Resonance

Last lesson we talked 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 Feefee 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.

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 "Jim...maybe you need to check your eyesight or lay off the coffee because in my house, I'm not seeing everything jiggling." Well, you may be right about both of those things, but indeed, everything is wiggling and jiggling. I don't mean that your couch is jumping up and down or that your dinner table is vibrating out of the room or anything like that. However, if you could get super, super small you could see that the atoms that make up that couch or that table are vibrating at a specific frequency (speed of vibration). All things vibrate at specific frequencies and this is called their natural frequency. The size, the weight and the material of something 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. Try the following experiment:

Experiment 1

Ring the Bells

You need:

4 or 5 glasses

Water

Spoon

1. Line up your glasses.
2. Fill the first glass with about an inch of water.
3. Fill the next one with about two inches of water.
4. Fill the next one with about three inches of water and so on.
5. Now take the spoon and tap each glass, one at a time.
6. Did you hear the different tones/notes from each glass.
7. If you have any musical talent (which I don't), you can adjust the note by changing the amount of water in each glass. If you wish, you can create a water xylophone and play Yankee Doodle at the next family gathering!

What you just did was control the natural frequency of each glass. By altering the amount of water, you altered the material and the weight of each glass. That changed the natural frequency of each glass and so each glass vibrated at a different frequency and created a different note. (Remember that the frequency of a sound determines the pitch of a sound.) Everything vibrates at a specific frequency and the frequency something vibrates at determines the sound it makes.

Resonance

Here's the concept that pulls all that we've been talking about into one nice little package. Sound is energy right? And energy can move something against a force over a distance right? Resonance is energy moving something else. If one thing is vibrating, its vibrations may have enough energy to cause something else that has the same natural frequency to vibrate as well. We've talked about this a little in past lessons so it may sound a little familiar. Honestly, resonance happens with other forms of energy besides sound energy but it is most commonly noticed when it comes to sound energy. Let's play with this a bit and it should become a little clearer.

Experiment 2:

Shake that Balloon Thing

You Need:

Stereo with speakers

Keyboard or an instrument that can get fairly loud (optional)

Balloon

1. Blow up the balloon fairly nice and big.
2. Turn on the stereo a bit loud. (If the neighbors complain, say that it's for science.)
3. Place the tips of your fingers on the balloon.
4. As the stereo plays you should be able to feel the balloon vibrate. Can you feel if the balloon vibrates more or less with the high or low notes? Try balloons that are less inflated. Do you notice a difference with them?

5. If you have a piano keyboard or an instrument that can get fairly loud, play one note at a time. Go from the lowest note, to the highest note. Does the balloon vibrate with every note? Does it vibrate more with some notes than with others?

We did this same basic experiment when we talked about sound and vibration but now I want you to look at it a different way. The vibrations coming from the speaker created an energy that moved by longitudinal waves through the air. This energy causes anything that has the same natural frequency range to vibrate. The balloon has a fairly similar natural frequency range as the speakers so the sound coming from the speakers vibrated the balloon. This is resonance; one thing vibrating causing something else to vibrate. If you were able to do this experiment with the instrument, you may have noticed that at certain notes (usually the very high ones) the balloon did not vibrate. The natural frequency range of the balloon did not reach high enough to be vibrated by the high note of the instrument. Balloons that are more inflated tend to have a greater natural frequency range. Under inflated balloons seem not to resonat at higher frequencies.

Experiment 3

Swing Time

You need:

12 to 18 inches of string

A weight (a washer, ball anything that you can tie to the end of a string)

Tape

Table

1. Create a pendulum by tying something to the end of a string approximately 12 to 18 inches long.

2. Tape your pendulum to the side of a table.

3. Try to get you pendulum to swing by blowing gently on it. You'll discover that you will have to time your blow just right to get your pendulum to keep swinging with a nice steady motion.

If you were able to get the pendulum swinging in a nice steady motion, you became a resonator and you resonated the pendulum. Did you notice that you had to blow with a very specific frequency? The timing of each blow had to be just right or else the pendulum wouldn't swing steadily. The frequency you had to blow at is the same frequency that the pendulum has. (If you want you can determine the frequency of the pendulum just like we did during the vibrations lesson.) The frequency of your blows matched the natural frequency of the pendulum. Whenever you swing on a swing, rock a rocking chair, or yo a yo-yo, you have to match the natural frequency of the object to get it to work right.

You may have notice something else here too. As you blew on the pendulum, you did not have to blow harder to get it to swing more. (Try it again if you didn't notice this.) This is a really interesting part of resonance. As long as energy (the blow), is continued, the vibration (the swing) will get greater and greater. When you're pumping a swing, you really don't have to pump harder to swing more right? As long as you keep pumping, your swing will swing more and more. Specifically, the amplitude (the size) of the vibration will get greater and greater as long as energy is continuously put into the system at the correct frequency. Look up Tacoma Bridge on the internet if you'd like to see an amazing example of what resonance can do. The Tacoma Bridge collapsed due to the fact that the frequency of the winds strangely matched the natural frequency of the bridge. That bridge got to swinging and swaying so much that it finally collapsed!

It is thanks to resonance that we can hear. Sound waves resonate our ear drums. We can hear sound between the frequencies of 20 Hz and 20,000 Hz. That means that our ear drums' natural frequency is in the range of 20-20,000 Hz. So if something vibrates at that frequency, our ear drums vibrate, and we can hear it.

By the way, the next time you dance, realize that you're not just dancing, you're resonating! You are moving your body to the frequencies of the music. The music is "moving" you, so in a way you're resonating! So let's get out there and hit the resonating floor!

In a Nutshell

Everything has a natural frequency.

The natural frequency of an object is due to the size, weight, and material the object is made of.

Natural frequency is how fast something vibrates.

Resonance is energy from one thing moving something else.

When something is vibrating at a natural frequency that matches the natural frequency of something else, that something else may begin to vibrate as well.

As long as energy continues, the object that is being resonated will continue to vibrate at higher and higher amplitudes. In other words, the vibration will get larger and larger.

Our ear drums have a natural frequency between 20-20,000 Hz. Any thing that vibrates with enough energy, at those frequencies, can resonate our ear drums and cause us to hear sound.

Did You Get It

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?

Answers

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!