.

2 unblocks slide projector to show Resonance definition slide

4) This car on the air track has a natural frequency too. Launch it with driving power supply off. Now the way resonance works is that if you push or "drive" something at its natural frequency, it will absorb lots of energy and have a large amplitude vibration. Let me show you how that works for this car. Here is the natural frequency of this car. We measured it earlier and its natural frequency is 3.78. Now I'm going to use this little motor to push the car at a higher frequency of 6.0: see, the red tag that is attached to the motor is moving back and forth pretty fast. Drive above natural frequency at 6.0 V. The car hardly moves. When we do science we like to measure things and plot them on a graph so I'm going to take some data. Let me measure it with this ruler we have on the track: the amplitude of motion is about 8 cm. Show what you are measuring with your hand. Layered slide shows first data entry in frequency/amplitude table. Now I can also set the motor to a frequency that is lower than the natural frequency. I want to set it to 2.0. Adjust voltage to 2.0. (Don't let the car pass through the resonance–turn voltage off and come back from the low voltage side.) This doesn't do much either. The amplitude is still only about 8 cm. Show measurement with hand. Add next data entry to slide. Now let's set the motor so the driving frequency matches the natural frequency of 3.78. Adjust to 3.78. Measure amplitude. Look: even though the motor isn't moving any more than before point to red tag the amplitude of the car is now enormous. Its amplitude is over a 100 cm. There is a mathematical formula for how the amplitude is expected to change with driving frequency. Let's compare our data with a graph of this theoretical curve. Here is the theory. Turn off car and point to screen as you talk. Add graph. The x axis is driving frequency and the y axis is amplitude. The theory predicts that the amplitude gets very large when the driving frequency matches the natural frequency. The three measurements we made are shown in red. Here is our low frequency of 2.0 with its small amplitude. Here is our resonant frequency of 3.78 with its large amplitude. Here is our high frequency of 6.0 with its small amplitude. We see that the theory does a pretty good job of describing our experiment. If you want to make a big wave, drive the *system at its natural frequency.*

Earthquake balls

2) Here is the same basic idea in a different system. Remember my three rods with the high frequency, the medium frequency, and the low frequency. Excite each of them as you speak. I'm going to shake the bottom back and forth. Let me see your hypothesis by a show of hands. Who thinks the red one will vibrate the most? The yellow? The blue? Excite whichever one is selected least. Actually this is a cheat. I could have made it the yellow if I wanted excite it or the red excite it. What did I do differently in each case? That's right, I matched the shaking frequency to the natural frequency of the rod I wanted to give a large amplitude. That way I pumped a lot of energy into that rod without giving much to the others, just like with the car on the air track. Resonance occurs when you drive a system at its natural frequency.

Middle school only: Laser

1) Lot's of natural systems use resonances. It is an important part of how large-amplitude light waves are made in a laser. There is a gas in a laser; in this case it's helium and neon. The gas molecules have certain natural frequencies. The laser is arranged so light waves bounce back and forth in the tube at the natural frequency of the molecules. This resonance makes it so that the amplitude of the light wave gets larger and larger.

Spring standing waves Standing Wave slide

1) Often, resonances occur when waves bounce back and forth. When this happens, the bouncing waves add to each other at certain natural frequencies. At these frequencies, it is easy to drive the system to large amplitudes. The waves make a special pattern called a "standing wave." This is what was happening in our singing rod 3 holds up and our trombone 3 holds up and our loud fire tubes 4 holds up. In those examples, we could hear the standing waves but we could not see them. With a spring, it is easy to see the standing waves. 2 holds opposite end as 1 stretches spring. If I slowly vibrate my hand back and forth make the fundamental, I make a large amplitude wave that looks like a jump rope. If I vibrate my hand faster at the correct frequency, I can make a different pattern make 2nd, 3rd, or 4th harmonic. I can make other patterns too make another harmonic. But, if I wiggle my hand at a frequency that is different than any of the natural frequencies, I get a messy pattern do it and it is hard to pump energy into the spring. When I vibrate my hand at a natural frequency do it, I make one of the standing-wave patterns you see on the screen.

4) pointing to screen You are making this standing wave pattern now.

Propane standing waves 3) In this final demonstration, we use fire to see the standing wave pattern formed by sound waves. This tank has propane in it. People burn propane in barbeques. I'll open this valve to put propane in this long pipe. The pipe has small holes on the top and propane leaks out of the holes. Let me light my "barbeque." At this end of our tube, we have a speaker and an amplifier that will vibrate the gas in the tube. I'll adjust the frequency of the sound wave to match a natural frequency of the tube, then turn up the amplitude of the wave to make a large standing wave pattern in the tube. See the pattern! Now I'll change the frequency of the sound waves to make a different standing wave pattern. Let me turn the amplitude back up. Notice how the pattern has changed: before we had 7? peaks but now we have 5? peaks in the pattern.

BE SURE THE TANK VALVE (ROUND,BRASS KNOB LOCATED AT THE TOP OF TANK) AND HOSE VALVE (BLACK PLASTIC VALVE LOCATED NEAR THE HOSE) ARE BOTH TURNED OFF!

Oscilloscope

Review slide

4) You may have noticed the oscilloscopes around the room. Point at one. They are connected to speakers to measure the sound waves in the room. An oscilloscope is basically a graphing machine. Time is plotted on the x-axis and amplitude is plotted on the y-axis. They are just like the graphs projected on the screen. Let's review. Which wave has the largest amplitude? Point to screen. Do you all have your answer? It is C. Which wave has the largest frequency? This one may have tricked you. It is B–even though it has a small amplitude, it vibrates through many cycles so it has the highest frequency.

Springs, earthquake balls, and oscilloscopes for hands-on portion as time permits.

1) 3 helps hold spring Now it is time for you to do some experiments. One experiment you can do is with these springs. You can make a vibration and watch the wave travel down the spring.

2) Another thing you can do is vibrate the bottom back and forth and make a resonance with one of the colored weights.

4) A third thing you can do is make loud and soft & high and low sounds in a speaker and watch the oscilloscope graph the sound waves you make.