TEAK
Traveling Engineering Activity Kits

Biomedical Engineering Kit: Artificial Sensory
Artificial Hearing Activity
**Instructor Preparation Guide:** Artificial Hearing Activity

**Bioengineering Overview**

“Bioengineering is the application of engineering principles to address challenges in the fields of biology and medicine. Bioengineering applies the principles of engineering design to the full spectrum of living systems.”[1]

**Ear Overview**

The purpose of the ear is to collect, convert and send sound signals to the brain. The outer ear, the middle ear, and the inner ear make up the human ear. These three parts are necessary in producing a sound signal which the brain understands.

![Figure 1: Anatomy of the ear. [1]](image)
The Outer Ear:

The outer ear is also known as the pinna or auricle. The sole purpose of the outer ear is to collect sounds. The outer ear is pointed forward with numerous curves that enable a person to determine the direction of sound.

The Middle Ear:

After the sound waves are collected in the outer ear, it is passed along the ear canal to make its way to the middle ear. As sound waves travel through the eardrum, it produces a vibration. The eardrum is a sturdy and sensitive piece of skin that can oscillate back and forth even with the slightest air pressure. The eardrum also acts as a divider between the outer ear and the ossicles. The ossicles are made up of three tiny bones which regulate sound towards the inner ear. The vibrations produced by the eardrum are passed through to the hammer which causes the anvil to vibrate and finally the stirrup. After the stirrup, the vibration travels to the inner ear.

The Inner Ear:

When sound reaches the inner ear, it enters the cochlea which is shaped like a small shell filled with liquid. Within the cochlea is contains microscopic cells covered in hairs. Vibrations that enter the cochlea cause the hair the move. The movement of hairs produces nerve signals which the brain interprets as sound.
Hearing Aid Overview

All hearing aids contain the following parts: Microphone, Amplifier, Speaker, and Battery.

The Microphone- The microphone collects the sound waves and converts them into an electrical signal which is passed to the amplifier.

The Amplifier- The amplifier is a circuit that takes the electrical signals from the microphone and amplifies it to a desired level and then transmitted to the speaker.

The Speaker- Also called the receiver, converts the amplified electric signals back into sound and sends it to the ear canal.

The Battery- The battery powers all the electrical components of the hearing aid.
Electrical Components Overview

Resistor- A resistor is an electrical component with 2 terminals that is designed to reduce electrical current. Resistors of higher resistance produce less current. The resistance of a resistor is determined by the colors of the band around it.

Capacitor- A capacitor is an electrical component with 2 terminals that is designed to store electrical charge. As the capacitor is charging, current will flow, but once the capacitor is fully charged, the current will stop flowing. There are two types of capacitors: Polarized and Non-Polarized. Polarized capacitors have to be connected in a certain way because of its positive and negative ends. Non-Polarized capacitors can be connected in any way.

Potentiometer- A potentiometer is an electrical component with 3 terminals that can be designed to manually adjust resistance. Potentiometers are used in applications where there are different levels of output. For example, it is used to change volume and brightness.

![Amplifier Circuit Diagram](image-url)
Activity Preparation Guide – Artificial Hearing Activity

Overview

This kit contains activities for students to gain a better understanding for how engineers design devices to help people with hearing problems. Students will be exposed to devices such as a decibel meter and hearing aids. Students will gain understanding by observing, recording, discussing and drawing conclusions. The main focus of this activity is how to amplify sound.

Learning Objectives

After this activity, students should be able to:

- Describe how engineers measure sound.
- Explain how a hearing aid helps people who’ve lost their hearing.
- Explain how the volume of a hearing aid works.
- Explain the dangers of loud sound.

Engineering Connection

Biomedical engineers work with doctors and surgeons in designing devices to overcome the loss of hearing. In order for engineers to be successful in their designs to fix hearing damage, they must first understand the levels of decibels. In the case of hearing loss, a simple solution is usually to amplify the sound. When designing devices such as hearing aids, the engineer must know how much the sound needs to be amplified in order for the brain to process it while not damaging the other vital parts of the ear. Other devices include cochlear implants, insertion of tubes in the ear drum, and the replacement of the ossicles in the ear. The cochlear implant is a tiny device implanted under the skin that performs the function of the ear drum, the three tiny bones, and the cochlea. A microphone, a speech processor, a transmitter, and electrodes make up the cochlear device. It functions by direct stimulation of the auditory nerve via the electrodes.
Activity Descriptions

A.) Introductory Discussion: Sound Properties 6 Minutes

- This discussion will focus on the introduction of the sound properties such as waves, frequency and amplitude. The students will get an understanding of how our auditory system functions so that we can perceive sound.

B.) Measuring Decibel Activity: 15 Minutes

- In this activity the students will learn the decibel levels of different sounds. Included in this kit will be a decibel meter. Students will measure the amount of decibels they produce when they speak, whisper, or yell. This will give the students a sense of how loud a 60 or 80 decibel level is. Following this activity, the students will be divided into groups. Each group will be given a worksheet with a list of sound descriptions. The task is to group these sound into 4 different categories; Danger Zone, Damage Zone, Under 15 Minutes Only Zone, and Comfortable Zone. The main focus of this is that the understanding of various decibel levels is necessary for engineers to effectively design devices to fix hearing damage.

C.) Amplifier Circuit Activity: 25 Minutes

- This activity allows the students to work in a group to make an amplifier. Each group will be given an mp3 player and a decibel meter. The student will build an amplifier that would be connected to the mp3 player. Students will place electrical components onto a breadboard as if they are playing battleship. Using the mp3 player, the students will play a song to the decibel meter. Students will then connect the amplifier to the mp3 player in addition to changing the resistors to different values and describing how that affects the sound output of the amplifier. Students will then replace the resistor with a potentiometer. The potentiometer acts like a volume control in a hearing aid in that the knob adjusts the resistance.

D.) Closing Discussion Artificial Hearing Devices 4 Minutes

- The focus of the discussion will surround bioengineering principles as they pertain to ear functionality and design, engineering design principles, and practical applications of how engineers are currently working to improve the quality of life for hearing loss patients through the development of advanced hearing aids and cochlear implants. Biomedical engineers must work in conjunction with doctors in order to evaluate, design, and fabricate hearing devices that drastically improve the quality of life for individuals with hearing loss.
E.) Engineering Team Roles:

*Technical Engineer* – Reads out instructions.

*Sound Engineer* – Controls the MP3 player.

*Hardware Engineer* - Places the electrical component onto the breadboard.

*Verification Engineer* - Assists the hardware engineer and verifies that the components are placed in the correct locations.
**New York State Learning Standards**

Discuss how best to test the solution; perform the test under teacher supervision; record and portray results through numerical and graphic means; discuss orally why things worked or did not work; and summarize results in writing, suggesting ways to make the solution better.

Plan and build, under supervision, a model of the solution using familiar materials, processes, and hand tools.

**New York State Health Learning Standards**

**Standard 1: Engineering Design**

- T1.1 Identify needs and opportunities for technical solutions from an investigation of situations of general or social interest.
- T1.3 Consider constraints and generate several ideas for alternative solutions, using group and individual ideation techniques.
- T1.3a generate ideas for alternative solutions.
- S1.2a independently formulate a hypothesis.
- S2.1b conduct an experiment designed by others.
- S2.1d use appropriate tools and conventional techniques to solve problems about the natural world, including: measuring, observing, describing, classifying, and sequencing.
- S3.2a accurately describe the procedures used and the data gathered” [2]
The Sensory System

DURATION

45-50 Minutes

CONCEPTS

Bioengineering
Sensory System
Sound Properties
Biomedical Applications
Bioengineering Discussion: (2 Minutes)

Background Information:

“Bioengineering is the application of engineering principles to address challenges in the fields of biology and medicine. Bioengineering applies the principles of engineering design to the full spectrum of living systems.”[1]

Group Discussion: Bioengineering Background

(Pose the following questions to the group and let the discussion flow naturally… try to give positive feedback to each child that contributes to the conversation)

What do you think bio (biology) means?

- The study of life and a branch of the natural sciences that studies living organisms and how they interact with each other and their environment.
- The study of the environment.
- The study of living organisms and living systems.

What do you think engineering is? What do you think it means to be an engineer?

- A technical profession that applies skills in:
  - Math
  - Science
  - Technology
  - Materials
  - Structures

Discuss with the students what bioengineering is and the broad scope of areas that bioengineering includes. For this discussion, provide students with examples of bioengineered products and applications.

- Bioengineering applies engineering principles in the fields of medicine, biology, robotics, and any other living system.
- Examples of products that have been bioengineered are:
  - Hearing Aids
  - Cochlear Implants
Sound and Hearing Discussion: (4 Minutes)

Background Information:

The sound we hear requires a few manipulations before it is processed. First the sound waves are collected, then converted into electrical impulses, and finally sent to the brain via the auditory nerve for the brain to understand. A sound wave has characteristics just like any other type of wave, including amplitude and frequency.

Simplified Definitions:

A.) **Amplitude**- The amplitude is the volume or strength of a sound. Referring to sound waves, the amplitude would be the biggest displacement from zero. The unit of measurement for the loudness of is decibels. Since decibel is logarithm based, every difference by 1 means that a sound is either 10 times louder or softer.

![Figure 5: Plot of amplitudes.](image)

B.) **Frequency**- The frequency is the number of vibrations per seconds measured in hertz. This is also referred as pitch. High frequency generates high, screeching sounds. Low frequency generates low, deep sounds.

![Figure 6: Plot of frequency waves.](image)
**Group Discussion: Sound and Hearing**

(Pose the following questions to the group and let the discussion flow naturally… try to give positive feedback to each child that contributes to the conversation)

**If you woke up one day and had trouble hearing things, what are some things that you would have a hard time doing?**

- Listening to music
- Watching T.V.
- Talking to people

**What can cause a person to have hearing trouble?**

- Born with it
- Head injury
- Exposure to loud sounds

**Why do we cover our ears when we hear something really loud?**

- It is important to reduce the amount of time exposed to loud sounds because it can lead to hearing loss and/or deafness.

**What are some ways that we can do to keep our ears healthy?**

- Try to avoid exposure to loud sounds
- Regular check ups
- Don’t stick anything in the ear canal

**What are some sounds that can damage your ears if you listen to it for too long?**  
*Example: Police Siren*

- Plane engine
- Gunshot
- Firecrackers

**Since we can’t see sound waves, what are some things which we can see that acts like a wave?**

- Water ripples
- Flags on a windy day
- Slinky going down a stair
**Measuring Decibel Activity**

**Learning Objectives**
By the end of this exercise, students should be able to …
1. Give examples of sounds that correspond to certain decibel levels.
2. Identify if a certain sound is safe for the ears.
3. Describe how engineers measure sound.

**Materials**
1. Decibel Meter
2. Common Sound Worksheet

**Procedure**
1. Get the students into 5 groups.
2. Explain to the students that engineers use a decibel meter to measure how loud a sound is.
3. Have each student in the group talk and whisper to the decibel meter and record the level.
4. Hand out the Common Sound Worksheet
5. The students should work together in the group to put each sound description in the appropriate categories.
6. Review the findings with the class.

**Expected Results**
See Common Sound Worksheet Answer Guide.

**End Measuring Decibel Activity**
# Common Sound Worksheet Handout

Name(s) __________________________

<table>
<thead>
<tr>
<th>Sound Description</th>
<th>Comfortable Zone (Under 65 dB)</th>
<th>15 Minute Only Zone (70 dB - 99 dB)</th>
<th>Damage Zone (100 dB - 119 dB)</th>
<th>Danger Zone (Greater than 120 dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alarm Clock</td>
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<tr>
<td>Baby Crying</td>
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<tr>
<td>Barking Dog</td>
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<tr>
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<td>Breathing</td>
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<td>Car Horn</td>
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<td>Door Bell</td>
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<td>Electric Drill</td>
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<td>Firecracker</td>
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<tr>
<td>Jet Engines</td>
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<td>Talking</td>
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<td>Rain</td>
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<tr>
<td>Refrigerator</td>
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<td>Rock Concert</td>
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<td>Shotgun</td>
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<td>Snow Blower</td>
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<td>Thunder</td>
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<td>Train</td>
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<tr>
<td>Vacuum Cleaner</td>
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<tr>
<td>Whisper</td>
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</tbody>
</table>

*There are 5 sound descriptions in each category*
# Common Sound Worksheet Handout Answer Key

<table>
<thead>
<tr>
<th>Sound Description</th>
<th>Comfortable Zone (Under 65 dB)</th>
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<th>Damage Zone (100 dB - 119 dB)</th>
<th>Danger Zone (Greater than 120 dB)</th>
</tr>
</thead>
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<td>Blender (100 dB)</td>
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<td>Breathing (10 dB)</td>
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<tr>
<td>Car Horn (110 dB)</td>
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<td>X</td>
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<td>Door Bell (80 dB)</td>
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<td>X</td>
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<td>Electric Drill (94 dB)</td>
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<td>X</td>
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<td>Firecracker (130 dB)</td>
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<td>X</td>
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<td>Jet Engines (140 dB)</td>
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<td>Talking (60 dB)</td>
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<td>Rain (50 dB)</td>
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<td>Refrigerator (40 dB)</td>
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<td>Rock Concert (130 dB)</td>
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<td>X</td>
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<td>Shotgun (130 dB)</td>
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<td>X</td>
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<td>Snow Blower (105 dB)</td>
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<td>Whisper (20 dB)</td>
<td>X</td>
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</tbody>
</table>
**Closing Discussion:** (4 Minutes)

**Background Information:**

The decrease in the ability whether full or partial to detect or understand sounds is considered a hearing loss. Sound waves vary in amplitude and in frequency. When a person is unable to detect some frequencies or amplitudes of a sound, he/she has a hearing impairment. Hearing loss can be categorized depending on which part of the auditory system was damaged. The three categories of hearing loss are: conductive hearing loss, sensory hearing loss and neural hearing loss.

**Simplified Definitions:**

A.) **Conductive Hearing Loss**- This refers to any problem that involves the middle or outer ear. Those with conductive hearing loss are regarded as having a mild hearing loss because it can be corrected through medical treatment.

B.) **Sensory Hearing Loss**- This refers to the destruction or damage of the hair cells causing the inability of the cochlea to function correctly. In most cases, this results in permanent hearing and speech impairment.

C.) **Neural Hearing Loss**- This refers to complications within the inner ear. Specifically the nerves that transmit the signals from the cochlea to the brain.

**Group Discussion: Hearing Loss Devices**

*Pose the following questions to the group and let the discussion flow naturally… try to give positive feedback to each child that contributes to the conversation*

**What do you think can be done to improve this hearing device?**

- Extra components can be added to the circuit to reduce noise and smooth the wave signal.

**If someone was very sensitive to sound, what kind of device can be created to help them?**

- A device like the hearing aid could be created but instead of amplifying sound, it can reduce sound.
What are some things bioengineers have done to help people with hearing problems?

• Design hearing aids
• Place tubes in the ear
• Cochlear Implants
• Replace part of the bones in the middle ear with wires
Amplifier Circuit Activity

Learning Objectives
By the end of this exercise, students should be able to …

1. Identify parts of a hearing aid
2. Explain how a volume control works
3. Explain how a hearing aid helps people with loss of hearing

Materials
1. (1) 400 Contact Breadboard
2. (2) 10,000Ω resistor
3. (1) 470Ω, 330Ω, 100Ω resistor
4. (1) 9V battery
5. (1) 9V battery snap connector
6. (1) Potentiometer
7. (1) Voice Recorder
8. (1) Decibel meter
9. (1) 8Ω speaker
10. (1) 250μF, 10μF, 0.47μF capacitor
11. (1) LM386 Audio Power Amplifier

Procedure
1. Get the students into 5 groups.
2. Take out all the materials listed above.
3. Build the amplifier circuit according to the “Circuit Handout”.
4. Connect the circuit to the voice recorder and battery. Now play the music and listen to it through the speaker. Record the observation in the worksheet.
5. Referring to “Circuit Handout- Extra” find the 470Ω resistor (Trial 2) and insert them in the coordinates pictured. Play the music and listen to the sound through the speaker. Record the observation in the worksheet.
6. Remove the 470Ω and insert the 100Ω resistor (Trial 3) in the same spot. Play the music and listen to the sound through the speaker. Record the observation in the worksheet.
7. Remove the 100Ω resistor and attached a potentiometer “Circuit Handout- Extra”. Turn the knob and record what is happening to the sound.

Expected Results
1. As the knob is turned counterclockwise, the sound should get louder.
2. An increase in resistance results in a decrease in sound.

End Amplifier Circuit Activity
Amplifier Circuit Worksheet

How loud is the sound heard in Trial 1? (Circle one)

Not very loud  I can hear it fine  Loud  Very Loud

How loud is the sound heard in Trial 2 compared to Trial 1? (Circle one)

Softer  About the same  Louder

How loud is the sound heard in Trial 3 compared to Trial 2? (Circle one)

Softer  About the same  Louder

What happens to the sound when the resistor value gets smaller?

If this is the sound wave from using a 470Ω resistor, what do you think a sound wave from using a 940Ω would look like?

If the hearing aid is making a sound that is too loud, what can an engineer do to lower the sound?

When the knob is turned to the left, is the resistor value getting smaller or larger? Why?
Circuit Handout

*Important: Please make sure each component matches the picture exactly!!

**Trial 1**

**Step 1.**

**Step 2.**

THE CIRCUIT SHOULD LOOK LIKE THIS
Circuit Handout - Extra

The final circuit should look like this

**Trial 2 - 470Ω Resistor**

**Trial 3 - 100Ω Resistor**

**Potentiometer**
Decibel Meter/MP3 Player Instructions

Measuring Decibel Activity:

1. Turn dial to “70”.
2. Press “Response” once so that the response is slow.
3. Point speaker to the person speaking
4. The number on the screen is the decibel level.
5. After using the decibel meter, turn dial to “OFF”

To play music from the MP3 player:

1. To turn on the MP3 player, press and hold “Menu” until something comes on the screen.
2. Press “+” or “-“ to scroll up or down until you see “Music” on the screen.
3. Press “play”.
References

Text

http://en.wikipedia.org/wiki/Bioengineering

[2] New York State Education Department. May 12, 2009

Images

http://media-2.web.britannica.com/eb-media/04/14304-004-6C1B7EB1.gif

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