LEMELSON-MIT
JV InvenTeams

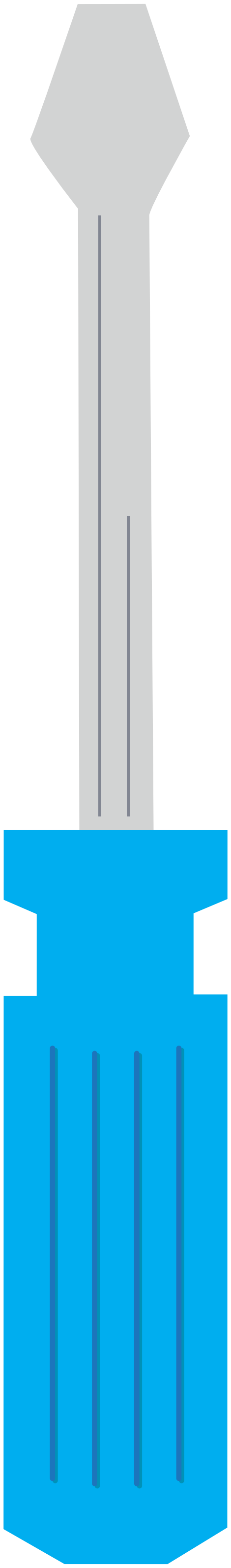
EDUCATOR GUIDE

ACTIVITY OVERVIEW

MEETINGS

APPENDIX

INTRODUCTION TO JV INVENTEAMS



Welcome to JV InvenTeams, where students develop skills in science, technology, engineering, and math (STEM) through fun, invention-based design activities and challenges.

About Lemelson-MIT

The Lemelson-MIT Program (**https://lemelson.mit.edu**) is dedicated to honoring those who have helped improve our lives through invention. The Program was established in 1994 at the Massachusetts Institute of Technology (MIT), by one of the world's most prolific inventors, Jerome Lemelson (1923 -1997), and his wife, Dorothy. It is funded by The Lemelson Foundation and administered by MIT's School of Engineering. The Lemelson-MIT Program recognizes outstanding inventors, encourages sustainable new solutions to real-world problems, and enables and inspires young people to pursue creative lives and careers through invention.

The Lemelson-MIT Program encourages great inventors through various outreach programs such as InvenTeams (**https://lemelson.mit.edu/inventeams**), a national grants initiative for inventive high school students who have a strong foundation in scientific and technical skills. InvenTeams are teams of high school students, teachers, and mentors that receive grants of up to $10,000 to invent technological solutions to real-world problems. The Lemelson-MIT Program developed JV InvenTeams in order to reach slightly younger students and provide them an introduction to inventive thinking and doing.

About JV InvenTeams

The goal of JV InvenTeams is to cultivate new ways of thinking and develop technical skills for students with limited access to hands-on STEM enrichment opportunities. Through prescribed activities, students will add to their own "toolkits" of minds-on knowledge and hands-on skills while having fun!

Students will learn how to identify a need in their lives or in the world around them and develop their own invention after completing the main activity in each unit. They will pull from their expanding toolkit to come up with solutions.

JV InvenTeams Activity Guide Components

Each unit of JV InvenTeams activities is presented in the same format. The Educator Guide includes specific notes and segments, while the student version is more streamlined and includes working space for the students. The educator may decide how much of the information should be shared with the students and in what manner—e.g., read out loud or read individually. Each meeting within the unit is estimated to take between 1.5 and 2 hours to complete.

Each group of young people will be different, so the pace of each unit is up to the educator. Know that there are numerous resources to balance the unit to meet your needs. Some may find that breaking meetings into a couple of sessions will allow the think-time needed for your group. Others may want to streamline items and skip some of the videos.

INVENTOR'S TOOLKIT

HANDS-ON

- General shop safety

MINDS-ON

- Biomechanics
- Biomimicry

Each unit has the following in the first pages:

- Title page with summary of the unit and learning objectives
- Summary of each meeting within the unit
- Master consumable materials and tools lists

Each meeting within the unit includes the following:

- "Toolkit" of hands-on and minds-on skills to be learned
- List of tools and materials
- Agenda
- Key terms
- Safety message(s)
- Video clips
- Instructions with step-by-step procedural notes
- Pop-outs that include any of the following: Historical Connections, Inventor and Invention Spotlights, Related Patents, Extend the Learning, High School Connections and College Connections
- Student Self-Assessments that serve as exit slips
- Indicators of a successful meeting

KEY TERM(S)

Insole (n): The fixed inner layer of a shoe.

Isometric Drawing (n): Visually representing a 3D object in two dimensions on paper.

SAFETY

Wear protective gloves and safety glasses for this activity. Avoid breathing in the release agent spray. Use it in a well ventilated room or outdoors.

INVENTOR SPOTLIGHT

In 1902, mechanical engineer Willis Carrier patented the air conditioner, a device he originally invented to solve a problem facing a paper printing plant in Brooklyn, New York. Read more about his invention—and how the invention of air conditioning helped expand Southern cities such as Houston and Atlanta.

Students may ask, “Why should I invent?” Here are some of the reasons you can share during the first meeting. Invention…

- solves world problems;
- helps people;
- allows people to explore a creative process that often involves teamwork;
- provides fulfilling careers: inventors are often scientists and engineers who improve areas of health, energy, food and transportation;
- can also lead to a high-paying career with many job opportunities as an engineer or scientist; and
- is fun!

Group Size

JV InvenTeams is recommended for approximately 20 students in Grades 7-10. Most activities require students to work in teams of four.

Partnerships

The Lemelson-MIT Program encourages participating schools to seek community partnerships to sustain JV InvenTeams. Partnership opportunities include:

- Science and technology museums, to provide direct mentoring;
- Local technology and engineering companies, to provide funding for future extension ideas, materials, or mentors;
- Local universities or colleges, to provide collegiate mentors; and
- Hardware stores, to provide tools or materials.

Flexibility

The JV InvenTeams has built flexibility into the program to meet the needs of educators, school systems, and grants-based clubs and organizations. Following are some examples:

- Each unit is designed to stand on its own. Educators can lead one unit, a few units, or all of the units.
- The program can be held in any educational setting with a science or technology educator facilitating the activities.
- Each unit has approximately 6 meetings of 1.5–2 hours duration.
- Meetings can take place multiple times a week or once a week.

Inventive Thinking

Both educators and students will develop an understanding of the invention process as you navigate through JV InvenTeams. This new way of thinking, part of the minds-on toolkit, may take some time to adopt since learning within the school day increasingly focuses on standardized tests of academic knowledge.

Invention is a variable, non-linear process. JV InvenTeams introduces the curiosity and creativity of recognizing problems and addressing them with novel solutions. You will not need to worry about knowing the "right" answer since there are countless possibilities. Experiencing failure is part of the invention process.

Inventing is creating something new that is useful or helpful, by means of one's own investigation, experimentation, and thinking. An invention is the product of the inventing process. It can be a device, a material, a system, and even a plant. Invention refers to a new physical thing made possible by technology. Inventive thinking challenges what people come to expect or anticipate. Revolutionary inventions, known as macro- inventions, make a huge impact on the way we live. Examples include the internal-combustion engine for the automobile and the integrated circuit for consumer electronics. Most inventions are micro-inventions, or adaptations that grow from larger-scale inventions. This means making an existing product faster, stronger, cheaper, easier, safer, more efficient, or more useful.

User-Centric

The key to inventing is to make sure the invention is user-centric. This means that students need to think about and understand problems affecting real people and their specific needs. Researching the unique characteristics and needs of the user is essential to coming up with an effective design – as is working directly with them! Students will develop empathy for the beneficiary during the process.

An example of this would be a student noticing that his or her grandmother has difficulty moving around the house in her slippers, due to slippery floors.

The student should investigate by first asking his or her grandmother:

- Do you wish your slippers had a better grip?
- What parts of the slipper do you like? What parts would you change? Why?

After learning from the user, the student can further investigate. Questions he or she might ask include the following:

- Does the solution lie in changing the floors or the footwear?
- How can I change her slippers to make the grip better?
- Is there another product on the market that provides the ease and comfort of slippers with the safety features of shoes with more grip?

These questions will inform research and allow the student to develop meaningful solutions.

Deciding on a Good Problem to Solve

Identifying a good problem to solve can be challenging, but it is just like any other skill: it becomes easier with practice. Therefore, at the beginning of each unit in JV InvenTeams, students will be given a problem or scenario that requires devising an original solution. Coming up with solutions to problems can be difficult at first, but students will gain confidence in generating new ideas over time. One way to accomplish this is through transgressive thinking – applying flexible or "out of the box" thinking in one area to another. The SCAMPER technique is a good technique to start with because it provides a framework to come up with solutions.

Scamper

The SCAMPER brainstorming technique was developed by Bob Eberle and published in a book by the same title. SCAMPER is based on the notion that something new can be modified from something that already exists. Each letter in the acronym represents a different way you can mentally view the characteristics of the challenge. It's a "mash-up" of disparate things to conceive something new.

S = **Substitute** *(playing basketball with a softball)*

C = **Combine** *(toothbrush combined with a pencil to create a new product)*

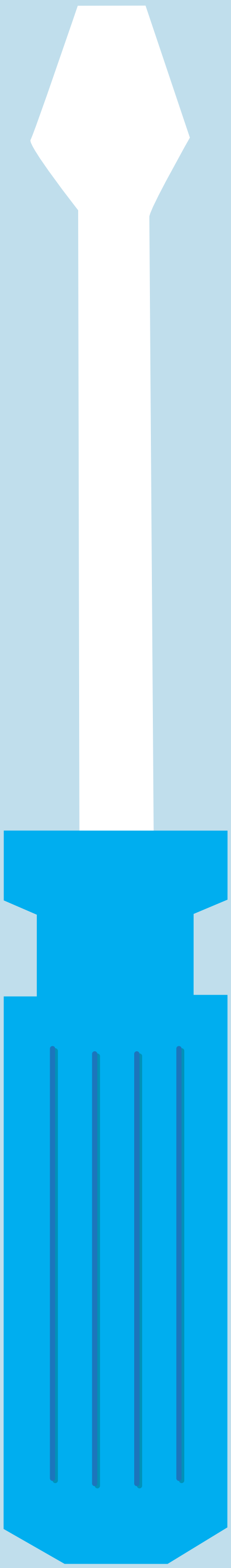
A = **Adapt** *(how would you eat your spaghetti without a utensil?)*

M = **Magnify** *(how would your chair function if its legs were wider and longer?)*

P = **Put to Other Uses** *(could your fork be used as a comb?)*

E = **Eliminate** *(could you play tennis without a racket?)*

R = **Rearrange** *(what if the laces of a shoe were placed on the bottom and not the top?)*



The SCAMPER technique involves the students first stating the problem they would like to solve, which defines the challenge. Then it's a matter of asking questions, using SCAMPER to guide the students. No idea is a "good" or "bad" idea at this point. There can certainly be good ideas!

Documentation

Students should be encouraged to document their progress along the way. This includes saving sketches, designs, research data, graphs, images, and early prototypes. Most of this work, with the exception of the actual prototypes, can be compiled in the Student Guides. Students should routinely review their guide, adapting what they have learned and experienced to new challenges.

Patents

Since this program is all about invention, it is important that educators and students familiarize themselves with the United States laws that protect the intellectual property of inventors.

A patent is one type of intellectual property that can be legally protected through the U.S. Patent and Trademark Office (USPTO). The other types of intellectual property are trademarks and copyrights. A trademark includes any word, name, or symbol used to distinguish one manufacturer from another (e.g., brand name). Copyrights are recorded with the U.S. Copyright Office in the Library of Congress for original authored works like books and music.

According to the U.S. Patent and Trademark Office, patents provide legal protection to inventors' intellectual property by excluding others from profiting from their property in the U.S. for a specific amount of time, in exchange for the inventors' disclosure of their idea according to the criteria for granting a patent. There are three different types of patents. Utility patents are granted to inventors who discover a new and useful process, machine, article of manufacture, or a new and useful improvement. Design patents are granted to those who invent a new, original, and ornamental design for an article of manufacture. Finally, a plant patent is granted to an inventor who invents a new variety of plant. The basic components of a U.S. patent are: patent number, title, inventors, assignee (optional transfer of intellectual property to a company or other individual), abstract (short overview of invention), drawings, description (technical details), and claims (legal information). To learn more about the patent process, visit: **http://www.uspto.gov/.**

Students will be required to search patents to ensure that their idea is unique. Patent searches can be done through Google Patents and Free Patents Online. Both have easier search functions than the U.S. Patent and Trademark Office.

Jerome Lemelson, founder of The Lemelson Foundation, had a productive life as an inventor, holding more than 600 patents. He was awarded his first patent in 1953 for a toy cap, and spent the next 45 years coming up with inventions that led to products such as bar code readers, automatic teller machines, cordless phones, cassette players, fax machines, machine vision and personal computers.

It is important to keep in mind that not all inventions are patented. Some inventors purposefully do not seek a patent with the idea that their inventions are immediately and widely available. An example is open source software, which allows anyone to use the software without paying a fee.

This openness can spur further invention since anyone can access it and make adaptations. In spite of the changes in patent law through the Innovation Act of 2013, students should adopt the habit of recording and dating their work, including early sketches and research. This practice will be useful for future science exploration and invention. To learn more, visit: **https://govtrack.us/congress/bills/113/hr3309**.

UNIT SUMMARY

Students will explore sound, speakers, instruments, and electric pickups in this unit. They will build and understand how a speaker and an electric pickup work. They will think about how to use their knowledge of sound to create purposeful and useful inventions.

Through readings and hands-on experimentation, students will understand the basics of sound waves, electromagnetism, and how a speaker functions. Students will continue to explore sound creation and, through the iterative process, continue to improve both their products and their understanding.

Students will also explore ideas of motion by building and exploring a musical instrument made from everyday materials. They will focus on three questions: What is vibrating? How can the user adjust the vibrations? How does the choice of material affect the sound?

Students will have the opportunity in the final meetings of the unit to design and build their own electric instruments. Students will also work in groups to conceptualize an invention related to their understanding of sound, speakers, instruments, and electromagnets.

MEETING SYNOPSES

1 Invention Introduction

Students are introduced to invention and JV InvenTeams. Students complete warm-up activities and discuss invention. Students play “Four Corners” to determine their strengths for team assignments.

2 Hearing Sound

Students brainstorm how they think sound works and are introduced to the basics of sound and human hearing. Students dissect earbuds to find and identify components of a speaker. Students are introduced to speakers and electromagnetism and build their own electromagnet to examine its properties.

3 Build a Paper Speaker

Students use their understanding of speakers to build a paper plate speaker. They then work in groups to refine their speaker according to a goal they select.

4 Making a Sound

Students are introduced to the human larynx and how we make sound through speech. Students apply their knowledge of sound production as they design and build a musical instrument out of everyday materials.

5 Build an Electric Instrument

Students are introduced to electric instruments using the diddley bow as an example. Students build an electric pickup and design a musical instrument to electrify. Students build, test, and refine their electric instruments.

6 Invention Extension

Students display their images in printed form and provide feedback to other teams. Students conceptualize a new purposeful invention that uses lens design, optical principles, and the prototyping process.

FACILITATION TIPS

Word Wall

Consider using the Key Terms to construct a Word Wall. Use the Word Wall to help young inventors review what was covered in the previous session, reinforce concepts that may need some review, and reinforce the use of new words to promote vocabulary growth.

Idea Board

Consider creating an Idea Board out of poster board that serves as a repository for new ideas and questions. Students can post new invention ideas here, which can be referenced for the development of their inventions at the end of the unit.

Teamwork

Students will be working in teams throughout this program. Consider inviting a coach from one of your school's sports programs to talk about how important teamwork is on and off the field.

Facilitating Redesign

Teams test their first lens prototypes and think about ways to improve them. You may find that your students would like to design a second prototype and test again. If you have the time and resources to facilitate a second round of designing and testing, follow these tips to help you engage your students in engineering practices as they work:

<u>Encourage students to improve only what needs to be improved</u>. It is a natural impulse to want to throw away an entire design idea because one element of it needs improvement. Encourage students to think hard about what elements of their design work well and what elements do not. Help them narrow their focus so they are truly improving specific elements of their original design, as opposed to starting from scratch.

<u>Have students link their improvement ideas to particular results from their first test and from peer feedback they received</u>. Make sure students use evidence from their test results and specific ideas from peers to justify each improvement. This helps students stay grounded in their actual design.

<u>Encourage students to learn from the work of others before implementing improvements</u>. Engineers and inventors always learn from the work other people have done! Have students do some more research on lenses before deciding on their improvements. Encourage students to link their improvement ideas to specific information they learned in their research.

Have students predict how their results might change based on the improvements they made before testing. Students will likely have lots of ideas about how their second prototype will perform, as compared to their first prototype. Allow students to explain what they think will happen and why. Encourage students to apply their understanding of lens properties and focal length to the design process.

Have students reflect on the strengths and weaknesses of their second prototype after testing. Encourage students to identify what worked well and what did not in their second design. Have students brainstorm further improvements and justify their ideas with evidence from their previous tests. Tell students that inventors often repeat this process of prototyping and testing many, many times before releasing a final design!

JV INVENTEAMS SELF-ASSESSMENT: ELECTRONIC TEXTILES

Inventors need to be confident and know their own strengths and weaknesses. Use this table to think about how likely you are to complete these skills with confidence. Check the response that best describes your confidence right now.

I CAN...	PROBABLY	MAYBE WITH HELP	PROBABLY NOT
use tools like saws, hammers, and soldering irons safely.			
make something useful out of material like cardboard, wood, or fabric.			
work as part of a team.			
apply my understanding of electromagnetism to build a speaker.			
build an electric pickup and a musical instrument.			
identify a real-world problem to solve.			
apply my skills to solve a real-world problem.			

TODAY

Which skill was the most challenging?

____

Which skill was the most enjoyable?

____

IN THE FUTURE

What will YOU invent?

____

How is it unique?

____

How is it useful?

____

PROBLEM STRIPS (INVENTION INTRODUCTION)

Copy and cut out these Problem Strips prior to leading the Invention Introduction with students.

You want to eat soup but you don't have a spoon.
You need to walk across a hot concrete parking lot after going to the beach, but you don't have any shoes.
You hit a baseball over a barbed-wire fence and need to get it back.
A fly is buzzing in your room and the noise it makes is bothering you.
You lost an item under your heavy dresser and want to get it back.

JV INVENTEAMS
GENERAL SHOP SAFETY RULES

Discussing shop safety helps set the tone to introduce inventing with electronics in the classroom. It introduces safe practices and helps students understand why these practices are used. Asking your students to help develop the rules may help with the ownership and understanding of the lab safety rules. You may also choose to set the rules. Either way, make sure students understand these rules and why they are necessary. You may ask students to create posters for display in the room throughout the year to emphasize safety and remind students of the specific safety rules. Keep these safety rules posted throughout the unit.

SAFETY

1. **Wear safety glasses.**
2. **If you are in doubt about how to use a tool, ask!**
3. **Have a plan for what you are going to do with the tool.**
4. **Be mindful of others who might enter into your workspace accidentally.**
5. **Secure the workpiece.**
6. **Have a balanced stance while using a tool.**
7. **Remove all jewelry, watches, and loose clothing before working with machinery.**
8. **Pin up long hair and wear closed-toe footwear.**
9. **Never work when you are tired or unfocused.**
10. **Leave the workspace cleaner than you found it.**

NOISE MAKERS
MEETING 1: INVENTION INTRODUCTION

KEY TERMS

Engineering (n): Using science and technology to design and improve objects and systems to solve a problem or meet a need.

Invention (n): A unique and useful device or process.

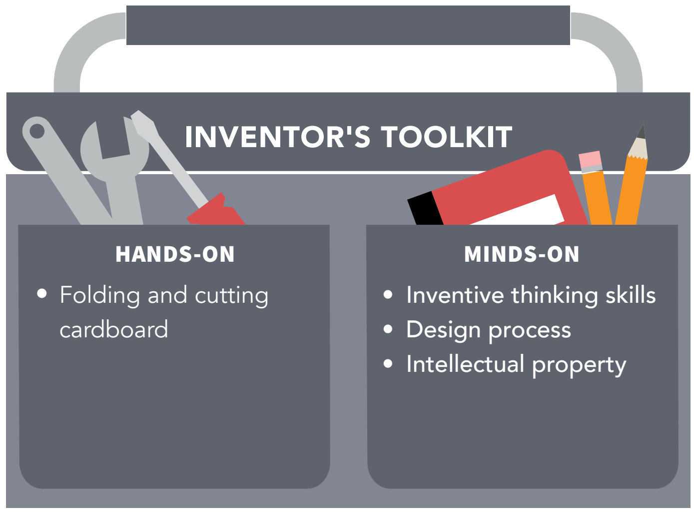
Iteration (n): A version of a design in a series of designs.

Modification (n): The act of making small or partial changes.

Patent (n): An intellectual property right issued by the U.S. **Patent** and Trademark Office, excluding others from making or selling the **invention** in the U.S. for a specified period of time in exchange for disclosing the **invention**.

PhD (n): A postgraduate academic degree awarded by universities.

Prototype (n): A model of something built to test a concept. Many **iterations** are created before the final design is determined.



Tools & Electronics

- Writing utensils
- Utility knives or sharp scissors
- Projector and computer to show video

Materials & Shop Supplies

- Student guide
- Shipping tape
- Cardstock
- Cardboard and scrap materials from the recycling bin
- Problem strips
- Self-Assessment

Procedure

- Distribute Guides and Introduce JV InvenTeams
- Introduction to **Invention** and Problem Solving
- Design a Cell Phone Stand
- Watch Some **Invention** Videos
- Research an **Invention**
- Discuss Improvements to an **Invention**
- Investigate Real-World Improvements
- Watch Videos about the Design Process
- Set Rules and Develop Teams
- Self-Assessment

MEETING 1

DISTRIBUTE GUIDES AND INTRODUCE JV INVENTEAMS

1. Let students know that today they will learn about the basics of **invention**. Get everyone thinking about **invention** by asking:
   - How would you define "**invention**?"
   - Why do you think people invent things?
2. Distribute one JV InvenTeams guide to each student. Tell students that their **invention** guides will be a portfolio of their work. Explain that the grid paper and blank paper at the end of each meeting can be used to sketch, brainstorm, and document ideas.
3. Explain that items written in **bold underline** represent links to be clicked.

INTRODUCTION TO INVENTION AND PROBLEM SOLVING

1. Tell students that we all run into challenges on a daily basis. They will now get a taste of what being an inventor means by coming up with ideas to address some of these problems.
2. Divide the class into teams of 3 or 4 and give each team one of the Problem Strips you prepared.

Early prototypes of the Polaroid camera from the MIT Museum collection

3. Have teams devise a quick **invention** that solves their problem by using materials from the recycle bin.
4. Bring everyone back together and have teams take turns sharing their solutions. To facilitate sharing, students can ask the following:
   - What else would you do if you had more time?
   - What would you add or change if you had more expensive supplies?
5. Explain that inventors often use inexpensive, everyday materials to create **prototypes** of their **inventions**. That's because they don't want to waste expensive materials in the early stages of designing. Failure and mistakes are common and part of the process.

EDUCATOR NOTE

Consider constructing a Word Wall with these Key Terms to help young inventors review what was covered in the previous session, reinforce concepts that may need some review, and reinforce the use of new words to promote vocabulary growth.

EDUCATOR NOTE

The cell phone activity could take even longer if students get invested. Consider breaking this meeting into two sessions if you want to take your time.

Hands-On and Minds-On

MIT's motto is Mens et Manus, which translates to Mind and Hand. Inventors are resourceful and use many tools. Some "tools" are based on learned knowledge stored in our minds from science and math classes. Other "tools" are practiced – hands-on skills like drawing and building things.

EDUCATOR NOTE

After Cell Phone Stand

It is beneficial for students to conduct some peer evaluation if you have extra time. Have students leave their finished cell phone holders on their table tops. Leave a blank piece of paper and pen next to each stand. Students can walk around the room and anonymously leave some constructive feedback. A few students can share their feedback and explain how they would improve their project.

DESIGN A CELL PHONE STAND

1. Ask students if they ever get annoyed by phones not being able to stand up on their own. Explain that inventors think outside of the box and often create **prototypes** of their ideas using everyday materials.

2. Tell students that their challenge is to invent a low- cost cell phone stand using recycled materials like cardboard and tape.

3. Before students start, have them watch **Josh Ramos' Cardboard Videos** to learn some cardboard cutting tips and tricks. Josh earned his **PhD** in Mechanical **Engineering** from MIT in 2018.

4. If students are having difficulty coming up with their own design, they can check out **Josh Ramos' Cardboard Phone Stand.**

5. When finished, have students respond to the follow-up questions (below) in their guides.
   a. What do you like about the stand you made?
   b. How would you change your design if you wanted to watch a video in the landscape format (sideways)?
   c. Where are the speakers on your phone? How might you use the placement of the cardboard or other materials to improve the sound?

6. Have students share their design with another student.

7. Ask students how they would incorporate their peer's comments and their own in their next design? Tell them to describe this next design **iteration** in words or pictures in their Student Guide.

8. Tell students that during the JV InvenTeams initiative, they will learn about new tools and materials through **invention** activities like this one. They will think of **iterations** to improve or change their designs, after successfully meeting challenges these activities present.

Cellphone stand example

Students folding cardboard

WATCH SOME INVENTION VIDEOS

1. Explain that each year, teams of undergraduate and graduate students apply for the Lemelson-MIT Student Prize. Have students check out some cool videos from previous winners and finalists on the **Lemelson-MIT Program's** website.

- **Alice Chen's Inventions Make Our Lives Healthier** (2:27)
- **Ben Peters' Inventions Make Our Lives More Engaging** (1:57)
- **Eduardo Torrealba's Inventions Make Our Lives Easier** (first 9 min)

2. Explain that all good **inventions**, including the ones presented in these videos, stem from a real problem or need. Most **inventions** do not produce radical change in society, but rather build upon previous **inventions** to make aspects of life easier, safer, more comfortable, more engaging, and/or healthier.

PATENT PROFILE

MIT alumna Alison Wong invented **Keyprop**, a simple solution to the problem of keeping your smartphone propped up.

MEETING 1

EDUCATOR NOTE

After Videos: Debrief

Engage students in a discussion about the videos. Students should be asked to think and converse about the common themes, the inventors' approach, and why failure during the process is okay.

EDUCATOR NOTE

Extend the Learning

An additional resource that may inspire **invention** research is a video called **Extend the Learning: InvenTeens**. Produced by the Museum of Science in Boston.

EDUCATOR NOTE

Before Product Discussion

Ask students in small teams or as a class to devise a list of problems or things that don't work quite right in their daily lives. Give them a few examples to help them get started, such as a grandparent slips walking in socks, their laptop computer wires get tangled up, and they can't wake up to an alarm.

EDUCATOR NOTE

Before Real-World Examples

Explain to the students that **invention** follows a process of identifying needs, brainstorming ideas, sketching, building a **prototype**, testing, modifying, and re-testing. Potential users are consulted for feedback throughout the process.

RESEARCH AN INVENTION

1. Have students identify an object in the room. Ideas include a specific type of desk, piece of technology, chair, tool, writing utensil, or article of clothing.

2. Explain that we often take the daily products and tools in our world for granted. Each of these items has a history of evolution. Scientists, engineers, and designers made **modifications** over time that produced the modern product you see today.

3. Tell students that they will conduct research on **inventions** using **Google Patent Search**. Explain that Google **Patents** list U.S. **patents** as well as international **patents**. **Patents** are sequentially numbered; for example, search for "student desk" and look at the images for US7571959B2.

4. Give students a few minutes to conduct research on the product they identified.
   - How can this product continue to improve?
   - What information can you gather from the technical drawings?
   - Why are detailed images such an important part of a **patent**?

DISCUSS IMPROVEMENTS TO AN INVENTION

1. Tell students they will learn to carefully observe the world around them in search of problems that can be addressed with a technological solution.

2. Have students work in small groups to brainstorm how they could improve one product or process they use during a typical day. Students will respond to the following prompts in their guides:
   - How might you go about making the improvement? Describe your process.
   - What might be some challenges to meeting this need?
   - Thinking further, do you notice anyone in your family or community who struggles to complete a certain task? What **invention** might improve this aspect of their life?

INVESTIGATE REAL-WORLD IMPROVEMENTS

- **Sesame Ring**: Several MIT undergraduate students were having difficulty locating their reusable train tickets upon entering the train station. Their solution is a wearable reader in the form of a customizable ring.

- **Tile**: Do you ever have difficulty finding your keys or wallet in your home? The solution is a small piece of plastic with a chip that connects to an app on your smartphone.

- **uBeam**: Meredith Perry, a graduate of the University of Pennsylvania, was sick of long electrical wires for laptop computers. She started a company, uBeam, that is working on a wireless charger.

WATCH VIDEOS ABOUT THE DESIGN PROCESS

1. Have students watch the **MIT Design Process Videos**. The videos cover: Design Introduction, Observation, Brainstorming, Idea Selection, and Prototyping.

2. Give students time to outline the design process in their guides.

SET RULES AND DEVELOP TEAMS

1. Tell students that JV InvenTeams is all about hands-on fun. To make this possible, here are a few important rules to follow:

Allison Wong, Illustrator

   - Safety is the number one priority! Watch tutorial videos before using new tools and materials.
   - Ask for help. Don't guess, especially about how a tool works.
   - Consider all ideas. No idea is "dumb." As an inventor, focus on the ideas with the most potential when developing a **prototype**.
   - Embrace failure. Failure is a part of the **invention** process.
   - Value your team. Everyone brings different skill sets and knowledge to the table.

2. Explain that most of the projects require working in small teams. Diverse teams are successful teams.

3. Use the directions on the next page to play "Four Corners." This game will help you place students into diverse teams.

EXTEND THE LEARNING

You can continue exploring invention by researching well-known inventors in your community. How? Go to Free Patents Online. The login is free. Click on the SEARCH tab, then use the "Quick Search" feature to enter your location under "Inventor Fields." You may want to search chronologically by the last 20 years.

MEETING 1

EDUCATOR NOTE

After Design Process Videos

Ask a volunteer to recap the steps of the design process. Have them draw a visual outline to include on the Idea Board. Survey the students to see if they have any questions before proceeding.

Steps of the design process are:

- identifying needs,
- brainstorming ideas,
- sketching,
- building a **prototype**,
- testing,
- modifying, and
- re-testing.

EDUCATOR NOTE

Before Setting Rules

You can create a bold list of these rules to place on the Idea Board or somewhere else that is visible in the classroom.

SELF-ASSESSMENT

Collect the completed self-assessments as exit slips when students leave.

INDICATORS OF A SUCCESSFUL MEETING

Students can build a cardboard cell phone stand. They can demonstrate how to think like an inventor, and they understand how the design process works.

FOUR CORNERS GAME

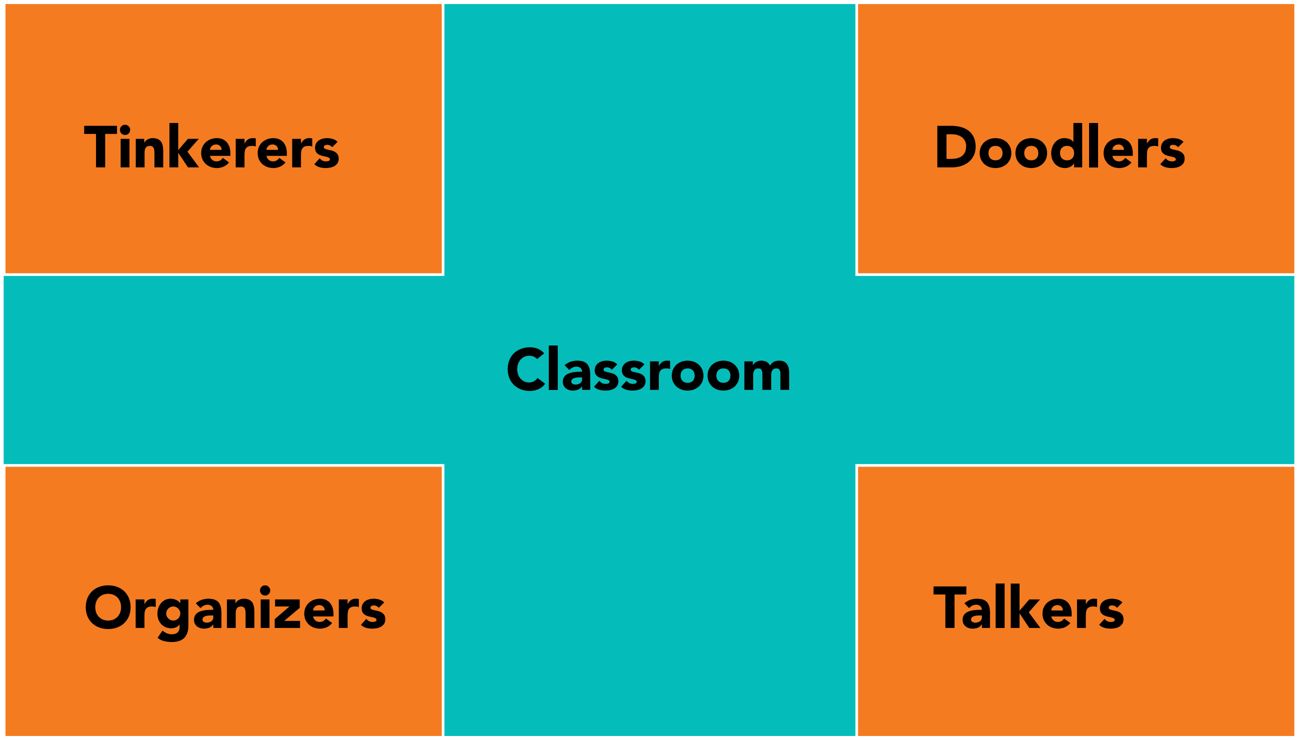
Teams of inventors include people with different interests and skills. Ask students to think about their own interests and skills to help you organize the class into diverse teams. Have students draw a line from each type of team member on the left to the best-matching description on the right.

The corners of your classroom will be marked with the four types of team members. Students will decide which corner best matches their interests and skills.

Ask students to go to their respective corners based on their "sounds most like me" description. The corners will have an equal number of students in an ideal world. If they don't, mention to the students that equal numbers are needed in order to make well-balanced teams. Have students in the larger group(s) look at their "sounds almost like me" description and compare with the corners needing students. Ask students to consider rearranging.

Types of Team Members	**Your Interests and Skills**
Tinkerer: I like to take things apart and build things.	Sounds most like me
Talker: I like to talk to people and I enjoy public speaking.	Sounds almost like me
Doodler: I like to draw things and express my thoughts through drawing.	Sounds a little like me
Organizer: I like to organize people and things.	Sounds least like me

Have students count off within their corners once each has a nearly equal number of students. Finally, have all 1s, 2s, 3s, and 4s come together to form their **invention** teams. Write down the names and teams in your notes. These teams will come into action when students start designing.



MY NOTES

NOISE MAKERS
MEETING 2: HEARING SOUND

KEY TERMS

Compass (n): A floating, magnetized needle that responds to the Earth's magnetic field to indicate direction for navigation.

Current (n): A flow of electric charge.

Cymatics (n): The study of sound waves and their visible representations.

Electromagnet (n): A soft iron or steel core surrounded by a coil of wire that temporarily becomes a magnet when an electric current flows through the wire.

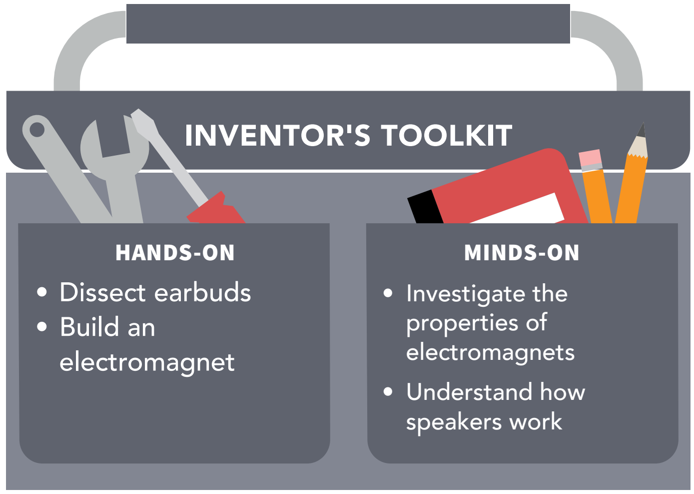
Frequency (n): The number of cycles of a sound wave in a given amount of time.

Iron (Fe) (n): A chemical element with the atomic number 26.

Magnet (n): A piece of material that is able to attract certain metals.

Polarity (n): The direction of a magnetic or electric field.

Resonance (n): The tendency of a system to vibrate strongly at particular frequencies.



Tools

Per Team

- Writing utensils
- Projector and computer to show video
- Device that plays music through a speaker
- Tweezers, pliers, and/or screwdrivers
- Magnifying glasses
- **Compass** (magnetic)

Materials

- Student Guides
- Rubber bands
- Earbuds
- 24 AWG **magnet** wire; red
- 3" nail
- Masking tape and electrical tape
- Paper clips
- 3 sheets of plain paper
- Sandpaper; 220 grit
- D cell batteries
- Pink erasers
- Self-Assessments

Procedure

- Introduction to Sound: Round-Robin and Readings
- Review Shop Safety
- Dissect Earbuds
- Introduction to Speakers and Electromagnetism
- Build an Electromagnet
- Self-Assessment

INTRODUCTION TO SOUND: ROUND-ROBIN

1. Let students know that today they will be learning how we hear sound. Tell students that they will use their knowledge of sound throughout the unit to design and refine musical instruments and sound amplification systems.

2. Tell students you are going to demonstrate three different sounds. Demonstrate the following sounds in front of the class:

- talking,
- plucking a stretched rubber band, and
- playing a song through a **speaker**.

3. Students, as they listen, should ask themselves: "What exactly is happening that allows me to hear this sound?"

4. Hang up three pieces of paper around the room. Label one "human voice," one "rubber band," and one "**speaker**."

5. Divide the class into three groups. Tell students they will have a few minutes to write or draw their ideas about how they think these sounds get from the object to their ear. They will write their ideas on the piece of paper. At the end of the round-robin, the entire class' ideas will be collected.

6. Once students are finished, have them respond to the prompt below in their guides:

- What do you still wonder about how sound works?

7. Students who finish early can start the reading on the next page.

MEETING 2

KEY TERMS (CONT'D)

Sound (waves) (n): Vibrations that travel through the air or another medium and can be heard when they reach a person's or animal's ear.

Speaker (n): A machine that converts electrical energy into movement producing sound.

Steel (n): A metal and modified form of iron.

Tympanic membrane (n): The part of the external ear that passes sound waves to the middle ear through vibrations.

Voice coil (n): The wire coil in a speaker that becomes an electromagnet when a current passes through it.

HIGH SCHOOL CONNECTION

The 2011 Berlin High School InvenTeam (Cherry Plain, New York) invented a device for the deaf and hearing impaired designed to alert the user to incoming traffic when participating in a sporting activity. The device uses an ultrasonic sensor designed to trigger a feedback device. Learn more: Alert Device

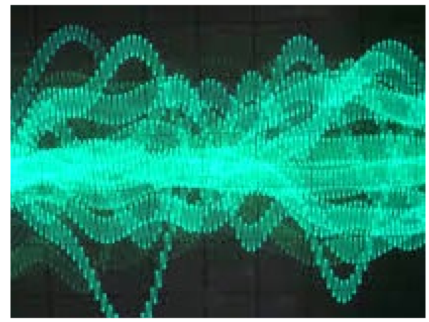
Credit: lemelson.mit.edu

INTRODUCTION TO SOUND: READING

How do we hear sounds? Why do we hear some sounds and not others? What is sound, anyway?

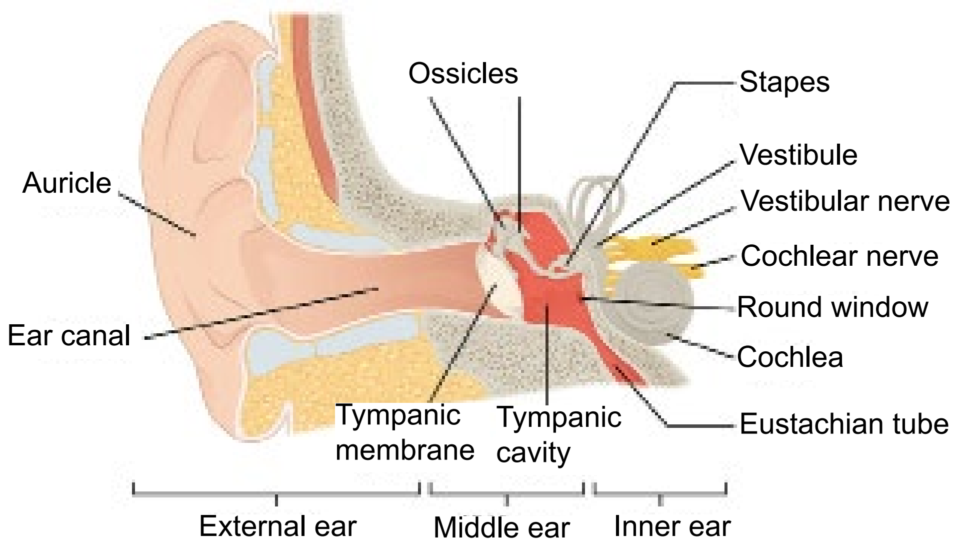
Sound starts as a motion that causes the particles around it to vibrate. These vibrations are called sound waves. Sound waves can travel through solids, liquids, and gases.

We hear sounds when sound waves enter our ears in the form of vibrations. These vibrations are then translated into electrochemical impulses that can be understood by our brain.



Credit: commons.wikimedia.org

Take a closer look at the anatomy of our ears. Notice that the ear is divided into three sections: the external ear, the middle ear, and the inner ear. Each of these sections plays a specific role in transforming sound waves into a form that our brain can understand.



Source: commons.wikimedia.org

Sound enters through the external ear, which is the part of the ear you are probably most familiar with, since you can see and feel it easily. The external ear focuses sound waves onto the **tympanic membrane**, also called the eardrum.

The **tympanic membrane** is connected to a series of three tiny bones called ossicles that lead to the inner ear. The vibrations travel to the inner ear through these bones when sound waves hit the **tympanic membrane**.

The inner ear is filled with liquid. Have you ever tried to listen to someone talking from land while you were underwater? Liquid resists sound waves passing through it more strongly than air does, which results in you hearing less of the original sound.

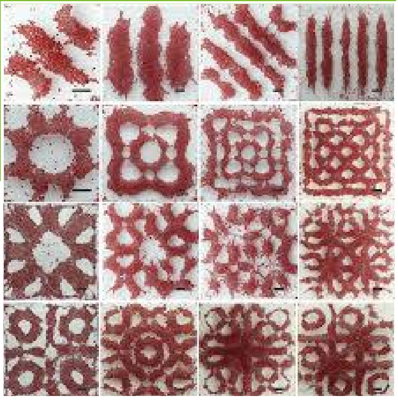
This does not happen in our ears, though. The ossicles act to accentuate the sound vibrations, enabling them to pass into the inner ear in a way that does not diminish the sound waves.

The cochlea, a bone in the inner ear, transforms sound vibrations into electrochemical impulses that are sent to the brain and recognized as hearing.

Watch **Do We Listen With Our Jaw Bones?** (4:10) to learn more about the role our bones play in hearing and how our hearing system may have evolved.

EXTEND THE LEARNING

Evan Grant makes sound waves visible in his TED talk: Making Sound Visible Through Cymatics (5:00). Watch this video to learn how scientists, linguists, educators, and artists are exploring cymatics as a way to understand and represent the world.



Source: commons.wikimedia.org

REVIEW SHOP SAFETY

1. Tell students that shop safety is of the utmost importance so that nobody gets hurt. They will be using hand tools such as utility knives. Tools should always be used in the way they were designed to be used. Have students watch a general **shop safety** video (10 min).

2. Review the general shop safety rules:

- Wear safety glasses.
- If you are in doubt about how to use a tool, ask!
- Have a plan for what you are going to do with the tool.
- Be mindful of others who might enter into your working space accidentally.
- Secure the workpiece.
- Have a balanced stance while using a tool.
- Remove all jewelry, watches, and loose clothing before working with machinery.
- Pin up long hair and wear closed-toe footwear.
- Never work when you are tired or not focused.
- Leave the workspace cleaner than you found it.

DISSECT EARBUDS

1. **Sound waves** are vibrations. We cause something to vibrate every time we make a sound.

2. Revisit the three pieces of paper students made as a class. Have students identify possible sources of vibration in the examples of the human voice, rubber band, and speaker. You may want to demonstrate making sound with the rubber band again so students can see how it vibrates.

3. Tell students that they will look more closely at the vibrations that cause human speech later. Today's goal is to begin to understand how our electronic devices, like speakers, make sound.

4. Ask students, "How do you think electricity is transformed into mechanical vibrations (**sound waves**)?"

Source: en.wikipedia.org

5. Students will look specifically at earbuds. Just as they looked at the anatomy of the ear to better understand hearing, they will look at the "anatomy" of an earbud to better understand making sound.

6. Divide the class into pairs for the earbud dissection. Distribute a set of earbuds to each pair and point out the tweezers, pliers, and/or screwdrivers students can use as tools.

Tell students they should work together to dissect the earbud and make a detailed drawing or written observation of what they find. They can tape the parts to pieces of paper and use a magnifying glass to inspect them. Visit Earbud Anatomy to find a useful image.

7. Guide students to reflect on the following questions:

- What parts did you find in your earbud?
- What part do you think vibrates to create **sound waves**? Why?
- Why do you think there are batteries in earbuds?

MEETING 2

INVENTION SPOTLIGHT

The latest in earbud evolution is the wireless earbud, first introduced in 2016 with Apple's AirPods. Wireless earbuds allow more freedom and comfort without wires pulling on your ears. They are stored in a compact, chargeable container. You can wear one earbud at a time, providing more opportunity to connect with your outside surroundings. Read more about this listening innovation here: Earbuds

Source: Wiki Commons

The modern speaker was developed in the 1920s using a magnetic field to move a coil. However, horns were the earliest form of amplification and did not require electricity. The first voice radios used the horn, but they were quickly replaced by the electrodynamic loudspeaker. Learn more about speaker history and the inventors who paved the way by visiting: Loudspeakers

HISTORY

Credit: lemelson.mit.edu

HIGH SCHOOL CONNECTION

The 2019 Valley STEM + ME2 Academy InvenTeam from Canfield, Ohio invented a danger alert system for schools. The system places microphones in classrooms to detect and locate gunshots. When a gunshot is detected, nearby classroom doors are shut and an electromagnetic lock is activated to keep people in the classroom safe. Red, green, and yellow lights are located in the hallway above each classroom to demonstrate the current threat level based on the closeness to the gunshot. Learn more here: [InvenTeam]

INTRODUCTION TO SPEAKERS AND ELECTROMAGNETISM

1. Check that all students found a **permanent magnet** and a wire coil (called a **voice coil**) in their earbuds.

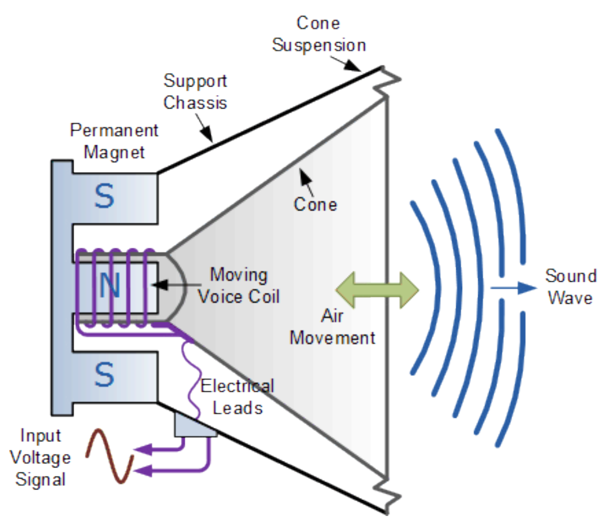
2. Explain that these components make up a miniature **speaker**. **Speakers** are machines that transform electric audio signals into sound.

3. Tell students that the **magnet** inside the speaker has an invisible magnetic field around it. It can attract or repel other **magnets**.

4. Explain that when electric **current** flows through the **voice coil**, a different magnetic field is created. This is called an **electromagnet**. An **electromagnet** can also attract and repel other **magnets**, but unlike a permanent **magnet**, **electromagnets** can be “turned off” by stopping the flow of electric current through the **voice coil**.

5. Tell students that when the **voice coil** becomes magnetized, it will interact with the permanent **magnet** by pushing or pulling against it. When you change the direction of the current moving through the **voice coil**, you change its **polarity**: a push becomes a pull, and a pull becomes a push. This motion of the **electromagnet** pushing and pulling generates sound vibrations in a speaker.

6. Play **Speakers:** [**Magnetism and Sound**] (stop at 2:20) to see how speakers work using **electromagnets**.



Source: www.electronics-tutorials.ws

BUILD AN ELECTROMAGNET

*This activity is adapted from AAAS Science NetLinks: **Build an Electromagnet**.

Students will build their own **electromagnet** so they can investigate some of its properties and predict outcomes.

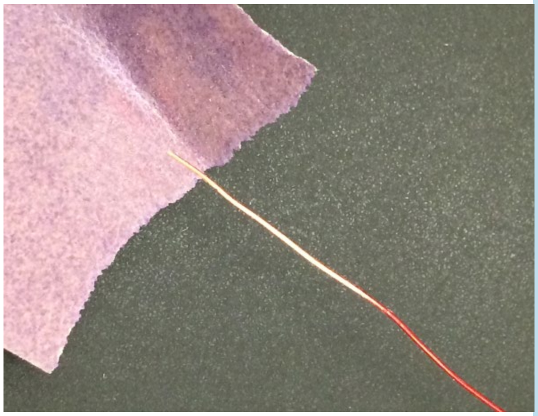
Instructions for building an electromagnet

1. Provide students the following materials:

   - 24-gauge red enamel-coated **magnet** wire cut into 3 yard lengths per pair of students
   - D cell battery—1 per pair of students
   - Pink eraser—1 per pair of students
   - Electrical tape
   - Paper clip and other metal objects that can be picked up with **magnets**
   - 3” nail—1 per pair of students
   - 220-grit sandpaper torn into 3” squares 1 square per pair of students

2. Divide students into pairs. Every student should wear safety glasses to protect his or her eyes from the sharp ends of the wire. Dust masks should also be worn during sanding.

3. Instruct the students to use the sandpaper to remove ½” – 1” of red enamel coating at both ends of the magnetic wire.



EXTEND THE LEARNING

Glass has a natural **resonance** and will vibrate if exposed to a matching **frequency**. If the sound at this particular **frequency** is focused enough, the glass can vibrate so intensely that it shatters. See the power of sound for yourself: **Breaking Glass with Sound**

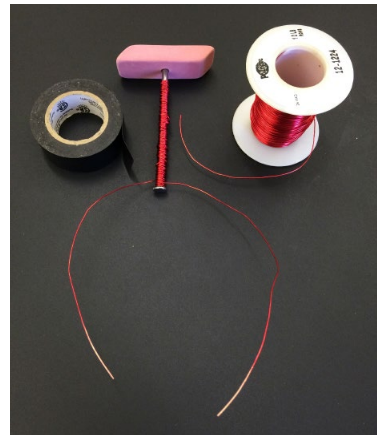
LEMELSON-MIT JV InvenTeams

SUSTAINABLE SOLUTIONS

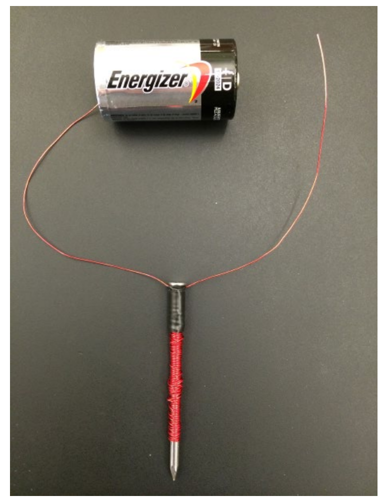
There are a lot of different types of batteries. Single use batteries change stored chemical energy into electrical energy to power things like flashlights, toys, and digital cameras. Alkaline batteries depend on a chemical reaction between zinc (negative electrode) in the presence of an alkaline electrolyte and manganese oxide (positive electrode) to produce electrical energy. Alkaline batteries are purchased as AAA, AA, C, and D size cells. Fully discharged or dead batteries should be discarded according to each state's regulations. Some states like California consider all batteries as hazardous waste and they cannot be discarded in the trash. How should batteries in your city or state be discarded? Learn more here:

[Recycling Laws Map]

4. Have students gently push the tip of the 3" nail into a pink eraser. Explain that the eraser offers a base to hold the nail safely. Have them wrap the **magnet** wire around the nail in a clockwise motion. They should start wrapping the wire at the head of the nail, leaving 6" of wire loose. Tell them to wrap the 3 yards of wire to form a coil around the nail, and when they get toward the eraser base they should wrap back up to the head of the nail in the same clockwise motion until they have finished coiling. The coils should end at the head of the nail.



5. Have the students tape the coil tightly at the head of the nail with electrical tape, allowing the two sanded ends of the wire to extend past the head of the nail.

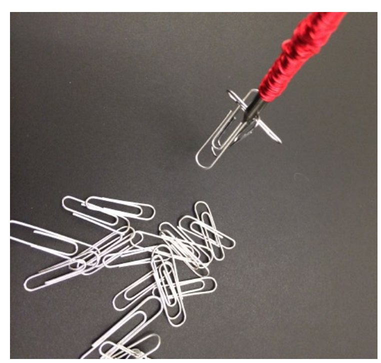


6. Tell the students to attach one sanded end of the wire to the negative (-) end of the D cell battery with electrical tape. Remind them that the negative end is the flat end.

7. Instruct students to close the circuit by holding the other sanded end of the wire to the positive nub. The circuit gets hot so tell them not to use tape to keep the circuit closed. They can use their fingers to open and close the circuit by touching the positive nub.

8. Have them pick up a paper clip with one end of the nail.

9. Tell the students they have created an **electromagnet**! Have them use the prompts below to guide their investigation of **electromagnet** properties.



Strength Test

How many paperclips can you pick up with your **electromagnet**?

Try to make your **electromagnet** stronger with the materials you have. What did you try? How did it work?

Pushes and Pulls

Opposite poles on **magnets** pull (attract) and the same poles on **magnets** push (repel). You can change the direction of the **current** moving through the wire, which changes the **polarity** of your **electromagnet**. A push becomes a pull (attract) and a pull (repel) becomes a push. It is this motion that generates sound vibrations in a speaker.

Can you predict how to change the direction of the **current** moving through the wire coil? Can you use a **compass** to test your prediction?

Speakers

How might a speaker with a strong **electromagnet** work differently than a speaker with a weak **electromagnet**? How could you test this idea?

Have the students use the blank pages at the end of this meeting to draw a design for a simple speaker based on what they now know about speakers, sound, and **electromagnets**.

SELF-ASSESSMENT

Collect the completed self-assessments as exit slips when students leave.

INDICATORS OF A SUCCESSFUL MEETING

Students discuss how sound travels. They build an **electromagnet** and explore its properties. Students identify the parts of a speaker and their functions.

EXTEND THE LEARNING

Is there a difference between light waves and sound waves? In fact, there are many differences between light and sound waves. Watch Making Waves with Sound and Light to learn about these two different phenomena.

HISTORY

Watch: How a Compass Works
The magnetic or navigational compass points towards Earth's North magnetic pole. It was invented as early as the Chinese Han Dynasty (221-207 BC). The Song Dynasty (960-1279 AD), with its permanent navy, adopted the compass for navigation; Chinese sailors actively used the magnetized compass needle in 1119 AD. Uses of navigational compasses were referenced in medieval Europe and in a Persian book from the thirteenth century. Inventions of and improvements to magnetic compasses have continued into modern times. Today, there are even electronic compass applications for smart phones that aid navigation.

NOISE MAKERS
MEETING 3: BUILD A PAPER PLATE SPEAKER

KEY TERMS

AWG (n): American Wire Gauge; a standardized system for the diameters of electrically conducting wire.

Bass (n): Tones in low frequency or range.

Cone (n): A component of a speaker that is attached to the voice coil and has a large surface area to move more air.

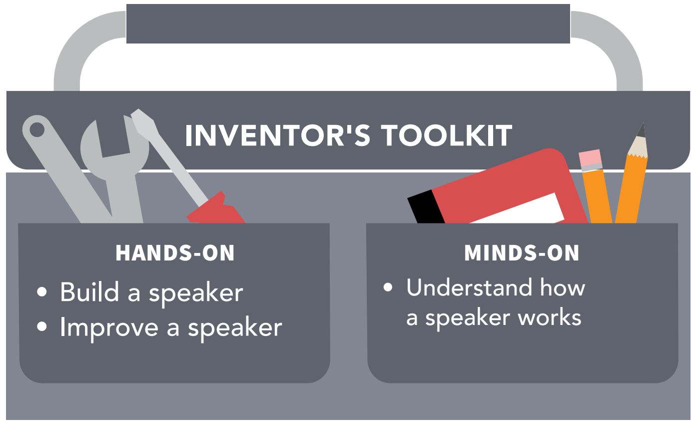
Criterion (n): Principle or standard against which something can be judged or decided.

Constraints (n): Limitations or restrictions.

Neodymium magnet (n): A widely used type of rare-earth magnet; a permanent magnet made from an alloy of neodymium, iron and boron to form the $Nd_2Fe_{14}B$ tetragonal crystalline structure.

Spider (n): The component of a speaker that helps keep the voice coil over the magnet.

Surround (n): The strong, sturdy, flexible roll at the edge of the cone in a speaker.



Tools

- Writing utensils
- Projector and computer to show video
- Laptop or computer that can play music
- Mono audio cable (strip one end before the meeting)
- Scissors
- Alligator clips
- Hot glue gun
- Sandpaper
- Wire stripper/cutter

Materials

- Student Guides
- Magnet wire, **AWG** 32 (enameled)
- **Neodymium magnets** (1/2" diameter, 1/4" thick)
- Masking tape
- Paper and cardboard from recycling
- Paper and styrofoam plates
- Glue for hot glue gun
- Self-Assessments

Procedure

- Review How Speakers Work
- Build a Paper Plate Speaker
- Troubleshooting
- Meet Lee Zamir from Bose®
- Invent a Better Speaker
- Self-Assessment

SAFETY

There are hazards associated with **neodymium magnets** because of their strength. They can cause injury if skin gets pinched between two magnets. These magnets should not be within reach of babies or young children. They can cause serious injury or death if swallowed. **Keep out of reach of children.**

MEETING 3

REVIEW HOW SPEAKERS WORK

1. Remind students that speakers are machines that convert electrical energy into mechanical energy (sound waves). In the last meeting, students investigated two components of speakers—the **voice coil** and the magnet—to better understand how electrical energy is transferred into mechanical vibrations.

2. Remind students that in the last meeting they also found a thin piece of plastic inside their earbud speakers. This plastic was attached to the **voice coil**. Ask students:

- What do you think is the purpose of this plastic piece?

3. Tell students that this plastic piece is called the **cone**. The **cone** vibrates with the **voice coil**, creating strong sound waves. Ask students:

- What properties do you think it is important for the **cone** to have? Why?

Source: commons.wikimedia.org

Cone made of paper pulp

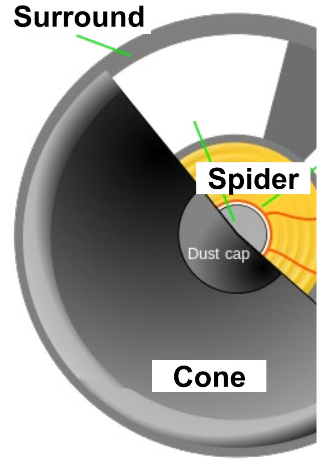
4. Explain that **cones** are purposefully designed to have a large surface area so that they can move more air with their vibrations. **Cones** are often made out of a lightweight, stiff material that can be moved easily without distorting.

SUSTAINABLE SOLUTIONS

The Defense Advanced Research Projects Agency (DARPA) created a system that can help put out flames using sound! The team arranged two speakers on either side of a flame to demonstrate how fire can be controlled by an acoustic field. The sound increases air velocity, which thins the area of the flame where combustion occurs, known as the flame boundary. Once the boundary area is thinned, the flame is easier to extinguish. Learn more: [Wall of Sound]

5. Explain that today students are going to build a speaker out of everyday materials. Their speakers will include a voice coil, a magnet, and a **cone**.

6. Introduce two other parts of the speaker—the **spider** and the **surround**. The **spider** is attached to the bottom of the voice coil and is often made from fabric. The **surround** is a strong, sturdy, and flexible roll at the edge of the **cone**.

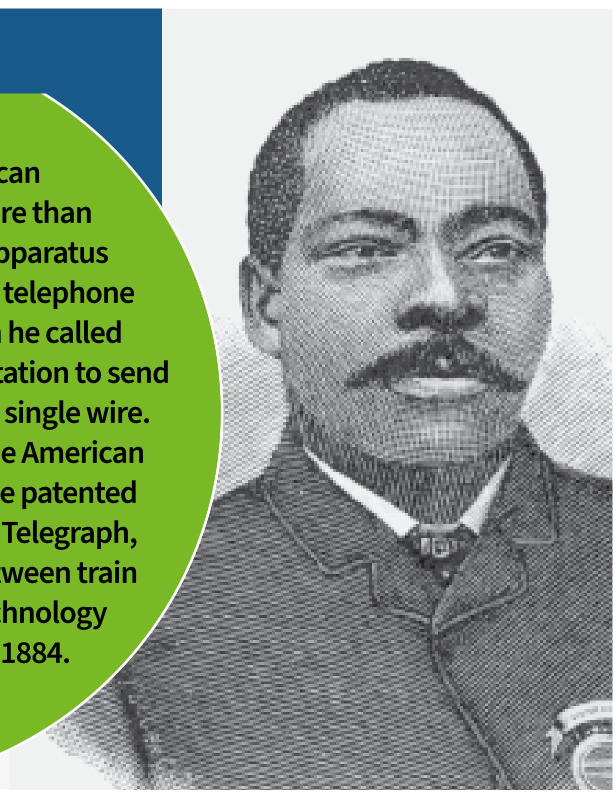


Source: commons.wikimedia.org

7. Explain that together, the **spider** and **surround** help keep the coil centered over the magnet, and they move the coil and **cone** quickly back into place after they've been pushed or pulled by the magnet. They help keep the **cone** from wobbling, which can cause audio to sound scratchy.

HISTORY

Granville Woods was an African American inventor who held more than 50 patents. Woods patented an apparatus in 1885 that was a combination of a telephone and a telegraph. The device, which he called "telegraphony," allowed a telegraph station to send voice and telegraph messages over a single wire. He sold the rights to this device to the American Bell Telephone Company. In 1887, he patented the Synchronous Multiplex Railway Telegraph, which allowed communications between train stations from moving trains, a technology pioneered by Lucius Phelps in 1884.


Source: en.wikipedia.org

BUILD A PAPER PLATE SPEAKER

Divide students into pairs and have them follow the instructions below to build a simple speaker.

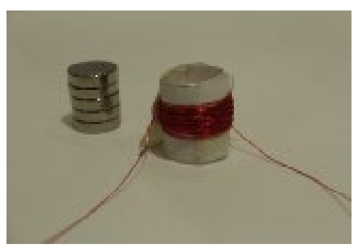
How to Build a Paper Plate Speaker

1. Provide students the following tools and materials:

   - 5 **neodymium magnets**
   - Magnet wire
   - Tape and scissors
   - Scrap paper
   - 2 paper plates
   - Sandpaper
   - Glue and hot glue gun

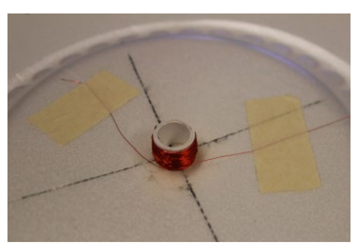
2. Have students wrap a strip of paper around the stack of magnets and tape it to itself. Caution them not to tape the paper to the magnets!

3. Tell them to wrap another strip of paper around the first and tape it to itself. Have them separate the two and discard the inner paper tube—the one with the smaller diameter.



4. Students should trim the paper tube so it is slightly longer than the magnets inside it.

5. Instruct the students to wrap a piece of magnet wire tightly around the tube 50 to 60 times. They should now have a hollow paper tube with magnet wire wrapped around it. Have them make sure both ends of the magnet wire are roughly 6 inches long.



6. Tell students to use a small piece of sandpaper to remove the coating from the ends of the magnet wire.

INVENTOR PROFILE

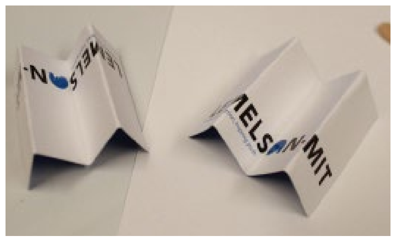
Thomas Edison invented and improved on communications devices in the late 1870s. He tinkered with both the telephone and telegraph machines, and attempted to make a machine that could record the voice. Edison finally had success with his invention of the phonograph in 1877. The first audio recording was Edison reciting the nursery rhyme, "Mary Had a Little Lamb." Read more: Edison

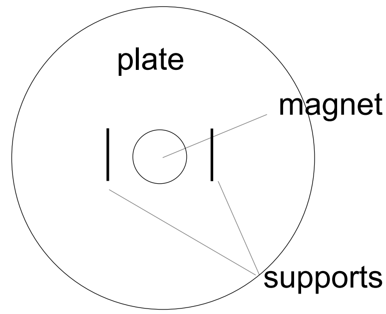
Credit: en.wikipedia.org

7. Have students glue the voice coil they just made to the center of the bottom of a paper plate. They should use a ruler and marker to mark the center point before they glue. Have them tape the ends of the magnet wire to the plate.

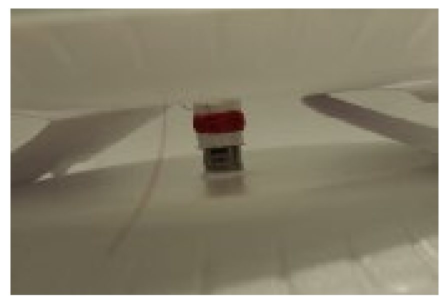
8. Instruct students to glue the stack of magnets to the center of the bottom of a different paper plate.

9. Have students create two accordion-fold supports and glue the supports to the plate with the magnets using this diagram:





10. Instruct students to place the plates so that the voice coil slides over the magnets, then glue the top of the supports to the plate with the voice coil.



EXTEND THE LEARNING

Team Up for Stereo Sound

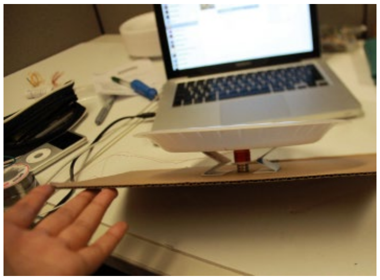
Have each team partner with another team to connect both speakers to the computer for stereo sound! Tell them to connect one speaker to the right cable and the other to the left cable.

While the music plays, have them take turns placing their heads directly between the two speakers. Can they find a song that sounds like it has a voice or instrument floating between the two speakers?

SUSTAINABLE SOLUTIONS

Researchers from MIT, Adobe, and Microsoft have developed an algorithm to extract audio information from video footage. They recovered intelligible speech from a video of a potato chip bag that was shot at a distance of 15 feet behind soundproof glass. Learn more about their research: [Sound from Silence]

Source: en.wikipedia.org



11. Students should use the alligator clips to hook their speakers to the audio cable at the computer or other device. Remind them that audio cables can vary. For example, one type can have three wires, so they should test the various wires until it works. Have them test the speaker by playing a song!

Have students refer to the following troubleshooting tips (included in their guides) if their speakers aren't working correctly.

General Troubleshooting

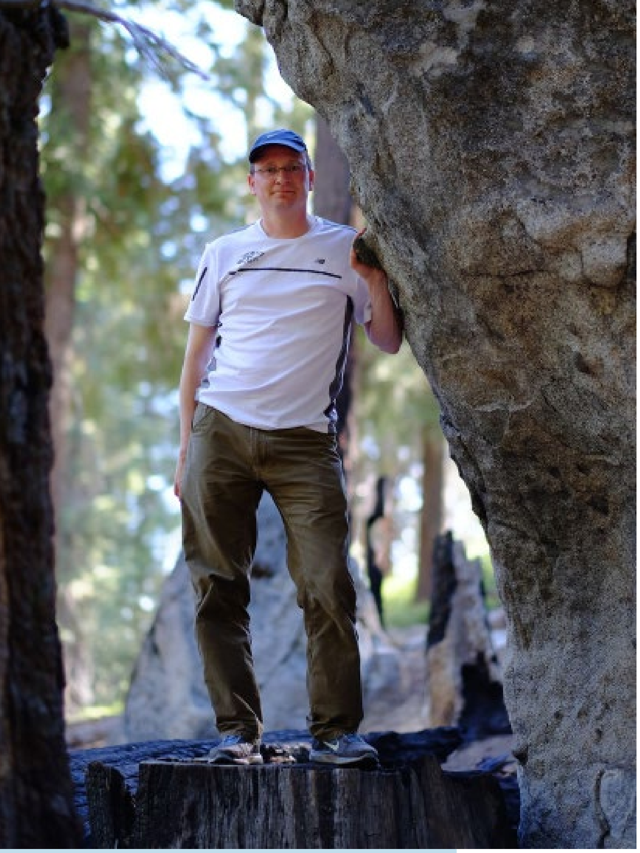
- Make sure the magnet is resting in the voice coil when not hooked up to the audio source.
- Make sure the magnet wire ends are sanded smoothly.
- Turn the volume up to max on your audio device.
- Make sure the magnets aren't resting too low.
- Make sure the coil isn't too low.
- Make sure the magnet sits in the coil when at rest.

If the speaker sounds terrible, check the following:

- Make sure the wires are coiled tightly and are not rubbing against other pieces.
- Make sure the voice coil is not touching the magnet.
- Make sure the **cone** (plate) is not damaged.

If the sound is too quiet or there is no sound, check the following:

- Be sure the voice coil is at the same height as the magnet.
- Make sure the supports are parallel. Try adjusting their position for better sound.
- Double-check your connections.



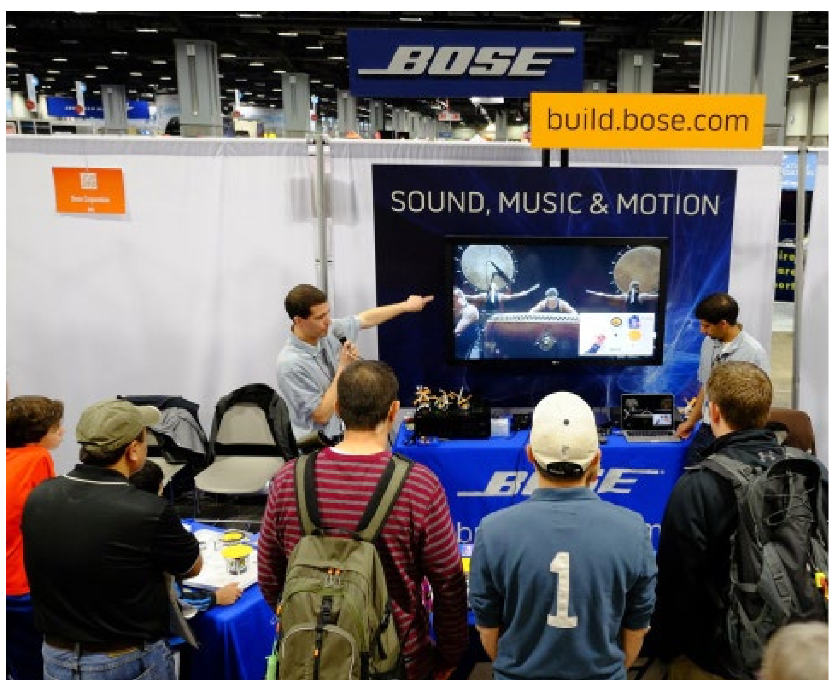
Credit: bose.com

MEET LEE ZAMIR FROM BOSE®

Lee Zamir went to MIT to study engineering. There, he received his bachelor's and master's degrees in electrical engineering and computer science. He joined Bose Corporation shortly after graduating from MIT in 1997. While at Bose, he has held various positions that span engineering, research, sales, and marketing. He became the director of the New Business Development Lab in 2012; there he and his team identify and develop new products that go beyond audio entertainment.

Who were your role models as a kid?

"My math teacher was a terrific role model because he made us not just try to get an answer to the math problems, but challenged us to bet him on the answer for points on the next test. This encouraged me to have conviction about the answer and to care about figuring things out. My parents were also great role models. They always encouraged me to make my own things instead of just buying them. That way you get what you want and you have a sense of joy and pride in the things you have."



Credit: bose.com

Did you do any tinkering or inventing at a young age?

"I was the youngest of three kids so there was a basement full of toys that had already been played with and built by my older brother and sister. I would take the old toys and try to invent new ways of using them so they would feel like new toys. For instance, I took an old block set and some old plastic train tracks and constructed a marble raceway. I would launch two marbles on the two train track grooves and see which marble would finish the course the fastest."

How did you get interested in speaker/sound technology?

"Like most kids, I was getting into music and had a simple little radio that I could listen to in my room. My parents decided to buy a sound system for their living room and I decided I would 'help' them research what to get—knowing that I would be able to listen to music as well. When I saw how much these systems cost, I thought I would never be able to afford one. So I found an after school speaker-building workshop and convinced my parents to let me enroll. The cost of the workshop was far less than any of the systems my parents were considering buying and I enjoyed making them myself."

What advice can you give kids who want to become inventors?

"Make things every chance you get. Anytime you want something, ask yourself if you could imagine making something for yourself that's even better than what you could buy. This can be anything - from a sandwich to a pair of sneakers to a speaker. Go for it and make it for yourself. It may end up better than what you could buy."

What do you do for fun outside of work?

"I play Ultimate Frisbee, I like to hike and I love making furniture and things out of wood."

EXTEND THE LEARNING

We have all seen slow motion, but what about slow sound? The MIT Lincoln Lab filmed in slow motion and slow sound in the 1960s many common sounds, such as popcorn popping, nails dropping, and glass breaking. Watch the video: Slow Sound

Source: en.wikipedia.org

INVENT A BETTER SPEAKER

1. Break students into pairs. Facilitate pair discussions around the following questions:
   - What are the strengths of the speakers we just built?
   - What are some weaknesses of the speakers we just built?
   - How could we improve our speakers?
2. Guide pairs to choose ONE improvement goal. Examples include:
   - louder sound
   - louder **bass** (low pitches)
   - smaller size
   - more stable **cone**
   - more contained structure
3. Tell students they will use the rest of the meeting to design and build a speaker that will meet their selected goal.
4. Let students know that their selected goal is considered a design **criterion**. They will also be working within design **constraints**, which in this case are limited time and materials.
5. Encourage students to use the blank pages in their guides to brainstorm ways to meet their **criterion**.
6. Ask that students show you a written or drawn plan before they get their materials and begin working.
7. Check in on the students as they work and ask each pair questions like:
   - What is your goal for this speaker?
   - How does your design work?
   - What is working well in your design so far?
   - What is not working well?
   - How are you working together to meet your goal?

8. Encourage students to test their speakers and informally evaluate their design. Students can ask questions such as:

- Does our speaker meet the goal we chose for it?
- How does this speaker compare to my first speaker?
- Why do I think this speaker does/does not work well?
- How would we improve our speaker if we had more time or different materials?

9. Invite pairs to share their design process and their final speakers with the class.

SELF-ASSESSMENT

Collect the completed self-assessments as exit slips when students leave.

INDICATORS OF A SUCCESSFUL MEETING

Students build, test, critique, and improve a speaker using everyday materials. They improve their understanding of how sound works.

Source: Paul Esch-Laurent | Unsplash.com

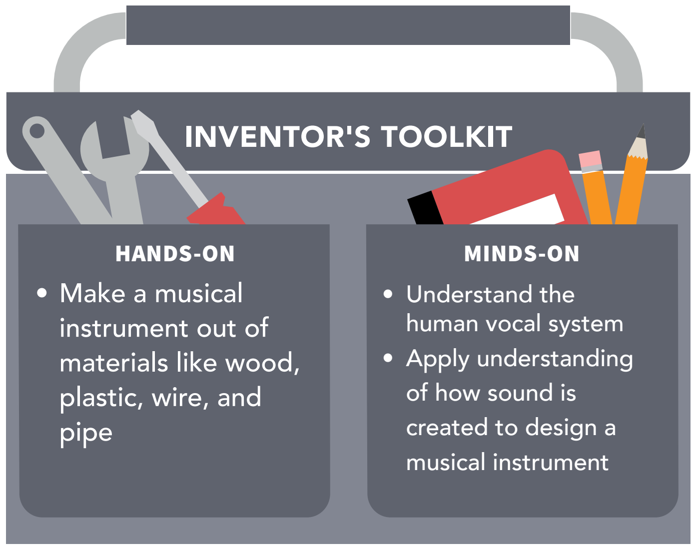
NOISE MAKERS
MEETING 4: MAKING SOUND

KEY TERMS

Larynx (n): The organ forming an air passage to the lungs and containing the vocal cords.

Pitch (n): In music, the number of vibrations per second; high and low pitches correspond to high and low notes.

Vocal cords (n): Folds of tissue that vibrate as air passes along their edges to create sound.



Tools

- Writing utensils
- Projector and computer to show video
- Wire stripper/cutter

Materials

- Student Guides
- Latex-free gloves
- Rubber bands
- Music wire
- Fishing line
- Nails, varied
- Self-Assessments

Procedure

- Introduction to the **Larynx**
- Meet Nate Ball
- Make a Musical Instrument
- Types of Musical Instruments
- Notes on Materials
- Self-Assessment

INTRODUCTION TO THE LARYNX

1. Tell students that today they are going to learn more about creating sound by building a musical instrument out of everyday materials.

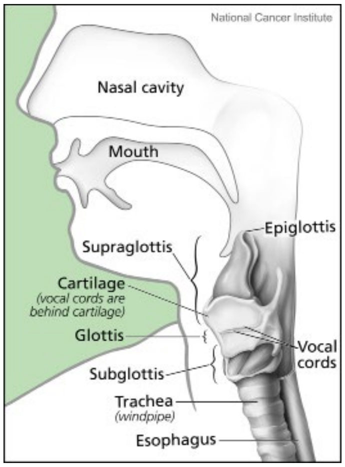
2. Explain that first they are going to learn more about how the human voice works so they can use that knowledge to inform their instrument design.

3. Remind students that they hypothesized how the human voice works in an early meeting. If you still have the papers with everyone's ideas on it, have the class review them now.

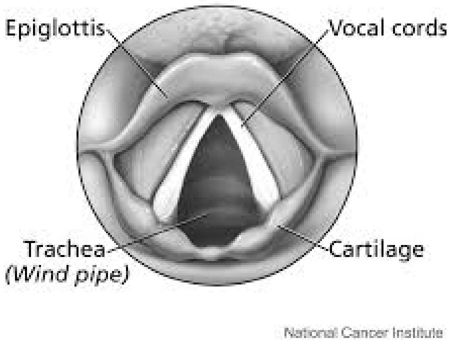
4. Ask students:

  - Based on what you know about sound, what do you think is vibrating that causes the human voice?
  - How do you think we can make low sounds and high sounds?
  - Why do you think adults' and children's voices have different **pitches**?
  - Do you think it's possible to make a high and low **pitch** at the same time with your voice? Why or why not?

5. Have students look at the diagrams below as you introduce how the human voice works. The first diagram shows a side view of the **larynx** and nearby structures. The second diagram shows a cross-section of the **larynx** directly over the **vocal cords**.



Source: commons.wikimedia.org



Source: commons.wikimedia.org

6. Explain that our **vocal cords** (or vocal folds) are muscles that we can control. Sound waves come out through the mouth if we vibrate the **vocal cords** while exhaling. We can also stretch them to create differently-**pitched** sounds.

MEETING 4

JV InvenTeams LEMELSON-MIT

COLLEGE CONNECTION

In the fall of 2018, several cross-disciplinary projects at MIT explored the technological and visual limits of sound, resulting in new innovations. Some of these include motion-sensing headphones that allow runners to keep a steady pace, a virtual 3-D reconstruction of a spider's web with each strand tuned to a different note, and "The Laughing Room" installation that allows artificial intelligence to decide what is funny using a recorded laugh track. Learn more:

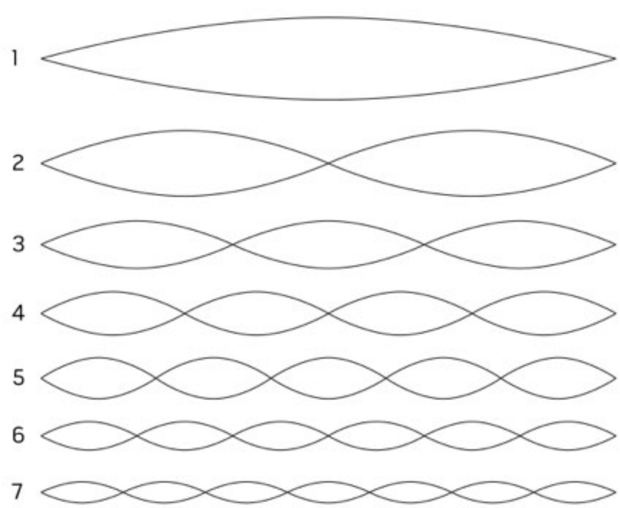
[Sound Technology]

7. Let students know that adults tend to have longer, thicker **vocal cords** than children. Just as vibrating a long, thick rubber band will create a lower **pitch** than vibrating a short, thin rubber band, an adult will typically have a lower voice than a child.

8. Explain that humans use more than just their vocal cords to create speech. We use our lips, tongue, and mouth to shape sounds and add percussive elements.

9. Ask students if they think it's possible for humans to make a sound with more than one **pitch** at once. It turns out that we can! A vibrating string generates a fundamental frequency, which is what we tend to hear as **pitch**. If you divide the string into sections, the rate of vibrations increases (see the diagram below). These rapid vibrations generate other **pitches** that all relate to the fundamental **pitch** in some way.

HARMONIC SERIES OF A VIBRATING STRING



10. Explain that we typically do not hear these **pitches** because they are weaker than the fundamental **pitch**. Some singers have learned to amplify these other **pitches** in order to sing multiple notes at once. Have the students check out **[Tuvan Throat Singing]** to learn more.

Source: en.wikipedia.org

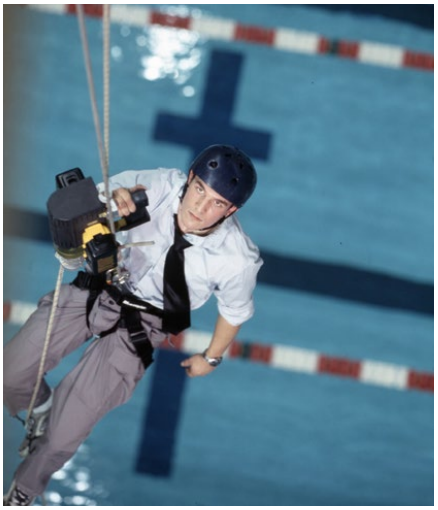
MEET NATE BALL

Source: lemelson.mit.edu

Nathan "Nate" Ball's passion for invention was coursing through his veins long before he could define the word. He created a bottle-rocket launcher in fourth grade that shot bottles of water 100 feet skyward. This was followed by a hovercraft powered by a vacuum cleaner motor, which he constructed in sixth grade.

By the time Ball was in the eighth grade, he was attempting to build a Tesla coil in his parent's garage, making capacitors out of glass bottles and aluminum foil. "I saw Tesla coils on the Internet shooting lightening," said Ball. "It was the coolest thing I'd ever seen, and I knew I had to build one."

Amazingly, Ball never touched a machine tool until he reached college. He credits limited resources during his formative years for his ability to think unconventionally about problems and to engineer efficient solutions.



Source: lemelson.mit.edu

Ball received his Bachelor of Science and Master of Science degrees in mechanical engineering at MIT. He cofounded Atlas Devices, LLC to develop and commercialize the ATLAS Powered Rope Ascender, which uses a rope-handling mechanism conceived by Ball. This portable device can raise more than 250 pounds at 10 feet per second, giving rescuers, emergency personnel and soldiers faster and more controllable climbing capabilities.

Ball is also trained in classical piano. For fun, he enjoys playing jazz keyboard and beat boxing. Check out **Nate Ball's TED Talk** (start at 10:14) to see a beatboxing **larynx** in action! Note how he uses his knowledge of sound and vibration to create deep bass.

Who were your role models as a kid?

"My dad and granddad were both great role models. I learned even more from them by observing than I did from having them teach me things, though they did plenty of that too. By seeing how they would approach a problem, I learned ways to go about 'figuring it out,' regardless of the project. It was awesome! They had many hands-on skills to begin with, and I loved watching them use tools to build things. It was also inspiring to see what they would do when they had to get past a challenge."

"I also loved reading kid's books about Leonardo Da Vinci, Thomas Edison, and Nikola Tesla, and hearing stories of ancestors of mine who were also inventors (look up Elisha Gray, my great-great-grand-uncle!)."

Did you do any tinkering or inventing at a young age?

"All kinds. I loved playing with blocks and legos and wanted to build forts constantly. In fourth grade I built my first 'real' project that had plans and an awesome outcome when it worked: a 2 liter bottle rocket launcher! I realized I could build lots of cool things in real life—not just models out of blocks and legos. I started dreaming up other cool things to build, like an alarm system for my bedroom, a catapult for my back yard, and a go-kart powered by the wind that I could drive on the beach. Though every project came with its own challenges and setbacks, I loved every minute of every project, and I've really never stopped."

How did you discover beatboxing?

"I still remember it so clearly: I had just used Napster to download an mp3 of the famous beatboxer Rahzel doing the 'beat and the chorus at the same time,' and I was utterly amazed. I played that track for everybody I knew. My parents were amazed. My friends were amazed. I couldn't stop thinking about it! How did he beatbox and sing at the same time? I grew up playing music and loved making drum noises with my mouth from an early age, so finding out that "beatboxing" was an actual thing people were good at was pretty exciting. But especially exciting was the idea you could do two things at once—the beat along with the words. I spent about a month straight working on it, and finally figured it out. It didn't sound very good early on, but the satisfaction was immense and I was totally hooked! Spread out through the day, I often still beatbox for 30 to 60 minutes. It kind of runs along in the background for me, like humming for some people. But I get to keep improving as I go."

MEETING 4

What advice can you give kids who want to become inventors?

"Dive right in! Do it! And enjoy the process. It really helps to have a project that you're just so excited about, you can't even think of not trying to make it happen. Inevitably, it will get hard—you'll be in over your head, not knowing what the next step is, frustrated that it's not going how you planned, and unsure if you should continue. But if you're really driven and can still envision that goal, it can help you get through those tough times. The more driven you are to bring that idea into reality, the more ways you'll identify to make it happen, even when it gets hard."

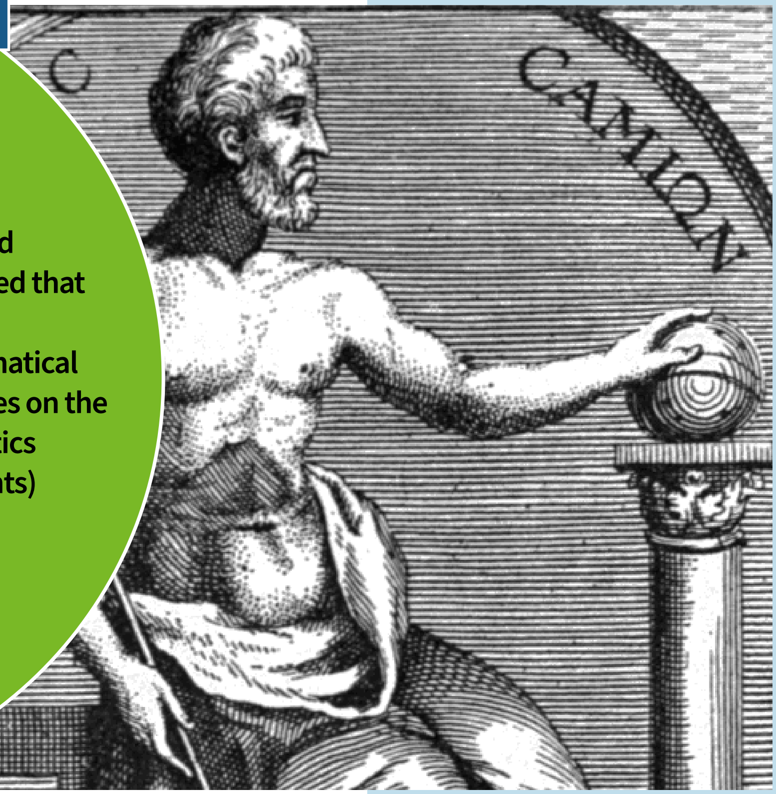
What do you do for fun (besides beatboxing) outside of work?

"I still do some pole vaulting and parkour tricks, play piano (mostly jazz), make TV shows (Design Squad!), write kids' books, build extra-fun projects like a web-enabled temperature monitor for my house, do awesome stuff with my partner Catherine, and enjoy how much fun it is to learn and do new things with our baby son Calvin."

HISTORY

Pythagoras was an ancient Greek philosopher and mathematician who lived in the late 6th century BC. Pythagoras discovered that scientific law could be applied to music: musical notes could be translated into mathematical equations. Learn more about Pythagoras' theories on the relationship between music and mathematics (specifically with vibrating string instruments) by visiting:

Music and Mathematics



Source: commons.wikimedia.org

EDUCATOR NOTE

Before Making a Musical Instrument

Consider taking students on a walk outside to gather materials they can use in their musical instruments.

Cutting with Saws

You may need to demonstrate safe cutting procedures to your students. Visit **HowToons: Cut to the Point** for some helpful tips on cutting with saws.

MAKE A MUSICAL INSTRUMENT

1. Let students know they will spend the rest of today's meeting designing and building a musical instrument. Encourage students to use this time to investigate a component of sound that is interesting to them.

2. Encourage students to ask themselves the following questions as they work:
   - What is vibrating?
   - How can the player control and change the vibration?
   - How does the choice of material impact the sound?
3. Tell students they have access to a variety of everyday materials. They can also use tools like saws and hammers if they want to work with wood.
4. Point out the resources on the next two pages. Tell students they should look at these resources to help them determine the type of instrument they want to make and also what materials might be helpful to them.

SAFETY

Dust masks and safety glasses must be worn when cutting wood.

5. Have students use the blank pages at the end of this meeting to brainstorm ideas and sketch designs before building.
6. Encourage students to share their instruments with the class at the end of the meeting.

TYPES OF MUSICAL INSTRUMENTS

There are many instruments in the world and many ways to organize them into categories. One popular sorting system is the Hornbostel-Sachs system, which divides instruments into four types.

Credit: en.wikipedia.org

Idiophones

These instruments make sound when the body of the instrument vibrates. Examples include sticks, gongs, bells, and xylophones.

Photo: the triangle

Credit: commons.wikimedia.org

Membranophones

These instruments make sound when a stretched membrane vibrates. Examples include drums and kazoos.

Photo: a drum set

Credit: en.wikipedia.org

Chordophones

These instruments make sound when a stretched string vibrates. Examples include guitars, violins, and pianos.

Photo: piano strings

Credit: commons.wikimedia.org

Aerophones

These instruments make sound when a column of air is made to vibrate. Examples include flutes, accordions, and trumpets.

Photo: a wooden recorder

Not all instruments fit neatly into this sorting system, but it is a helpful way to think about the source of vibrations in an instrument. What type of instrument will you create?

EDUCATOR NOTE

Extend the Learning

Students may need additional prompting to develop their instrument. Explore the ideas below. Additional supplies may be needed:

- Build a simple guitar using a small cardboard box or empty tissue box. Attach rubber bands or music wire across the top opening (strings). Make the neck with a paper towel tube and duct tape.
- Make a **PVC flute**
- Build a **canjo**, a single string musical instrument

Explore other **simple ideas**, categorized by type of instrument.

NOTES ON MATERIALS

Everything has natural frequency at which it vibrates. This means that the material you choose has a lot to do with what sound you get. You can adjust the vibrations and alter the sound by adjusting certain properties like tension, weight, and length.

What materials will you choose for your instrument?

Credit: Zuzana Kacerová | Unsplash.com

Credit: commons.wikimedia.org

SELF-ASSESSMENT

Collect the completed self-assessments as exit slips when students leave.

INDICATORS OF A SUCCESSFUL MEETING

Students discuss how the human vocal system works and design, build, and test a musical instrument.

INVENTOR PROFILE

Hedy Lamarr was an Austrian actress who became a prominent inventor when she moved to the United States. She developed a "Secret Communications System" to help defeat the Nazis during World War II. Lamarr manipulated radio frequencies at irregular intervals between transmission and reception to form an unbreakable code to prevent classified messages from being intercepted by enemies. Her "spread spectrum" technology laid the groundwork for future wireless technologies. Learn more:

Spread Spectrum Technology

Credit: commons.wikimedia.org

NOISE MAKERS
MEETING 5: BUILD AN ELECTRIC INSTRUMENT

KEY TERMS

Gauge (n): The thickness, size, or capacity of something, especially as a standard measure, in particular.

Humbucker (n): Type of electric guitar pickup that uses two coils to cancel out sound interference.

Pickup (n): A device that captures mechanical vibrations from stringed instruments and converts them to an electrical signal.

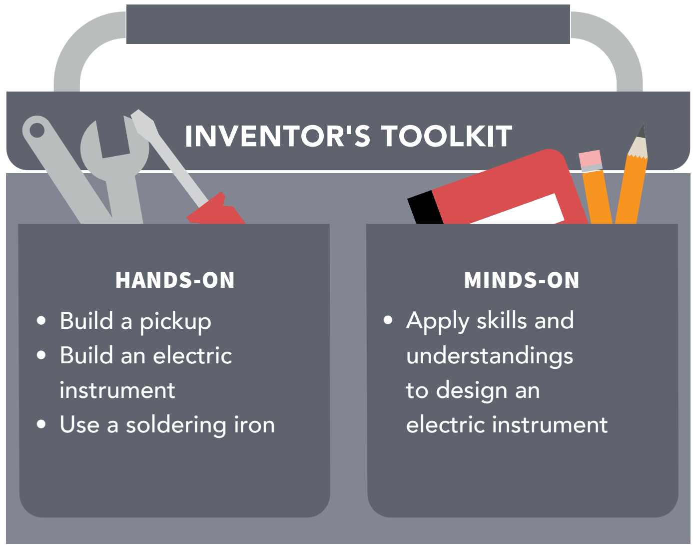
EDUCATOR NOTE

Timing

Building the **pickup** and instrument is likely to span at least two meetings. Consider having students build the **pickup** in the first meeting and the instrument in the second meeting.

Soldering

SparkFun developed a comprehensive tutorial and video demonstration on how to solder electronic components. Have your students **explore these resources** before getting started.



Tools & Electronics

- Writing utensils and permanent markers
- Projector and computer to show video
- Hand saws
- Hammer
- Tin snips
- Soldering iron (see **MIT's Soldering Guide** for tips on how to use)
- Soldering stands and "helping hand" (optional)
- Solder
- Electrical tape
- Hot glue gun and glue
- Sandpaper
- Ruler
- iRig guitar adapter for iPhone/iPad

Materials

- Student Guides
- Remaining materials from Meeting 3
- 32 AWG enameled wire
- 1/2" x 1/4" neodymium magnet (1 per project)
- 3' long 0.032"diameter music wire (1 per project)
- Small rectangular tin box with hinges
- 18 AWG enameled wire
- 1/4" mono jack (1 per project)
- Self-Assessments

Procedure

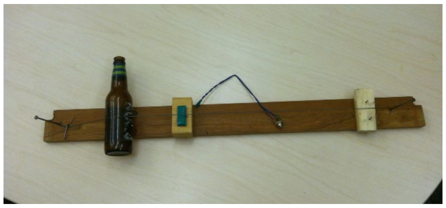
- Introduction to the Diddley Bow
- Invent an Electric Instrument
- Meet Jay Silver
- Self-Assessment

INTRODUCTION TO THE DIDDLEY BOW

1. Students will each build their own musical instruments, incorporating their new minds-on skills in electromagnetism and sound.

2. Ask students if they have ever heard of a diddley bow. The diddley bow is a one-stringed guitar made out of a piece of wood with a wire tensioned between two nails over a glass bottle for amplification.

3. The diddley bow was first popularized by African-American blues musicians; its sound greatly influenced the development of American blues music.



4. Tell the students that musicians began creating electric instruments in the 1920s, including electric diddley bows. Mention that electric instruments use a **pickup** to capture mechanical vibrations and convert them to an electrical signal.

5. Tell them that **pickups** have three main components: a metal core, a magnet, and many coils of wire. Ask them what they think are the functions of these three components.

6. Inform the students that the metal core acts much like the cone in a speaker. Instead of vibrating the air with its surface area, it picks up vibrations from the instrument and transfers these vibrations to the magnet. The vibrating magnetic field then causes a vibrating current to flow through the coils in the form of electricity.

Credit: commons.wikimedia.org

7. Watch **Jack White Makes an Electric Guitar** to see an electric diddley bow being constructed and to hear its powerful sound. Read **How Electric Guitars Work** to learn more about electric instruments.

INVENT AN ELECTRIC INSTRUMENT

1. Students will spend the rest of this meeting and the next one designing and constructing an electric instrument.

2. Divide students into groups of four. Explain that groups can create any kind of instrument they want.

3. One component every instrument will have in common is the **pickup**. Show students the instructions for building the **pickup**.

Where would you place the pickup on this instrument?

Credit: en.wikipedia.org

4. Give groups time to figure out what type of instrument they would like to create. Students can use what they learned to plan their instrument design.

5. Encourage groups to decide on the criteria and constraints for their instrument design.

Examples of criteria are:

- The **pickup** must amplify the desired sounds while not picking up other movements
- The instrument will be ___________ type of instrument
- The instrument will have _________ strings

Examples of constraints are:

- Limited time
- Limited tools and materials

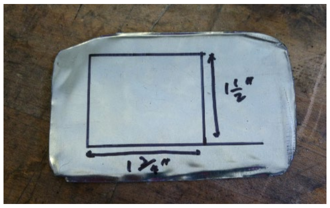
6. Groups can start to build their instrument once they have established the criteria and constraints for their design and have decided on a plan.

How to Make a Pickup

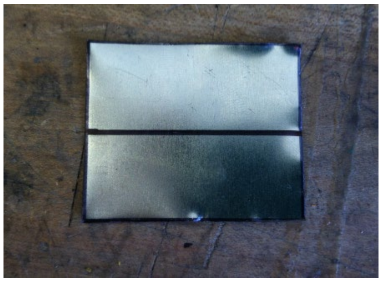
1. Have the students gather the following materials:
   - small rectangular tin box with hinges
   - neodymium magnet
   - tin snips
   - sandpaper
   - permanent marker
   - ruler
   - 32-**gauge** wire
   - 18-**gauge** wire
   - ¼” mono jack
   - clamp
   - soldering equipment

2. Instruct the groups to cut out the bottom of the tin with tin snips. Remind them that the edges will be sharp, so they should use sandpaper on the edges to make them safer to handle.

3. Students should flatten out the metal as much as possible. Have them measure a 1 ½” x 1 ¾” rectangle, then cut the rectangle with tin snips.



4. Have students measure ½ the length and draw a line with a permanent marker across the middle of the rectangle to mark a fold line.



SAFETY

Wear safety glasses during all building steps.

EDUCATOR NOTE

While some students are coiling the wire in step 8, other students can research how to build a musical instrument to extend the learning.

Credit: lemelson.mit.edu

INVENTOR SPOTLIGHT

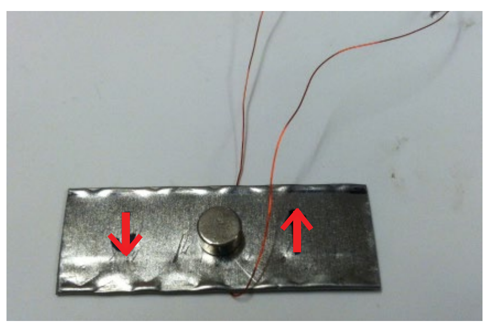
Amar Bose invented stereo speakers that produce high-end sound in spite of being modest in size. Bose was raised in Philadelphia in the 1930s, the son of an immigrant from Calcutta, India. He first became interested in technology at age thirteen when he started repairing model trains to provide additional income for his family. Amar Bose attended MIT and soon after became determined to invent a stereo loudspeaker that would reproduce the vivid sound of being in a concert hall. In his lifetime, he earned over two dozen patents for his inventions.

Learn more: [Amar Bose]

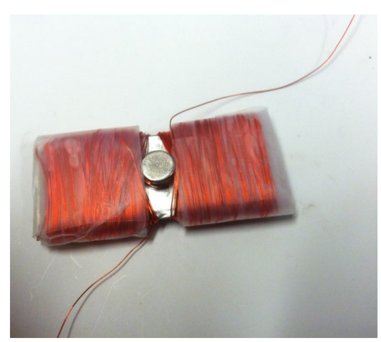
5. Tell students to fold the metal in half, and clamp the metal down on a desk (with the bend mark right at the edge of the desk).

6. Students should place a neodymium magnet in the middle of the folded metal piece.

7. Have them prepare the materials for making the wire coil. Instruct them to coil the wire in one direction on one side of the magnet and in the other direction on the other side of the magnet (see the arrows in the photograph). Tell them this coiling method is called a **humbucker pickup**, which minimizes interference. Have them lay the wire underneath the metal so they have two ends to begin coiling with.



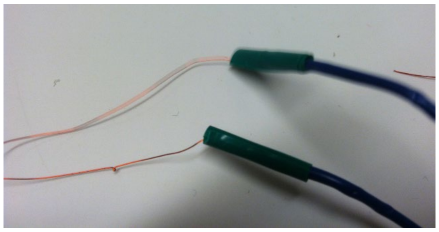
8. Tell the students to coil the wire as shown in the photograph; they will need 400 wraps of the wire on each side of the magnet! Have them take turns with their teammates. Suggest that they may want to occasionally wrap the wire in tape to make sure the coils don't slip. Once they are finished, have them tape it up again. Tell them that each end of wire should have about two inches sticking out.



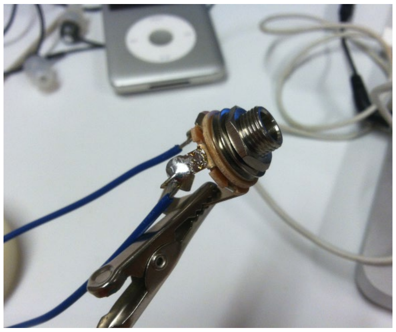
MEETING 5

9. Remind students that the thin 32-**gauge** wire is covered in enamel, so they should sand approximately ½” of each end to expose the bare wire.

10. Have the students solder the thin wire to a thicker 18-**gauge** wire, and wrap the connection in electrical tape.



11. Tell them to solder the 18-**gauge** wire to a ¼” mono jack. Inform them that their **pickup** is now complete!



12. Have students use the iRig and an iPhone or iPad. Tell them to plug the **pickup** into the iRig to turn their device into an amplifier.

EDUCATOR NOTE

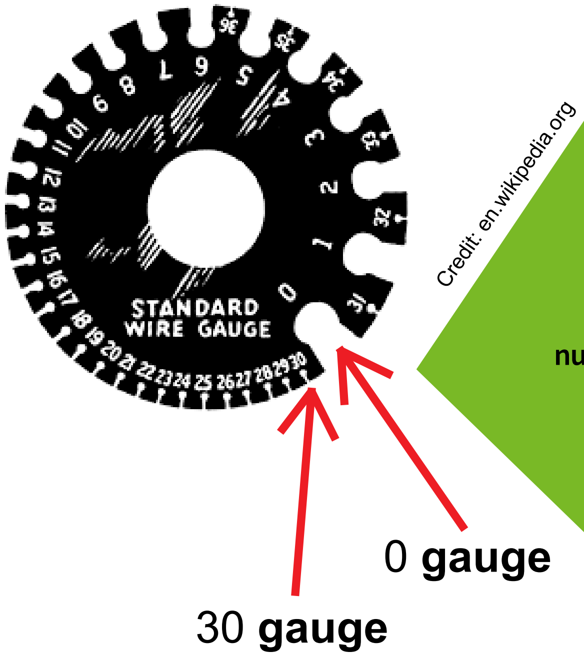
Extend the Learning

Students can attach their **pickups** to a musical instrument to amplify the sound. This may require additional time and supplies. Students can build the diddley bow, previously described in this meeting, and then attach their **pickup**. Another idea is building a **cigar box guitar** and attaching their own **pickups**.

Students can also try connecting their **pickups** to pre-existing string instruments such as violins, acoustic guitars, and basses.

EXTEND THE LEARNING

Increasing **gauge** numbers denote decreasing wire diameters, which is similar to many other non-metric gauging systems. This **gauge** system originated in the number of drawing operations used to produce a given **gauge** of wire. When you look at the image below you can see the difference in between the 30 **gauge** wire and the 0 **gauge** wire diameters. Learn more: **Wire Gauge**




Credit: lemelson.mit.edu

MEET JAY SILVER

Jay Saul Silver received his PhD in the Lifelong Kindergarten Group at MIT Media Lab, and works for Intel Lab's "Interaction Experience Research" group, helping develop a Maker Culture. Time named one of his inventions "Top 15 Toys for Young Geniuses," and he has put out many creative platforms, including **Drawdio**, **Singing Fingers**, and **Scratch**, collectively in the hands of millions.

Jay has given talks at TEDx Sacramento, TEDx Santa Cruz, and TEDx Amherst. He has exhibited internationally at museums such as the National Taiwan Museum of Fine Arts, the Exploratorium, and ARS Electronica. He also runs digital prototyping workshops for clients such as IDEO, LEGO®, and Intel®.

Jay studied electrical engineering at Georgia Tech where he was named Engineer of the Year. He was awarded a Gates Scholarship to earn a master's in Internet Technology from Cambridge University. He also holds a master's in Media Arts and Sciences from MIT Media Lab, where he invented "Camera for the Invisible."

Watch Jay Silver's TED talk, **Hack a Banana, Make a Keyboard!** to learn more about Jay's work and inspiration.

SUSTAINABLE SOLUTIONS

A group at the MIT Media Lab called the "Opera of the Future" explores concepts and techniques to help advance the future of musical composition, performance, learning, and expression. Their research includes musical instrument design, concepts for new performance spaces, interactive touring and permanent installations, and "music toys." Learn more: Opera of the Future

MEETING 5

SELF-ASSESSMENT

Collect the completed self-assessments as exit slips when students leave.

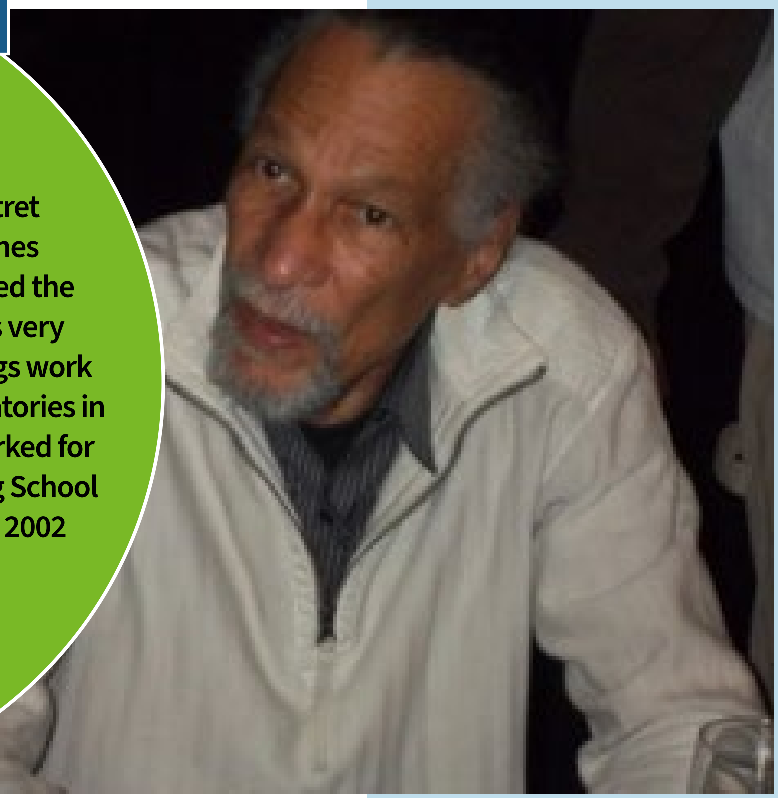
INDICATORS OF A SUCCESSFUL MEETING

Students construct a **humbucker pickup**; solder; and design, build, and test a musical instrument.

INVENTOR PROFILE

James E. West is the co-inventor of the electret microphone, which is used in most telephones and tape recorders. His invention revolutionized the telephone and recording industries. West was very young when he became fascinated by how things work and why. He was hired as an intern at Bell Laboratories in the mid-1950s, when few African Americans worked for laboratories. He joined the faculty of the Whiting School of Engineering at Johns Hopkins University in 2002 after working for Bell Labs. Learn more:

James West

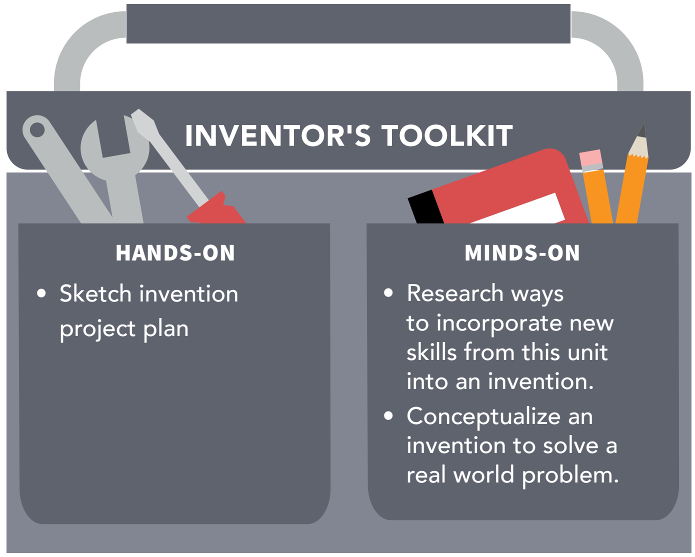


Credit: commons.wikimedia.org

NOISE MAKERS
MEETING 6: INVENTION EXTENSION

KEY TERM

Empathy (n): The ability to understand and share the feelings of others.



Tools & Electronics

- Writing utensils

Materials

- Student Guides
- Self-Assessments

Procedure

- Introduction to Invention Challenge
- Review Real-World Examples
- Identify a Need
- Brainstorm Solutions
- Make a Plan
- Self-Assessment

INTRODUCTION TO INVENTION CHALLENGE

1. Tell students that today they will conceptualize a project using the hands-on and minds-on skills they have developed within this unit.

2. Explain that although time and resources will limit the design process to conceptualization, students can continue working on projects outside of meeting time. The most useful and unique ideas have the possibility of becoming InvenTeams projects in subsequent years.

3. Explain that invention is centered on **empathy** and fulfilling the need of an individual or group of people with a unique solution to a real-world problem.

The most important thing today is identifying a real need and conducting research before jumping into project development.

4. Let students know that people throughout the world use products pertaining to sound—whether it's speakers to listen to music, machines to record speech or music, or musical instruments to produce music.

REVIEW REAL-WORLD EXAMPLES

1. Review the following examples as a class. These projects may inspire your students' design thinking.

Example 1: Jabberstamp

Jabberstamp is the first tool that allows children to synthesize their drawings and voices. First, children create drawings, collages or paintings on normal paper. They then press Jabberstamp's special rubber stamp onto the page to record sounds into their drawings. When children touch the marks of the stamp with a small trumpet, they can hear the sounds play back, retelling the stories they have created.

Jabberstamp can be used as a communication tool, as a learning tool, and as a step toward writing.

Watch **Jabberstamp** to see this invention in action.

Credit: lemelson.mit.edu

HIGH SCHOOL CONNECTION

The 2014 School of Dreams Academy InvenTeam (Los Lunas, New Mexico)invented "Police ALERT," a monitoring device that detects potential threats within a 40-foot radius around a patrol car.

The police officer in the car is warned via an in-cab indicator when motion is detected. The in-cab indicator includes both audio and visual cues.

Learn more: **Police ALERT**

Example 2: Clear Lake High School InvenTeam

The 2012 Clear Lake High School InvenTeam (Houston, Texas) invented a compact, multifunctional medical unit that generates power, sterilizes water, and stores medical equipment.

Credit: lemelson.mit.edu

Sterilization occurs in an ultrasonic machine that employs high-intensity sound waves to eradicate pathogens. The invention costs $2,500 and is aimed at providing clean drinking water to people in Bangladesh.

Example 3: Mt. Edgecumbe High School InvenTeam

The 2014 Mt. Edgecumbe High School InvenTeam invented a search and rescue unmanned aerial vehicle (UAV) for the Sitka Search and Rescue in Sitka, Alaska. The UAV addresses the issue of lost and injured individuals on remote waterways and mountains that surround Sitka.

Credit: lemelson.mit.edu

The UAV includes a high-resolution camera, a forward-looking infrared camera, and a two-way audio communication system. The open, two-way communication system helps alleviate the fear that arises in these situations to reduce the danger to rescue workers. The communication system has a range of a one-mile line of sight and a flight time of 10 minutes. Visit **Search and Rescue** to learn more.

SUSTAINABLE SOLUTIONS

The world generates approximately 1 billion tons of garbage each year. The people of Cateura, Paraguay in South America transform the trash that surrounds their community into musical instruments. Watch the Landfill Harmonic Video (3:27) to see this group of children and music teacher create instruments solely out of garbage.

Example 4: Woody Norris

Credit: lemelson.mit.edu

"What if you could aim sound the way you aim light?" asks Woody Norris.

Norris' hypersonic sound (HSS) system is designed to control and focus sound, just as lasers focus and control light. When aimed directly at a listener it has the effect of wearing headphones, almost like a voice inside one's head.

Norris anticipates his HSS system to be used in advertisement, noise-cancellation, entertainment, and for military purposes. What do you think this system could be used for?

Watch **Woody Norris' TED talk** to learn more.

Example 5: InvenTeams

Flip back through this unit and check out the High School Connection pop-outs. They are all examples of former InvenTeams projects related to sound.

These projects all demonstrate a clear beneficiary, a unique solution, and technological means for solving a real-world problem. Moreover, all of these students connected with local partners and mentors to facilitate the completion of their project.

Your idea should be ambitious enough to span the course of an academic year. However, it should also be realistic and doable.

Visit the **InvenTeams website** to search current and past teams to get more information about their projects.

IDENTIFY A NEED

1. Have students reflect on the new toolkit of skills they have acquired in this unit. They have gained minds-on skills such as understanding sound, electromagnets, speakers, and electric instruments. They have practiced hands-on skills such as making electromagnets and speakers, cutting wood, and soldering.

2. Explain that invention is centered on **empathy** and fulfilling people's needs.

3. Ask students how they could use their new skills to solve a real problem? Tell them their challenge is to select a person or group of people with a need and apply their skills to invent a solution.

4. Explain that before students decide WHAT to invent, they must research a real need and determine WHO they will be helping. They can think locally, regionally, nationally, or even internationally. If they choose the last, they can research the needs of a particular country or region to develop a product that may be useful. Perhaps their school has a partnership with a "sister city" in another country.

5. For additional information on problems/needs in other countries, have students explore the **World Bank** website.

6. Encourage students to share their ideas with their teams and work together to brainstorm new ones. They should try to apply their new hands-on and minds-on toolkits as they brainstorm. Examples are below:

- Modify your speaker to meet a real-world need
- Address an educational need
- Address a social need
- Incorporate sound into your invention

7. Have groups use the Invention Challenge Brainstorm on page 54 of this meeting to develop and track their team's ideas about needs they would like to address.

Credit: lemelson.mit.edu

HIGH SCHOOL CONNECTION

The 2017 Pine School InvenTeam from Hobe Sound, Florida invented a device using audio and video components to monitor the health of the Indian River Lagoon. The device consists of a hydrophone and camera that are enclosed in a waterproof housing and can be lowered 5 - 7 ft. Learn more: Pine School InvenTeam

BRAINSTORM SOLUTIONS

1. Once teams have decided on needs they'd like to address, have them use SCAMPER to brainstorm design solutions.

2. Explain that SCAMPER is a process for coming up with solutions. It is based on the notion that many new things are modifications of something that already exists. Each letter in the acronym represents a different way students can arrange the characteristics of what is challenging them to help come up with new ideas:

   S = **Substitute** *(playing basketball with a softball)*

   C = **Combine** *(toothbrush combined with a pencil to create a new product)*

   A = **Adapt** *(how would you eat your spaghetti without a utensil?)*

   M = **Magnify** *(how would your chair function if its legs were wider and longer?)*

   P = **Put to Other Uses** *(could your fork be used as a comb?)*

   E = **Eliminate** *(could you play tennis without a racket?)*

   R = **Rearrange** *(what if the laces of a shoe were placed on the bottom and not the top?)*

3. Say that to use the SCAMPER technique, you would first state the problem you would like to solve. Then, ask questions about it using the SCAMPER checklist.

4. Have students do some personal brainstorming using SCAMPER. Afterward, they should discuss their ideas with their teams and streamline them. They should select one idea (or a combination of multiple ideas) to take to the next step.

Make a Plan

1. Remind students that all ideas are good ideas. They should record all ideas in their guides.

2. Ask students the following questions to make sure they are on target:

- Is the product offering something useful and unique?
- Who will benefit from the invention?
- Does your project incorporate sound in some way?
- Are you excited and motivated to develop your idea?
- What additional research would you need to conduct?
- What new tool and/or material skills would you need to learn?
- If the product meets a local need, would a community group, university, or company want to get involved with the project?

3. Groups should use the invention worksheet in their guides to document and sketch their ideas. This worksheet is a version of what high school InvenTeams use in their project proposals.

4. Have groups share their plans with the class if time allows. Encourage groups to consider **apply for an InvenTeams grant** if they are interested in continuing their work!

SELF-ASSESSMENT

Collect the completed self-assessments as exit slips when students leave.

INDICATORS OF A SUCCESSFUL MEETING

Students test their sound prototypes, get feedback from others, and determine what changes they would make. They also conceptualize and plan their new invention ideas. This planning can continue beyond the unit.

INVENTION CHALLENGE BRAINSTORM

For this brainstorm, it's important that you get ALL of your ideas down, especially the wacky ones! You never know when a wacky idea will turn into a great invention.

WHO will you help?

WHAT will you invent?

What problem do you want to solve?

S = Substitute
(Playing basketball with a softball.)

C = Combine
(Toothbrush combined with a pencil to create a new product.)

A = Adapt
(How would you eat your spaghetti without a utensil?)

M = Magnify
(How would your chair function if the legs were wider and longer?)

P = Put to Other Uses
(Could your fork be used as a comb?)

E = Eliminate
(Could you play tennis without a racket?)

R = Rearrange (or Reverse)
(What if shoelaces were placed on the bottom and not the top?)

INVENTION WORKSHEET

Our JV InvenTeam members are:

The product we are inventing is: ______________________________

to: ______________________________

____

It is useful for: ______________________________

____

because: ______________________________

____

____

It is unique because: ______________________________

____

It functions by: ______________________________

____

____

The tools we need are: ______________________________

____

The materials we need are: ______________________________

____

____

The estimated total cost of our invention is: ______________________________

LEMELSON-MIT JV InvenTeams™

The Lemelson-MIT Program congratulates ______________________________

on completing the Noise Makers unit of JV InvenTeams on __________________

You did a wonderful job as an inventor and made an incredible speakers and instruments!

Thanks for all your contributions to the team.

Award for ____

NOISE MAKERS

Signed,

____

Your JV InvenTeam Educator

engineering

invention

iteration

modification

patent

PhD

prototype

current

cymatics

electromagnet

frequency

magnet

resonance

- -

sound(wave)

- -

speaker

tympanic mem-
brane

- -

voice coil

- -

cone

constraints

criteria

neodymium mag-
net

spider

surround

larynx

pitch

vocal cords

gauge

humbucker pickup

pickup

empathy

bass

iron

steel

polarity

compass

AWG

Noise Makers
Massachusetts Science and Technology/Engineering Standards - Middle School

Meeting	Science Standards	Technology/ Engineering Standards	Cross-Cutting Concepts	Practices
Meeting 1: Invention Introduction		6.MS.ETS1-1 6.MS.ETS1-5* 6. MS.ETS1-6 6.MS.ETS2-2 7.MS.ETS1-2* 7. MS.ETS1-7 7.MS.ETS3-4 8.MS.ETS2-4	• Structure & Function • Systems & Cycles • Cause & Effect	• Asking Questions & Defining Prob-lems • Constructing Explanations & Design-ing Solutions • Engaging in Argument from Evi-dence • Obtaining, Evaluating, & Communi-cating Information
Meeting 2: Hearing Sound	7. MS-PS2-3* 7. MS-PS2-5*	6.MS.ETS1-1* 6.MS.ETS1-5* 6.MS.ETS2-2 6. MS.ETS2-3 7. MS-ETS1-4 7.MS-ETS1-7	• Structure and Function • System and System Models • Cause and Effect • Patterns • Energy and Matter	• Asking questions and defining problems • Developing and Using a Model • Planning and Carrying out Investi-gations • Analyze and Interpret Data • Constructing Explanations and De-signing Solutions
Meeting 3: Build a Paper Plate Speaker		6.MS.ETS1-1 6.MS.ETS1-5* 6.MS-ETS1-6 6.MS-ETS2-1* 6.MS.ETS2-2 6.MS.ETS2-3 7.MS.ETS1-7 7.MS-ETS1-2 7.MS-ETS1-4	• Structure & Function • System & System Models • Energy and Matter	• Asking questions and defining problems • Developing and Using a Model • Constructing Explanations and De-signing Solutions
Meeting 4: Making Sound	6. MS-PS4-1*	6.MS.ETS1-1 6.MS.ETS1-5* 6.MS-ETS1-6 6.MS-ETS2-1 6.MS.ETS2-2 6.MS.ETS2-3 7.MS.ETS1-7	• Structure and Function • System and System Models • Patterns • Energy and Matter	• Asking questions and defining problems • Developing and Using a Model • Constructing Explanations and De-signing Solutions
Meeting 5 & 6: Build an Electric Instrument		6.MS.ETS1-1 6.MS.ETS1-5* 6.MS-ETS1-6* 6.MS.ETS2-2 6.MS.ETS2-3 7.MS.ETS1-7	• Structure & Function • System & System Models • Energy and Matter	• Asking questions and defining problems • Developing and Using a Model • Constructing Explanations and De-signing Solutions
Meeting 7: Invention Extension		6.MS.ETS1-1 6.MS.ETS2-2	• Influence of Science, En-gineering, and Technology on Society and the Natural World • Structure & Function • System & System Models	• Asking questions and defining problems • Constructing Explanations & Design-ing Solutions

* Loosely aligned

Standards alignment conducted by graduate students at Boston College's Lynch School of Education

Noise Makers
Massachusetts Science and Technology/Engineering Standards - High School

Meeting	Science Standards	Technology/ Engineering Standards	Cross-Cutting Concepts	Practices
Meeting 1: Invention Introduction		HS.ETS1-3 HS.ETS1-6 HS.ETS2-1	• Structure & Function • Systems & Cycles • Cause & Effect	• Asking Questions & Defining Problems • Constructing Explanations & Designing Solutions • Engaging in Argument from Evidence • Obtaining, Evaluating, & Communicating Information
Meeting 2: Hearing Sound	HS.PS2-5 HS-PS3-3 HS-PS3-5* HS-PS4-5*	HS.ETS1-2 HS.ETS1-5* HS.ETS1-6*	• Structure and Function • System and System Models • Cause and Effect • Patterns • Energy and Matter	• Asking questions and defining problems • Developing and Using a Model • Planning and Carrying out Investigations • Analyze and Interpret Data • Constructing Explanations and Designing Solutions
Meeting 3: Build a Paper Plate Speaker	HS-PS3-3 HS-PS4-5	HS.ETS1-2 HS.ETS1-3 HS.ETS1-5* HS.ETS1-6 HS.ETS2-1	• Structure & Function • System & System Models • Energy and Matter	• Asking questions and defining problems • Developing and Using a Model • Constructing Explanations and Designing Solutions
Meeting 4: Making Sound	HS-PS3-3 HS-PS4-1 HS-PS4-5	HS.ETS1-2 HS.ETS1-3 HS.ETS1-5* HS.ETS1-6* HS.ETS2-1 HS.ETS2-4*	• Structure and Function • System and System Models • Patterns • Energy and Matter	• Asking questions and defining problems • Developing and Using a Model • Constructing Explanations and Designing Solutions
Meeting 5 & 6: Build an Electric Instrument	HS-PS3-3 HS-PS4-5	HS.ETS1-2 HS.ETS1-3 HS.ETS1-5* HS.ETS1-6* HS.ETS2-1	• Structure & Function • System & System Models • Energy and Matter	• Asking questions and defining problems • Developing and Using a Model • Constructing Explanations and Designing Solutions
Meeting 7: Invention Extension		HS.ETS1-1 HS.ETS1-2 HS.ETS2-1	• Influence of Science, Engineering, and Technology on Society and the Natural World • Structure & Function • System & System Models	• Asking questions and defining problems • Constructing Explanations & Designing Solutions

* Loosely aligned

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Noise Makers
Next Generation Science Standards - Middle School

Meeting	Core Ideas	Science Standards	Cross-Cutting Concepts	Practices
Meeting 1: Invention Introduction	ETS1.A ETS1.B	MS.ETS1-1 MS.ETS1-2	• Structure & Function • Systems & Cycles • Cause & Effect	• Asking Questions & Defining Problems • Constructing Explanations & Designing Solutions • Engaging in Argument from Evidence • Obtaining, Evaluating, & Communicating Information
Meeting 2: Hearing Sound	ETS1.A ETS1.B	MS.PS2-3 MS.PS2-5* MS.ETS1-1* MS.ETS1-4	• Structure and Function • System and System Models • Cause and Effect • Patterns • Energy and Matter	• Asking questions and defining problems • Developing and Using a Model • Planning and Carrying out Investigations • Analyze and Interpret Data • Constructing Explanations and Designing Solutions
Meeting 3: Build a Paper Plate Speaker	ETS1.A ETS1.B ETS1.C	MS.ETS1-1 MS.ETS1-2 MS-ETS1-4*	• Structure & Function • System & System Models • Energy and Matter	• Asking questions and defining problems • Developing and Using a Model • Constructing Explanations and Designing Solutions
Meeting 4: Making Sound	ETS1.A ETS1.B	MS.ETS1-1 MS.ETS1-2 MS.PS4-1*	• Structure and Function • System and System Models • Patterns • Energy and Matter	• Asking questions and defining problems • Developing and Using a Model • Constructing Explanations and Designing Solutions
Meeting 5 & 6: Build an Electric Instrument	ETS1.A ETS1.B	MS.ETS1-1 MS.ETS1-2	• Structure & Function • System & System Models • Energy and Matter	• Asking questions and defining problems • Developing and Using a Model • Constructing Explanations and Designing Solutions
Meeting 7: Invention Extension	ETS1.A ETS1.B	MS.ETS1-1 MS.ETS1-2	• Influence of Science, Engineering, and Technology on Society and the Natural World • Structure & Function • System & System Models	• Asking questions and defining problems • Constructing Explanations & Designing Solutions

* Loosely aligned

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Noise Makers
Next Generation Science Standards - High School

Meeting	Core Ideas	Science Standards	Cross-Cutting Concepts	Practices
Meeting 1: Invention Introduction	ETS1.A ETS1.B	HS.ETS1-3	• Structure & Function • Systems & Cycles • Cause & Effect	• Asking Questions & Defining Problems • Constructing Explanations & Designing Solutions • Engaging in Argument from Evidence • Obtaining, Evaluating, & Communicating Information
Meeting 2: Hearing Sound	ETS1.A ETS1.B	HS.ETS1-2 HS.PS3-3 HS.PS2-5* HS.PS3-5* HS-PS4-5*	• Structure and Function • System and System Models • Cause and Effect • Patterns • Energy and Matter	• Asking questions and defining problems • Developing and Using a Model • Planning and Carrying out Investigations • Analyze and Interpret Data • Constructing Explanations and Designing Solutions
Meeting 3: Build a Paper Plate Speaker	ETS1.A ETS1.B ETS1.C	HS.ETS1-2 HS.ETS1-3 HS-PS3-3 HS-PS4-5	• Structure & Function • System & System Models • Energy and Matter	• Asking questions and defining problems • Developing and Using a Model • Constructing Explanations and Designing Solutions
Meeting 4: Making Sound	ETS1.A ETS1.B	HS.ETS1-2 HS.ETS1-3 HS-PS3-3 HS-PS4-1* HS-PS4-5*	• Structure and Function • System and System Models • Patterns • Energy and Matter	• Asking questions and defining problems • Developing and Using a Model • Constructing Explanations and Designing Solutions
Meeting 5 & 6: Build an Electric Instrument	ETS1.A ETS1.B	HS.ETS1-2 HS.ETS1-3 HS-PS3-3 HS-PS4-5*	• Structure & Function • System & System Models • Energy and Matter	• Asking questions and defining problems • Developing and Using a Model • Constructing Explanations and Designing Solutions
Meeting 7: Invention Extension	ETS1.A ETS1.B	HS.ETS1-1 HS.ETS1-2	• Influence of Science, Engineering, and Technology on Society and the Natural World • Structure & Function • System & System Models	• Asking questions and defining problems • Constructing Explanations & Designing Solutions

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It is the responsibility of the JV InvenTeam educator to completely review the manufacturer’s manual(s) of the power tool(s) and/or associated equipment included in this kit and inspect all tools and equipment prior to each use, to ensure that they are safe for operation.

Note: As required by the manufacturer’s manual, follow all operating instructions provided, including use of the appropriate personal protective equipment, for the safe operation of the tools or equipment. WATCH General Shop Safety video with the students for additional safety rules to follow for the use of hand tools.

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