12: Sound Conductors

Approximate time to complete: 45 minutes

You will need:

Ruler (D)
Stethoscope (D)
Egg timer (D)
Large ziplock bag (approx. 13 x 13 in.) (R)

What is sound? This is a definition that sometimes troubles people. There's an old riddle that asks, if a tree falls in the woods and there is no one there to hear it, did it make a sound? This question raises a lot of arguments, but most of these arguments can be settled quickly if we give good definitions to some important words.

Wouldn't you agree that, if sound is what your ear receives and your brain interprets as sound, then the answer to this question would be *no*. If a tree falls in the woods, and sound requires an ear and a brain, and there is no ear and brain available, then there is no sound. On the other hand, if we define sound as waves created by a vibration, then those waves are created when the tree falls whether there was anyone present to hear them or not. (People would spend a lot less time arguing if they would just listen to me. If I speak truth and no one listens to me, am I still right?)

For the purposes of this lab, I will define sound as **vibrations** in a **medium** caused by any **oscillator**. Don't you just hate it when people define terms with terms you don't understand? Hold onto your shirt for just a minute and I'll explain.

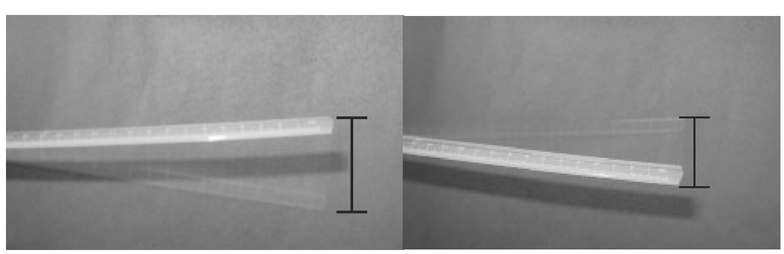
An oscillator is something that moves back and forth. Some examples might include the pendulum on a grandfather clock, a vibrating spring, a guitar string, a piece of glass crystal that has been struck with a fork, your vocal cords when they are moved by air from your lungs, and the list goes on and on.

But wait! I said the pendulum on a clock! You can't hear the pendulum on a clock swoosh through the air! Okay, but I defined sound as "any oscillator that causes vibrations in a medium." If that pendulum makes any vibrations in the air around it, then, according to my definition, it *does* make a sound, *even if my ears don't hear it!*

For example, a dog whistle cannot be heard clearly by human ears. But it *does* cause vibrations in the air, and those vibrations can be heard very clearly by a dog, even though humans can't hear them at all. Why? Because different oscillators create vibrations that have different **frequencies**. Dogs can hear frequencies that humans can't hear.

To demonstrate different frequencies, place your ruler flat on the tabletop and hang all but three inches of it off the edge of the table. Hold the three-inch portion firmly against the table. Pluck the free end of the ruler with your other hand to make it vibrate up and down as shown in Figure 1.

Figure 1. *When there is more of the ruler hanging over the edge of the table to oscillate (as on the left, below) the oscillation is larger and slower, so the pitch of the sound is lower. When less of the ruler is oscillating, the oscillations are smaller, faster and higher pitched. This is not just true for rulers, but for anything--the larger and slower the oscillation, the higher-pitched the sound.*



Because most of the ruler is hanging off the table, the free end can make big vibrations. The part of the ruler touching the table vibrates against the table top with a certain frequency (a certain number of times per second), and those vibrations are detected by your ears.

Now do the same thing, but after you pluck the ruler, move the three-inch portion backward from the edge of the table by one inch so that four inches of the ruler are on the table. What happens to the sound?

How have the vibrations changed?

Do this again. Starting at four inches, move the ruler back another inch. Each time place your hand on the ruler right next to the edge of the table. What happens to the sound and to the vibrations each time?

What you have just observed is universally true. Shorter, more rapid vibrations make higher-pitched sounds. Larger, slower vibrations make lower-pitched sounds.

Do you suppose it would be possible to make a sound that is so high-pitched that human ears can no longer hear it? Yes, not only is it possible, but that's exactly what that dog whistle does. Humans can't hear the high-pitched vibrations caused by such rapid oscillation that come from a dog whistle. But dogs can hear higher-pitched sounds that humans can't hear.

Do you suppose it would be possible to make a sound that is so low-pitched that human ears can no longer hear it? Once again, it happens all the time. That's exactly what the pendulum on a grandfather clock does. It vibrates so slowly, and its vibrations are so long that our ears can't detect any vibration.

Children can hear sounds in a higher frequency range than adults. Adults lose some of that ability as they grow older. That's right—you can hear some sounds that your parents can't hear. Using those sounds, you could communicate with a friend in Morse code across a room full of adults and your conversation would go completely unnoticed. While most teenagers can hear sounds up into the 16 and 17 kHz frequency range, people over age 25 can't. The older you get the more of that high-frequency range of sounds you lose. Men tend to lose somewhat more than women as they age.

So far we have discussed the role of the oscillator in making sound and the role of the detector, or the "ear," in detecting the sound. We have learned that different oscillators oscillate at different frequencies, and different detectors detect different frequencies. Whether or not a sound is heard, depends on the match-up between the oscillator and the detector.

But that's not all there is to this little story. Whether and how well a sound can be heard also depends on the medium that carries the sound. You and I have been discussing sound carried in the air, but any kind of gas (not just air) can carry sound. Also, sound can be carried by other media besides gases. Liquids and solids of all kinds can carry sound waves. In fact, sound travels faster and farther through liquids and solids than it does through the air. So air is not the strongest medium for carrying sound, but it is the one we live in, so it's a good thing that our ears can detect vibrations in it.

Let's demonstrate that our ears can also hear sounds carried by other media. We need an oscillator—something to create vibrations. For this, we will use the egg timer. Fill the plastic ziplock bag with tap water and zip it shut. Set the egg timer to start it ticking. Place the bag to your ear and press the egg timer against the bag. Can you hear the timer through the water?

Does it sound louder to you through the water than through the air alone?

Of course, you have to appreciate that the water is not right up against your eardrum. There is a small distance of air inside your ear that the sound has to travel through as well. You could do this same experiment in a baby pool by filling your ear with water and putting the egg timer in the water at the opposite end of the pool to see if you could hear it through nothing but water.

Next, lay the egg timer down on a table, and go to the other end of the table. Place your ear flat against the table while closing your other ear with your hand to see if you can hear the sound of the timer coming off the table. Does sound travel through the solid stuff your table is made of?

Move closer and closer to the timer placing your ear against the table in different locations. Does the distance from the timer make a difference in how loud the timer sounds as it does in air?

Go from the table to a countertop, a concrete or asphalt driveway (with your parent's permission), carpet, and as many other solid surfaces as you can find around your house. Does the *kind* of solid make a difference in sound conduction?

So then, all these things have an impact on sound: the frequency and strength of the oscillator, the sensitivity and frequency range of the detector, the kind of medium (whether solid, liquid or gas, and the *kind* of solid, liquid or gas), and the distance of the detector from the oscillator.

Why do you suppose the distance between the oscillator and the detector makes a difference in how strong the sound is? There are two reasons. First, sound waves spread out as they travel through a medium. The farther they travel, the more spread out they become. If they are more spread out, they are less intense.

The second reason is that sound waves have only so much energy. The farther they travel, the more their energy gets absorbed by the medium. They get weaker and weaker as they travel. Finally, they get so weak that your ears can't detect them anymore. They no longer have enough energy to vibrate your eardrum.

Now that you understand the principles of sound, let's put them to practical use. You have already used your stethoscope to listen for sounds inside your body. Today, we'll use it for some other things. I'd like to remind you to use your stethoscope carefully, so that you do not get an uncomfortable, loud sound in your ears.

When you listened to your heartbeat, you were hearing the "lub-dup" of your heart valves closing. You could hear those sounds because the closing of the valves sent waves of vibration through many layers of flesh, bone and fluid. The sound passed through the muscle and bone of your rib cage, the muscle and connective tissues of the heart, the tissues surrounding your heart and through your skin. Do those things carry sound better than, or not as well as, the air?

We can answer this question with certainty. First, listen to your heartbeat again like you did before. After you have heard it, remove the stethoscope approximately one centimeter from your body. (Look at your ruler if you don't know how long a centimeter is.) Do you still hear the heartbeat? Compared to the stuff in your body, how good is air at carrying sound? It appears that the fluids, soft tissues and bones in your body are better at transmitting (carrying) sound waves from your heart than even the smallest little distance through the air.

The truth is that most liquids carry sound waves about four times faster than air. Although solids can be widely different in their abilities to carry sound, on average they carry sound about four times faster than liquids. The reason is that sounds travel from particle to particle. The atoms in solids are much closer together than the atoms in liquids. The atoms in liquids are closer together than the atoms in gases.

Of course, how fast sound waves travel is not the only indicator of how well they are transmitted. They may go fast but not far, or far but not fast. They may lose energy faster in some media than others or spread out faster in some media than in others.

Place the egg timer on the table again. First, listen to it with your ear against the table, then listen to it with the stethoscope held against the tabletop (carefully now, don't bang the head of the stethoscope on the table). You see how the stethoscope amplifies the sound; it takes those little sound waves and makes them bigger.

Ears are made for interpreting sounds in air. That's a good thing, since most of us do not live in the water. If God had made us ears that work well in water, and then we moved to land, we would always be saying, "Huh?"

Although humans can hear sounds made under water, it is more difficult to interpret language through water, and ears are made for (among other things) interpreting language. However, it turns out that water (and other liquids too) carries sound much farther than air does.

Wood is an excellent sound conductor. It's a really good thing we don't have ears that are created to interpret sounds in wood or we would be able to hear only woodpeckers and termites. We wouldn't be able to communicate with each other except through two-by-fours.

Please put away your stuff!