Robot Sensors and Sound

What do robot sensors do?

- **Gather information** **from the surroundings and send it to the computer** (called the "intelligent brick" in a LEGO robot)

- **Robot sensors can only be used if the robot's program asks for information from them!**

- **Similarly, the robot can only act on information from the sensors if its program tells it to do so!**

How do sensors send signals to the computer brick?

- **The sensors send information through the wires (similar to the nervous system in your body) that connect them to the computer brick, which uses the information appropriately.**

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How do robot sensors work?

Touch Sensor

- **Button-like protrusion**
- **When bumped, it sends an electrical signal to the computer brick via the wires saying that it has been touched**

What human sense is this similar to?

Light Sensor

- **Detects the amount of light in front of the sensor and sends an electrical signal via wires to the computer brick**

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How do robot sensors work? (continued)

Sound Sensor

- **Our ears detect *changes in pressure* as sound**

- **A sound sensor senses the changes in air pressure, and sends an electrical signal to the computer brick via the wires saying that it has heard a sound**

- **This is similar to how a microphone senses the changes in pressure of sound (when you sing) and sends it to a speaker!**

What is the equivalent human sensor and how does it work?

What is a microphone?

A microphone is a **sound sensor** similar to the LEGO sensor we just discussed. It converts sound energy to electrical energy.

The microphone below has a **diaphragm that moves with sound**.

This motion is converted to electricity using a magnet and coil (as you will learn later in physics and engineering).

Wires carrying electrical audio signal

Sound Waves

Magnet

Coil

Diaphragm
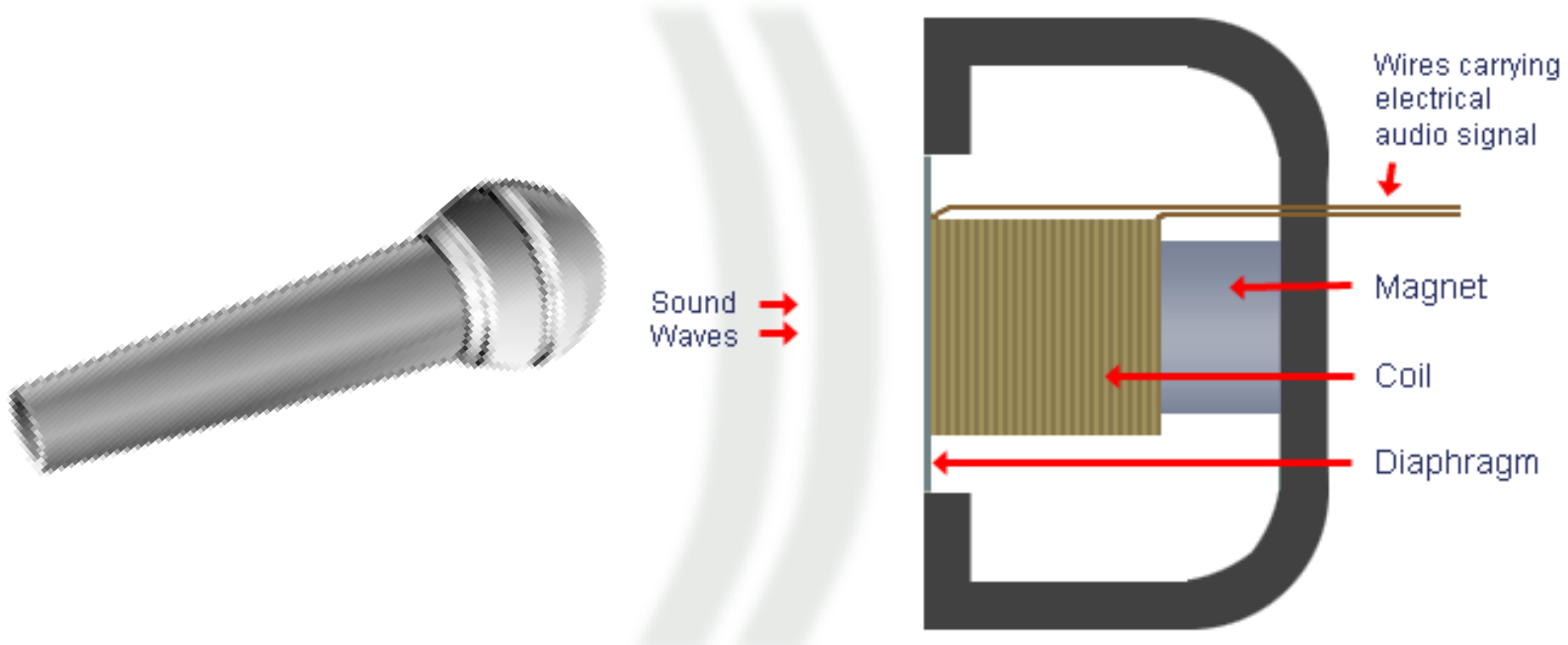
How do robot sensors work? (continued)

Ultrasonic Sensor

▸ **The sensor looks like a pair of eyes (they are <u>not</u> eyes!)**

▸ **Imagine an object is in front of this sensor. The sensor emits a sound from one side and receives the reflection on the other side. The time it takes for the signal to reach the other side helps it estimate the distance to the object.**

▸ **This is similar to how a bat estimates the distance away of objects in its path. The estimate of the distance is sent via the electrical wires to the computer brick.**

▸ **You will learn more about this sensor in later lessons.**

What are machine equivalents of human sensors?

Human Sensor	Equivalent LEGO Sensor
eyes	light sensor, ultrasonic sensor
ears	sound sensor
skin	touch sensor
smell	"electronic nose" under development; some use in industry
taste	"electronic tongue" under development

What Is Sound? Activity

Sound Pre-Quiz

1. **What is sound?**

2. **Can sound travel through water?**

3. **Can sound exist on the moon or in space?**

4. **What is a microphone?**

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Sound Pre-Quiz Answers

1. **What is sound?**
   Sound is created by the vibration of air particles.

2. **Can sound travel through water?**
   Yes. Sounds needs a medium to travel, and water can act as a medium.

3. **Can there be sound on the moon or in the space?**
   Sound waves need a medium (such as air) to travel (remember the vibration of particles). There is much less air on the moon, and so we can have sound on moon. But outer space has no air, and so astronauts are not be able to hear sounds in outer space.

4. **What is a microphone?**
   A microphone is a sound sensor. That is, it converts / transduces sound into electrical impulses that it sends via wires to what it is attached to.

What is sound?

Oscillation of air pressure is felt by humans as sound.

When air is pushed repeatedly, as by a speaker diaphragm, it creates what we call a sound wave.

Watch this video to learn more:

NASA "Science of Sound" (5 minutes)

http://www.youtube.com/watch?v=_ovMh2A3P5k

What is sound?

Sound is a mechanical wave:

Changes in air pressure (vibrations) produce the movement of air particles. These particles start bumping into the other air particles, and this causes a wave that travels in all directions.

Your ears can detect the wave (as shown in the video).

The mechanical energy in the wave is sensed by our ears and converted to electrical energy, which is transmitted to the auditory cortex, and our brain recognizes this as sound.

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How do sounds differ?

- **Vibrating air is sensed as sound.**
- **This vibration is like a wave, as shown to the right.**

WAVELENGTH
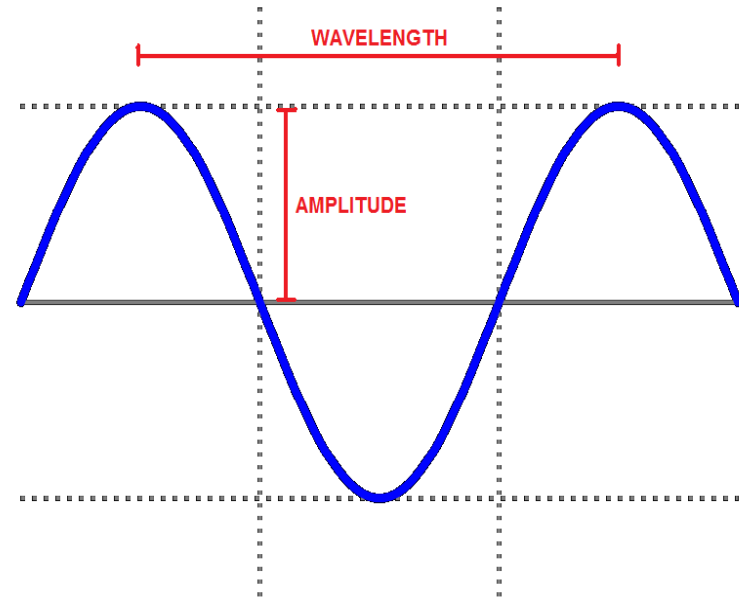
AMPLITUDE

- **The "loudness" or intensity of sound is measured in decibels (dB), and is related is related to its amplitude. The higher the amplitude (higher its dB), the louder it sounds.**
- **The pitch of the sound is its frequency, that is, how many waves happen in one second (see the next slide).**
- **The higher the pitch, the more shrill it sounds.**

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More about sound

- **Wavelength** is the distance between any two successive "peaks" on the wave.

- **Period** is the time required for one complete cycle of the vibration.

- **Frequency** of the sound is the inverse of period,
  that is, frequency = 1/period.

- **Amplitude** is the height of the wave. A loud sound has a high amplitude and soft sound has a lower amplitude.

WAVELENGTH

AMPLITUDE
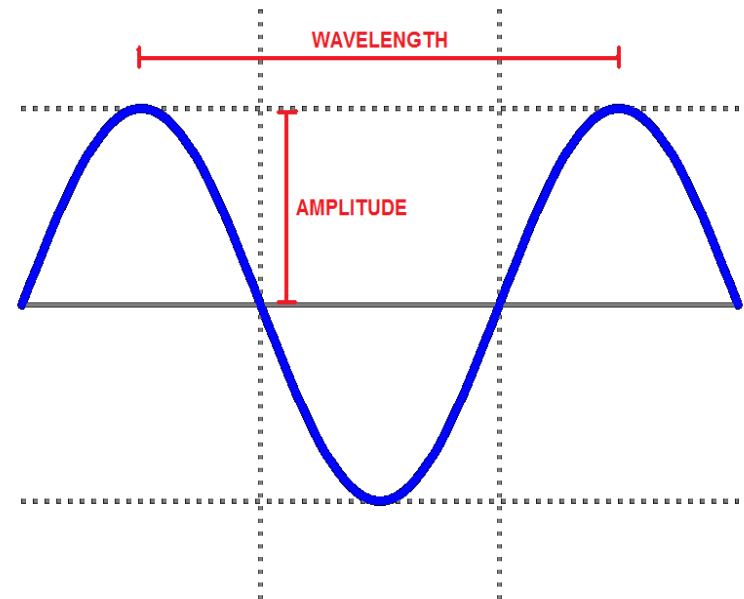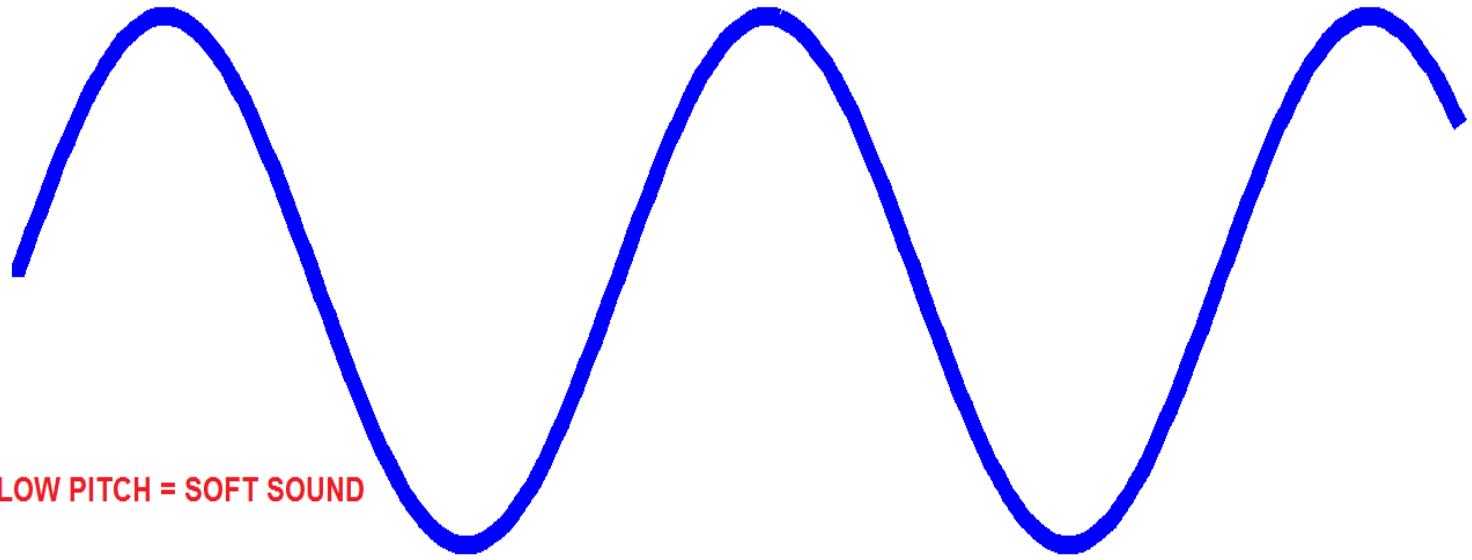
LOW PITCH = SOFT SOUND
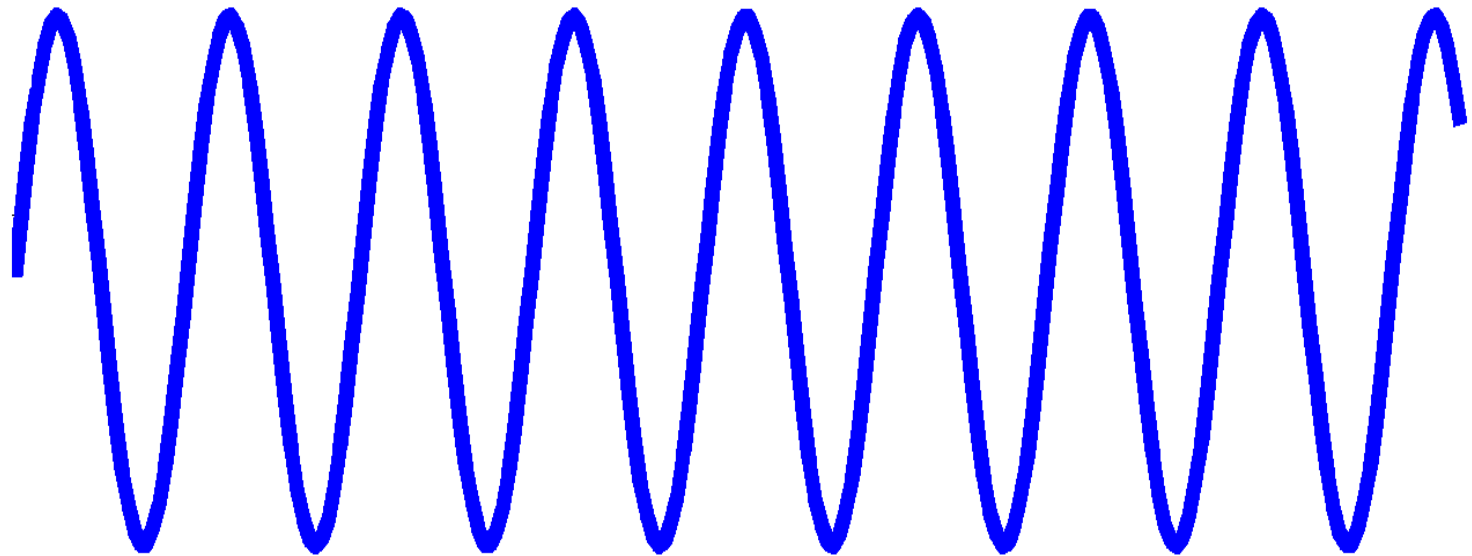
HIGH PITCH = LOUD SOUND

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To the experiment!

Although you cannot "see" sound, you can record it and study its properties.

In this experiment we are going to use the microphone port in a computer (to capture your voices and other sounds) and software that transforms the electrical signal from the microphone into a waveform.

Sound waveforms are like the rings of waves formed when you throw a stone into a still body of water ➜

Seeing Sound

Watch these additional optional videos:

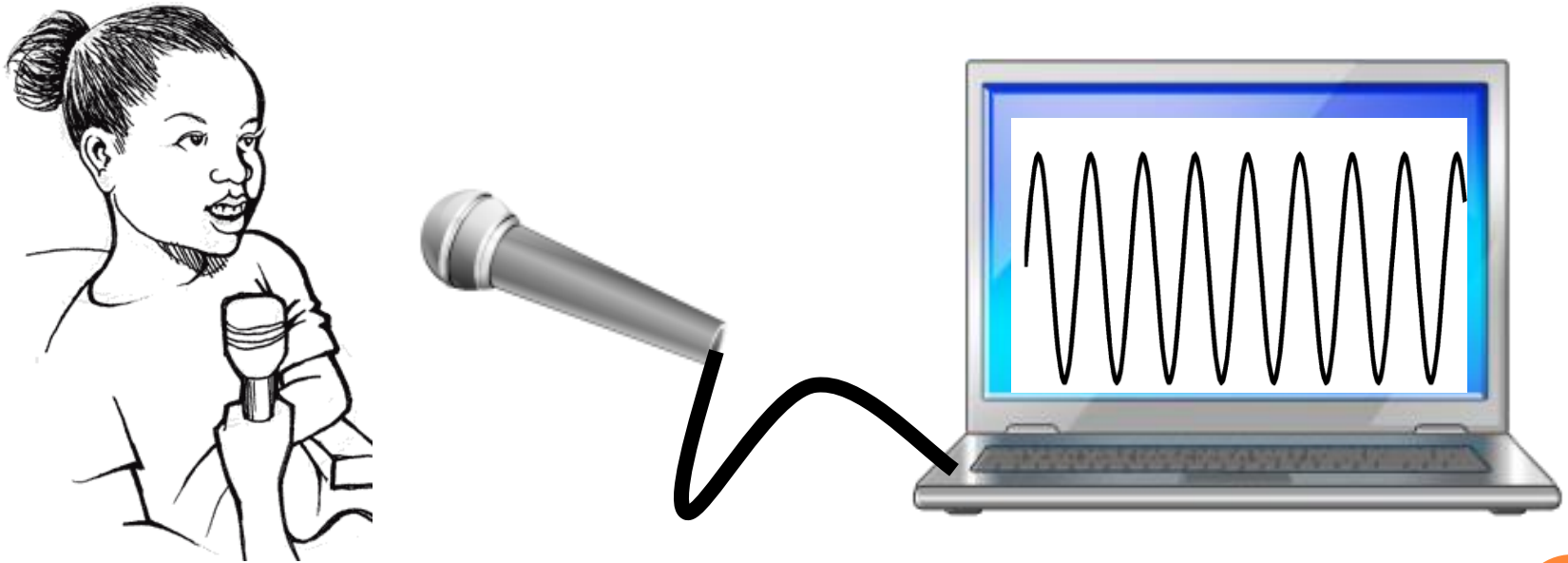**Acoustic water dance; water on speaker (4:44 minutes)**

http://www.youtube.com/watch?v=tI6S5CS-6JI

Seeing sound waves at different pitches (2:10 minutes)

http://www.youtube.com/watch?v=s9GBf8y0lY0

Activity Setup

A **microphone** is a sound sensor that converts sound to an electrical signal, which can then be displayed on a computer screen.

Activity Setup (continued)

- **Your voice is a complex sound wave that contains lots of different pitches (frequencies). Boys and girls have different pitches in their sounds.**

- **Irregular repeating sound waves create "noise," while regular repeating waves seem "musical" to our ears and brain.**

- **In this activity, you will learn more about the properties of sound waves.**

Sound Worksheet

1. What were your observations when you generated sounds with 50, 100, 200, 500, 800,1000, 10000 Hz frequencies and played them?

2. How do "tone" and "noise" differ in their waveforms and how they sound?

3. Tap in/on the desk below the computer and see what sound is captured by the microphone. *What do you observe?*

4. Try singing the solfege notes (do-re-mi-sol-la-ti) one at a time, for 5 seconds each. *What do you observe?*

5. Try speaking the same word (like "hello") in three different tones (whisper, normal and loud). What are the main differences between the waveforms?

Activity Instructions (Using Audacity®)

- We are using a free, open-source software called **Audacity** to record and edit sound files.

- Start Audacity on your computer > go to File > select New to open a file to record sounds.

- Begin by using Audacity to generate waves and see what they sound like when played.

- Go to **Generate** > from its options, select **Tone**. For this tone, select a frequency and amplitude. **Pick frequencies** of 50, 100, 200, 500, 800,1000, 10000 Hz, and **leave the amplitude as 0.8**. Zoom in and note your observations. To delete any record, go to Edit > Remove Audio > Delete.
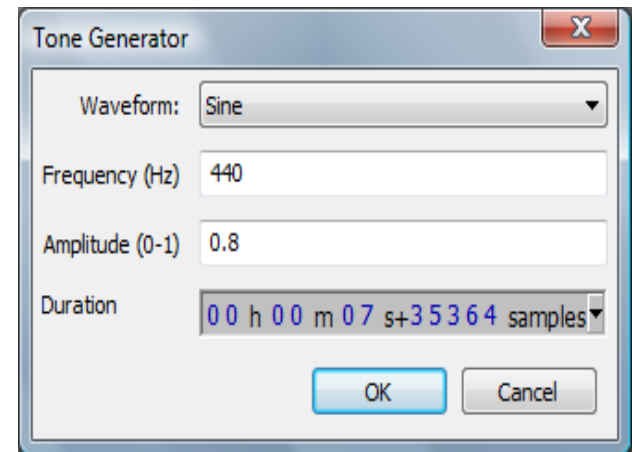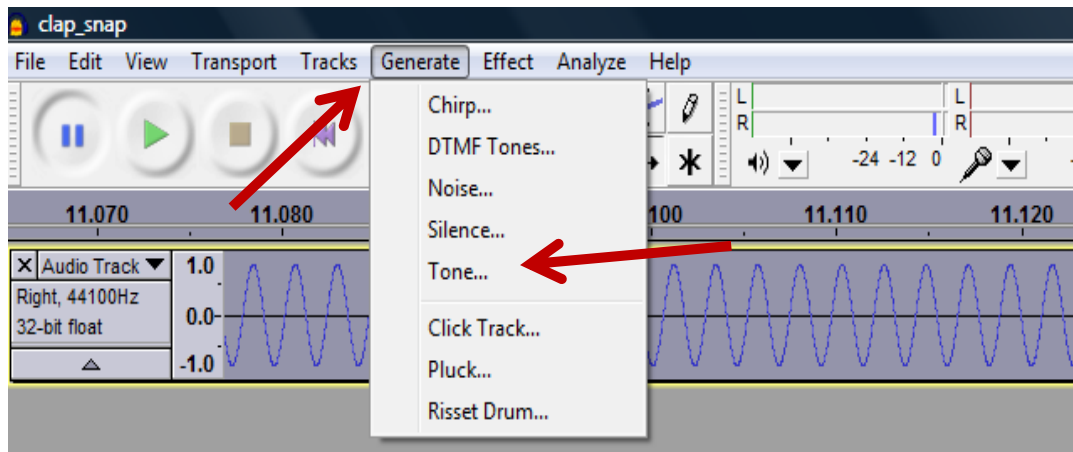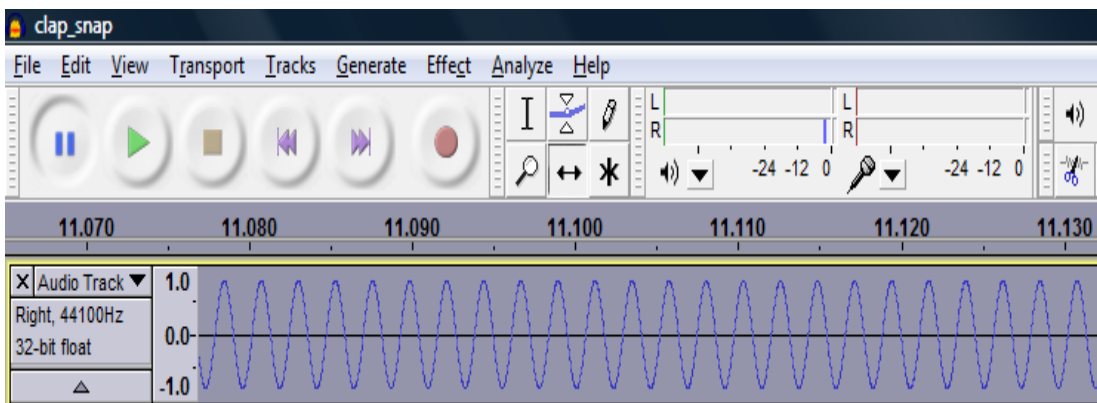
Activity Instructions (Using Audacity)
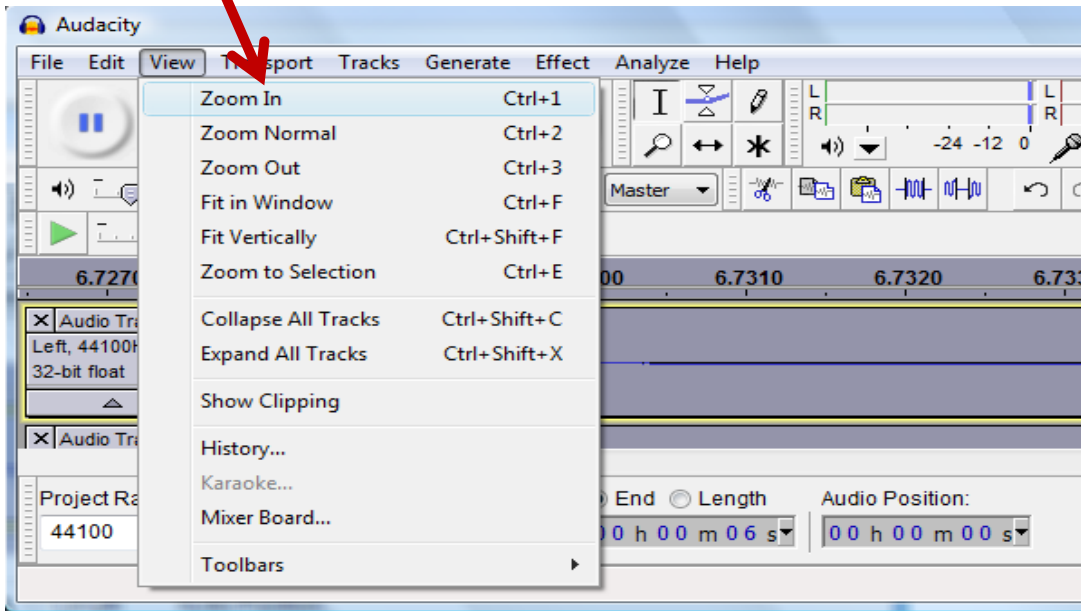
Under the View menu, click **Zoom In** until you get a clear view of the waveform.

You may need to do this several times until you see waves like those shown here.

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Activity Instructions (Sounds Generated by Software)

- **Now try different waveforms than sine, and also try increasing the amplitude. *What do you observe?***

- **If you want to delete what you have recorded, go to Edit > Remove Audio > Delete.**

- **Go to Generate and from its options > select Noise and check what that sounds like. Then try the others, such as Chirp.**

- **Again, *record your observations* on the worksheet.**

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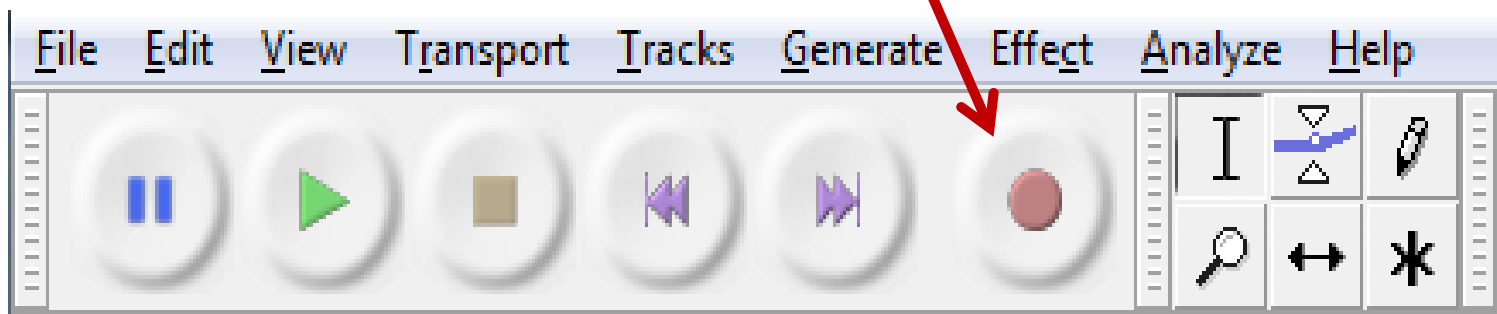# Activity Instructions (Sounds Generated by You)

Next, **record your own voice** and see what the waveform looks like.

Either delete the wave in your present file, or open a new project file: **go to File > New**

To record your own voice using the **microphone**, click on the circular red button (**record button**) on the playback toolbar, say "hello" and see what is being recorded.

After you record it, play it back using the **play button** on the control panel shown below.

Record your voice using the red "Record" button

Activity Instructions (Sounds Generated by You)

- **Press Record** and say some words (like "hello") **to see the resulting waveforms.**

- **Then play back what you recorded to see if it sounds like what you recorded.**

- **The recorded wave form should look like this** ⬊

- **TIP: To get a better look at the frequencies and amplitudes, click on View > Zoom In. You may need to keep on clicking several times (6-10x closer) to get a clear view of the waveform that goes up and down. It should look like the one in the figure.**

- **Use the slider at the bottom to browse through the entire wave.**

- **As you can see, the recorded sound has variable amplitudes and multiple frequencies, compared to previously "generated" waves with fixed amplitude and frequency.**
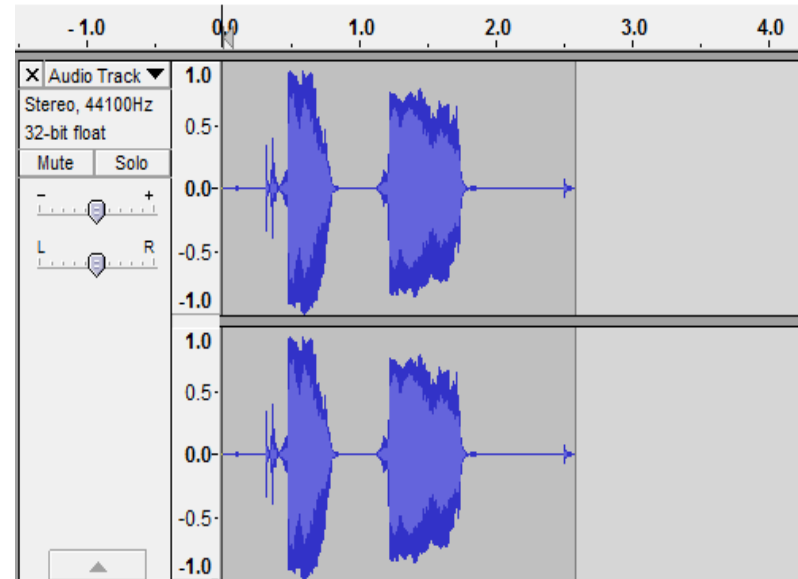
All sounds are waveforms with frequencies and amplitudes!
Complex sounds have many frequencies of different amplitudes.
This is true of your own sounds.

Sound Post-Quiz

1. **What is sound?**

2. **What is the difference between a loud sound and a soft sound in terms of pitch?**

3. **Draw sound waves for high-pitch and low-pitch sounds.**

4. **When you hum the same note continuously, does it produce a distinguishable waveform?**
How about when you scream?

Sound Post-Quiz **Answers**

1. **What is sound?**

   Sound is created by the vibration of air particles.

2. **What is the difference between a loud sound and a soft sound in terms of pitch?**

   They differ primarily in amplitude and not pitch (frequency).

3. **Draw sound waves for high-pitch and low-pitch sounds.**

   A high-pitch sound has more waves per unit time, compared to a low-pitch sound. (See slide 15 for an example drawing.)

4. **When you hum the same note continuously, does it produce a distinguishable waveform?
   How about when you scream?**

   **A note usually is close to a "sine" in form,
   while a scream has lots of frequencies.**

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Vocabulary

- **olfactory**: Related to smell.
- **sensor**: A device that converts one type of signal to another; for instance, the speedometer in a car collects physical data and calculates and displays the speed the car is moving.
- **ultrasonic**: A sound of a frequency that humans cannot hear, but dogs and bats can.
- **peripheral**: Surrounding.

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Image Sources

Slide 1: three girls yelling; source: Microsoft® clipart: http://office.microsoft.com/en-us/images/results.aspx?qu=yelling&ex=1#ai:MP900439297|

Slides 2, 3, 4, 7: LEGO parts; source: LEGO MINDSTORMS NXT User's Guide

Slide 5: microphone; source: Microsoft® clipart: http://office.microsoft.com/en-us/images/results.aspx?qu=microphone&ex=1#ai:MC900433836|

Slide 5: Cross section of dynamic microphone; source: Total Venue: http://www.totalvenue.com.au/articles/microphones/microphones.html

Slides 13, 14, 15: wave lines and graphs by the author

Slide 16: water nodal lines; source: Microsoft® clipart: http://office.microsoft.com/en-us/images/results.aspx?qu=water&ex=1#ai:MP900402205|

Slide 17: sand shapes from sound waves; source: pulled from YouTube Seeing Sound Waves video: http://www.youtube.com/watch?v=s9GBf8y0lY0

Slide 18: girl, microphone, sound waves by author using clipart

Slides 21, 22, 24, 25: screen capture images by author