

## Loudspeakers, PA Systems, and the “Wall of Sound”

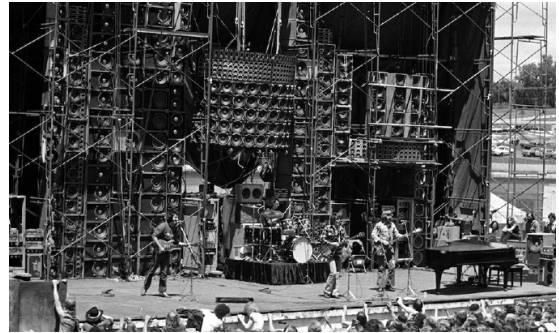
### OVERVIEW

#### ESSENTIAL QUESTION

What is a PA system, how does it work, and how were the Grateful Dead pioneers in live sound technology?

#### OVERVIEW

“It was absolutely apocalyptic. It was like the voice of God.” - Phil Lesh, Grateful Dead bassist, recalling the band’s famed “Wall of Sound” PA system.



Grateful Dead bassist Phil Lesh was enthralled with his band’s monumental PA (public address) system. The early 1970’s rig was an immense state-of-the-art structure, affectionately and begrudgingly known as the “Wall of Sound.”

The late 1960’s were an era of emerging music technology. In 1966, The Beatles had ceased performing concerts, in part because they felt they could not be heard well in large venues. However, by 1969, sound engineer Bill Hanley had successfully engineered a sound system that could reach the hundreds of thousands of listeners at Woodstock. Still, for touring bands, the early 1970s was a time of inconsistent sound reproduction. What was limiting to some, however, was an exciting challenge to others, perhaps none more so than Augustus Owsley Stanley III, a serial tinkerer known as “Bear” in the Grateful Dead’s sprawling creative community.

Bear’s lead role in improving how the Grateful Dead were heard and experienced at their shows came about as the band’s popularity, and thus the size of their concert audiences, increased. The group dreamed of a system that could deliver their music clearly and dynamically to a larger crowd, but found their options limited by the rudimentary equipment available in the early 1970s. So, like any good tinkerer, Bear set out to invent the solutions to the band’s problems. Bear’s ingenuity and innovative design, greatly assisted by the techs and laborers with whom he built the sound system, resulted in the “Wall of Sound”—a 600 speaker, over 40 foot tall pioneering feat in PA system technology and the largest and loudest mobile sound system in the world at that time.

Although most PA systems from the early 1970’s pale in comparison to what is available today, they did contain the basic electrical components found in modern systems: a sound source, amplifier, and loudspeaker. The sound source produces an electrical signal— whether it’s a voice captured by a microphone or an audio component in a home stereo system. The amplifier boosts the electrical signal and sends it to the loudspeaker. The loudspeaker then takes the amplified electrical signal and converts it into sound that can be perceived.

Electrical sound systems are often used to serve a basic need—to project sound above the physical limitations of acoustic delivery. An additional benefit is that these systems can deliver sound simultaneously to multiple locations via a centralized system, such as a school intercom or the speakers throughout a sports stadium.

Speakers, which are fairly simple devices, are the final phase in transmitting sound. Discovering how speakers are constructed and operate, as students will do in this lesson, allows us to have a better understanding of how often we interact with sound systems in our daily lives.

In this lesson, students will identify basic components in sound systems, and then assemble a working loudspeaker. Students will also gain a deeper appreciation for the Grateful Dead’s historic role in pioneering live sound technology by watching video clips from *Long Strange Trip*.

### **Materials required for this lesson:**

1. For students:

- Cups, bowls, and plates made from various materials (paper, plastic, metal, etc.)
- Magnet wire (a spool of 30AWG wire is recommended)
- Clear Tape
- Wire Cutters

2. For teachers:

- Neodymium Magnets: 6 or more (*Please be advised that neodymium magnets should be handled with care, they are very strong magnets. Students may need assistance if they are stacking them together and pulling them apart. The magnets should be kept at least 12 inches away from mobile devices, desktop computers, etc.*)
- Sound device with headphone port: mobile phone, laptop, desktop computer, mp3 player, etc.
- 3.5mm tipped stereo cable
- Alligator clips (red and black)
- Wire Cutters
- Wire Stripper tool or Sandpaper (very light grain for removing coating from magnet wire)

## OBJECTIVES

Upon completion of this lesson, students will:

### 1. KNOW (KNOWLEDGE):

- What a PA system is and its three basic components
- How to assemble a working loudspeaker
- The Grateful Dead's historic role in pioneering live sound technology for concerts

### 2. MASTERY OBJECTIVE

- Students will be able to identify the basic components in a PA system by assembling a working loudspeaker.

## ACTIVITIES

### PREPARATION

1. Watch **Clip 1, Building Your Own Speaker**, to get step-by-step instructions on the entire process of building a speaker. (The steps presented in the video will be split between teacher activities and student activities in the lesson.)
2. Cut a 3.5mm stereo TRS (tip-ring-sleeve) audio cable about 5 inches from the tip so that both the black and red cables are visible. Use wire strippers or fine grain sandpaper to fully remove the insulation and expose the inner copper wire.
3. Plug the 3.5mm audio cable into your audio source (mobile phone, laptop, desktop computer with headphone port, mP3 player, etc.)
4. Connect one clip of the black alligator wire to the exposed bare copper wire at the end of the black insulated wire of the 3.5mm audio cable.
5. TeachRock's **The Birth of the Microphone** lesson may be a beneficial resource for historical background, tech terminology, and lesson activities for voice amplification, projection, and production.

### MOTIVATIONAL ACTIVITY

1. Ask students:
  - What might be some ways to make your voice louder?
  - What might be some tools you can use to project your voice farther?
2. Display **Image 1, Acoustic Voice Projection Techniques**. Ask students:
  - How do these techniques look similar?
  - How do these techniques look different?

- Which technique might produce louder sound?
  - Which technique might project sound farther?
  - Have you utilized these techniques before? If so, why?
3. Have students experiment with how they can acoustically make their voice louder and project it farther. Instruct students to use two specific techniques: (1) cupping their hands and (2) using a piece of paper to create a cylindrical device similar to an acoustic megaphone. After students experiment with these voice amplification techniques, ask them:
- Which technique produced a louder sound?
  - Which technique projected your voice farther?
  - Did your voice sound different between the two techniques? How?
  - Why might these techniques make your voice louder?
  - What may be the limitations of using these techniques when trying to make your voice louder?
  - In your own words, what is sound?
4. Display **Image 2, “Sound” Definition**. Ask students:
- Can we also perceive sound by other senses? (*Remind students that sound vibrations are invisible but that certain sound vibrations can also be felt—low frequencies especially.*)
  - In what situations might we need to make sound louder and project it farther?
  - Can you think of any electronic systems that make sound louder and project it farther over a large area?
  - Can you think of any sound systems you’ve experienced in public that make sound louder and project it farther?
5. Display **Image 3, “PA System”** definition. Ask students:
- Have you had any experience with a PA System? (*If needed encourage students to think of places where music or speech is broadcast across many speakers, such as in their school, a grocery store, a church, or stadium*),
  - In these places you’ve just named, why do you think the PA system is used?
  - Do you think a PA System might require specialized knowledge and training in order to assemble and operate?

## PROCEDURE:

1. Tell students they will now view clips from *Long Strange Trip*, a documentary about the band Grateful Dead. Play **Clip 1, "The Wall of Sound."** Ask students:
  - Why might the Grateful Dead have wanted to present a "better quality sound" to their audience?
  - Why might the Grateful Dead's PA system be described as "the most unbelievable PA you could imagine" and known as the "Wall of Sound"?
  - What might be the reasons for the Grateful Dead having to build their own PA system? (*Remind students of the time period that the system was being built and the limited technology available at that time.*)
  - Do you think the Grateful Dead and their crew were experts at building PA systems? What in the clip tells you they might not have been?
2. Display **Image 4: Tech Sheet.** As a class, view the images and review the definitions of the components that comprise a basic PA system. Ask students:
  - How many components comprise a basic PA system?
  - Are you familiar with any of the components? Where have you seen them before?
  - What is the final component at the end of the signal path that produces sound to be perceived? (*Guide students to recognize that a loudspeaker is the final component of a basic sound system.*)
- Can you think of a device that has all of these components integrated into one device? (*Guide students to recognize that a mobile phone has a sound source, amplifier, and loudspeaker all contained within the device.*)
3. Display **Image 5: Loudspeaker Schematic.** Ask students:
  - According to this image, what are the main components to a loudspeaker? What materials might they be constructed out of?
  - Do you think these components can be purchased at a local retail store or online?
  - Could you construct a loudspeaker?
4. Keep **Image 5** displayed at the front of the classroom. Organize students into groups of 4-5, and instruct the groups that they will be assembling a working loudspeaker. Hand out a set of materials (bowls/cups/plates, clear tape, magnet wire, and wire strippers) to each group. Ask students:
  - Considering the discussion of **Image 5**, does your group have the necessary materials to build a working loudspeaker? (*Students should survey their materials and confirm that they have all the necessary parts for a loudspeaker except a "magnet."*) Inform students that they will construct all parts of the loudspeaker except for the magnet component. The teacher will provide the magnet.
5. Encourage students to build a loudspeaker as a group with the teacher providing step-by-step instruction using the following steps (*students can review the entire process by watching **Clip 1, Building Your Own Speaker***):



- From the selection of all types of plates and bowls available, choose a **basket** for the loudspeaker.
  - Spool off 60-72 inches of magnet wire and snip it. Leaving about 6 inches of each end of the wire as opposite tails, wrap the remainder of the wire around a large marker, highlighter, or similar cylindrical device about 50 times, creating a **voice coil**. Remember to leave about 6 inches of each end of the wire trailing out from the voice coil.
  - Slide the voice coil off of the large marker (or other cylindrical device) used to maintain the coiled shape and hold it together so that it does not unravel and remains flat.
  - Place your basket face down. Use a piece of clear tape to secure the voice coil to the bottom of the basket. Make sure the voice coil lays flat and maintains its coiled shape. Use two more pieces of tape to secure the tails of the voice coil to the basket so they are at a 180 degree angle from the voice coil. Leave the tips exposed and not taped. The tails of the voice coil should protrude from the side of the basket.
  - Use a small piece of light grain sandpaper to remove the insulation from the tips of the voice coil exposing the copper wire.
6. Distribute **Handout 1: Loudspeaker Basket Comparison** to students. Have each group bring their assembled loudspeaker one at a time to the front of the classroom to be tested with a **magnet** and heard by the classroom by using the following steps:
- Lay the student group's loudspeaker basket bottom down so that the tails of the voice coil are protruding from the sides.
  - Connect one clip of the **black** alligator wire to one "tail" of the voice coil.
  - Connect one clip of the **red** alligator wire to the remaining "tail" of the voice coil.
  - Play audio on your device.
  - Hold the stacked magnets and point them down at a perpendicular angle to the voice coil. Sound should be heard coming from the basket!
7. After hearing each group's loudspeaker (*students may need to stand close to hear it*), ask students to note their observations on the chart in **Handout 1: Loudspeaker Basket Comparison**. Ask students:
- Why might the magnet be a necessary component to the operation of the speaker? (*The magnet amplifies the electrical current being sent from the audio source.*)
  - What is the magnet doing to the coil? (*Transferring the electrical signal from the wire to the voice coil.*)
  - What is the basket (paper plate, cup, etc.) doing? (*It is vibrating to project the sound waves.*)
  - What kinds of things might effect the strength or volume of the speaker? (*Encourage students to consider the strength of the magnet and the size of the wire coil.*)



## SUMMARY ACTIVITY

1. Once all loudspeakers have been presented and tested at the front of the classroom, ask students:
  - What basket did your group choose? Why did you choose that particular basket?
  - What did you notice with your basket compared to the basket choices of other groups?
  - Might you choose a different basket if building another loudspeaker? Do you think your different choice would produce a louder sound? Do you think your different choice would project the sound farther? Why or why not?
  - Can you think of any additional design ideas that might make the speaker louder or clearer? (*Ask students to consider the effects of a stronger amplifier, thicker wire, etc.*)
  - Might you have another reason for choosing a different basket?
  - Might you know of other options for loudspeaker baskets that weren't available with this activity? What are they and why should they be considered?

## EXTENSION ACTIVITY

1. **Create your own Sound System company.**
  - In their groups, instruct students that they will be creating their own PA System company. Distribute **Handout 2 - Sound System Company Profile**. Ask students to answer the questions on the handout - providing brief details of the company and sketching a logo. Then, ask students to share their company profile and logo with the class.
2. **Meet your school's PA system!**
  - Organize a class trip to visit the PA system(s) in your school. Visit the multiple systems in the school (the main administration office, a performance theatre for music and drama events, etc.), and ask students to fill out **Handout 3 - Your School's PA System(s)** for each PA system they visit. Then, ask students to write a short essay on their school's PA system or conduct a class discussion based on the observations they made on Handout 3.





## NEXT GENERATION SCIENCE STANDARDS (NGSS)

1-PS4-4: Use tools and materials to design and build a device that uses light or sound to solve the problem of communicating over a distance.

3-PS2-2: Ask questions to determine cause and effect relationships of electrical or magnetic interactions between two objects not in contact with each other.

MS-PS-3: Ask questions about data to determine the factors that affect the strength of electric and magnetic forces.

MS-PS2-5 : Conduct an investigation and evaluate the experimental design to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact.

## COMMON CORE STATE STANDARDS

### *College and Career Readiness Anchor Standards for Reading (K-12)*

Reading 1: Read closely to determine what the text says explicitly and to make logical inferences from it; cite specific textual evidence when writing or speaking to support conclusions drawn from the text.

Integration of Knowledge and Ideas 7: Integrate and evaluate content presented in diverse media and formats, including visually and quantitatively, as well as in words.

Integration of Knowledge and Ideas 8: Delineate and evaluate the argument and specific claims in a text, including the validity of the reasoning as well as the relevance and sufficiency of the evidence.

### *College and Career Readiness Anchor Standards for Writing (K-12) (Extension Activities only)*

Text Types and Purposes 2: Write informative/explanatory texts to examine and convey complex ideas and information clearly and accurately through the effective selection, organization, and analysis of content.

Production and Distribution of Writing 4: Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.

Research to Build and Present Knowledge 7: Conduct short as well as more sustained research projects based on focused questions, demonstrating understanding of the subject under investigation.



### *College and Career Readiness Anchor Standards for Language (K-12)*

Language 1: Demonstrate command of the conventions of standard English grammar and usage when writing or speaking.

### *College and Career Readiness Anchor Standards for Speaking and Listening (K-12)*

Comprehension & Collaboration 1: Prepare for and participate effectively in a range of conversations and collaborations with diverse partners, building on others' ideas and expressing their own clearly and persuasively.

Comprehension & Collaboration 2: Integrate and evaluate information presented in diverse media and formats, including visually, quantitatively, and orally.

Presentation of Knowledge 4: Present information, findings, and supporting evidence such that listeners can follow the line of reasoning and the organization, development, and style are appropriate to task, purpose, and audience.

## **NATIONAL CURRICULUM STANDARDS FOR SOCIAL STUDIES – NATIONAL COUNCIL FOR THE SOCIAL STUDIES (NCSS)**

Theme 1: Culture

Theme 3: People, Place, and Environments

Theme 5: Individuals, Groups, and Institutions

Theme 7: Production, Distributions, and Consumption

Theme 8: Science, Technology, and Society

## **NATIONAL STANDARDS FOR MUSIC EDUCATION – NATIONAL ASSOCIATION FOR MUSIC EDUCATION (NAFME)**

### *Core Music Standard: Responding*

Interpret: Support interpretations of musical works that reflect creators' and/or performers' expressive intent.

Evaluate: Support evaluations of musical works and performances based on analysis, interpretation, and established criteria.

### *Core Music Standard: Connecting*

Connecting 11: Relate musical ideas and works to varied contexts and daily life to deepen understanding.



## RESOURCES

### VIDEO RESOURCES

- Building Your Own Loudspeaker
- *Long Strange Trip* - "The Wall of Sound"

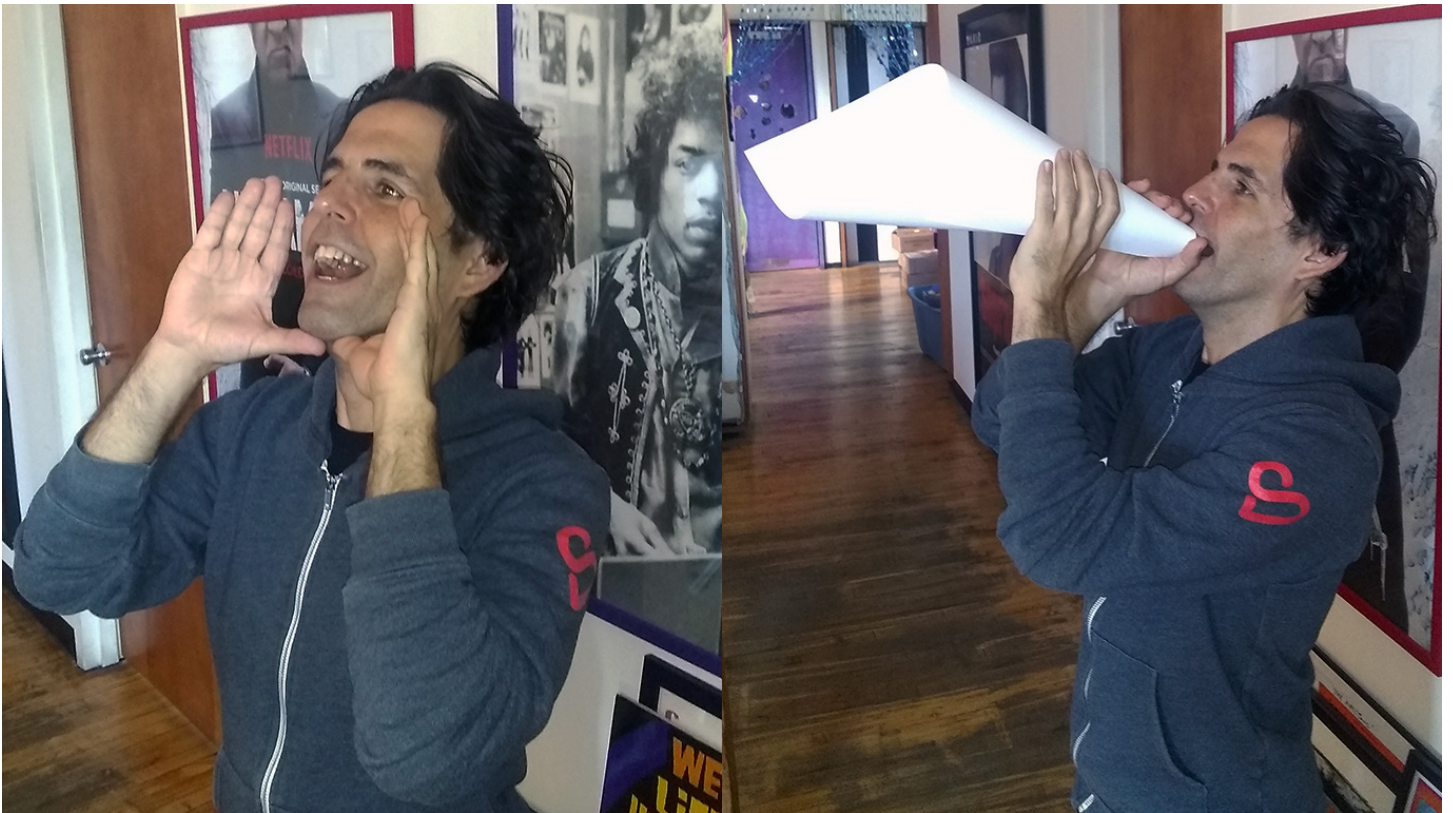
### HANDOUTS

- Handout 1 - Loudspeaker Basket Comparison
- Handout 2 - Sound System Company Profile
- Handout 3 - Your School's PA System(s)

# Lesson Materials



## Image 1, Acoustic Voice Projection Techniques



## Image 2, Sound Definition

### **SOUND**

Vibrations that travel through the air or another medium and can be perceived by the ear.

### Image 3, PA System Definition

## **Public Address (PA) System**

An electronic sound system comprising sound sources, amplifiers, loudspeakers, and related equipment. The system increases the loudness of the sound source and projects it over a large area.

## Image 4, Tech Sheet

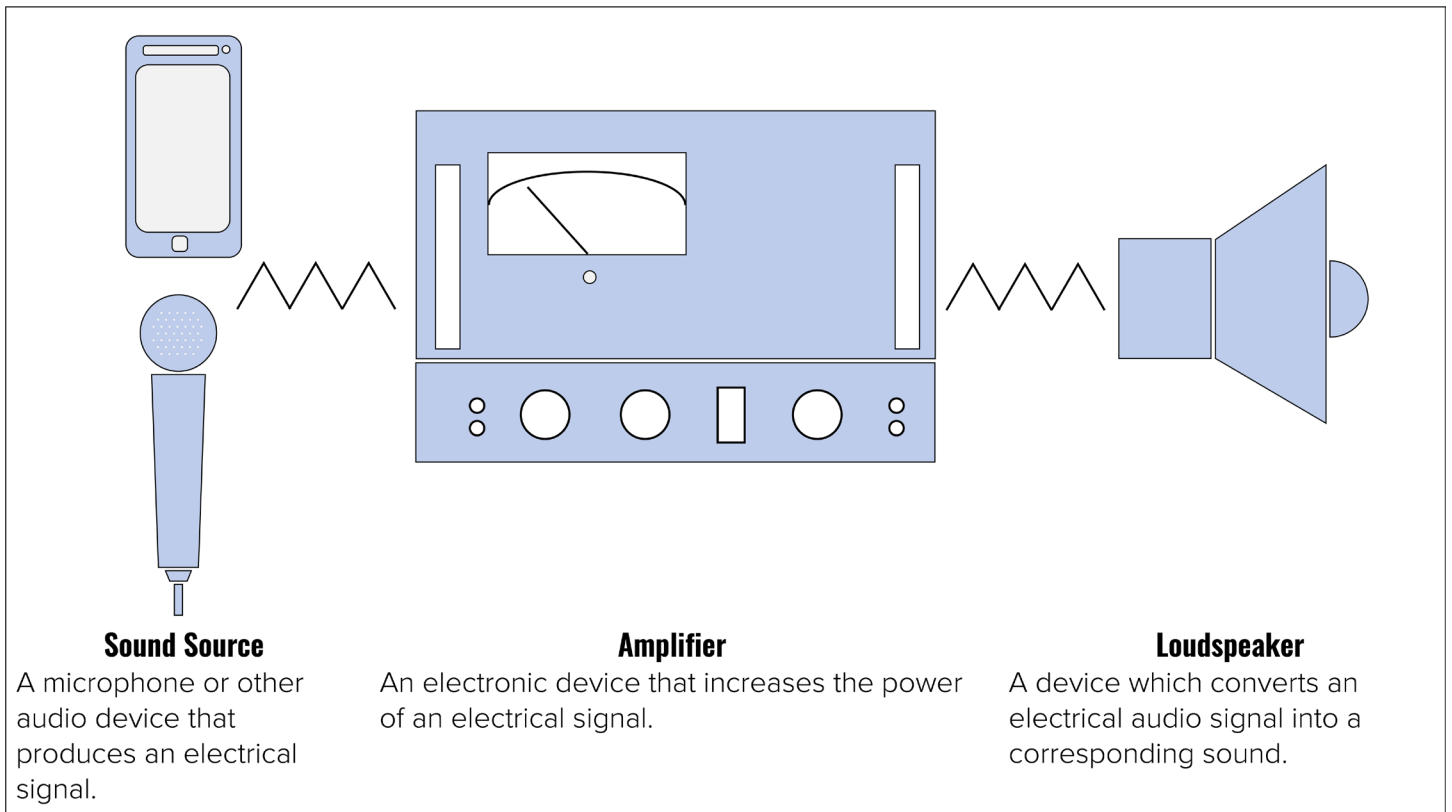
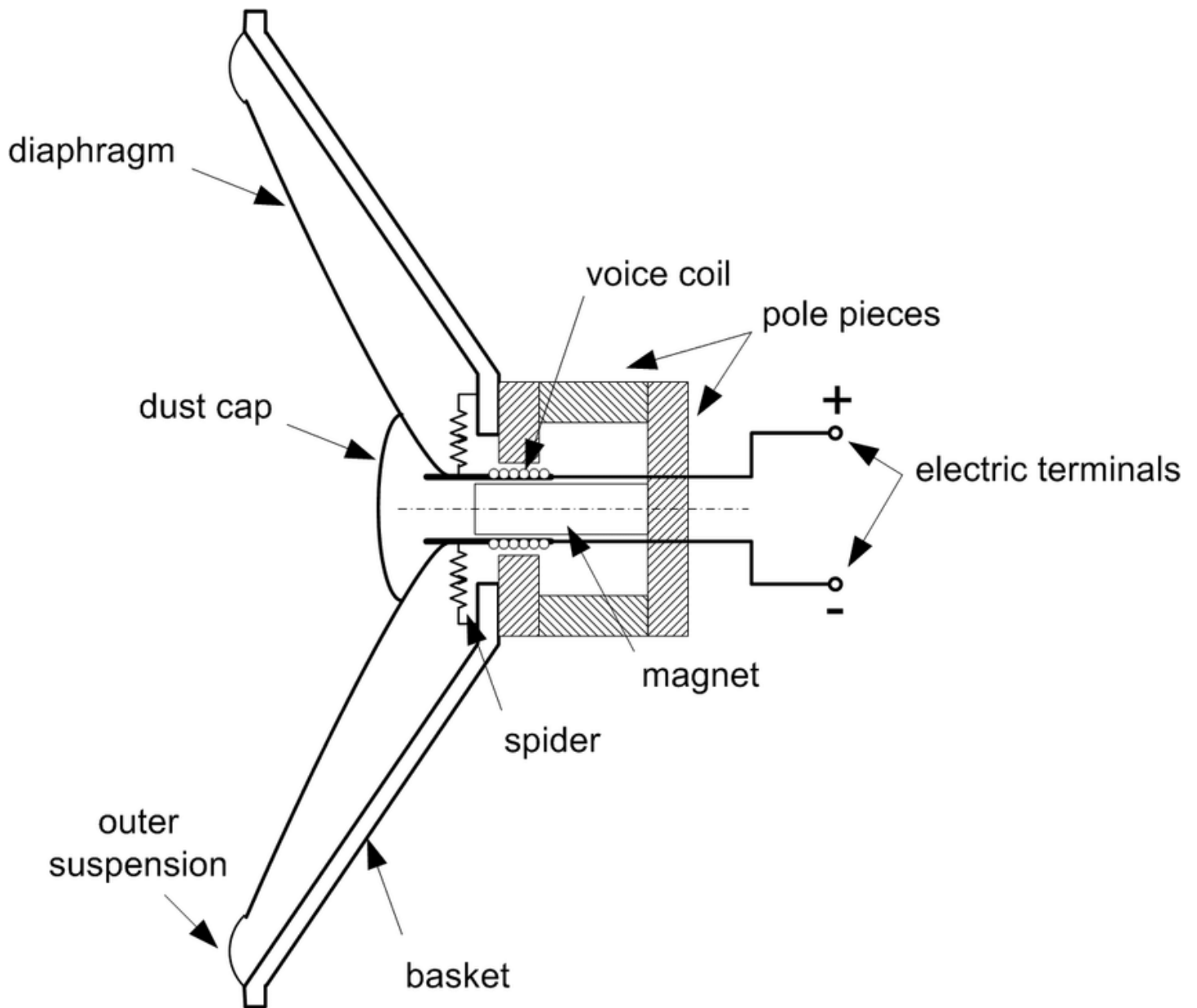




Image 5, Loudspeaker Schematic



## Handout 1 - Loudspeaker Basket Comparison

Basket Material	Observations
Paper cup	Quiet, hollow, muffled



## Handout 2 - Sound System Company Profile

*Create your own sound system company by brainstorming the questions below as a group:*

1. What is the name of your company?
2. Choose the type of space that your company provides sound system services. Options might include sound systems for schools, government buildings, churches, concert halls, homes, sports arenas, and so on. How would you cater your product to this type of space?
3. Create a slogan that you think will help attract business for your company, keeping in mind the type of space you are providing sound services for. Why did you choose this slogan?
4. Below, provide a sketch of your company's logo. Make sure that it reflects the services you provide and the slogan you've created to attract business.



## Handout 3 - Your School's PA System(s)

*Visit and learn more about a PA system in your school by answering the following questions:*

1. What brand is the system? Do you recognize the brand? Would you consider it a commonly known brand?
  
  
  
  
  
  
  
  
  
  
2. How old is the system?
  
  
  
  
  
  
  
  
  
  
3. What staff members, faculty, or students use the system in the school? Were they trained to operate it?
  
  
  
  
  
  
  
  
  
  
4. What is the system primarily used for at the school?
  
  
  
  
  
  
  
  
  
  
5. Can you find all of the system's components that you learned about in the lesson? (Microphone, Amplifier, Loudspeaker[s])